# Urban Health in Medieval Canterbury: An Osteoarchaeological Examination of Health Outcomes

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*“Whan that April with his showres soote*

*The droughte of March hath perced to the roote,*

*And bathed every veine in swich licour,*

*Of wich vertu engendred is the flowr;*

*Whan Zephyrus eek with his sweete breeth*

*Inspired hath in every holt and heeth*

*The tendre croppes, and the young sonne*

*Hath in the Ram his halve cours yronne,*

*And smale fowles maken melodye*

*That sleepen al the night with open yë*

*So priketh hem Nature in hir corages*

*Thanne longen folk to goon on pilgrimages,*

*And palmeres for to seeken straunge strondes*

*To ferne halwes, couthe in sondry londes;*

*And specially from every shires ende*

*Of Engelond to Canterbury they wende,*

*The holy blishful marty for to seeke*

*That hem hath holpen whan that they were seke.”*

- Geoffrey Chaucer, The General Prologue,
The Canterbury Tales, lines 1-19 (Greenblatt 2012)

# Abstract

The sacred city of Canterbury was a renowned theological centre during the medieval period (11th to 15th century). It attracted numerous pilgrims with the hopes of gaining miracles from the spirits of saints. Thus, this influenced the people of Canterbury to make a profit off the pilgrims, ultimately influencing the urban centre. The social environment, such as social status, behaviours, and ideologies, impacts urban health. The physical environment, such as dense housing conditions, inadequate food supply, unhygienic disposal of waste, and adverse weather conditions, have negatively impacted urban health in medieval England. Previous biological anthropological studies on medieval Canterbury focused on pathological cases, biorhythms, maturation, enamel microevolution, and behaviour from bone histology. Little is known about the effects of the urban environment on the population's health; therefore, this research examines urban health in medieval Canterbury.

A macroscopic analysis of individuals from St. Gregory's Priory (11th to early 16th century) skeletal collection was conducted for this study. Childhood growth, survivorship and mortality risk patterns were selected to assess non-adults' health. Raunds (Raunds Furnells), Newcastle (Black Gate), and York (All Saint's Church) skeletal collections were also analysed for childhood growth to identify similar and different urban and rural health outcomes. For the health of adults, pathological conditions (periosteal new bone formation and cribra orbitalia as a proxy for parasitic infections), and survivorship and mortality risk patterns were assessed.

The findings indicate that non-adults from Canterbury (from birth to 3 years and 4 years and older) had a lower risk of delayed tibial and femoral diaphyseal growth compared to those from Newcastle. Contrarily, there are no significant differences between the risk of delayed femoral and tibial diaphyseal growth of non-adults from Canterbury and Raunds from birth to 3 years and 4 years and older. On the other hand, the risk of delayed femoral and tibial diaphyseal growth of non-adults 4 years and older from Canterbury is lower than those from Raunds. In addition, non-adults from Canterbury (from birth to 3 years and 4 years and older) had a lower risk of delayed femoral diaphyseal growth compared to those from York. Also, there is no significant difference between high- and low-status adults with parasitic infections. Additionally, Low-status non-adults had increased survivorship compared to high-status non-adults. Similarly, low-status adult males had increased survivorship and lower mortality risk compared to high-status adult females. Urban health in medieval Canterbury was significantly

influenced by the pilgrimage culture, breastfeeding and weaning practices, dense housing conditions, polluted water resources, inadequate sanitation, and dietary intake.

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This manuscript is being prepared for submission for peer review in the *American Journal of Biological Anthropology*

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# List of Abbreviations

| | |
|---|---|
| 95% CI | 95 percent confidence intervals or comparison intervals |
| ADBOU | Anthropological Database, Odense University |
| Adults | Individuals aged 18 and older |
| B | beta-coefficient |
| CAT | Canterbury Archaeological Trust |
| CO | cribra orbitalia |
| df | degrees frequency |
| MM | millimetres |
| P-value | calculated probability value |
| PNB | Periosteal new bone |
| SPSS | Statistical Package for Social Sciences |
| TA2 | Transition analysis method developed by Boldsen and colleagues (2002) |
| TB | tuberculosis |
| VIF | variance inflation factor |
| $X^2$ | chi-square |

# List of Definitions

| | |
|---|---|
| Adults | Individuals ages 18 years and older |
| Biological Anthropological studies | Studies that focus on biological anthropology; include but are not limited to forensic anthropology, human biology, and osteoarchaeology |
| Clergy | Ordained members of the church, only men |
| Data chapters | Chapters that describe and analyse research data |
| Medieval Canterbury | 11$^{th}$ to early 16$^{th}$ century Canterbury |
| Non-adults | Individuals aged in-utero to 17 years |
| Osteoarchaeological studies | Studies on human remains from archaeological contexts. Also known as bioarchaeology |
| Physical environment | Refers to the design and layout of communities and physical features of the earth (e.g., housing and waterways) |
| Skeletal lesions | Abnormal skeletal characteristics |
| Social environment | Refers to people's beliefs, customs, practices, and behaviours (e.g., socioeconomic status and culture) |
| St. Gregory's Priory | The priory or the skeletal collection consisting of individuals who were buried in the priory and the cemetery |
| The Church | The Roman Catholic Church |
| Urban Health | The results of good or poor health of individuals caused by the social and physical environment within an urban setting |

# Chapter 1 Introduction

Over half of the world's population live in urban areas, and this is estimated to increase to 68% by 2050 (WHO 2021). Urban centres often influence poor population health, such as the densely built environment causing the spread of infectious diseases and varying degrees of accessibility to resources influencing the obtainability of non-communicable diseases (Vlahov *et al.* 2007; WHO 2021). The social and physical environment within an urban area affects the quality of health of individuals and communities (Wuerzer 2014; Ettman, Vlahov and Galea 2019).

The physical environment, such as housing, transportation, and infrastructure, influence impoverished health of people based on the inadequate quality of waste management, water, and air (Wuerzer 2014; Ettman, Vlahov and Galea 2019). Outdoor air pollution from industrial and fuel emissions (largely from sources of coal, oil, gas, and cement) and indoor pollution from poorly ventilated houses, materials used in the construction of buildings, and climatic environmental conditions causing damage to housing structures influence cardiovascular disorders (such as cardiac failure and stroke) and respiratory diseases (such as asthma, bronchiolitis, and chronic obstructive pulmonary disease) (Ettman, Vlahov and Galea 2019; Ségala *et al.* 2008; Sint, Donohue and Ghio 2008; Holguin 2008; Lokken *et al.* 2010; Brook 2008; Abelsohn and Stieb 2011; Spengler and Chen 2000; Maheswaran 2016; Hulin *et al.* 2012; Devien *et al.* 2018; Pathak, Gupta and Suri 2020; Bentayeb *et al.* 2013). Waste such as food, paper, textiles, organic chemicals, masonry, and excretion refuse from households, industrial organisations, construction, and consumer goods industries influence respiratory diseases (due to gases emitting from landfills), organ failures and birth defects (due to consistent contact with toxic chemicals), and the spread of viruses and bacteria (due to sewage sludge) (Rushton 2003; Ziraba, Haregu and Mberu 2016; Giusti 2009). Water resources (e.g., rivers, groundwater, and desalinated seawater) are often contaminated by toxic chemicals, sewage spillages, and municipal waste (Halder and Islam 2015; Haseena *et al.* 2017). Consumption and skin absorption of contaminated water causes viral, bacterial, and parasitic infections, birth defects and complications, central nervous system disorders, and death (Rushton 2003; Afroz *et al.* 2014;Walker *et al.* 2019; Grossman and Slusky 2019; Wang, Chen and Li 2022).

The social environment, such as socioeconomic status, social marginalisation, and social behaviour, influence impoverished health of people based on access to healthcare, suitable food, and adequate housing structures (Wuerzer 2014; Ettman, Vlahov and Galea 2019). There are various indicators that measure the levels of socioeconomic statuses, which are often correlated with the knowledge of health and accessibility to healthcare (Brown *et al.* 2018; Chan, Lee and Low 2018). For example, financial instability, lack of health literacy, and low levels of educational attainment will influence people's lack of knowledge for various care services (e.g., intensive care, inpatient care, hospice, and advance care planning) and for planning healthy eating and physical activities, as well as influence screenings and treatments to be ignored due to high cost (Brown *et al.* 2018; Chan, Lee and Low 2018). Individuals who are socially marginalised (e.g., racial and ethnic minorities, immigrants, economically disadvantaged individuals, individuals with disabilities, and individuals with chronic health conditions) are likely to neglect using healthcare services due to the risk of economic, cultural and language barriers, previous medical mistreatment, biased healthcare environments, issues with navigating through complex medical care systems, and lacking transportation and sustainable housing (Bharel *et al.* 2013; Waisel 2013; Wallace *et al.* 2021). Also, Social behaviour has been shown to have an influence on the lack of health literacy through religious and cultural beliefs (Kim-Godwin 2003; Jimenez *et al.* 2012; Vaugh, Jacquez and Bakar 2009).

The health outcomes of the social and physical environments (i.e., the results, obtained by those, of good or poor health as a consequence of the social and physical environment) within an urban setting are defined as urban health (Wuerzer 2014; Ettman, Vlahov and Galea 2019). Urban health is commonly known to be represented as poor population health, as shown in the examples above. Throughout time, urban centres have negatively impacted peoples' health. This is especially true for medieval England. Osteoarchaeological studies on medieval English urban centres have reported that various aspects of social and physical environments adversely affected population health (Roberts and Manchester 2005; Roberts and Cox 2003; DeWitte and Betsinger 2020; Betsinger and DeWitte 2021; Roberts 2020; Rawcliffe 2013). For example, dense housing and structural communities perhaps influenced the spread of infectious diseases, and water resources contaminated with household and industrial waste caused breeding grounds for parasites that led people to obtain anaemia in medieval London and York (Sullivan 2005; Godde and Hens 2021). Low-status females in medieval York had the shortest lives compared to individuals from other socioeconomic status groups (Sullivan 2004). This was perhaps influenced by childbearing and birth complications caused by inadequate diets during these periods, infectious diseases common to urban centres that migrants rarely encountered from their home in rural areas, and the social ideology that women were inferior to men, which caused resources to be less accessible (Sullivan 2004). Similarly, adult females in medieval

London had a higher risk of dying and decreased survivorship compared to adults from rural Barton upon-Humber in Lincolnshire (Walter and Dewitte 2017). This is suggested to have been caused by the dense structural community, water pollution from waste disposal, and air pollution from insufficient ventilation for controlled fires within homes and businesses (Walter and Dewitte 2017). Many osteoarchaeological studies on medieval English urban health predominantly focus on major centres, London and York (e.g., Sullivan 2004; Sullivan 2005; Grauer 1989; Grauer and Roberts 1996; Walter and Dewitte 2017; Godde, Pasillas and Sanchez 2020; Godde and Hens 2021; DeWitte 2014a; DeWitte 2010; Yaussy and DeWitte 2018; Yaussy, DeWitte and Redfern 2016; DeWitte 2015; DeWitte 2014b; DeWitte 2017; DeWitte and Wood 2017; Lewis 2002; Addyman 1989; Grauer 1993; Lewis, Charlotte A Roberts and Manchester 1995; Burt 2013; Kowaleski 2014). The lack of research on other medieval English urban centres assumes that urban health was the same for all urban areas regardless of differences in population size, social structures, social behaviours, financial advantages, etc. This, therefore, leads to insufficient knowledge of urban health in other cities in medieval England.

From the 11th to 15th centuries, Canterbury was a distinguished sacred place for theology. 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 have donated 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 the food supply leading to sporadic famines resulting in people developing nutritional deficiencies (Rubin 1974). Previous biological anthropological studies on medieval Canterbury have focused on understanding biorhythms (Pitfield, Deter and Mahoney 2019; Pitfield, Miszkiewicz and Mahoney 2019) and socioeconomic status influence on individual's health (Mahoney *et al.* 2016;Walker *et al.* 2019;

Miszkiewicz 2015; Miszkiewicz *et al.* 2019). Little is known about urban health in medieval Canterbury due to the lack of research. Therefore, this thesis examines the health of individuals influenced by Canterbury's urban environment from the 11th to early 16th centuries. Before urban health in medieval Canterbury can be understood, the factors that influenced urbanisation and the physical and social environments within the urban setting must be explored. This is done by first describing the components that caused Canterbury to become an urban area and then illustrating the characteristics of the physical and social environments based on historical and archaeological records written by historians and archaeologists.

## 1.1 Influences on Urbanisation

It is essential to identify the factors that influenced urbanisation because it assists with understanding the dynamics of medieval Canterbury's physical and social environments. By way of description, the factors that influenced urbanisation in medieval Canterbury are recognised as the cause of migration, a dense population, and multiple businesses in the city. Theology and non-agricultural occupations influenced the initial phase of medieval Canterbury (11th to 12th century) to transform into a progressive urban city. As the delegate to the Roman Catholic church (the Church) in southern England, it allowed the archbishop to hold an administrative seat at Canterbury Cathedral (Clegg 2003). Thus, many clergy travelled to Canterbury, from various English towns and European countries, for theological education or employment. Also, Canterbury Cathedral and various churches established shrines of saints who played important roles in Canterbury, which encouraged the frequency of pilgrimages to the city (Webb 2000). The high numbers of clergy and pilgrims entering the city motivated people to migrate to Canterbury to start businesses that provided lodgings, food, and souvenirs (Hopper 2002). This section discusses the influence that the Church, saints, pilgrims, and different occupations had on how Canterbury became an advancing urban centre.

### 1.1.1 The Church

The Roman Catholic church controlled the lifestyles of people living in western Europe (Clegg 2003). People were taught to follow the teachings of the Church to find salvation for their souls and avoid purgatory in the afterlife (Clegg 2003). The Pope was the head of the Church who supervised the finances, court of law, and European countries court of justice (Clegg 2003). Ordained members (clergy), primarily men, were educated by the Church to perform task within the treasury, court of law, and courts of justice (Clegg 2003). The Church was the only means to obtain an education, considering that schools were theological foundations organised by cathedrals or chantry chapel priests (Clegg 2003). Thus, the Church provided European

Kings and Princes with government officials and cathedrals, churches, and monasteries with skilled administrators (Clegg 2003). This influenced ordinary people to view the clergy as possessing a prestigious intellect.

Most ordinary people interacted with the secular clergy. These were individuals who conducted administrative duties for the church and provided religious needs for the people (Clegg 2003). There were various roles the secular clergy could obtain within the Church, recognised under two divisions known as the Major Orders and Minor Orders (Clegg 2003). Those who were in the Major Orders (e.g., bishops, priest, deacon, and subdeacon) were expected to commit the rest of their life to the church and celibacy (Clegg 2003). Whereas, individuals in the Minor Orders (e.g., porter, lector, exorcist, and acolyte) were not required to be celibate, could get married, and leave the church (Clegg 2003). Many people sought a role within the Minor Orders to start their professional careers or gain employment as government administrators or lawyers (Clegg 2003). However, not all ordained members wanted to participate in the professional duties of the Church.

Clergy who made a vow to disconnect themselves from society and, in some cases, lived in secluded monasteries were called Regular clergy (Clegg 2003). Regular clergy were divided into three main groups known as the military, monastic and mendicant orders (Clegg 2003). The military orders were most known for the crusade movements during the twelfth and thirteenth centuries (Clegg 2003). The monastic orders were the largest and characterised as living in monasteries built far away from towns (Clegg 2003). Individuals within these orders could not possess personal belongings but could share ownership of property within the community (Clegg 2003). The mendicant orders, also known as the friars, relied heavily on begging and charitable donations, and the clergy could not own or share possessions (Clegg 2003). As a result, properties of mendicant orders were built in urban areas (Clegg 2003).

Dominicans (the Black Friars), Franciscans (the Grey Friars), Carmelites, and Augustinians (the White Friars) were the common mendicant orders established in urban areas (Clegg 2003). The Grey Friars arrived at Canterbury in AD 1224 and received support, land, and a chapel from Canterbury Cathedral (Lincoln 1955). The Black Friars came to England in c. AD1221 and acquired a residence with land alongside the Stour River in Canterbury (figure 1.1) (Palmer 1880; Page 1926b; Lincoln 1955). In AD 1236, King Henry III granted an island in the Stour river to the Black Friars (Page 1926b). The White Friars arrived at Canterbury in c. AD1325 and possessed St. George parish (Page 1926a; Lincoln 1955).

**Figure 1.1** The Blackfriar's Refectory along the Stour River

#### 1.1.1.1 Religious Women

Women seemed eager to become a part of the Dominican, Franciscan, or Augustinian orders between the 12th and 13th century (Ward 2016). This could be due to the practice of child oblation, parents being required to give their children to monasteries for upbringing and education, ended in the twelfth century (De Jong 1996; Ward 2006). With children not being 'recruited' by monasteries, many marriages were arranged. Teenage girls would become a part of medicant and monastic orders to avoid marrying a man they dislike considering that the Church required religious women to be celibate (Ward 2006). Women were seen by the Church as sexual deviants and liable to seduce men (Ward 2016). Therefore, the roles of women within the Church were limited.

The primary professions women could obtain were nuns or anchorites. Nuns lived in an enclosed community and were expected to offer hospitality, charity, and education to children (Ward 2006; Ward 2016). Anchorites had to withdraw from the world and live in an enclosed chamber for the rest of their lives (White 1993). Anchorites and nuns typically lived in communities called nunneries or priories. Medicant and monastic orders and elite families primarily established nunneries or priories (Ward 2006). Most of these establishments required some form of payment, clothes, and equipment for entry (Ward 2016). Nunneries depended on the clergy for religious and labour services because women were not allowed to become members of the clergy (Ward 2016).

Nunneries often did not receive much recognition. St. Sepulchre's Priory, in Canterbury, gained attention during Elizabeth Barton, the Nun of Kent, challenges to King Henry VIII over his divorce; however it did not receive many newcomers and by AD 1511 there were one five nuns (Dobson and Edwards 2010: 99; Page 1926). Nunneries did not receive many endowments, and people tended to give donations to monks rather than nuns (Ward 2006). This is because the Church was a male dominated institution. Perhaps ordinary people believed that communities that primarily consisted of men were beneficial than those of women.

### 1.1.2 Kings and Archbishops

A sister of the Danish King, Sweyn, is said to have been murdered during a massacre, on Danish towns within England, ordered by the English King, Ethelred, in AD 1002 (Lincoln 1955). King Sweyn launched an invasion on England to avenge his sister (Lincoln 1955). In AD 1011, Danish troops arrived in Canterbury, set the town on fire within the city's walls, looted, and kidnapped Archbishop Alphege for not accepting their financial request from the cathedral (Lincoln 1955; Lyle 2002). Unfortunately, Archbishop Alphege was killed at a drunken feast in Greenwich (Lyle 2002). In AD 1023, Canterbury Cathedral received Alphege's body, gifts and grants for land from, Sweyn's son, King Cnut of England (Lincoln 1955; Webb 2000; Lyle 2002). King Cnut had converted to Christianity and was making amends for damages caused by his father (Lincoln 1955). The king assigned workers to restore Canterbury Cathedral (Lincoln 1955).

In AD 1042, the cathedral was completely restored when Edward the Confessor came to the English throne (Lincoln 1955). There were claims of William of Normandy being next in line, after King Edward's death, for the English throne which was strongly supported by the Pope (Lincoln 1955). However, elites in England had their own agenda for who would become King (Crofton 2007). This reached William and ultimately led to a war, known as the Battle of Hastings, over who would become the King of England (Crofton 2007). William murdered his opponent and became the King of England in AD 1066 (Crofton 2007). King William promoted his trusted advisor and friend, Lanfranc, to become the archbishop of Canterbury (Gibson 1995).

Lanfranc became archbishop in AD 1070, and his first task was to restore Canterbury Cathedral and the nearby monastic buildings that were destroyed by a fire in AD 1067 (Martin 1950; Brooks 1995). After construction of the newly built cathedral finished, Lanfranc conducted formal ceremonies for the relics of saints that it possessed (Lincoln 1955). Archbishop Lanfranc was known for being an advocate of the Church. He founded hospitals and a leprosarium in Canterbury, endowed monasteries, and restored the ownership of manors to Canterbury Cathedral (Martin 1950; Lincoln 1955). A goal of Lanfranc was to make Canterbury primacy of England for the Church (Cowdrey 2003). This did not succeed and was an ongoing process after his death (Cowdrey 2003). Archbishop William de Corbeil continue the pursue Canterbury as primacy but was postponed (Cowdrey 2003; Barlow 2004a). In response, Pope Honorius II made Archbishop William vicar and legate in England and Scotland (Barlow 2004a).

William de Corbeil died in AD 1136 when King Stephen's authority in England and Normandy was invaded by Henry II (nephew), Matilda (sister), and his sister's husband (Barlow 2004b). After the death of King Stephen's wife and his son Eustace during England's invasion, Henry II became recognised as Stephen's associated ruler and next in line to the throne (Barlow 2004b). King Stephen invited Theobald to London to be elected archbishop of Canterbury (Barlow 2004b). Archbishop Theobald recruited Thomas Becket as well as others to become his clerks and actively participated in the negotiations between Stephen and Henry II (Barlow 2004b). King Stephen appointed Thomas Becket as Henry's chancellor (Hopper 2002). This encouraged a strong friendship between them (Hopper 2002). It is possible that their friendship could have influenced Theobald's decision to appoint Thomas as his successor after his death (Hopper 2002).

However, Thomas understood that the archbishop of Canterbury position would reinforce the difference between the goals of the church and country (Hopper 2002). When Henry became

King of England, he recognised potential problems with their professional relationship (Hopper 2002). Henry believed that Archbishop Thomas was plotting to oppose him and called a council meeting at Northampton to submit charges against Thomas (Hopper 2002). Upon leaving Northampton, Thomas was verbally and physically attacked by Henry's barons (Hopper 2002). This influenced ordinary people to view Thomas Becket as rebellious against the political leadership of the monarch and they began to highly respect him (Martin 1950; Hopper 2002). The monarch had less authority over the Church and their government court of justice. King Henry wanted to extend his authority over the Church and the court of justice specifically in England (Martin 1950; Lincoln 1955; Ekelund, Hébert and Tollison 2012). Becket denied Henry's request which led Henry to exile Becket to France (Hopper 2002). As a result, the Pope threatened to end Henry's participation in the sacraments and services of the Church (Hopper 2002).

Thus, Henry allowed Becket back into England. When Becket arrived in Canterbury people crowed the streets to welcome him (Martin 1950). As Archbishop of Canterbury, Thomas Becket excluded three bishops, who supported Henry's political ideas, from participating in the sacraments and services of the Church (Lincoln 1955). Henry was enraged and said, 'Are there none who will rid me of this turbulent priest?' (Martin 1950; Lincoln 1955). Four knights over heard what Henry had said and took it upon themselves to murder Becket at the alter in Canterbury Cathedral in AD 1170 (Martin 1950; Lincoln 1955). A shrine was later established for Thomas Becket at Canterbury Cathedral, and the Pope canonised him in 1173 (Knowles 2019).

### 1.1.3 Saints and Pilgrims

Individuals were sainted by the Church through a centralised process called canonisation (Clegg 2003). Upon completion of heroic acts, generally after death, individuals were declared saints by the Pope (Hopper 2002). Ceremonies and shrines were established by monasteries and Canterbury Cathedral for saints of the city. People revered saints because of their commitment and pride for Christianity (Clegg 2003). It was believed that God channelled his energy through saints to perform holy miracles (Hopper 2002). Frequently, there were reports of people receiving miracles by visiting shrines of saints (Hopper 2002). There is a story about a blind man who was cured of his blindness when he spent the night in prayer at St Dunstan tomb in Canterbury (Webb 2000).

These reports increased the importance of shrines and attracted pilgrims in search of relief from their mental or physical pain (Hopper 2002). Pilgrims might have spent days, nights, or weeks offering their prayers and devotions at saints' shrines (Hopper 2002). A shrine was established for St. Alphege and it became an important holy site in Canterbury (Webb 2000; Lyle 2002). Osbern of Canterbury, a monk of the cathedral, wrote about Alphege life as well as other saints and stories on people who received miracles after visiting their shrines (Rubenstein 1995; Webb 2000). Another monk, Eadmer of Canterbury, also wrote about miracles that saints performed for people's lives (Webb 2000; Hayward 2016). Documents record that Lanfranc brought remains of Canterbury's and the county of Kent's saints to the Cathedral and St. Augstine's Abbey and ordered lavish chapels for them (Lyle 2002). The wealth of the cathedral grew because of the offerings that pilgrims provided (Lincoln 1955).

Churches encouraged people to pilgrimage for general indulgences (Ekelund *et al.* 1996; Hopper 2002). This means that churches would pray for people, who pilgrimage to them, to not receive punishment for their sins (Hopper 2002; Sorabella 2011). Indulgences were paid for with money and land (Clegg 2003). When people received their benefits from the saint, they would then visit the shrine and give offerings once or annually (Webb 2000). However, many people preferred to make pilgrimages to experience or witness miracles. Pilgrims, typically, visited shrines of saints who inspired people and represented heroic faith and virtue.

The murder of Thomas Becket increased the number of pilgrimages made to Canterbury. There were multiple stories told about people receiving miracles when they visited his shrine. Citizens were discovered scrabbling for blood-soaked relics from St. Thomas Becket's corpse, and a man's, named Manwin, sight was restored by a drop of his blood received from a neighbour (Lyle 2002). Another man, Robert from the Isle of Thanet, journeyed to the shrine with his daughter and wife, and was cured of blindness after smearing Becket's blood in his eyes (Robertson 1876). The shrine was also visited by Edilda of Canterbury, who was paralysed from the knee down, with assistance from three women and was cured (Robertson 1876).

Becket's shrine held both theological and political significance (Hopper 2002). Some pilgrims visited to 'experience' his piety, bravery and martyrdom (Hopper 2002). St. Thomas shrine was visited by European monarchs (Lincoln 1955). In AD 1174, King Henry journeyed barefoot from Westgate to Becket's shrine (Martin 1950; Lincoln 1955). Henry's leadership was under attack in England by his wife, eldest son and youngest son, and he felt this was punishment for Thomas Becket's murder (Knowles 2020). The priests at Canterbury Cathedral scourged and morally punished Henry (Martin 1950; Lincoln 1955). After Henry's pilgrimage, the rebellion against him had diminished (Knowles 2020). This event influenced other monarchs to travel to Canterbury or provide the cathedral with gifts annually (Webb 2000). King Louis VII of France travelled to Canterbury in AD 1179 for the recovery of his son, Philip Augustus, from a serious illness (Webb 2000). These visits from monarchs also increased the number of pilgrims visiting the city (Lincoln 1955).

### 1.1.4 Migration and Occupations

The increase of pilgrims encouraged people to start businesses in Canterbury that provided for the needs of pilgrims (Hopper 2002) as well as people who lived in the city. The clergy of Canterbury Cathedral engaged in trade and commerce (Lincoln 1955). They owned many of the ships that were docked at Fordwich and regulated the rules of their trading activities (Lincoln 1955). Ordinary men who migrated to Canterbury often built houses or rented property to start businesses in skilled trades, law, medicine, and other professional fields (Dyer 2002). There were a variety of occupations such as potters, millers, bakers, metalworkers, spinners and weavers, tanners and leatherworkers, butchers, and shopkeepers, mercers, goldsmiths, and moneyers (Harmsworth and Canterbury Archaeological Trust 2001; Lyle 2002). Potters created bowls, cooking pots, jugs, vessels, pans, and floor and roof tiles (Dyer 2002). They made plain and decorated pots out of local clay (Harmsworth and Canterbury Archaeological Trust 2001). Decorated, especially glazed, pottery was sold at a higher price than plain pottery (Harmsworth and Canterbury Archaeological Trust 2001). Metalworkers created various goods out of iron such as locks and keys, swords, knives, hinges, axes, pins, and horseshoes (Dyer 2002). Goldsmiths made goods out of gold and silver such as jewellery, cups, and plates (Harmsworth and Canterbury Archaeological Trust 2001). There were eight mints in Canterbury for moneyers to struck coins under licence from the King (Lincoln 1955; Lyle 2002).

Various occupations such as millers, butchers, spinners, and tanners brought goods from farmers. Millers brought grains from local farmers and ground them, between two stones at the mill, into flour (Havlidis 2016). Millers rented one of the eight mills along the Stour River owned by the Archbishop of Canterbury or the Abbot of St. Augustine's Abbey (Harmsworth and Canterbury Archaeological Trust 2001; Lyle 2002). Bakers brought their flour from millers to make loaves of bread, pies, cakes, and buns (Dyer 2002; Adamson 2004). Flour, water, and yeast were mixed together to make dough for bread, and the dough was left in a warm place before it was placed in an oven (Adamson 2004). Between 1948 and 1950, Canterbury Archaeological Trust discovered a medieval bread oven in Burgate (Harmsworth and Canterbury Archaeological Trust 2001). Butchers brought chickens, cows, sheep, and pigs from farmers to slaughter for meat (Rawcliffe 2013; Dyer 2002; Adamson 2004). They often tied animals to a post to be attacked by dogs because it was viewed as the meat would be more tender (Harmsworth and Canterbury Archaeological Trust 2001). Spinners mainly consisted of women washing, combing, and spinning wool, brought from a farmer, to make yarn (Dyer 2002). Weavers consisted of men who wove the yarn into clothes, dyed it, beat it in water to shrink and make it thicker, and then set the clothes out to dry (Dyer 2002). Tanners brought animal skins from farmers, and soaked and cleaned the skins to be transformed into leather (Dyer 2002). Tanners then sold the leather to leatherworkers (Dyer 2002). The leatherworkers cut and stitched the leather to create shoes, trousers, belts, gloves, and saddles (Dyer 2002). Mercers traded cloth and silk that came from China and countries around the Mediterranean Sea (Lyle 2002; Lincoln 1955). Craftspeople and traders sold their goods from temporary stalls at the weekly markets and/or owned a shop on High Street or nearby (Lyle 2002; Lincoln 1955). Shops had wooden shutters that were used as display counters during the day and closed them up as borders at night (Dyer 2002). Typically, shops selling similar goods were grouped on the same street such as Mercery Lane and Butchery Lane (Lyle 2002; Lincoln 1955).

Businessmen would have needed assistance with building the structure and upkeeping their company. Masons and labourers would have been hired by businessmen to dig foundations, haul stone and timber, mixing and applying daub to wattle walls, carry water to construct houses and buildings (Dyer 2002). They worked on wooden scaffolding, and stone was lifted up into baskets using cranes and pulleys (Dyer 2002). Masons were trained for many years to build castles, cathedrals, and monasteries (Harmsworth and Canterbury Archaeological Trust 2001; Dyer 2002; Lyle 2002). They carved blocks of stone for building walls, pillars, statues, and decoration around doorways and windows (Dyer 2002; Lyle 2002). Most people in the city worked as labourers and lived in their own household in a rented house or cottage (Dyer 2002). The jobs for labourers were short-term, and some people would go to a meeting place in the morning to be offered a job for the day (Dyer 2002). Women and children were more likely to migrate to Canterbury to obtain work as servants or apprentices (Miller and Hatcher 1995; Dyer 2002). These jobs consisted of carrying out domestic tasks or working in a specific trade or craft, which usually meant living where they worked, such as servant's quarters (Ryan 2013; Dyer 2002). Employers provided food, accommodation, and clothes for their servants, and apprentices (Dyer 2002). The city also attracted beggars requesting free food or money from pilgrims, wealthy households, and churches (Dyer 2002). As a result, Canterbury's population grew from six thousand to ten thousand with properties being subdivided and dense (Lyle 2002).

## 1.2 The Physical Environment

The factors of the physical environment that medieval urbanisation influenced have impacted are housing and infrastructure. Pilgrims influenced migration, and migration influenced a dense population. By AD 1200, there were six main gates (Westgate, Northgate, Burgate, Newingate, Ridingate, and Worthgate) in the high stone wall that surrounded the city for people to enter (Harmsworth and Canterbury Archaeological Trust 2001) (figure 1.2). The streets on both sides of Stour River's eastern branch were well populated with various infrastructures (e.g., homes and businesses) (Lyle 2002). Around two hundred shops existed within people's homes, some large properties were divided into seven-foot shop frontals on various major streets and in wards (districts) such as High Street (stretched from Westgate to Newingate) and Burgate Ward (district near Burgate) (Lyle 2002). Weekly markets were held on major streets and wards for local businesses and farmers to sell produce (Lyle 2002; Harmsworth and Canterbury Archaeological Trust 2001). Houses and businesses were closely built together, and streets were narrow, which led to the upper floors of homes being built to hang over streets (Harmsworth and Canterbury Archaeological Trust 2001). Streets were not paved and there were no drains for rainwater runoff or excretion refuse from houses, and as a result, the streets were often muddy (Lyle 2002; Harmsworth and Canterbury Archaeological Trust 2001). Most people emptied buckets and pots filled with excretion refuse into streets, the river, or outside of the city's walls (Harmsworth and Canterbury Archaeological Trust 2001). Stour River acted as the main water supply to the city; therefore, dumping refuse into it influenced water pollution (Roberts and Cox 2003; Harmsworth and Canterbury Archaeological Trust 2001). These conditions, along with adverse weather, often induced the spread of infectious diseases (Rawcliffe 2013; Rubin 1974). This section discusses the housing and infrastructure (e.g., water resources, waste management, and markets) conditions of Canterbury as well as famines and disease outbreaks.

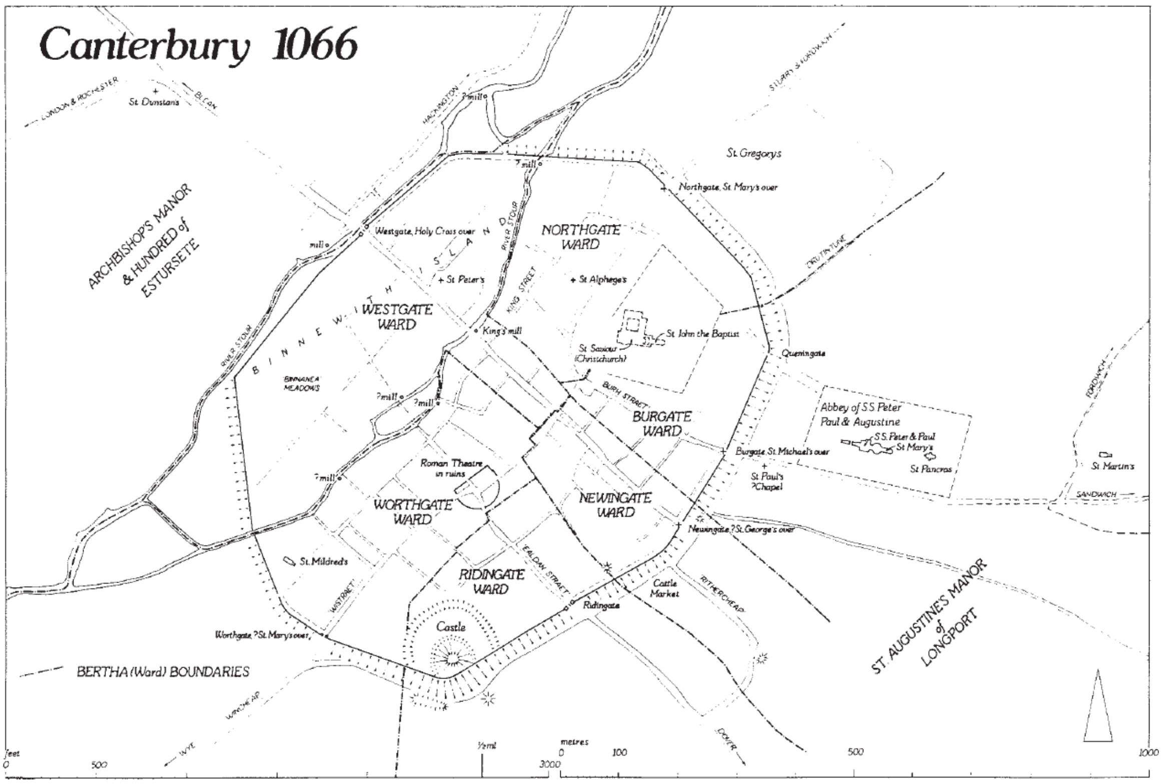



**Figure 1.2** Map of 11th to 12th century Canterbury (Anderson, Hicks and Tatton-Brown 1990)

## 1.2.1 Housing Conditions

Many people lived in wealden style houses that fronted on to streets (Roberts and Cox 2003). These homes were made of only wood or wood and stone with a straw, thatched, or tiled roof (Dyer 1989). The wood were placed in lattice patterns and bounded together with a combination of animal manure, wet soil, and straw (Dyer 1989; Harmsworth and Canterbury Archaeological Trust 2001). The outside walls were painted to make them waterproof (Harmsworth and Canterbury Archaeological Trust 2001). There were two traditional structures for the wealden style houses. The first type of traditional structure was a one story with two rooms, one for cooking or sleeping and another for a living space (figure 1.3) (Dyer 1989). The floor was made of dirt and gravel, and slabs of stones or tiles were set up in the middle of one room to be used for a fire (Harmsworth and Canterbury Archaeological Trust 2001). The second type of traditional structure was a terraced house with two to four floors (figure 1.4) (Roberts and Cox 2003; Dyer 1989; Dyer 2000). The upper floors protruded out above the streets. These types of homes typically cost more than the first type (Harmsworth and Canterbury Archaeological Trust 2001). They had a large living room with a tiled floor, tapestries on the walls, and a hearth (open fireplace) in the middle (Harmsworth and Canterbury

Archaeological Trust 2001). Terraced houses also had private rooms for the family and storage rooms for food and beer (Harmsworth and Canterbury Archaeological Trust 2001). Besides the living room, floors in other rooms were made of dirt, chalk, gravel, or pebbles (Harmsworth and Canterbury Archaeological Trust 2001). Additionally, there would have been a separate room for a kitchen or it was built outside the house to avoid the risk of a fire (Harmsworth and Canterbury Archaeological Trust 2001).

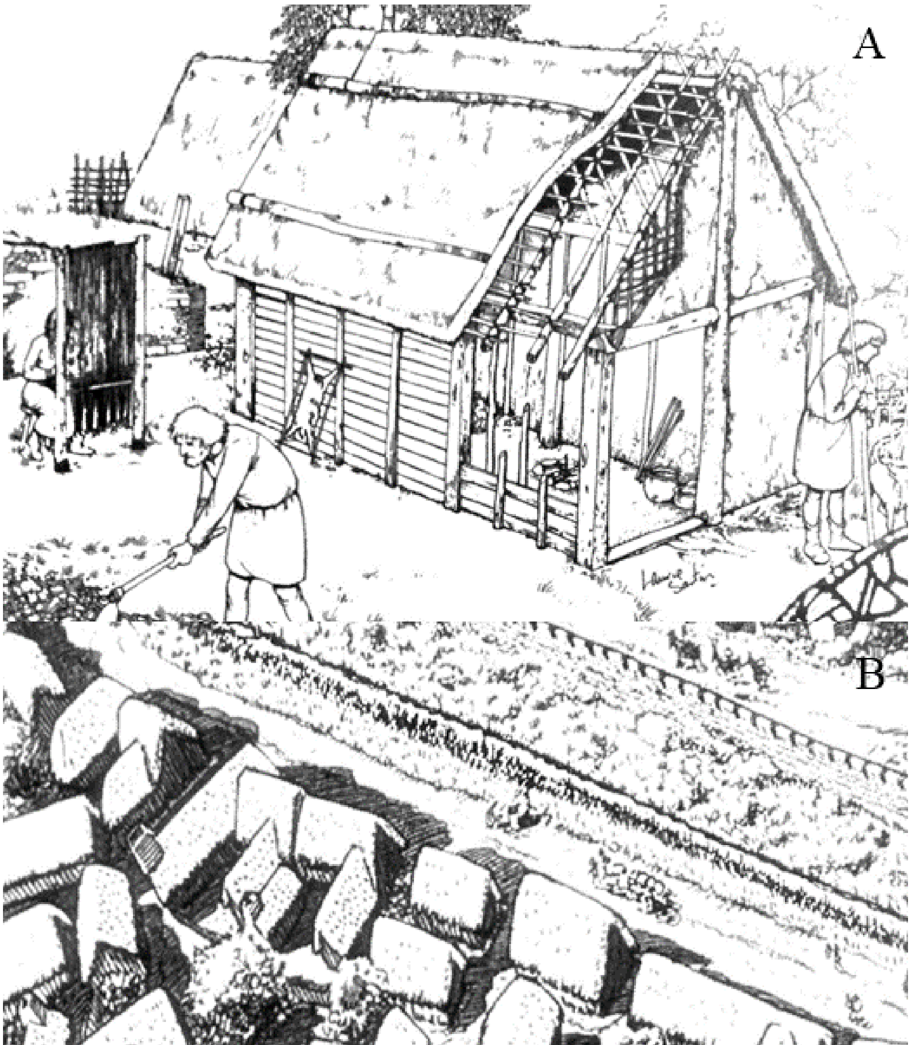



**Figure 1.3** Reconstruction of One Storey Style Wealden Houses. **A**. Example of a One Storey Wealden House (Sartin 2001). **B**. Example of a Community Outside of the City's Wall (Bowen 2001).


**Figure 1.4** Examples of Wealden Style Terraced Houses. **A**. The Three Storey Old Weavers House dating to the 14th century (name given based on Flemish and Huguenot weavers who settled in Canterbury during the 16th and 17th centuries). **B**. Example of Three Storey Terraced Houses on All Saint's Lane near High Street. **C.** Example of Four Storey Terraced Houses Across from the Entrance of the Cathedral.

One storey and terraced houses had doors, small windows with wooden shutters or window panes made of thin sheets of polished horn, and small holes in the rooves for smoke from fires to escape or to keep the inside of the houses at reasonable temperatures (Dyer 1989; Harmsworth and Canterbury Archaeological Trust 2001). Unfortunately, these openings did not prevent gust of winds from entering the homes during the winter, and small windows did not provide much ventilation during the warmer months (Dyer 1989). Smoke from fries would still have been in the atmosphere of the house even with small windows and holes in the rooves.

Hearths were used as the main source of heat within homes (Dyer 1989), but they also caused major fires within the city. After a fire in AD 1174, the monks at Canterbury Cathedral insisted that thatched rooves should be replaced with tile on all nearby buildings (figure 1.5) (Lyle 2002). Housing structures were closely packed with little to no spaces between them (Dyer 1989), which made it easy for fires to spread across the city quickly.

**Figure 1.5** Reconstruction of titled rooves on buildings nearby the cathedral's entrance (Bowen 1991)

Inside homes, animals such as pigs and hens roamed around or were kept in designated areas (Harmsworth and Canterbury Archaeological Trust 2001; Roberts and Cox 2003; Lyle 2002; Dyer 2000). Many terraced houses were homes of craftspeople, and they had separate rooms for their workshops and/or established the first floor of their home as a shop, while the upper floors were used for living spaces (Lyle 2002; Lincoln 1955; Roberts and Cox 2003). Behind houses were private or shared small plots of land for growing vegetables and fruit, to access wells, and/or to utilise cesspits (Roberts and Cox 2003). Shared cesspits, additionally, were in alleyways behind houses (Roberts and Cox 2003). As mentioned above, terraced houses' upper floors protruded above the streets, enabling excretion waste to be dumped straight onto the street from a latrine (Harmsworth and Canterbury Archaeological Trust 2001). As such, excretion refuse would accumulate on the streets below. Houses with upper floors that were situated along Stour River protruded out above the river (Roberts and Cox 2003). Thus, a latrine on the upper floors released excretion waste into the river.

Additionally, some hospitals were situated along the river or on bridges over the river. It was common for medieval English hospitals to be in close proximity to rivers, at the city's gates, or outside of the city's gates along a path that is frequently utilised (Gilchrist 1995; Orme and Webster 1995). Hospitals outside of the city centre had room for building and garden expansion for a cheaper price than those within the city walls (Orme and Webster 1995). Hospitals accommodated those who were poor without means of support by family, those who were ill, travellers, those who were disabled, and pilgrims (usually poor) temporarily or permanently (Orme and Webster 1995; Gilchrist 1995; Laumonier 2022; Ziegler 2018). Some hospitals only provided for specific needs because they could not afford to accommodate everyone (Magilton 2008a; Ziegler 2018; Orme and Webster 1995; Prescott 1992). Hospitals varied in size from 12 to as many as 200 people they could accommodate (Kealey 1981; Laumonier 2022; Prescott 1992).

Hospitals typically had a large hall with beds for inmates, a chapel, living quarters for the staff, a kitchen, and a courtyard (Ziegler 2018; Huggon 2018b; Laumonier 2022). The large hall would have been laid out in the shape of a T or L with side aisles for beds for the inmates and a central aisle for staff to walk and move equipment from bed to bed (Ziegler 2018; Huggon 2018b). The layout of the hall would have allowed the inmates to view the altar and participate in communion and daily mass from their bed (Huggon 2018b). The chapel would have consisted of one or more altars that had oil lamps that burned all day (Ziegler 2018). The courtyard contained a garden with fruits and vegetables, access to the river or wells, and access to other buildings. The living quarters for the staff were separated from the hall for inmates (Huggon 2018b; Prescott 1992; Orme and Webster 1995). Further details on medieval hospitals are discussed in 1.3.3 Perspective of Health section below.

## 1.2.2 Infrastructure

The infrastructure of medieval Canterbury is described as the fundamental systems and social networks that provided resources that supported community life. The infrastructure consisted of water resources, waste management, and markets.

The Stour River was the primary source of water supply (figure 1.6) (Miller and Hatcher 1995; Lincoln 1955), used for mills, drinking water, fishing, household needs such as cleaning and bathing, and industry needs such as cleaning and soaking leather and cloth materials (Havlidis 2016; Rawcliffe 2013; Roberts and Cox 2003; Miller and Hatcher 1995). Buckets and carrying poles attached to buckets were used for transporting water to households and workshops (Havlidis 2016; Rawcliffe 2013; Miller and Hatcher 1995). Wooden buckets and glazed clay pots were used for storing water (Havlidis 2016; Dyer 1989). Mills in Canterbury were all water mills built next to the river with large wheels in the water, which were turned by the river's flow (Harmsworth and Canterbury Archaeological Trust 2001). As the water flowed through the wheels and away from the mills, fish would get trapped in ponds or canals and provided people with a food source (Havlidis 2016). Other water supply sources came from springs or public or private wells (Harmsworth and Canterbury Archaeological Trust 2001). Wells accessed groundwater by a rope attached to a bucket or a pump with a chain attached to two wheels (Havlidis 2016). Canterbury Cathedral used a private, extensive water pipe network throughout the property (Bennett 1983).


**Figure 1.6** Examples of the River Stour accessways. **A**. The Old Weavers House. **B**. Housing next to Westgate. **C.** Westgate Gardens

Water from the water pipes in the cathedral and private and public wells would have been fresh and unrecycled, unlike the Stour River's recycled water. The river was frequently used to dispose of waste such as human and non-human animal excretion refuse, blood and undesirable pieces of butchered animals by butchers, and liquids from dyes by tanners (Miller and Hatcher 1995). Also, when contaminated and rotten food were noticed, people would discard them into the river (Miller and Hatcher 1995). In addition to the river, waste were dumped on the nearest unoccupied plot or in a cesspit behind houses (Rawcliffe 2013; Miller and Hatcher 1995). Public and private latrines were often placed over the river, streams, or designated spots over the streets or neighbouring properties (Dyer 1989; Miller and Hatcher 1995; Rawcliffe 2013). Thus, refuse massively accumulated in these areas and influenced the spread of infectious diseases through breeding grounds for parasitic larvae along streets and in the river (further discussion of this is below in section 1.2.3 Famines and Disease Outbreaks). Swindlers would have also used water from the river, to mix with other liquids, to sell as 'the blood of St. Thomas Becket' at the markets to pilgrims (Miller and Hatcher 1995).

Pilgrims as well as people who lived in Canterbury would have acquired various goods from the markets. Food, beverages, crafts, and other portable resource were typically sold at markets (Miller and Hatcher 1978). Pilgrims could obtain souvenirs of Canterbury and the city's saints from the markets (Lyle 2002). Markets, generally, were weekly and held inside and outside of the city's gates (Lincoln 1955; Harmsworth and Canterbury Archaeological Trust 2001). Local farmers and craftsmen from nearby rural areas travelled to Canterbury weekly to sell produce, and merchants from mainland Europe sold luxury goods such as silks, spices, and jewels (Harmsworth and Canterbury Archaeological Trust 2001; Dyer 2000; Miller and Hatcher 1995). A market called Longmarket covered three streets: Burgate, Butchery Lane, and the Parade (Rady 1990). It is suggested that this market catered to wealthy and influential citizens (Rady 1990). Decorated tableware and pottery such as vessels and jugs from London, the Rhineland, France, Spain, North Africa, and West Asia were discovered from the Longmarket site by Canterbury Archaeological Trust in 1990 (Rady 1990; Harmsworth and Canterbury Archaeological Trust 2001). Other markets include: a market where grains were sold was held on High Street, nearby a market that sold baskets called Rushmarket was held, a market that sold cattle was held outside of Riding Gate, and a town (Wincheap) delegate as a market town sold wine (Lincoln 1955; Harmsworth and Canterbury Archaeological Trust 2001). Additionally, a nearby town called Staplegate was a designated market town (Lincoln 1955).

People in the city had little time to produce their own resources for living such as food, crafts and firewood because of consistently being occupied with their jobs (Dyer 2002; Miller and Hatcher 1995). Most people relied on the markets to obtain goods that their jobs did not produce. Goods were sold from booths, tables, carts, wagons, baskets, barrels, and blankets on the ground (Miller and Hatcher 1995). Ale was sold frequently because it was the safest to drink (Talbot 1967). The food sold at markets were a part of the regular supply of goods. For example, bread, cheese, eggs, seasonings, and a large variety of salted and fresh fish or meat were regularly sold (Talbot 1967). Fish mostly comprised of bream, cod, pike, conger-eel, sturgeon, mullet, herrings, and lampreys (Talbot 1967). Meat included beef, pork, rabbits, mutton, venison, and boars' flesh (Talbot 1967). The primary seasoning was salt, and it was placed on dining tables in everyone's homes (Adamson 2004). Many dishes consisted of some form of soup, broth, or gravy and eaten with bread (Adamson 2004).

The food quality could have been better, considering the meat was cured incorrectly and the bread contained barley or rye contaminated with bacteria and fungi (Rubin 1974). Open food, especially meat, had the tendency to attract flies (Rawcliffe 2013). The insufficient quality of food increased during the poor harvest seasons. This was due to the excessively cold, high winds, and drought weather throughout the year along with the wet summers (Miller and Hatcher 1978). The food supply decreased during this time of crisis, which means either crops did not grow or were contaminated with fungi and bacteria (Adamson 2004).

### 1.2.3 Famines and Disease Outbreaks

The Great Famine and prolonged agricultural crisis occurred from AD 1314 to AD 1334 (Miller and Hatcher 1978; Lincoln 1955; Mate 2010; Pribyl 2017). The wet and cold weather in AD 1314, AD 1315, AD 1319, and AD 1323 as well as the warm year of AD 1318 affected the growth and quality of crops (Rawcliffe 2013; Pribyl 2017). This caused the food supply to tremendously decrease which included fruits, vegetables, and the grains used to make bread (Rawcliffe 2013; Pribyl 2017). It is possible that this event caused people to obtain nutritional deficiencies and become susceptible to infectious diseases (Rubin 1974; Rawcliffe 2013). The Great Famine also influenced the health of livestock to decline (Slavin 2012).

From AD 1319 to AD 1334, Canterbury experienced an increased mortality rate for cattle and sheep (Mate 2010). Cattle and sheep were likely encountered by a zoonotic plague from eating contaminated crops and non-consumable items (Slavin 2012). This affected the food supply of meat to decrease. Consequently, the increase cattle and sheep mortality and poor quality or absence of crops may have left many people with little to nothing to eat. As a result, people either rationed out food or stretched out their supply by adding beans to flour for bread (Adamson 2004; Dyer 2000).

The Great Famine and prolonged agricultural crisis were followed by the Black Death (also known as the Plague or Great Pestilence) in the late AD 1340s. The Black Death was caused by the pathogenic bacterium *Yersinia pestis* that relies on fleas as their vectors to transmit via blood feeding from host to host (Roberts and Manchester 2005; Ben Ari *et al.* 2011). These fleas primarily occupy rodents as their host (Barnes 2005). Bubonic and pneumonic plague were the common types of Black Death. Bacteria transmitted from a flea bite causes the bubonic plague (CDC 2021). Untreated bubonic plague or encountering someone who has pneumonic plague causes pneumonic plague to develop (CDC 2021). The combination of unhygienic waste managements, compact housing structures, domestic animals living spaces within and near homes, and thatched/straw roofs attracted rodents to for dwellings (Dyer 1989; Rawcliffe 2013) and influenced the spread of the Black Death. It became a national threat by causing a decline in the population of England from about four million to less than two and a half million (Lincoln 1955). People swarmed to Canterbury because they believed they would gain Heaven's protection from the Black Death (Lincoln 1955).

In AD 1348, Canterbury's population dropped from ten thousand to 50% and continued to fall as reoccurring outbreaks hit the city (Lincoln 1955). Other record outbreaks occurred in AD 1412 and AD 1447 in Canterbury (Pribyl 2017; Lincoln 1955). During these years, there was a shortage of labour that caused the lack of harvest gathering, death of unattended livestock, acres to flood, and abandoned seawalls and ports (Lincoln 1955). Along with the Black Death, other diseases such as tuberculosis, sweating sickness, typhus, smallpox, dysentery, diphtheria, pneumonia, and measles roamed the urban environment (Talbot 1967; Lyle 2002; Rawcliffe 2013).

Often, viral, bacterial, and parasitic infections would have been confused with each other due to similar symptoms and the lack of understanding of the development and nature of each disease. Bubonic plague symptoms are fever, headache, chills, swollen lymph nodes, fatigue, apathy, delirium, and vomiting (CDC 2021; WHO 2022). Pneumonic plague symptoms are fever, shortness of breath, cough, headache, and sometimes bloody or watery mucous (CDC 2021; WHO 2022). Tuberculosis (fever, cough, fatigue, and bloody mucous), typhus (chills, fever, and headache), diphtheria (swollen lymph nodes, shortness of breath, fatigue, fever, chills, and watery mucous), pneumonia (cough, fever, chills, and shortness of breath), measles (fever, cough, and watery mucous) and typhoid (headache, fever, fatigue, and cough) have similar symptoms to the Black Death (NHS 2019; NHS 2021; CDC 2021; WHO 2022; Mena Lora 2020; Zimmer and Freifeld 2020; Donahue and Eberly 2022; Mandell and Niederman

2022; Barnes 2005). Typhus (a group of closely related diseases) is caused by rickettsia bacteria transmitted to humans by fleas, ticks, lice, or mites that are transferable from rodents, cattle, other non-human animals, and people (Mena Lora 2020). These diseases could have often been confused with the Black Death, and the outbreaks were possibly caused by more than one disease (Talbot 1967; Barnes 2005).

Leprosy is another disease that potentially was common between AD 1050-1350 (Roffey 2012; Burfield 2012). Leprosy, also known as Hansen's disease, is a chronic infectious disease caused by *Mycobacterium leprae* and *Mycobacterium lepromatosis* (Roberts and Manchester 2005; Ortner 2003). It can cause skin lesions to appear and if left untreated they can become quite noticeable (Sermrittirong and Van Brakel 2014). Since the knowledge of various pathological conditions was limited, individuals who had psoriasis, eczema, lupus or any types of skin lesions and scab-related conditions could have been diagnosed with having leprosy. Individuals who had leprosy or experiences symptoms similar would had been admitted into *leprosariums* (further details are discussed in 1.3.3 Perspective of Health section below) (Rubin 1974; Burfield 2012). Leprosy was a disease that had an influence on the social environment.

# 1.3 The Social Environment

The social environment factors that impacted the influences of medieval urbanisation are the pilgrimage culture, social status, and perspectives on health. Shrines were established for saints at Canterbury Cathedral and various churches encouraged people to take pilgrimages to them (Clegg 2003; Lyle 2002; Ekelund *et al.* 1996). The substantial amount of pilgrims that entered the city persuaded people to migrate to provide essential needs for pilgrims. People from different social status groups would have been able to make more than the average living standard compared to other medieval English towns (Dyer 2002). Various social status groups got involved with offering necessities such as accommodation, food, beverages, and souvenirs (Hopper 2002; Lincoln 1955). Accommodations for pilgrims varied from beds in people's homes, inns, and hospitals (Hopper 2002). Some hospitals were specific for either pilgrims or poor and sick people, while others accepted pilgrims, poor, and sick people (Ziegler 2018; Huggon 2018b). Hospitals in medieval Canterbury were Christian-based religious institutions that provided hospitality for those who could not provide for themselves (Sweetinburgh 2010). In many cases, hospitals were viewed as a place where sick people could receive indulgences or a smooth entrance into heaven (Orme and Webster 1995; Roberts and Cox 2003; Huggon 2018b). As a result of churches supporting and ministering to hospitals, clergy who were physicians would have provided medicinal care when thought to have been needed (Rubin 1974). The understanding of physical health was thoroughly connected to religion and the ancient Greek's comprehension of health (Talbot 1967; Rawcliffe 1995; Rawcliffe 2013). This section discusses the pilgrimage culture, social status groups, and health perspectives of medieval Canterbury.

### 1.3.1 Pilgrimage Culture

In AD1220, around 100,000 pilgrims journeyed to Canterbury Cathedral to visit Thomas Becket's shrine (Harmsworth and Canterbury Archaeological Trust 2001; Lincoln 1955; Lyle 2002). This amount of pilgrims continued into the 14th century (Harmsworth and Canterbury Archaeological Trust 2001; Lyle 2002). Canterbury was a popular place for pilgrimages, and this inspired Geoffrey Chaucer, the 14$^{th}$ century English poet, to write *The Canterbury Tales* about various pilgrims' journeys to Canterbury. Pilgrims frequently visited shrines of saints who were thought to have committed a heroic act during their lifetime (Hopper 2002; Webb 2000). Monterey donations would have been given to churches, hospitals, and beggars along the pilgrims' journey to the shrine. Thus, pilgrims expected to receive miracles from the saints whose shrines they visited (Webb 2000). Churches, in return, would provide indulgences to those who donated to them during their pilgrimage (Ekelund *et al.* 1996; Hopper 2002; Sorabella 2011). During the pilgrims' journey in Canterbury, the citizens would have sold them food and beverages at the weekly market or stalls along the streets nearby Canterbury Cathedral (Harmsworth and Canterbury Archaeological Trust 2001; Hopper 2002; Lincoln 1955) and souvenirs such as the pilgrim bell, ampulla, Becket Brooches, and vails filled with fake blood of saints (Miller and Hatcher 1995; Lincoln 1955; Harmsworth and Canterbury Archaeological Trust 2001; Lewis 2014; Canterbury Archaeological Trust 1988). Ampullae were small lead containers that held holy water or oil (Lewis 2014). The pilgrim bell (figure 1.7) was a popular souvenir in Canterbury because it is thought that the cathedral bells rang without being touched when Thomas Becket was murdered (Lewis 2014). In addition, the vails filled with fake blood was portrayed as blood that belonged to Thomas Becket (Harmsworth and Canterbury Archaeological Trust 2001; Lincoln 1955).

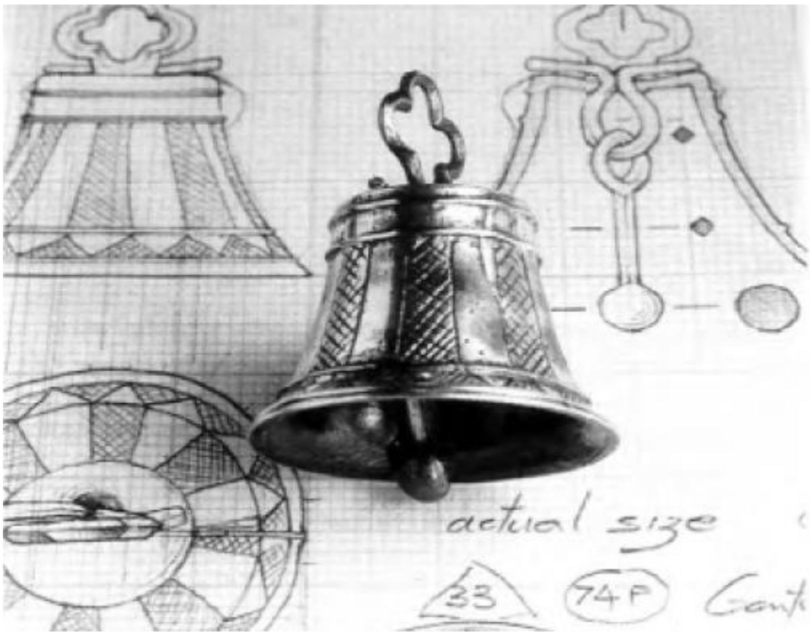



**Figure 1.7** Replica of a pilgrim bell found during excavations against Adelaide Place in 1980 (Canterbury Archaeological Trust 1988)

In addition, accommodation within inns or hospitals would have been provided for pilgrims in return for monetary funds (Lincoln 1955; Page 1926c). Popular inns for pilgrims near Canterbury Cathedral were the Checker of Hope and the Bull (Canterbury Archaeological Trust 1991).The Checker of Hope Inn was a three-storey timber-framed building that extended from the High Street along Mercery Lane to the Buttermarket in front of the cathedral’s entrance (Kent County Council 2023; Canterbury Archaeological Trust 1991). The ground floor had shops with stone cellars (Canterbury Archaeological Trust 1991). The first floor had a dormitory, balcony, and stairs that accessed the courtyard (figure 1.8) (Canterbury Archaeological Trust 1991). Access to the first floor’s dormitory was through the frontage on High Street (Kent County Council 2023). The dormitory had an open hall with hundreds of beds and individual rooms (Kent County Council 2023). Wealthy pilgrims would have stayed in the individual rooms on this floor (Canterbury Archaeological Trust 1991; Kent County Council 2023). The second floor was a dormitory with up to 100 beds under the roof where less wealthy pilgrims would have stayed (Canterbury Archaeological Trust 1991). The Bull Inn extended from Burgate Street to Butchery Lane (figure 1.9) and was built around a courtyard (Canterbury Archaeological Trust 1991). The ground floor contained shops, and the floors above were delegated as the dormitory (Canterbury Archaeological Trust 1991). Canterbury Cathedral had established several inns on Burgate Street, such as The Sun, The Dolphin, The Lion, The Mitre, and The Porpoise (Canterbury Archaeological Trust 1991).

Those who could not afford to stay in an inn would stay for a day or a few days at the Easterbridge Hospital (Page 1926c). Easterbridge Hospital was declared to have been founded by Thomas Becket for poor pilgrims (Page 1926c; Duncombe and Batteky 1785).

**Figure 1.8** 18th century engraving of The Checker of Hope Inn's courtyard with gateway opening to the High Street (Canterbury Archaeological Trust 1991)

**Figure 1.9** Reconstruction of The Bull Inn (Canterbury Archaeological Trust 1991)

## 1.3.2 Social Status

Social status in medieval England was based on those who had the power to control as well as their family and those who frequently interacted or closely worked with them (high-status), and those who did not (low-status) (Bartlett 2000). Royal members, aristocrats such as earls and lords, and clergymen had control over land, properties, and taxes (Dyer 1989). In medieval

Canterbury, the archbishops were the earls and lords which placed them at a higher position compared to other aristocrats in the English society (Lincoln 1955). Other high-status members in Canterbury include clergy members, visiting royal members, and nearby earls and lords (Dyer 1989). Lower status individuals were typically merchants, craftsmen, servants, and beggars (Dyer 1989).

High-status individuals lived in large residences such as Canterbury Cathedral, monasteries, or manors 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; 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; Dyer 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, beverage, 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 the cathedral and monasteries, administrative tasks were predominantly conducted by men (Clegg 2003; Ward 2006). Women were not allowed to participate in any administrative duties including at nunneries (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).

### 1.3.3 Perspective on Health

The concept of health was influenced by the ancient Greeks' understanding of health (Rawcliffe 2013). This idea was introduced by Muslim scholars who translated ancient Greek literature and established the belief that the human body has four humours similar to the earth having four elements (Talbot 1967; Rawcliffe 1995; Rawcliffe 2013; Holzwarth 2019). The four humours, blood (*sanguis*), phlegm (phlegma), yellow bile (chole) and black bile (melancholia), were linked with their own characteristics, internal organs, and elements of the earth (table 1.1) (Rawcliffe 1995; Rawcliffe 2013; Huggon 2018a; Kuropatnicki 2012; Holzwarth 2019). It was believed that the humours and their characteristics had to be kept balanced to maintain good health (Grigsby 2007). Also, it was though that illnesses and diseases would arise when the humours were unstable (Rawcliffe 1995; Rawcliffe 2013; Huggon 2018a). For example, it was believed that if 'polluted' air, bad smells, had been inhaled it would contaminate the heart and travel through the arteries to other vital organs, causing people to become sick or die (Rawcliffe 2013). Physicians recommended removing fluids from the body that were believed to have caused imbalanced humours through bleeding, sweating, regurgitating, and defecating (Holzwarth 2019). Bloodletting was often performed when patients had a fever, and this was done by bleeding from a vein or the application of leeches (Holzwarth 2019). Sweating was achieved by repeated application of hot cloths, patients bundled up with clothes and blankets near a fire, or patients being immersed into hot water (Holzwarth 2019).

**Table 1.1** Humours and their Characteristics and Associations

| *Humours (temperament)* | *Characteristics* | *Internal Organs* | *Earth Elements* |
|---|---|---|---|
| *Blood (sanguis)* | Moistness and warmth | Heart | Air |
| *Phlegm (phlegma)* | Moistness and coolness | Liver | Fire |
| *Yellow Bile (chole)* | Warmth and dryness | Spleen | Earth |
| *Black Bile (melancholia)* | Coolness and dryness | Brain | Water |

It was recommended that fresh air, a moderate amount of exercise, sleep, proper hygiene, a positive attitude toward life, and food would avoid the humours from being unbalanced (Adamson 2004; Holzwarth 2019). The simplest way to regulate a person's humours was through their diet (Adamson 2004; Kuropatnicki 2012). When the seasons changed, it was recommended that diet should change with it (Adamson 2004). During the winter months, warm food such as beef, pork, mutton, venison, and game were suggested to be eaten (Adamson 2004). In the summer, only light and cool food such as young chickens, goat, lamb, lettuce and other potherbs (Adamson 2004). While dry food during spring and warm food in the fall should be consumed moderately (Adamson 2004).

#### 1.3.3.1 Medicine

Monasteries were the centre of the scholarly study of medicine. Clergy translated ancient texts into Latin, grew plants, and distilled liquor, making them leaders in the maintaining health and medicine (Holzwarth 2019). Thus, this influenced the treatment of disease to be a combination of secular and spiritual activities (Holzwarth 2019; Rubin 1974). Since illness was viewed as punishment from God, medicinal remedies were required with Christian prayers and penance when patients were being treated (Holzwarth 2019). Prohibitions were placed upon clergy to forbid them from practising medicine; however, they were not restrictive (Amundsen 1978; Rubin 1974).

Monasteries primarily trained clergy to become physicians during the 11$^{th}$ to 13$^{th}$ century (Rubin 1974). Monastic physicians were expected to maintain a garden that supplied herbs for medications and attend to sick individuals when requested (Rubin 1974). Many of the herbs required for medicines were transported from the Mediterranean (Van Arsdall 2007). The

Anglo-Saxon 'leech', healer, also attended to those who were sick and provided them with remedies of local herbs (Van Arsdall 2007). Monastic physicians often charged more for their services than the local Leech (Rubin 1974), which led to people of lower status reaching out to a leech for healing but rarely (Rawcliffe 1995; Rawcliffe 2013). Remedies were written down in various manuscripts that were personal books or encyclopedias (Kroll 1977). Many remedies were combined with or altered from other physicians and leech work (Van Arsdall 2007). Monasteries had their own infirmaries or supported nearby hospitals for those who were sick (Rubin 1974). They would supply them with medicines and minister to the sick (Rubin 1974).

#### 1.3.3.2 Hospitals and *Leprosariums*

Medieval hospitals were religious and charitable institutions that supported those who could not provide for themselves (Huggon 2018b; Rubin 1974; Orme and Webster 1995). Charitable support was grounded in the Christian belief of hospitality (Huggon 2018b; Orme and Webster 1995). Support included housing pilgrims, nursing the sick, feeding and clothing the poor, and burying the dead (Gilchrist 1995; Sweetinburgh 2010; Roberts and Cox 2003). Canterbury was ideal for hospitals as it consistently interacted with pilgrims and people who migrated to Canterbury for "safety" from diseases and death (Lincoln 1955). Hospitals were often permanent residences for sick and disabled individuals and older adults (Orme and Webster 1995). Hospitals frequently provided for those with specific conditions because they could not afford to provide for everyone (Rubin 1974; Orme and Webster 1995). People who entered hospitals permanently had to follow specific spiritual regulations such as relinquishing possessions, daily prayer, sexual abstinence, and attending mass (Huggon 2018b). Permanent residents would have been bathed with fresh water and provided clean clothing and linens for beds to represent cleanliness and purity before becoming inmates (Orme and Webster 1995; Rubin 1974; Gilchrist 1995). Residents would have been cared for by monks and low-status volunteers, and the hospital was looked after by the masters, who were clergy (Huggon 2018b; Ziegler 2018). Low-status volunteers received accommodation, clothes, and food in return for permanent employment at hospitals (Ziegler 2018; Laumonier 2022). External employees included bakers and cooks who either brought food from their shops or made food at the hospital for inmates and staff (Laumonier 2022).

Hospitals of Canterbury included Easterbridge Hospital (cover of thesis), Poor Priests, St. Lawrence's Hospital, St. John's Hospital, and Cokin's Hospital (Lyle 2002; Sweetinburgh 2010). Easterbridge was established on and around the East bridge over Stour River (Duncombe and Batteky 1785). This hospital only accommodated poor pilgrims (Page 1926c).

St. Lawrence provided for 16 poor individuals in AD 1137 (Page 1926). Over 100 people lived at St. John's Hospital (Duncombe and Batteky 1785). It was located outside of Northgate, and the clergy at St. Gregory's Priory were to provide pastoral care for the inmates (Page 1926c; Hicks 1989; Hicks and Hicks 2001b; Rubin 1974). St. John's had a courtyard, garden, orchard extending to the river, and separate living quarters for men and women (Duncombe and Batteky 1785). A citizen of Canterbury, called William Cokyn, founded Cokin's Hospital, which was established in St. Peter's Parish (Duncombe and Batteky 1785). It provided care for clergy members and widows, and in AD 1203 it became a part of Eastbridge Hospital (Duncombe and Batteky 1785). Poor Priests hospital (figure 1.10) was established in St. Margaret's Parish and accommodated priests without money or possessions (Page 1926c).


**Figure 1.10** Poor Priests Hospital **A**. The Front of the Hospital. **B**. The Back of the Hospital along the Stour River

Since abbots and archbishops established hospitals in Canterbury, the cathedral and churches, along with masters of hospitals, would encourage donations to hospitals (Sweetinburgh 2010). Masters would have utilised donations for the upkeep of the hospital and the care of inmates. With the increase in establishments of leprosy hospitals, called *leprosariums*, between AD 1100 and AD 1250, people saw the need to provide substantial support to these institutions (Horden 2005). Leprosy was a disease regarded as a spiritual and physical affliction connected to sexual sin (Gilchrist 1995).Those who were thought to have had leprosy would have sought out religious penitent through a life of poverty (Rawcliffe 2006; Gilchrist 1995). Often, they would admit themselves into *leprosariums* as they were established in the same capacity as other hospitals requiring inmates to live a life of poverty (Gilchrist and Sloane 2005; Magilton 2008b). *Leprosariums* were located in suburban areas because they were seen as outcasts who committed sin and were discouraged from contact with "healthy" individuals (Gilchrist and Sloane 2005; Magilton 2008b). However, they were visible enough to encourage acts of charity (Huggon 2018b). St. Nicolas's Hospital was a leprosarium of Canterbury located in the suburb Harbeldown (Orme and Webster 1995; Page 1926c; Duncombe and Batteky 1785; Sweetinburgh 2010). Individuals who were admitted were required to give all their possessions to the hospital and not allowed to leave the hospital without permission or to get involved in a quarrel (Page 1926c). St. James Hospital was another *leprosarium* in Wincheap, a suburb of Canterbury (Page 1926c). Women suspected of leprosy were only admitted into St. James Hospital (Page 1926c; Sweetinburgh 2010). This hospital was cared for by a prioress and clergy members (Page 1926c). As a result of women not being allowed to participate in administrative duties or conduct religious and labour services, the clergy members would have provided those services for the hospital.

## 1.4 Summary

The Church influenced urbanization in Canterbury in various aspects, such as Canterbury Cathedral being the centre of theology in southern England and the archbishops performing various heroic acts that were shown to protect the cathedral and city (Clegg 2003). Thus, it motivated clergy to travel from other English towns and European countries for employment and education and inspired pilgrims to visit shrines of saints, many who were archbishops, to request relief from mental or physical pain (Clegg 2003; Webb 2000). As the number of pilgrims who entered the city increased, people decided that they would gain more financial opportunities by migrating to Canterbury and providing pilgrims with beverages, food, and/or souvenirs (Webb 2000; Hopper 2002). Additionally, more job opportunities for servants and labours became available to assist with a trade, craft, or the upkeep of various buildings (Ryan 2013; Dyer 2002). All of these things influenced the physical and social environment of medieval Canterbury.

The physical environment consisted of a dense population with homes and businesses built close together, markets held weekly that provided for citizens and pilgrims, and the primary use of the Stour River as a water resource as well as a waste disposal area (Lincoln 1955; Lyle 2002). These conditions, in addition to adverse weather conditions, influenced disease outbreaks (Rawcliffe 2013). The social environment consisted of receiving donations from pilgrims and providing essential needs for them while they were in Canterbury, living conditions and occupations of social status groups, and the relationship between Christianity and people's perspective on health (Lincoln 1955; Lyle 2002; Rubin 1974; Dyer 2002). To conclude, the social and physical environment was heavily influenced by the atmosphere of the Church within Canterbury and pilgrims.

# 1.5 Aim and Objectives

Urban health concerns itself with the relationship between the determinates of health (e.g., social and physical environments and specific conditions or circumstances within social and physical environments) and health indicators (e.g., mortality, infectious diseases, and mental health) within the urban context (Galea and Vlahov 2005; Harpham 2009; Ettman, Vlahov and Galea 2019). Health indicators include but are not limited to noncommunicable diseases, injuries and interpersonal violence, infectious diseases, mortality, fertility, mental health, children's nutrition and growth (Harpham 2009). Infectious diseases (Boldsen 2001; Kelmelis and Dangvard Pedersen 2019; Fonzo, Scott and Duffy 2020; Knorr *et al.* 2019; Sundman and Kjellström 2013; Walker *et al.* 2015; Toyne, Esplin and Buikstra 2020), nutritional diseases (Brickley, Mays and Ives 2007; Lewis 2010; Redfern, Millard and Hamlin 2012; Peacock *et al.* 2019), mortality and survivorship (Walter and Dewitte 2017; Betsinger *et al.* 2020; Lewis and Gowland 2007; Nagaoka *et al.* 2019; Redfern *et al.* 2015; Gamble 2020; Palubeckaite, Jankauskas and Boldsen 2002; Espinoza and Morfín 2015; Bourbou 2018; Reedy 2020; Yaussy, DeWitte and Redfern 2016), and children's growth (Arthur, Gowland and Redfern 2016; Lewis 2016; Cardoso *et al.* 2018; Mays, Ives and Brickley 2009; Newman, Gowland and Caffell 2019; Newman and Gowland 2017; Cardoso and Garcia 2009; Ives and Humphrey 2017; Geber 2016; Geber 2014) are indicators of health that are often used for osteoarchaeological research on urban health in the past. Osteoarchaeological studies on medieval English urban centres have reported that physical and social environmental conditions adversely affected the health of people (Walter and Dewitte 2017; Lewis, Roberts and Manchester 1995b; Roberts and Manchester 2005; Stone *et al.* 2009; Ives and Humphrey 2020; Agarwal 2012). Hence, studies have found that childhood growth was negatively impacted (Lewis 2016), people were at risk of obtaining pathological conditions (e.g., nutritional diseases, infectious diseases, and activity-related conditions) (Lewis 2016; Shapland, Lewis and Watts 2015; Stone *et al.* 2009; Roberts and Manchester 2005), and people had low survivorship and high mortality patterns (Walter and Dewitte 2017).

### 1.5.1 Childhood Growth

There are very few studies on childhood growth in medieval English urban centres; however, they focus on comparing sites from medieval and post-medieval England to provide insight into changes in growth patterns over time (Lewis 2002; Pinhasi *et al.* 2006). Lewis (2002) found that the femur lengths of individuals from 18$^{th}$ to 19$^{th}$ century Spitalfields (London) in the south were significantly shorter than those from medieval St. Helen-on-the-Walls (York) in the north, and suggested this was the consequence of detrimental conditions associated with industrialization. Pinhasi and colleagues (2006) identified deficiencies in growth values in industrial Broadgate (London) compared to medieval Raunds Furnells and industrial Spitalfields (London), with medieval St. Helen-on-the-Walls (York) having higher growth values than all three comparative groups. They suggested that socioeconomic status had a major impact on growth due to the availability of food resources, infant feeding practices, and health practices (Pinhasi *et al.* 2006). These studies do reveal that detrimental living environmental conditions in the past potentially influenced growth deficit patterns. Adverse conditions such as unhygienic waste management (e.g., waste dumped onto the streets or nearest unoccupied plot) and air and water pollution (e.g., waste disposal into the, Stour River, primary water supply and small windows and holes in rooves for fires from hearths to escape) in medieval Canterbury potentially influenced the chain reaction of infections to the lack of adequate nutrition (i.e., adequate proportions of lipids, proteins, and essential minerals and vitamins) to slow growth.

Childhood growth has been suggested to be strongly influenced by nutrition and pathological conditions (Gosman 2012). Adequate nutrition promotes hormones that regulate bone growth (Gosman 2012). Inadequate nutrition can slow down the normal bone growth process (Lejarraga 2012). Pathological conditions can influence inadequate nutrition by compromising the immune system and require the body to need twice as much of essential nutrients (Barnes 2005; Law 2005; Patel 2008) or become caused by inadequate nutrition through the lack of required nutrient intake such as vitamin D, calcium, and iron (Lejarraga 2012; Hans and Jana 2018). Thus, periods of inadequate nutrition and pathological conditions can result in periods of slow childhood growth (Ulijaszek and Strickland 1993; Lejarraga 2012). Interior air pollution concerning the poor ventilation from hearths inside medieval Canterbury homes may have influenced respiratory infections and disorders. Also, waste disposal into the Stour River, streets, and unoccupied plots provided breeding grounds for parasites (Barnes 2005). Parasitic infections, respiratory infections, and respiratory disorders negatively impact the immune system; thus, the immune system requires a substantial amount of nutrients, such as antioxidants and vitamins, to stimulate the cells in the immune system to fight off and/or adapt to these conditions (Shea-Donohue, Qin and Smith 2017; Berthon and Wood 2015). Hence, pathological conditions influenced by air and water pollution and unhygienic waste management in medieval Canterbury perhaps had a negative impact on childhood growth.

### 1.5.2 Pathological Conditions

There are various studies on pathological conditions such as the Black Death, leprosy, and tuberculosis in medieval urban settings (DeWitte and Wood 2008; Roberts and Cox 2003; Rawcliffe 2013; DeWitte 2014c; DeWitte 2015; Boldsen and Mollerup 2005; Kelmelis and Dangvard Pedersen 2019; Godde, Pasillas and Sanchez 2020; Kelmelis *et al.* 2020; Betsinger *et al.* 2020; Robb *et al.* 2021). However, studies on Black Death use skeletal collections that were designated Black Death burials. There is no known evidence that the Black Death affects the skeleton, thus, making it difficult to identify it in skeletal collections that were not designated Black Death burials. On the other hand, pathological conditions such as leprosy and tuberculosis affect the skeleton. However, studies on leprosy and tuberculosis focus on the prevalence of the diseases within urban centres rather than the relationship between the conditions and urbanisation (Ell 1988; Boldsen and Mollerup 2005; Kjellström 2012; Dangvard Pedersen *et al.* 2019; Kelmelis and Dangvard Pedersen 2019; Larentis and Tonina 2021). Therefore, leading to a minimal understanding of the relationship between pathological conditions and urbanisation in medieval England.

Skeletal lesions (i.e., abnormal skeletal characteristic) develop on bone during the advanced stages of pathological conditions that affect the skeletal system (Ortner 2003). When diseases produce distinctive lesions on the skeleton, it can be assumed that they are specific to the disease that developed it, but multiple diseases can produce the same lesions (Ortner 2003; Roberts and Manchester 2005). Skeletal lesions produced by multiple diseases are called non-specific skeletal lesions (Roberts and Manchester 2005). Often non-specific skeletal lesions are used in osteoarchaeological research for identifying frailty (in the sense of susceptibility to mortality) during famines and the Black Death (Dewitte and Bekvalac 2011; DeWitte 2014b; Yaussy, DeWitte and Redfern 2016; DeWitte 2017; Yaussy 2019; Betsinger and DeWitte 2017; Yaussy and DeWitte 2018; Betsinger *et al.* 2020). A study found that individuals with periosteal new bone were less susceptible to mortality during the famine than those without them (Yaussy, DeWitte and Redfern 2016). Also, individuals with linear enamel hypoplasia were more susceptible to mortality during the famine than those without in medieval London

(Yaussy, DeWitte and Redfern 2016). A study on the Black Death in medieval London found individuals with periosteal new bone on the tibiae, porotic hyperostosis, cribra orbitalia, and linear enamel hypoplasia were more susceptible to mortality during the Black Death than those without those skeletal lesions (DeWitte and Wood 2008). However, these studies compare individuals with lesions to individuals without them.

According to the 'Osteological Paradox', comparing individuals with lesions to those without would cause misinterpretations of inferences due to the relationship between hidden heterogeneity and selective mortality (Wood *et al.* 1992). Hidden heterogeneity is the aspects of individuals that are not observable on the skeleton, such as behavioural and cultural factors, exposure levels to disease vectors, and immune system functions (Wood *et al.* 1992; DeWitte and Stojanowski 2015; Milner and Boldsen 2018). Hidden heterogeneity persuades selective mortality by causing individuals with the highest susceptibility to disease and death at a specific age to be selected to die out of the population, most likely at that age (DeWitte and Stojanowski 2015; Milner and Boldsen 2018). Thus, comparing individuals with skeletal lesions to those without them would imply that those without were healthier than those with skeletal lesions (Ortner 1991; DeWitte and Stojanowski 2015). However, it is suggested that individuals with skeletal lesions were healthier than those without them because they survived long enough for the lesions to develop (DeWitte and Stojanowski 2015; Milner and Boldsen 2018). Additionally, individuals without skeletal lesions perhaps did not encounter the same pathological conditions as individuals with them. Also, individuals without skeletal lesions perhaps had different biological immune responses than those with skeletal lesions. A study identified that not all siblings with shared genes developed linear enamel hypoplasia in line with the same unfavourable environmental conditions (Lawrence *et al.* 2021). This demonstrates Wood and colleagues (1992) conclusion that the susceptibility to disease and death varies within populations. Thus, various misinterpretations can be implied when comparing those with and without skeletal lesions.

A non-specific skeletal lesion commonly found in skeletal collections is periosteal new bone on the tibiae (Weston 2012; Roberts 2019). Periosteal new bone is caused by various conditions such as, but not limited to, tuberculosis, leprosy, treponemal diseases, and parasitic infections (Weston 2012; Roberts 2019). These conditions can be influenced by socioeconomic status, population crowding, dense housing and structural communities, unhygienic waste management, and poor sanitation practices (Roberts and Cox 2003; Rawcliffe 2013). Examining periosteal new bone on the tibiae could show the relationship between multiple pathological conditions and urbanisation. Medieval Canterbury had a heavy population; people lived in close proximity to churches, neighbours, jobs, and markets; waste was disposed of into the river and onto unoccupied plots or neighbouring buildings; and the water from the river would have been used for drinking, bathing, and cleaning (Lincoln 1955; Lyle 2002). These conditions would have placed people at risk of obtaining multiple infectious diseases.

### 1.5.3 Survivorship and Mortality Risk Patterns

Studies on survivorship and mortality patterns have primarily focused on medieval London (DeWitte 2015; Yaussy and DeWitte 2018; DeWitte 2014c; Yaussy, DeWitte and Redfern 2016; DeWitte 2010; DeWitte *et al.* 2015; DeWitte 2017; Dewitte, Boulware and Redfern 2013; Godde and Hens 2021; Godde, Pasillas and Sanchez 2020). DeWitte (2017, 2015) found that individuals had low survivorship and high risk of mortality before the Black Death in medieval London. It is suggested that during the $13^{th}$ century, the population's health declined and caused high mortality patterns during the Black Death (DeWitte 2015; DeWitte 2017). Godde and colleagues (2020) found that individuals with one or more skeletal lesion had a higher risk of dying from the Black Death compared to those without skeletal lesions. They suggest that mortality was selective towards those who experience stress in early life due to adverse exposures (Godde, Pasillas and Sanchez 2020). Yaussy and colleagues (2016) found no significant difference between males' and females' mortality risk during famine and non-famine periods before the Black Death. Although, they found males had a lower mortality risk during non-famine periods after the Black Death (Yaussy, DeWitte and Redfern 2016). They suggest either the Black Death targeted vulnerable individuals or diets and living conditions improved, which increased individuals' chances of surviving the Black Death (Yaussy, DeWitte and Redfern 2016).

These studies use hazard and survivorship analyses to generate mortality patterns as an alternative to life tables. A life table is a table that shows the probability of an individual dying at a particular age within a population (Namboodiri and Suchindran 1987). Life table estimates of age-specific mortality were commonly used in the early years of identifying mortality patterns in osteoarchaeological studies (Wood *et al.* 1992; DeWitte and Stojanowski 2015; Boldsen, Milner and Ousley 2021). However, life tables require a lot of data, and osteoarchaeological skeletal collections are relatively small (Boldsen, Milner and Ousley 2021). Thus, utilising life tables to estimate mortality patterns would cause misinterpretations (Boldsen, Milner and Ousley 2021). Alternatively, age-at-death distributions were used for identifying mortality patterns (Wood *et al.* 1992; Wilson 2014). However, doing so assumes that the populations the skeletal collections are from were stationary (i.e., consistent population size) (Wood *et al.* 1992; Wright and Yoder 2003). As Wood and colleagues (1992) reported in the 'Osteological Paradox', demographic nonstationarity means that population sizes usually change. Thus, age-at-death distributions reflect fertility rather than mortality patterns (Wood *et al.* 1992; Wright and Yoder 2003).

As an alternative to age-at-death distributions and life tables, hazard and survivorship analyses are better for identifying mortality patterns. Hazard and survivorship analyses are statistically more powerful for small data (DeWitte 2018; Boldsen, Milner and Ousley 2021). Hazard analyses estimate the mortality and survivorship mathematical functions and age-at-death distributions (DeWitte 2018). Survivorship analyses estimate mathematical survivorship function and age-at-death distributions (Stel *et al.* 2011a; Stel *et al.* 2011b). Many osteoarchaeological studies use hazard and/or survivorship analyses to recognise the relationship between mortality and urbanisation (Redfern *et al.* 2015; DeWitte 2015; DeWitte 2014a; Dewitte, Boulware and Redfern 2013; Walter and Dewitte 2017; Yaussy and DeWitte 2018; DeWitte 2014c; Redfern and Dewitte 2011; Betsinger *et al.* 2020; Godde, Pasillas and Sanchez 2020; Godde and Hens 2021; Yaussy, DeWitte and Redfern 2016). Walter and DeWitte (2017) found that adults from medieval London had a higher risk of mortality and lower survivorship compared to those from rural Barton-upon-Humber, Lincolnshire. They suggest that the dense population, unhygienic waste management, and compact housing condition in medieval London were detrimental to the individuals health (Walter and Dewitte 2017). Similarly, medieval Canterbury had a dense population, compact housing structures, and unhygienic waste management. Thus, the urban environment in medieval Canterbury may have had a negative impact on survivorship and mortality patterns.

### 1.5.4 Summary

Medieval Canterbury's urban environment consisted of, but was not limited to, a dense population that caused people to live in compact housing structures, poor ventilation from hearths inside homes, the disposal of waste into the river and unoccupied plots, and markets that sold contaminated food (Rubin 1974; Dyer 1989; Lincoln 1955; Miller and Hatcher 1995; Roberts and Cox 2003). These conditions would have placed people at risk of obtaining parasitic infections, respiratory infections, respiratory disorders, and communicable diseases (Roberts and Cox 2003; Barnes 2005; Rawcliffe 2013). These pathological conditions would have become chronic, negatively impacting childhood growth, survivorship, and mortality patterns in medieval Canterbury. Thus, it can be assumed that Canterbury's urban environment had a negative impact on urban health.

Therefore, the aim of this thesis is to identify urban health in medieval Canterbury. This research achieves this aim through the following objectives:

1. To compare and assess childhood growth profiles of Canterbury to other medieval English towns.
2. To identify potential pathological conditions people obtained by investigating periosteal new bone patterns of adults.
3. To explore survivorship and mortality risk patterns of adults and non-adults.

## 1.6 Overview of Thesis

This thesis is composed of six chapters. Chapter 1 introduced this research and provided a historical background review of medieval Canterbury. Chapter 2 describes the materials and methods that were used for the three data chapters (chapter 3, 4 and 5). Each data chapter reflects the objectives of the thesis. Chapter 3 compares and assess childhood growth profiles of Canterbury to other medieval English towns by exploring settlement type analyses. Chapter 4 identifies potential pathological conditions people had by investigating age-related periosteal new bone patterns of adults and examining associations with social status, biological sex, and other skeletal lesions. Chapter 5 explores survivorship patterns of non-adults by social status groups and adults by biological sex and social status groups. Chapter 6 discusses the findings and their contribution to the aim, acknowledges the limitations, suggests future directions of this topic, and provides the conclusion of this thesis.

# Chapter 2 Materials and Methods

St. Gregory's Priory (11th to early 16th century) skeletal collection held in the Human Osteology Research Laboratory at the University of Kent was analysed to identify urban health in medieval Canterbury. Individuals from the skeletal collection were examined for age-at-death and biological sex. The data collected from the age-at-death estimations and biological sex assessments were utilised for statistical analyses. All analyses were conducted in the Human Osteology Research Laboratory at the University of Kent. This chapter discusses the history of and excavations of the burials from St. Gregory's Priory and specific age-at-death estimation, biological sex assessment, and statistical methods used for this research.

## 2.1 St. Gregory's Priory

### 2.1.1 History

In AD c.1084, Archbishop Lanfranc founded the church of St. Gregory on Northgate road as a sister establishment to St. John's Hospital (Hicks and Hicks 2001b; Sparks 2001; Cowdrey 2003; Orme and Webster 1995; Hicks 1989). The foundation charter of St. Gregory's included the ownership of St. Mary's (over Northgate), Holy Cross (over Westgate), and St. Dunstan's (outside of Westgate) parishes (Tatton-Brown 1995; Hicks 1989). St. Gregory's was a community of six priests and twelve clerks who heard confessions, ministered to sick individuals, performed baptism, supervised a singing and grammar school, and provided burial services (Hicks and Hicks 2001b; Sparks 2001; Cowdrey 2003; Rubin 1974; Tatton-Brown 1995; Hicks 1989). In AD 1085, the body of St. Eadburg, possibly the Abbess of Minster-in-Thanet (AD c.730-751), was supposedly transferred to St. Gregory's and by AD 1088, the body of Eadburg's predecessor at Minster, St. Mildred, were also claimed by the clergy to be held there (Hicks and Hicks 2001b; Hicks 1989). However, St. Mildred's body was at St. Augustine's Abbey and there is no information as to who St. Eadburg was (Sparks 2001). It is possibly that St. Eadburg was confused with the daughter of Kentish King Ethelbert, Etherlburg foundress of Lyminge (Sparks 2001).

In AD 1133, Archbishop William de Corbeil installed Augustinian cannons, in place of Lanfranc's clergy, transforming St. Gregory's into a priory (Hicks and Hicks 2001b; Sparks 2001; Hicks 1989). The priory was burnt down in AD 1145 and it was rebuilt with the help of Archbishop Theobald (1139-61) (Hicks 1989). St. Gregory's was closely connected with their patron and the archbishop (Hicks 1989). The archbishop's treasury and archives were kept there, and it was the centre for all important diocesan records from at least late 13th century

(Hicks 1989; Tatton-Brown 1995). It also accommodated important visitors of the archbishop, and there is record of some sessions of the archbishop's consistory court being held there in the later medieval period (Hicks 1989; Tatton-Brown 1995). St. Gregory's provided burial service free of charge for low-status people within the cemetery (Hicks and Hicks 2001b; Tatton-Brown 1995; Sparks 2001). Wills established in the late medieval period mentions people were requesting to be buried within the priory (Tatton-Brown 1989). For example, an AD 1478 will of Geoffrey Holman of St. Mary's parish (priest), an AD 1483 will of Henry Trewonwall (registrar of the consistory of Canterbury), and an AD 1495 will of Alice Consaunt (ordered her to be buried beside her husband) requested that these individuals be buried within the priory (Tatton-Brown 1989). Wills were provided mostly for wealthy people in church courts (Wray and Cossar 2012). Thus, those of high-status would have been buried within the church and later priory (Hicks 1989; Hicks and Hicks 2001b). St. Gregory's cemetery was the burial ground for St. John's Hospital, St. Mary's parish and other parishes until the late 16$^{th}$ century (Tatton-Brown 1995; Sparks 2001).

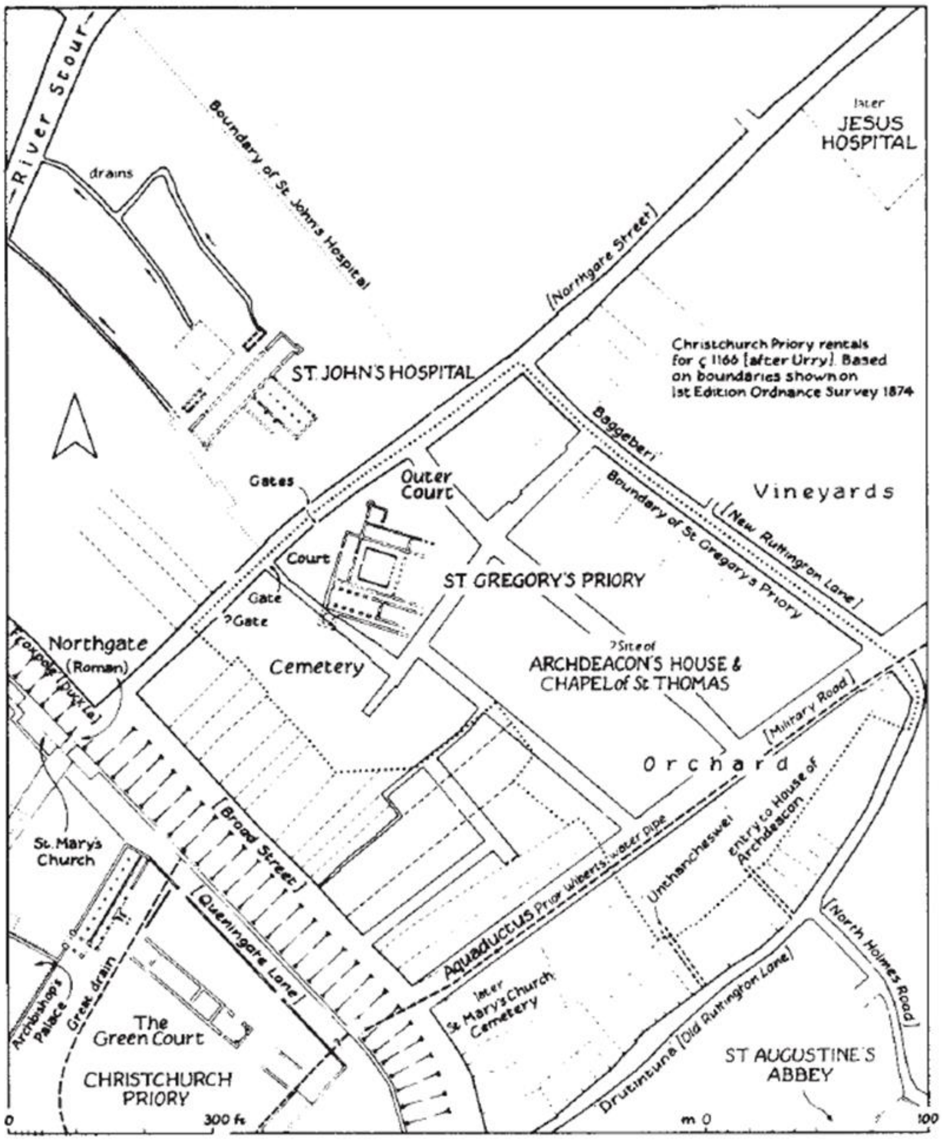



**Figure 2.1** Map of mid-12th century North East Canterbury (Anderson, Hicks and Tatton-Brown 1990)

## 2.1.2 Excavations of Burials

In 1988, the project excavations conducted by Canterbury Archaeological Trust (CAT) consisted of uncovering the building complex of St. Gregory's Priory (Bennett 1988). The demolition of a vacated Post Office building and associated car park revealed the layout of St. Gregory's structure as well as an associated cemetery (Bennett 1988; Anderson 1989; Anderson, Hicks and Tatton-Brown 1990). This site consisted of three phases (Anderson 1989; Anderson, Hicks and Tatton-Brown 1990). The first phase was in August of 1988, the second was in December of 1988, and the third was in May of 1989 (Anderson 1989; Anderson, Hicks and Tatton-Brown 1990). Art-historical dating of moulding and tooling marks of building stones was used for dating St. Gregory's Priory (Hicks and Hicks 2001a). Based on the dating technique, the Lanfranc foundation is suggested to have been c.1084 – 1145, and the later priory (Theobald's reconstruction) is suggested to have been c.1145 – 1537 (Hicks and Hicks 2001a). A graveyard was discovered with Lanfranc's foundation (Hicks and Hicks 2001b; Anderson and Andrews 2001). Additional graves were discovered within Lanfranc's foundation and the later priory (Hicks and Hicks 2001b; Anderson and Andrews 2001). A coffin burial discovered inside the later priory revealed an individual with a gold thread attached to the right phalanges, lower right ulna, right and left metacarpals, lowest four thoracic, upper three lumber, and lower ribs (Hicks and Hicks 2001a). This burial also had a chalice that was located above the pelvis (Hicks and Hicks 2001a). A conservator from the Textile Research Associates concludes that the gold thread and chalice display a burial of a priest and suggest that this individual was a priest (Hicks and Hicks 2001a). The conservator also suggested that the gold thread is from the 11th or 12th century (Hicks and Hicks 2001a). An elongated D-shaped iron buckle with a central pin was discovered in another burial inside the later priory (Hicks and Hicks 2001a). The conservator concludes that the iron buckle would have been clasped by a garment of fine wool twill, which is rare in medieval burials (Hicks and Hicks 2001a). It is suggested that this burial represents an individual of high-status which would have been worn by high-status non-clergy members (Hicks and Hicks 2001a). The conservator suggests that the iron buckle is from the 14th or 15th century (Hicks and Hicks 2001a). Burials from outside the priory were within the matrix of a standard late medieval form, did not have any evidence of grave goods, and could not be easily dated (Hicks and Hicks 2001a). The associated graveyard of Lanfranc's foundation was partially investigated in 1988 due to the project's research plan and budget (Hicks and Hicks 2001b). The excavation of the cemetery was completed in 1989 (Houliston 1989). A total of 1,342 articulated skeletons were excavated from the cemetery, church, and later priory (Anderson and Andrews 2001). 91 burials were associated with the church and priory (Anderson and Andrews 2001). Table 2.1 is provided below to show the distribution of the cemetery and priory graves.

**Table 2.1** Distribution of the cemetery and priory graves

| Site Phase Code | Number of Individuals | Geographic Location | Location on Site | Dates |
|---|---|---|---|---|
| NGA88 | 1,251 | Canterbury, UK (outside of Northgate) | Cemetery | Late medieval period |
| NGB89 | 91 | Canterbury, UK (outside of Northgate) | Graveyard associated with the church, the church and later priory | Church (c.1084-1145)<br>Priory (c.1145-1537) |

### 2.1.3 Previous Analysis, Classification of Individuals, and Ethical Considerations

St. Gregory's Priory skeletal collection was selected because of financial constraints, as the bulk of the collection is held at the University of Kent. A portion of the collection is held at CAT. The majority of the collection is held at the University of Kent due to a loan agreement with CAT and the School of Anthropology and Conservation. Due to time and financial constraints and lockdown due to COVID, the portion held at CAT was not examined for this thesis.

Previous research on this collection includes Trevor Anderson and Jon Andrews's contribution to *St. Gregory's Priory, Northgate, Canterbury Excavations 1988-1991* monograph to discuss the examination of the individuals who were buried in Lanfranc's foundation's associated graveyard, Lanfranc's foundation, and later priory combined. They discuss skeletal preservation, burial demographics, metric analysis, non-metric variation, and paleopathology (Anderson and Andrews 2001). Additionally, cases of arthrogryposis multiplex (Anderson and Thomas 1997) and cleft lip and plate (Anderson 1994) was researched on this collection. Other research consists of understanding biorhythms (Pitfield 2019), behaviour from bone histology (Miszkiewicz 2014;Walker *et al.* 2019), and enamel microevolution (Aris 2020).

Skeletal reports were created only for burials from the church and later priory by Trevor Anderson commissioned by CAT. However, the skeletal reports do not represent the remains in each box as the reports show different results from what is seen in the boxes. Additionally, no skeletal reports were created for burials from the cemetery (A. Teoaca 2023, personal communication, 16 January). Thus, analysis was redone for individuals from the church and later priory, and new analysis was done for individuals from the cemetery. By virtue of the burial charges being free in the cemetery and also being the burial ground for other parishes and St. John's Hospital, individuals from the cemetery will be classified as low-status in this thesis. Also, because of the grave goods found during excavation and late medieval people's wills requested burials within the priory, individuals from the church and later priory will be classified as high-status in this thesis. Furthermore, throughout this thesis, the graveyard associated with the church, burials within the church, and later priory will be classified as one unit (the priory) due to the sample size. Table 2.2 shows the distribution of males, females, and non-adults from the cemetery and priory.

This skeletal collection does not require any ethnical examination such as the Human Tissue Act 2004. The Human Tissue Act 2004 regulates the removal, storage, and use and disposal of human tissue (The National Archives 2004). This regulation comprises of materials 100 years old or less (The National Archives 2004). The individuals a part of the collection are more than 100 years old.

**Table 2.2** Distribution of males, females, and nonadults from the cemetery and priory.

| **Burial Location** | **Number of Adult Males** | **Number of Adult Females** | **Number of non-adults** |
|---|---|---|---|
| Cemetery | 262 | 283 | 251 |
| Priory | 30 | 17 | 27 |

## 2.2 Age-at-Death Estimation

Age-at-death estimation methods identifies, the skeleton's biological change associated with time and activity, biological age (Uhl 2013), rather than, the time passed since the birth of the individual, chronological age (Nikita 2017), of human skeletal remains. It is difficult to identify chronological age from archaeological remains because of the lack of birth and death documents on every individual in the past. Therefore, biological age-at-death is recorded from archaeological skeletal remains. Skeletons can be influenced by biomechanical load and physiological stress which leads to them manifesting older or younger characteristics than biological age. This makes is difficult to give precise age-at-death estimates for skeletal remains (Nawrocki 2010). Adult age estimates are mostly affected by this because methods are based on degenerative changes of different skeletal elements. In contrast, age estimates of non-adults rely on the development of various skeletal elements. The following sections discusses the age-at-death estimation methods, that minimise major errors in measuring age, that were used for this research.

## 2.2.1 Non-adult Age Estimation

The three standard techniques to estimate ages of non-adults are dental development and eruption (Ubelaker 1978; AlQahtani, Hector and Liversidge 2010), measurement of a long bone length (Maresh 1970; Fazekas and Kósa 1978), and the fusion stages of the epiphyses and apophyses (Scheuer and Black 2000; Cunningham, Scheuer and Black 2016; Ortner 2003). Dental development and eruption and long bone length measurements were used for this study. By reason, dentition and long bones are more likely to survive an archaeological environment compared to epiphyses and apophyses (Turner-Walker 2008; Cardoso 2007). Also, the development and eruption of dentition have been commonly regarded as the most accurate non-adult age estimation method (Brickley 2004; Buckberry and Brickley 2017). Therefore, dentition and long bones were examined for estimating age-at-death of non-adults. If neither of the methods were applicable due to preservation constrictions, then individuals were not included in this research.

### 2.2.1.1 Dental Development and Eruption

Dentition evolves in a predictable rate based on its formation and eruption (AlQahtani, Hector and Liversidge 2014). Humans develop only two different sets of teeth: deciduous, which develops throughout childhood, and permanent (Ubelaker 1978; AlQahtani, Hector and Liversidge 2010). Developmental stages of deciduous to permanent crowns and roots are displayed on dental age charts to estimate ages of non-adults (AlQahtani, Hector and Liversidge 2014). These can be used for estimating ages from utero to early adulthood (AlQahtani, Hector and Liversidge 2014). The most commonly used chart was produced by Ubelaker (1978). Ubelaker created a chart based on Native American prehistoric dental data combined with Schour and Massler's (1941) work to be used in osteoarchaeological contexts. On account of the development of dentition varying by population, the Ubelaker dental chart would cause issues with age estimation accuracy on British prehistoric skeletal remains.

Individuals from different populations may develop dentition at different rates. Therefore, to use the Ubelaker dental chart for this research would produce Native American age standards rather than British. AlQahtani and colleagues (2010) produced a dental chart and table, the London Dental Atlas, using British archaeological, modern, and radiographical materials. It displays the progression of dental development and eruption from 30 week in utero to 23 years of age. AlQahtani and colleagues (2010) modified Moorrees and colleagues (1963a; 1963b) crowns and roots developmental stages and Bengston's (1935) eruption stages for the chart to provide details on single and multirooted teeth resorption, formation, and completeness. This is useful for estimating non-adult ages of archaeological remains when teeth are displaced from the alveolar bone of the maxilla and/or mandible. For these reasons, age estimations of non-adults were examined using the London Dental Atlas. Individual were given an age range based on dental development and eruption.

#### 2.2.1.2 Long Bone Length Measurement

It has been suggested that there is a linear relationship between long bone lengths and age. This is mostly true for individuals under the age of 1 year. These individuals are either experiencing their mother's diet or weaning and become less susceptible to external factors that affect their growth (Dewey 2001). Non-adults aged 1 year and older, growth is affected by external factors after being weaned (Shaoul, Tiosano and Hochberg 2016). This causes non-adults under the age of 1 year to be more accurate than the ones 1 year and older. Data tables are often used for estimating ages of non-adults in various stages. The most commonly utilised data tables for non-adults age estimations based on long bone length measurements were created by Fazekas and Kósa (1978) for foetuses and Maresh (1970) for infants and adolescents (Cunningham, Scheuer and Black 2016).

Fazekas and Kósa (1978) constructed data tables based on the means of individuals crown heel length. An issue with this method is that the individuals used for the analysis were of unknown age (Lewis 2007). Scheuer and colleagues (1980) noticed that measurements of long bone length produce more accurate age estimations than crown-heel length. They established linear regression equations based on diaphyseal lengths of long bones combined with dental development of British foetuses (table 2.3). Therefore, the linear regression equations created by Scheuer and colleagues (1980) were used to estimate ages of foetuses in this research. An osteometric board was used to measure the long bones' diaphyseal lengths in millimetres (mm). The diaphyseal lengths were then calculated into the regression equations to produce the estimated age ranges by weeks. Individuals with at least one good preserved, non-fragmented, long bone diaphysis were estimated for age-at-death. Individuals with multiple non-fragmented long bone diaphyses were calculated into the appropriate regression formulae. Then they were given an age range based on similar standard errors of estimated weeks.

**Table 2.3** Scheuer *et al*. (1980) regression formulae for foetuses' long bone lengths

| Bone | Regression equation | Standard error of estimate (weeks) |
|---|---|---|
| **Femur** | 0.3303(length) + 13.5583 | ±2.08 |
| **Tibia** | 0.4207(length) + 11.4724 | ±2.12 |
| **Humerus** | 0.4584(length) + 8.6563 | ±2.33 |
| **Radius** | 0.5850(length) + 7.7100 | ±2.29 |
| **Ulna** | 0.5072(length) + 7.8208 | ±2.20 |

After birth, long bones develop at different rates (Malina, Bouchard and Bar-Or 2004) and gradually fuse with the epiphyses. Maresh (1970) long bone length data tables provide details on measurements of the diaphyses with and without partial fused epiphyses. However, it has been noted that Maresh (1970) correlates less with age (Primeau and Tipper 2017). Primeau and colleagues (2015) established regression formulae for estimating age-at-death of medieval Danish from infancy to young adulthood by measuring long bone lengths with and without epiphyses. They analysed known ages of modern and archaeological materials (Primeau *et al.* 2015). Due to the usage of individuals who represent north-western Europe's medieval period to establish the method, Primeau and colleagues (2015) regression formulae were used for this research (table 2.4 and table 2.5). Similar to the foetuses, an osteometric board was used to measure the diaphyseal lengths of long bones in mm. Additionally, an osteometric board measured diaphyseal lengths with epiphyses (partially and completely ossified) of long bones in mm. The measurements were then calculated into the regression formulae to produce the estimated age ranges by years. Individuals with at least one non-fragmented long bone were estimated for age-at-death. Individuals with multiple non-fragmented long bones were calculated into the appropriate regression formulae. They then were given an age range based on similar standard errors of estimated years.

**Table 2.4** Primeau *et al.* (2015) linear regression formulae including epiphyses from infancy to adolescence long bone lengths

| Bone | Formula | Standard error of estimate (years) |
|---|---|---|
| **Humerus** | (Length x 0.785) – 6.863 | ±61.95 |
| **Ulna** | (Length x 0.992) – 7.472 | ±1.41 |
| **Radius** | (Length x 1.078) – 7.053 | ±1.47 |
| **Femur** | (Length x 0.545) – 6.125 | ±1.48 |

| | | |
|---|---|---|
| **Tibia** | (Length x 0.663) – 5.674 | ±1.51 |
| **Fibula** | (Length x 0.661) – 5.594 | ±1.46 |

**Table 2.5** Primeau *et al*. (2015) linear regression formulae excluding epiphyses from infancy to adolescence long bone lengths

| Bone | Formula | Standard error of estimate (years) |
|---|---|---|
| **Humerus** | (Length x 0.779) – 6.777 | ±1.38 |
| **Ulna** | (Length x 0.988) – 7.433 | ±1.47 |
| **Radius** | (Length x 1.077) – 7.042 | ±1.48 |
| **Femur** | (Length x 0.538) – 5.982 | ±1.46 |
| **Tibia** | (Length x 0.670) – 5.779 | ±1.53 |
| **Fibula** | (Length x 0.655) – 5.499 | ±1.47 |

### 2.2.2 Adult Age Estimation

Most adult ageing methods identifies the morphological changes, from young to old, of various skeletal elements (Chamberlain 2006: 107; Milner and Boldsen 2011: 269). The traditional methods are the pubic symphysis characteristic scoring system (Todd 1921a; Todd 1921b; Brooks and Suchey 1990), auricular surface characteristic phases (Lovejoy *et al.* 1985; Buckberry and Chamberlain 2002), sternal end of ribs characteristic phases (Işcan and Loth 1986), and ectocranial suture closure stages (Meindl and Lovejoy 1985). Many of these methods were created using skeletal remains of known aged individuals from specific regions and time periods. Consequently, to use them on collections with unknown ages from different times periods and geographical regions is questionable (Boldsen *et al.* 2002; Larsen 2015; Hoppa 2000; Garvin *et al.* 2012; Kemkes-Gottenhaler 2002). These methods mimic the ages of the skeletal collections that were used to create them rather than produce genuine age estimates for individuals of unknown ages. This would give the assumption that people throughout time and across the world have the same patterns of skeletal maturation and degeneration. Adult age-at-death estimation techniques that are used to avoid mimicking the ages of reference collections are transition analysis methods (Boldsen *et al.* 2002; Chamberlain 2006; Uhl 2012; DiGangi *et al.* 2009; Kimmerle *et al.* 2008; Konigsberg 2015; Prince, Kimmerle and Konigsberg 2008).

#### 2.2.2.1 Transition Analysis

There are various transition analysis methods that estimate age-at-death (e.g., Boldsen *et al.* 2002; DiGangi *et al.* 2009; Kimmerle *et al.* 2008; Konigsberg 2015; Prince, Kimmerle and Konigsberg 2008). Transition analysis uses a hazard model and skeletal samples of individuals with known age-at-death and biological sex to estimate the transition from one known phase of biological age to another (Uhl 2012; Jooste *et al.* 2016). This analysis can be used to estimate age-at-death of unknown individuals because it provides a highest posterior density probability of age-at-transition (Uhl 2012). The most commonly used transition analysis technique in biological anthropological studies is Boldsen and colleagues (2002) method (e.g., Milner and Boldsen 2012; Fojas *et al.* 2018; Jooste *et al.* 2016; Yaussy, DeWitte and Redfern 2016; DeWitte 2017; DeWitte and Hughes-Morey 2012; Wilson 2014; DeWitte 2010; Yaussy 2019; Wittwer-Backofen *et al.* 2008).

Boldsen and colleagues (2002) created a standard transition analysis method (TA2) that is easily accessible and utilised. They developed Anthropological Database, Odense University (ADBOU) software that performs TA2, and is easily accessible through the website https://www.statsmachine.net/software/ADBOU2/. ADBOU produces lower 95%, maximum likelihood, and upper 95% age estimation probabilities. Skeletal remains of individuals with known age-at-death from the USA (Terry collection) and Portugal (Coimbra collection) were examined to develop TA2 (Boldsen *et al.* 2002). Similar to the traditional methods, a scoring system of the morphological age characteristic changes (age indicators) for the pubic symphysis, auricular area, and cranial sutures was developed from the skeletal remains (Boldsen *et al.* 2002). Additionally, a logit regression model was implemented, based on Bayesian analysis, to produce age-at-death estimates (Boldsen *et al.* 2002). This uses the information from the individuals of known age-at-death to calculate a percentage of posterior probability, which gives an age range (the lower and upper 95% and maximum likelihood probabilities produced by ADBOU) (Uhl 2012). This avoids mimicking the known age probability to theoretically produce genuine estimated ages for individuals with unknown ages (Milner and Boldsen 2012; DeWitte and Slavin 2013; Kim and Algee-Hewitt 2022).

In addition to avoiding age mimicry, it produces ages for older adults (50+ years), individuals missing multiple age indicators of the skeletal elements, and it observes asymmetry between two sides within an individual (Kim and Algee-Hewitt 2022). Validation studies of TA2 have confirmed that multiple age indicators provide more accuracy, the pubic symphysis and auricular area are great age indicators alone while the cranial sutures are the worse, and young individuals ages are most accurate (Kim and Algee-Hewitt 2022; Jooste *et al.* 2016; Maaranen and Buckberry 2018; Lopez-Cerquera and Casallas 2019; Fojas *et al.* 2018; Milner and Boldsen 2012). Unfortunately, classifying older ages becomes wider past the middle age range, although this is not statistically significant for validation studies (Kim and Algee-Hewitt 2022; Jooste *et al.* 2016; Milner and Boldsen 2012; Maaranen and Buckberry 2018). However, Maaranen and Buckberry (2018) suggest that TA2 is more suitable for individuals from archaeological contexts compared to other methods that were created based on individuals of known young ages that lack statistical corrections for older individuals. Therefore, the transition analysis created by Boldsen and colleagues (2002) were used for estimating adult ages in this research.

For this study, individuals were examined for pubic symphysis, auricular area, and cranial sutures to be scored based on Boldsen and colleagues (2002) scoring system. Individuals that displayed all of the age indictors skeletal elements were scored. As mentioned above, age indicators of the pubic symphysis, auricular area, and cranial sutures can be scored fragmented or missing. Individuals that displayed only the pubic symphysis or auricular area were scored. Individuals that only exhibited cranial sutures were not scored as it has been confirmed by validation studies as the least accurate age indicator. Individuals without evidence of the pubic symphysis, auricular area, and cranial were not included for age-at-death estimation for this study. The scores were placed into ADBOU program, male or female was selected based on biological sex assessment (see section 2.3 for biological sex assessment), white was selected for ancestry, and archaeological was selected for mortality model. For analysation, 95% probability was selected because it reports a larger more conservative age range. The 'All data (Corrected)' lower and upper 95% and maximum likelihood probabilities were used for age-at-death estimation.

## 2.3 Biological Sex Assessment

Biological sex assessment methods identify skeletal characteristic traits that reflect differences between male and female physical appearances. Non-adults develop these features during their advanced stages of skeletal development (Lewis 2007; Cunningham, Scheuer and Black 2016). For that reason, it is difficult to assess biological sex of non-adults who do not exhibit advance developmental stages. Additionally, non-adults reach advanced stages of development at different periods (Cunningham, Scheuer and Black 2016). This means not all of them experience sexual dimorphism at the same time. Therefore, non-adult skeletal remains were not assessed for biological sex because some will display the characteristic traits and others will not.

Thus, biological sex assessment only included adult skeletal remains for this research. There are various characteristic traits on the os coxae and skull that are frequently used for assessing biological sex of adult human skeletal remains (Roberts and Manchester 2005; Walker 2008; Gómez-Valdés *et al.* 2012; Klales, Ousley and Vollner 2012). These skeletal elements are known for their distinct sexual dimorphic features. For this reason, the ox coxae and skull were analysed for assessing biological sex of adult individuals for this study. The following sections discusses the methods that were used for assessing adult biological sex for this research.

### 2.3.1 Os Coxae

Studies have suggested that the os coxae is more reliable for assessing biological sex compared to other skeletal elements (Buikstra and Ubelaker 1994; Roberts and Manchester 2005; Byers 2002). The characteristics traits on the os coxae varies less between populations and are highly sexually dimorphic (Gonzalez, Bernal and Perez 2009; Gómez-Valdés *et al.* 2012; Velemínská *et al.* 2013). The pubic bone and greater sciatic notch are the standard skeletal features of the os coxae that are examined for biological sex.

Klales and colleagues (2012) created a statistical method for sex assessment of the pubic bone with the traits that Phenice (1969) describes. Phenice (1969) states: an arch on the ventral surface, curvature of the subpubic concavity, and a sharp ridge of bone on the medial aspect of the ischio-pubic ramus are all seen on female pubic regions and less likely on males. A scoring method was created, 1 to 5 (figure 2.1), based on the characteristics of the ventral arch (VA), medial aspect (MA), and subpubic concavity (SPC) described by Phenice (1969). This method calculates the scores into the following equation (Klales, Ousley and Vollner 2012):

$$2.726(VA) + 1.214(MA) + 1.073(SPC) - 16.312$$

The results provide high posterior probabilities of individuals likely being a male or female when they died (Klales, Ousley and Vollner 2012; Kenyhercz *et al.* 2017). This method has low estimated error rates compared to metric methods for biological sex assessment (Klales, Ousley and Vollner 2012; Kenyhercz *et al.* 2017). It can be used on various skeletal populations and is a valid and reliable method using Phenice's (1969) traits descriptions (Klales, Ousley and Vollner 2012; Gómez-Valdés *et al.* 2017; Kenyhercz *et al.* 2017; Brickley and Buckberry 2017). Thus, this method was used to assess biological sex of the individuals for this study. Klaes and colleagues (2012) created an excel spreadsheet calculator that produces posterior probabilities of male and female based on the selection of the scoring method. This calculator was used to assess biological sex of the pubic bone for this study.

This method was only applicable when an individual displayed a non-fragment pubic bone. Individuals with a fragmented pubic bone were examined for a non-fragment greater sciatic notch for biological sex estimation.

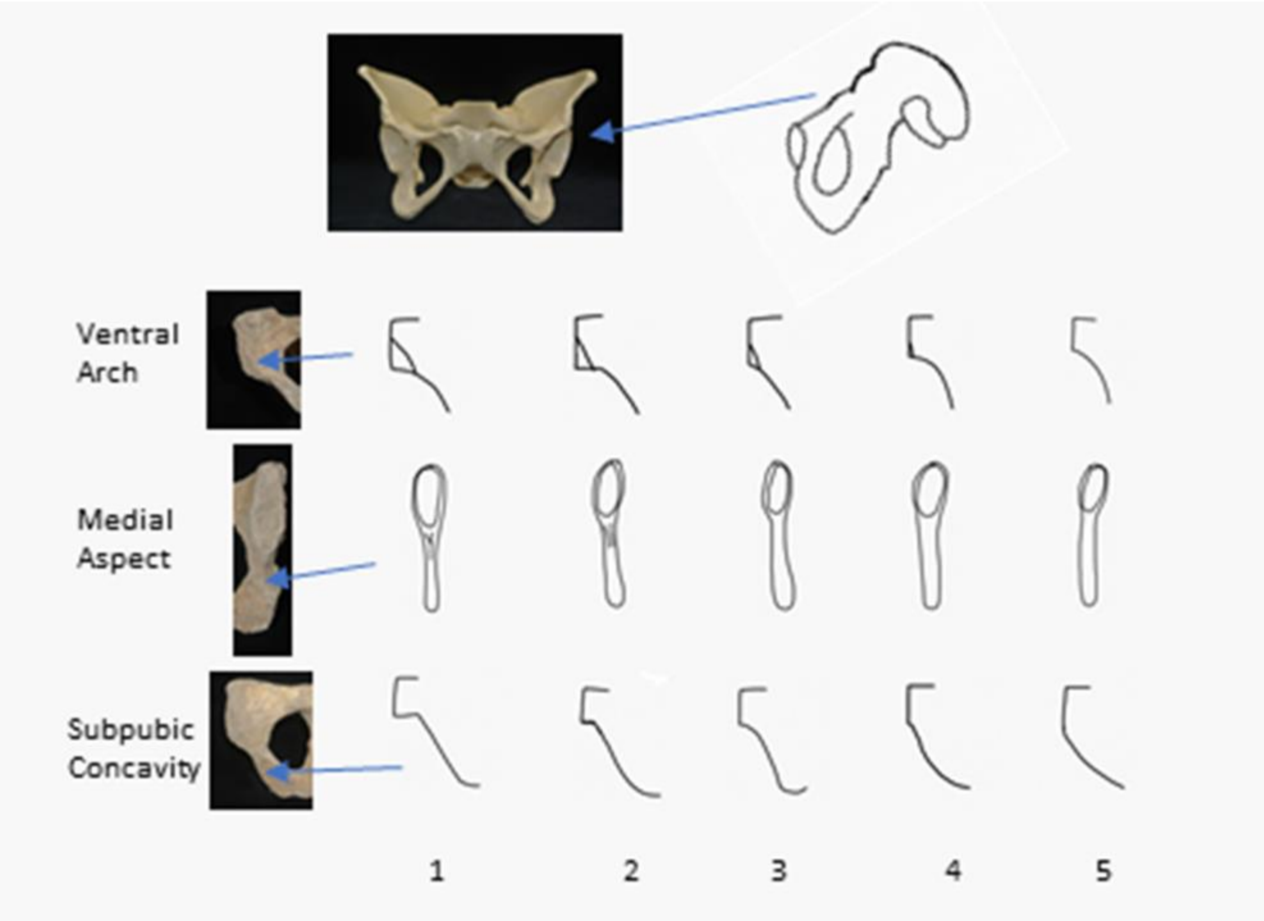



**Figure 2.2** Sex assessment scoring method for the pubic bone (reconstruction of Klales, Ousley and Vollner 2012 scoring method)

Unfortunately, the pubic bone is frequently affected by taphonomic processes which hinders its recovery from archaeological excavations (Gonzalez, Bernal and Perez 2009; Spradley and Jantz 2011; Velemínská *et al.* 2013). The greater sciatic notch is the most well-presevered skeletal element on the pelvis and has a high level of sexual dimorphism (Buikstra and Ubelaker 1994; Bruzek 2002; Walker 2005; Takahashi 2006). Buikstra and Ubelaker (1994) created a scoring method, 1 to 5 (figure 2.3), for estimating biological sex from the greater sciatic notch. Females tend to have broad and wide notches, to accommodate for childbirth, and males have narrow and U-shaped notches (Buikstra and Ubelaker 1994; Walker 2005). It is not a reliable indicator of sex because it can be affected by pathological processes, such as hip fractures, that can change its shape (Buikstra and Ubelaker 1994; Bruzek 2002). Therefore, for this study, the greater sciatic notches were examined with a pubic bone and/or a fragmented skull. Individuals with just the greater sciatic notches were included in examination only if both were available to see if pathological conditions may have affected the shape. Individuals with one sciatic notch and a non-preserved pubic bone and/or skull, then they were not included in examination.

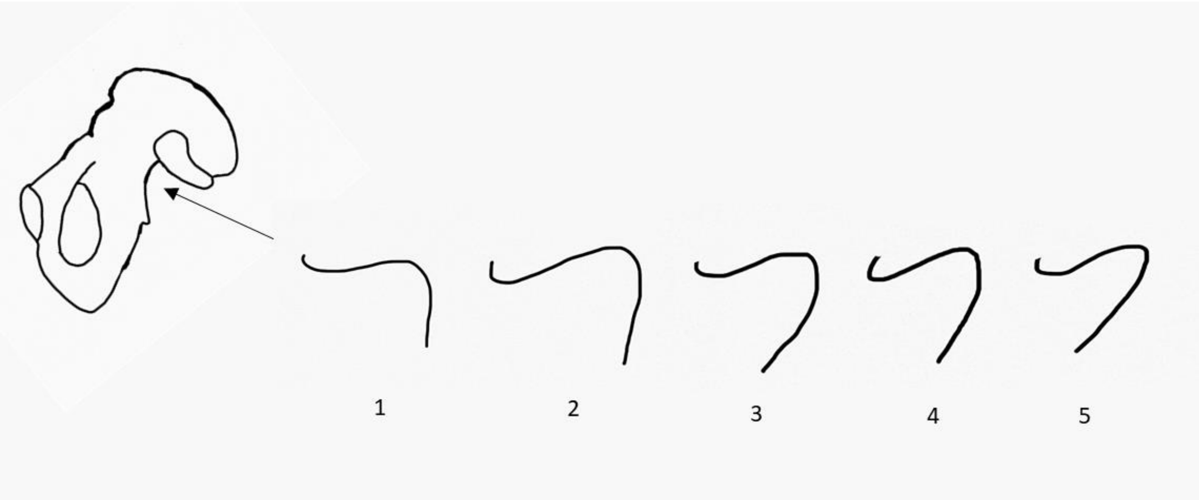



**Figure 2.3** Sex assessment scoring method for the greater sciatic notch (reconstruction of Buikstra and Ubelaker 1994 scoring method)

## 2.3.2 Skull

It is generally assumed that human males have robust skulls and females have faint characteristic features (Roberts and Manchester 2005). Buikstra and Ubelaker (1994) scoring method for sexually dimorphic cranial features is often used for estimating biological sex of individuals from osteoarchaeological contexts. It scores the morphology of the nuchal crest, mastoid process, supra-orbital margin, glabella, and mental eminence from 1 to 5 (figure 2.4). However, the morphology of the cranial traits can be affected by biomechanical loading (Tanne and Sakuda 1991; Lieberman *et al.* 2004; Paschetta *et al.* 2010) and vary based on populational differences (Walker 2008; Larsen 2015).

The morphology of the nuchal crest varies between populations (Walker 2008) and mastication requires the usage of the temporal and orbital regions' muscles (Lieberman *et al.* 2004; Paschetta *et al.* 2010). Hence, it tends to be difficult to assess sex based on the nuchal crest, mastoid process, and supra-orbital margin. The glabella (Garvin, Sholts and Mosca 2014) and features on the mandible (Brickley 2004; Brickley and Buckberry 2017) have been suggested to be more reliable with sex assessment compared to other cranial traits. Therefore, Buiksta and Ubelaker (1994) scoring method for the glabella and mental eminence were predominantly used for assessing sex from skulls. Individuals with a preserved glabella and mental eminence were examined with and without a preserved pubic bone and/or greater sciatic notches. Individuals with a preserved mastoid process, nuchal crest, and supra-orbital margin were only examined with a preserved pubic bone and/or greater sciatic notches. Individuals without a preserved glabella, mental eminence, pubic bone or greater sciatic notches were not examined for this study.

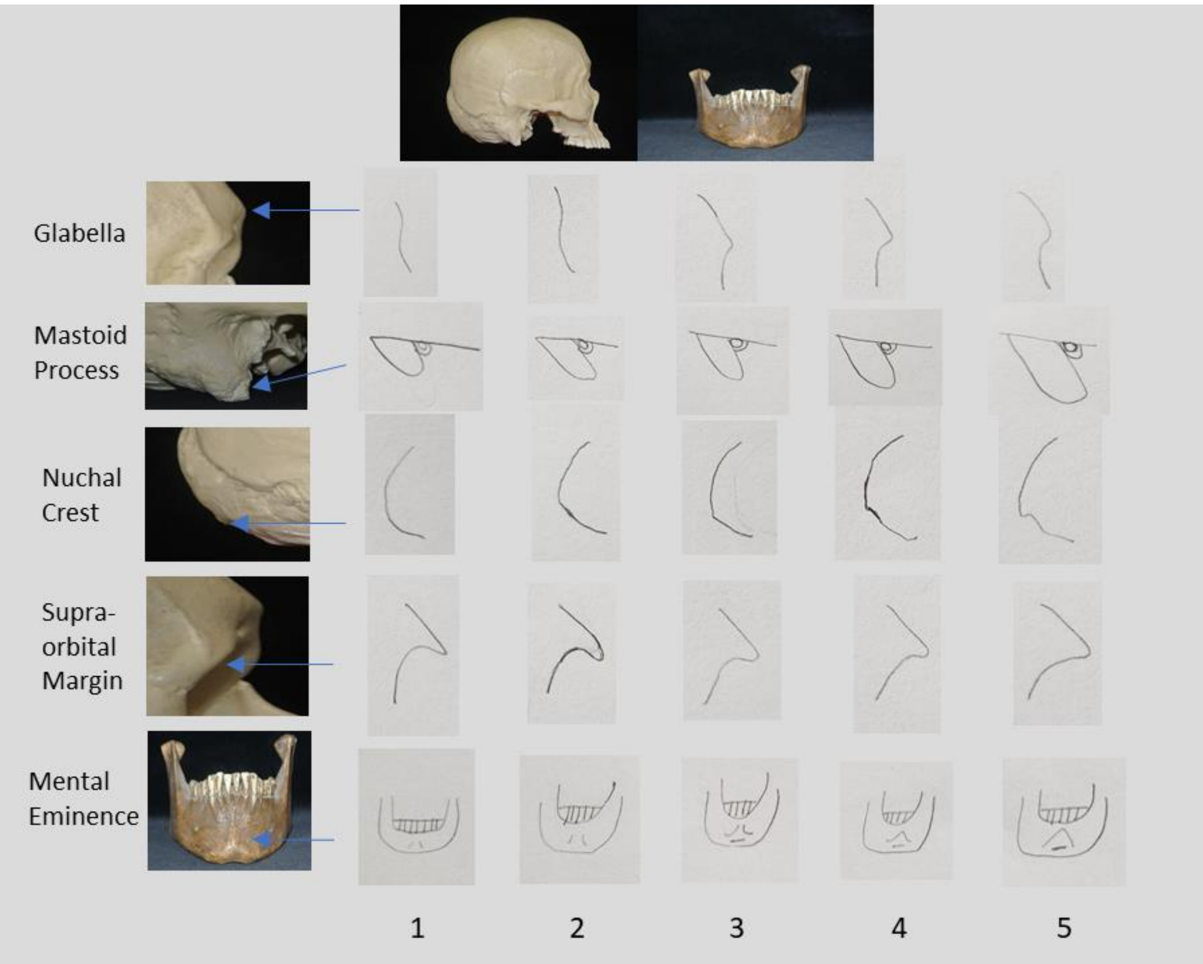



**Figure 2.4** Sex assessment scoring method for the skull (reconstruction of Buikstra and Ubelaker 1994 scoring method)

## 2.4 Statistical Methods

The primary statistical method used for this study is Cox regression. It is a semi-parametric test that only makes assumptions of the proportional hazards and not the distribution of data (Heitfield and Levy 2001; Paoletti and Asselain 2010). Cox regression estimates the size of the difference between groups (effect estimate) and a related confidence interval (Stel *et al.* 2011b). The effect estimate is the ratio of two hazards (hazard ratio) (Stel *et al.* 2011b). The hazard ratio (HR) can be interpreted as a relative risk, risk ratio, prevalence rate ratio, or incidence rate ratio (which are all mathematically equivalent to each other) (Lee and Chia 1993; Stel *et al.* 2011b; Diaz-Quijano 2012). It does not produce an odds ratio (OR), which can often be confused with risk ratio (RR).

It is often encouraged in social science, epidemiology, and medical studies to conduct logistic regressions (e.g., binomial regression or multinomial regression), which produces OR, to assess different factors that contribute to health, disease, or mortality (King 2011; Osborne 2011; Diaz-Quijano 2012). An odds ratio measures the association between exposure and outcome (Diaz-Quijano 2012). However, OR is often misinterpreted as RR (Lee and Chia 1993; King 2011; Osborne 2011; Diaz-Quijano 2012). An odds ratio is the ratio of the odds of an event, whereas a risk ratio is the ratio of the risk of an event (Deeks, Higgins and Altman 2011). For example, the odds of dying from an infection are 4.91 times greater for males relative to females, which technically means that for every male who did not die from an infection, 4.91 times as many males died from an infection (0.54) than the number of females who died from an infection for every female who did not die from an infection. Thus, OR inflates the effect estimate and can be tricky to interpret (Davies, Crombie and Tavakoli 1998). Conversely, RR is straightforward (Davies, Crombie and Tavakoli 1998). For example, the risk of dying from an infection is 2.45 times greater for males relative to females does not have a hidden meaning. Hence, Cox regression has been suggested to be used to obtain risk ratios since hazard ratios can be interpreted as risk ratios (Breslow 1974; Lee and Chia 1993; Diaz-Quijano 2012).

As with any regression analysis, an issue with Cox regression is multicollinearity (Hashemi and Commenges 2002). Multicollinearity is when two or more independent variables in regression analysis are correlated (McClendon 2002; Daoud 2017). Thus, increasing the standard error of the coefficients and making some variables statistically insignificant when they should be significant (McClendon 2002; Alin 2010; Daoud 2017). As a result of the high correlation between two or more independent variables, the relationship between the independent variables and the dependent variables is misrepresented by the strong relationship between the independent variables, which leads to an incorrect interpretation of relationships (Daoud 2017). It can be assumed that the most straightforward correction is to use the Bonferroni method to adjust the p-values to avoid false-positive (i.e., rejecting a true null hypothesis) (Hashemi and Commenges 2002). However, when the independent variables are highly correlated, the Bonferroni method would lead to very conservative results (Hashemi and Commenges 2002). It is suggested to measure how much the variance of the independent variables' coefficients are inflated. A tool to measure the variance is the variance inflation factor (VIF). Table 2.6 shows the interpretation of VIF. For this study, VIF was used to identify if the coefficients were reliable.

**Table 2.6** Variance inflation factor interpretation

| | |
|---|---|
| VIF = 1 | Not correlated |
| 1 < VIF ≤ 5 | Moderately correlated |
| VIF > 5 | Highly correlated |

Another statistical method used for this study is the Kaplan-Meier survival analysis. Kaplan-Meier is a non-parametric test that does not require the data distribution to be normal (Cantor and Shuster 1992; Harrell 2001). It produces a log rank test and survival curve. The log rank test is a statistical significance test that compares the survival of two or more groups (Bland and Altman 2004; Stel *et al.* 2011a). The survival curve is a step-wise cumulative survival function instead of a contiguous smooth function (Rich *et al.* 2010; Stel *et al.* 2011a). The curve estimates the probability of individuals in a population surviving by any given time (Bland and Altman 1998).

Kaplan-Meier and Cox regression was used to explore survivorship and mortality risk patterns of adults and nonadults for this study. Also, Cox regression was used to identify potential pathological conditions people obtained by investigating periosteal new bone patterns of adults and to compare and assess childhood growth profiles of Canterbury to other medieval English towns for this study. All statistics were conducted using Statistical Package for the Social Sciences (SPSS).

## 2.5 Conclusion

The primary skeletal collection analysed for this research is St. Gregory's Priory ($11^{th}$ to early $16^{th}$ century). Not every individual was examined for this research due to preservation or the requirements for the data chapters analyses. Age-at-death of non-adults were estimated using the London Dental Atlas (AlQahtani, Hector and Liversidge 2010), foetus long bone length regression formulae (Scheuer, Musgrave and Evans 1980), and infants to young adults long bone length regression formulae (Primeau *et al.* 2015). Biological sex was not examined for non-adults because of the lack of assessment methods for all age ranges of non-adults. For adults, age-at-death were estimated using transition analysis (TA2) (Boldsen *et al.* 2002). In addition, biological sex was assessed using the formula for pubic bone characteristics (Klales, Ousley and Vollner 2012) and examining characteristics of the greater sciatic notch, glabella, mastoid process, nuchal crest, supra-orbital margin, and mental eminence (Buikstra and Ubelaker 1994). However, the mental eminence and glabella were primarily examined on the skull because they are the most reliable characterises for sex assessment. Osteological analysis was conducted in the Human Osteology Research Laboratory at the University of Kent. The primary statistical method used for this research is Cox regression. Variance inflation factor tool was used to recognise if the coefficients of the cox regression results were reliable. Additionally, Kaplan-Meier was used to identify survivorship patterns for this research.

The purpose of this chapter was to describe the primary methods used for the data chapters. Each data chapter mentions the number of individuals and which osteological method was best used to for the chapters' data analysis (table 2.7). Additional methods and skeletal collections used in the data chapter are further explained in the data chapters.

**Table 2.7** Methods used in the data chapters

| Data Chapter | Age Group | Methods |
|---|---|---|
| **3: The Impact of Urbanisation on Growth Patterns of Non-Adults in Medieval Canterbury** | Non-adults | Age-at-Death<br>• The London Dental Atlas (AlQahtani, Hector and Liversidge 2010)<br>Statistical Methods<br>• Cox Regression<br>• Variance Inflation Factor |
| **4: Patterns of Periosteal New Bone Concerning Infectious Diseases in Medieval Canterbury** | Adults | Age-at-Death<br>• Transition Analysis (Boldsen et al. 2002)<br>Biological Sex<br>• Pubic bone characteristics (Klales, Ousley and Vollner 2012) |

| | | |
|---|---|---|
| | | • Skull characteristics (Buikstra and Ubelaker 1994)<br>Statistical Methods<br>• Cox regression<br>• Variance Inflation Factor |
| **5: Survivorship and Mortality of Social Status Groups in Medieval Canterbury** | Non-adults and Adults | Age-at-Death<br>• Foetus long bone length regression formulae (Scheuer, Musgrave and Evans 1980)<br>• Infants to young adults long bone length regression formulae (Primeau *et al.* 2015)<br>• Transition Analysis (Boldsen *et al.* 2002)<br>Biological Sex<br>• Pubic bone characteristics (Klales, Ousley and Vollner 2012)<br>• Skull characteristics (Buikstra and Ubelaker 1994)<br>Statistical Methods<br>• Kaplan-Meier<br>• Cox regression<br>• Variance Inflation Factor |

# Chapter 3 The Impact of Urbanisation on Growth Patterns of Non-Adults in Medieval Canterbury

## Abstract

The adverse living conditions of urban medieval Canterbury influenced infectious and nutritional diseases that may have negatively impacted childhood growth. Medieval English urban centres were detrimental to population health compared to rural and proto-urban areas. Therefore, it can be assumed that childhood growth in medieval Canterbury would be similar to another urban centre and different from proto-urban and rural areas. This study aims to assess the growth of children from urban Canterbury and other settlement centres in England to determine whether similarities and differences in health existed in the medieval period. Data on tibiae and femora maximum diaphyseal lengths and dental age of non-adults (0-13.5 years) from urban Canterbury (n = 69), urban York (n = 17), proto-urban Newcastle (n = 39), and rural Raunds (n = 38) were examined using Cox regression analysis. The results reveal that non-adults from Newcastle and Raunds had a higher risk of delayed growth than non-adults from Canterbury. Also, non-adults from York had a higher risk of delayed femoral growth compared to non-adults from Canterbury. The impact of the living conditions in medieval Canterbury may have been less detrimental to childhood growth, compared to medieval York, Newcastle, and Raunds, due to differences in weaning practices, deficiencies in weaning diet, and stable income that allowed for easy access to nutritious food.

## 3.1 Introduction

Growth and development is influenced by the relationships between genetics, hormones, nutrition, pathogenic mechanisms, socioeconomic factors, physical activity, environmental settings, and psychosocial conditions (Gosman 2012; Mays 2018; Matkovic *et al.* 2004). After birth, longitudinal bone growth (the process of endochondral ossification) is regulated by various hormones such as growth hormone (GH), insulin-like growth factors (IGFs), thyroid hormones, sex hormones (oestrogen and androgens), glucocorticoids, vitamin D, and leptin (Hartmann and Yang 2020; Ohlsson *et al.* 1993). Adequate nutrition (i.e., adequate proportions of lipids, proteins, and essential minerals and vitamins) stimulates hormones that regulate longitudinal bone growth (Gosman 2012). Influential factors such as diet and nutritional status, disease load, physical activity, and exposure to toxins can alter the genetic potential of long bone maximum growth (Matkovic *et al.* 2004; Cameron 2012). Disturbances to long bone growth can cause the growth rate to decrease (Cameron 2012; Gosman 2012). The main factors known to disrupt bone growth are inadequate nutrition and pathological conditions (Gosman 2012; Pinhasi *et al.* 2006; Forbes 1987).

Inadequate nutrition can either promote pathological conditions or become influenced by them. Parasitic infections and respiratory disorders (e.g., tuberculosis and chronic obstructive pulmonary disease) can cause individuals to become malnourished (Zuzarte-Luís and Mota 2018; Collins and Weeks 2019). Malnutrition can also motivate non-communicable diseases such as diabetes and cardiovascular diseases (Bhatia, Bhutta and Kalhan 2012; Barker 1999). The imbalances of nutrient-energy, protein, calcium, iron, zinc, folic acid, vitamin D, vitamin A, and vitamin B12 (i.e., malnutrition) can cause skeletal growth disturbances (Lejarraga 2012; Forbes 1987; Hans and Jana 2018; Wu, Imhoff-Kunsch and Webb Girard 2012). Adverse environments can lead to undernutrition and a susceptibility to contracting diseases, which in turn can result in periods of growth faltering of children (Ulijaszek and Strickland 1993). Urban settlements are commonly recognised for having adverse environments such as water and air pollution and dense housing and structural communities that influence individuals to become malnourished and obtain various diseases (Ettman, Vlahov and Galea 2019; Wuerzer 2014).

Previous biological anthropology studies of childhood growth and urbanisation have focused on growth patterns from industrial ($18^{th}$ to $19^{th}$ century) England and Ireland (Newman, Gowland and Caffell 2019; Newman and Gowland 2017; Mays, Brickley and Ives 2009; Geber 2016; Geber 2014; Ives and Humphrey 2017). Ives and Humphrey (2017) noticed a growth deficit between 2 and 4 months, and it became more pronounced during infancy and early childhood with long bone growth from 19th century Bethnal Green, London, England compared to a modern sample. They suggest this is due to poor sanitation, such as wells contaminated by nearby cesspools and cesspools overfilled into dwellings which likely contributed to waterborne bacterial illnesses (Ives and Humphrey 2017). Additionally, poor ventilation due to closely confined rooms influenced respiratory illnesses (Ives and Humphrey 2017). Also, inadequate nutrition linked to low socioeconomic status, such as early weaning or artificial feeding, because mothers needed to work to provide financial needs for the family (Ives and Humphrey 2017). Mays and colleagues (2009) found that in 19th century Birmingham, England, those with rickets displayed long bone growth deficiency over 2 years of age compared to those without rickets. They suggest industrial air pollution and compact housing and structural communities could have restricted exposure to sunlight and placed individuals at risk of developing rickets (Mays, Brickley and Ives 2009). Newman and colleagues (2019) identified no significant differences in long bone growth between 18th and 19th century London and Newcastle, England. They suggest Newcastle and London, England had similar influences, such as air pollution and child labour in manufactories (Newman, Gowland and Caffell 2019). Geber (2014) found that non-adults from Kilkenny, Ireland, compared to a modern sample were deficient in growth between 6 months and 12 years based on femoral lengths due to famine-induced stress linked to low socioeconomic status. Geber (2016) recognised that the average maximum length of femora of non-adults from Kilkenny, Ireland was similar to 19th century prepubertal non-adults from London, England. It is suggested that adverse factors (e.g., low socioeconomic status, air pollution, and dense housing conditions) from both places influenced growth similarly (Geber 2016). These studies have shown that factors such as low socioeconomic status, water and air pollution, and dense housing and structural communities within urban settings in the past have had a negative impact on childhood growth.

The urban setting in medieval (11th to 15th century) Canterbury could have had a similar impact on childhood growth. The pilgrimage culture immensely influenced the hustle and bustle of Canterbury's urban environment. The pilgrimage culture consisted of pilgrims receiving miracles and indulgences by visiting shrines of saints apart of the Roman Catholic Church (Clegg 2003; Hopper 2002; Ekelund *et al.* 1996; Sorabella 2011). Also, along their journey to the shrines, they would have donated financial goods to beggars and hospitals (Hopper 2002; Lyle 2002; Webb 2000). Thus, the pilgrimage culture motivated people in Canterbury to provide services such as lodgings, food, and beverages for pilgrims (Hopper 2002; Lincoln 1955). Additionally, it encouraged a dense population that led to closely compact housing and structural communities, narrow streets, unhygienic waste management linked to water pollution, and poorly ventilated houses linked to interior air pollution (Lyle 2002; Dyer 1989). In addition to these circumstances, adverse weather influenced the spread of infectious diseases such as the Black Death, typhus, pneumonia, and tuberculosis (Rawcliffe 2013; Lyle 2002; Talbot 1967). Moreover, continuous freezing rain one year and high-temperature weather the next negatively affected the crops, which caused periodic famines that resulted in people developing nutritional deficiencies (Rubin 1974; Pribyl 2017; Rawcliffe 2013). Hence, this study aims to compare childhood growth from Canterbury to other medieval English settlements.

### 3.1.1 Expectations

The types of settlements in medieval England consisted of urban (town), proto-urban (small town), and rural (village). Urban centres were built surrounding large cathedrals and/or castles, had population sizes from 5,000 to 80,000, and had compact housing and structural communities (Dyer 1989; Dyer 2002; Roberts and Cox 2003; Backman 2003). Terraced houses were common, but small areas were also delegated to one-story small homes (Dyer 1989). Proto-urban areas were constructed around castles, monasteries, or fortification centres, and contained between 50 to 400 houses, which were widely spaced relative to one another (Dyer 2003; Backman 2003). Rural settlements were established nearby manor houses, small administrative centres, or market centres (Miller and Hatcher 1978). They typically had less than 40 landholders (Ackerman 1976), and each house occupied a plot of 15 or 30 acres that was the same size and shape as its neighbours (Dyer 2002). The houses were organised along a street or beside vegetation (Miller and Hatcher 1978; Hamerow 2012).

Houses within the three types of settlements all had a hearth (open fireplace) in the main room that was used as the primary heat source (Dyer 1989; Roberts and Cox 2003). Small windows and holes in the roof of the houses were created for smoke to escape (Dyer 1989). However, they did not provide much ventilation and caused interior air pollution and major fires (especially considering the rooves were thatched) (Dyer 1989). Additionally, waste management and water pollution would have been similar within the three types of settlements. Human and non-human animal excretion refuse were discarded into rivers, streams, private and public cesspits, onto streets, and nearby unoccupied plots (Roberts and Cox 2003; Rawcliffe 2013). Latrines were placed on bridges over rivers and streams, on upper floors within homes, and along rivers (Roberts and Cox 2003; Rawcliffe 2013; Dyer 1989; Miller and Hatcher 1995). Rivers, streams, and ponds were used for drinking, cleaning, and bathing (Havlidis 2016; Roberts and Cox 2003; Rawcliffe 2013). However, they were also used for disposing of waste such as excretion refuse, liquid, dyes, blood, and butchered animals (Roberts and Cox 2003; Miller and Hatcher 1995). Other water sources were public or private wells that accessed groundwater (Havlidis 2016).

People who lived in urban centres would have grown fruit and vegetables on a small plot of private or shared land behind their houses for their personal consumption (Roberts and Cox 2003). Most would have obtained meat from butchers, and very few would have had livestock in their gardens or yards (Dyer 2002). Weekly markets would have also allowed urban people to acquire food especially exotic fruits and vegetables (Dyer 2000; Miller and Hatcher 1995).

Markets were a great place for agriculturalists to sell their surplus (Dyer 2000; Miller and Hatcher 1995). Individuals who lived in rural settlements relied on agriculture in order to provide food for themselves and the community (Miller and Hatcher 1978; Dyer 2002). They would have had large quantities of grains for bread and vegetables and few pieces of meat for pottage (Miller and Hatcher 1978; Dyer 2002). Those who lived in proto-urban areas grew fruits and vegetables and had easy access to rural settlements (Dyer 2003).

The different settlement environments suggest parasitic infections from unhygienic waste management and respiratory disorders from interior air pollution were similarly obtainable. Nevertheless, due to the differences in access to food and housing conditions concerning the vicinity, it is possible to assume that non-adults from rural and proto-urban areas likely experienced less growth disruption than those from urban centres. Therefore, this research tests the hypothesis that non-adults from Canterbury will have similar growth values compared to another urban area and different growth values compared to proto-urban and rural areas.

## 3.2 Materials

To gain insight into the growth of non-adults from medieval Canterbury, they were compared to individuals from medieval York, Newcastle, and Raunds, England (figure 3.1). The skeletal assemblages of St. Gregory's Priory from Canterbury and All Saint's Church from York are representative of urban populations. Black Gate skeletal assemblage from Newcastle represents a proto-urban population. Raunds Furnells skeletal assemble from Raunds represents a rural population. Osteological analysis for All Saint's Church, Black Gate, and Raunds Furnells was conducted by Dr. Charlotte Primeau and Dr. Sophie L. Newman. Table 3.1 displays the description of each site. See Appendix table 7.1 for data used.


**Figure 3.1** Map of England showing sites used in this study

**Table 3.1** Distribution of non-adults' femora and tibiae from each site

| Site | St. Gregory's Priory | All Saint's Church | Black Gate | Raunds Furnells |
|---|---|---|---|---|
| **Location** | Canterbury, UK | York, UK | Newcastle, UK | Raunds, UK |
| **Settlement** | Urban | Urban | Proto-Urban | Rural |
| **Period** | AD c.1084-1537 | AD 1091-1539 | AD c.700-1168 | AD 900-1040 |
| **# of Individuals** | 69 | 17 | 39 | 38 |
| **# of Femora** | 87 | 24 | 47 | 47 |
| **# of Tibiae** | 89 | 9 | 29 | 31 |

### 3.2.1 St. Gregory's Priory

The skeletal assemblage from St. Gregory's Priory derives from a total of 1342 individuals, excavated by Canterbury Archaeological Trust between 1988 to 1991 (Anderson and Andrews 2001). The Priory was founded in AD c. 1084 by Archbishop Lanfranc for a community of 6 priests and 12 clerks, and was built as a sister establishment to the hospital St. John (Hicks and Hicks 2001b). The clergy of St. Gregory's were responsible for providing pastoral care for the people at St. John's Hospital and free burial services for the poor of Canterbury (Hicks and

Hicks 2001b; Tatton-Brown 1995). The burial grounds were in use from AD c.1084 to AD 1537 (Hicks and Hicks 2001b). Based on the quality of preservation of the skeletal remains only 69 non-adults were examined for this study.

The pilgrimage culture dominated medieval Canterbury. After the death of Archbishop Thomas Becket in AD 1173 (caused by a possible misunderstanding between King Henry II and his knight), the number of pilgrimages to Canterbury increased (Martin 1950; Lincoln 1955). People revered Becket for essentially rebelling against the monarch and continuing to stay committed to Christianity (Clegg 2003). Canterbury Cathedral noticed this, spread the word of his death, established a shrine for him within the cathedral, and advertised the miracles pilgrims received from visits to his shrine (Clegg 2003; Webb 2000; Hopper 2002; Lincoln 1955). In addition to Canterbury Cathedral, people who lived there saw the pilgrimage culture as an opportunity to gain a stable income. Accommodation, food, and beverages were provided for pilgrims in homes, inns, and hospitals, with varying charges based on socioeconomic status (Lincoln 1955; Page 1926c). Weekly markets and stalls sold food, beverages, and souvenirs, such as vials filled with fake blood of saints, pilgrim bells, and becket brooches (Lewis 2014; Miller and Hatcher 1995; Lincoln 1955).

### 3.2.2 All Saint's Church

All Saint's Church, also known as York Barbican, was excavated by On Site Archaeology between 2007 to 2008 (McIntyre and Graham 2010). These excavations revealed that the site potentially belonged to the church of All Saint's in Fishergate, York (McIntyre and Graham 2010). It is thought that the church was given to Whitby Abby monastery around AD 1091 and 1095, and it did not survive much after the dissolution of monasteries in AD 1539 by King Henry VIII (McIntyre and Graham 2010). A total of 547 individuals were excavated from this site (McIntyre and Graham 2010). Based on the quality of preservation of the skeletal remains only 17 non-adults were analysed for this study.

The clothing and trading industries dominated medieval York, which made the city very prosperous (Palliser 2014). Regulations for crafts were established from the AD 1370s onwards to control the quality of crafts, tools used to make crafts, and working practices (Palliser 2014). Cloth making in York was considered high quality, and grains and wine were traded across the British Isles and to mainland Europe (Palliser 2014). The job market was reasonably open; thus, people migrated from other towns and villages in England, France, and Belgium, and the population size perhaps was around 20 – 30,000 (Palliser 2014).

### 3.2.3 Black Gate

Excavations of Black Gate were carried out by Newcastle City Council between 1973 to 1992 (Boulter and Rega 1993; Nolan 2010). A total of 679 individuals were excavated (Nolan 2010). Based on the coin evidence and radiocarbon dating of shroud pin types found at the site, the earliest burials are thought to have dated to the 8th century (Boulter and Rega 1993). The burials may be linked to the 7th century monastic settlement and the 8th to 9th century castle excavated (Nolan 2010). By the 10th century, the cemetery appears to have been well established with burials of individuals potentially from local agricultural and proto-urban communities (Nolan 2010; Boulter and Rega 1993). A Norman castle was constructed in 1080, and it is possible that some of the burials at Black Gate were from the castle garrison (Nolan 2010). It is suggested that burial usage ended in c. 1168 (Nolan 2010). Based on the quality of preservation of the skeletal remains only 39 non-adults were examined for this study.

There is little to no documentary evidence for this settlement, monastic centre, or castle during this period (Nolan 2010). During the 6th and early 7th centuries, this settlement was a part of the kingdom of Bernicia, which was united with the kingdom of Deira (Nolan 2010). Both kingdoms created the Anglian kingdom of Northumbria (Nolan 2010). After the death of King Edwin of Northumbria, the kingdom was unstable due to frequent invasions by neighbouring kingdoms (Nolan 2010). The sustainability of Northumbria declined in the mid-9th century with the Viking invasions along the northeast coast (Nolan 2010). The first documentary reference to this settlement is in early 12th century chronicles that mentioned William I's army camped in Newcastle after returning from a campaign in Scotland (Raine 1838; Simeon 2000).

### 3.2.4 Raunds Furnells

Trial excavations between 1977 and 1984 of the site Raunds Furnells led to the establishment of the Raunds Areas Project in 1985 (Boddington 1996a). The Raunds Area Project was jointly managed by the Northamptonshire County Council and the Historic Building Monuments Commission (English Heritage) (Boddington 1987). A church was discovered outside and adjacent to the manor house complex (Furnells manor) and estimated to have been constructed during the late 9th to early 10th century (Boddington 1996c). It has been identified that extensions to the church and a graveyard was constructed in the mid-10th century (Boddington 1996c). Ditches were cut to define a graveyard in the early 10th century (Boddington 1987). A total number of 376 individuals were excavated from this site (Powell 1996). Radiocarbon dates of charcoal and human bones suggest the graveyard was in use from 978 to 1040

(Boddington 1996b). Based on the quality of preservation of the skeletal remains only 38 non-adults were analysed for this study.

Raunds was perhaps an open-field agriculture and little woodland settlement. The farming system consisted of the relationship between livestock and arable farming (Banham and Faith 2014). Arable crops, such as wild oats, relied on the manure and labour of animals for development (Banham and Faith 2014). The Domesday Book indicates that in the late 11$^{th}$ century Raunds was held by two chief holdings identified with Furnells and Burystead manors (Courtney 2009a). Burystead estate was a subordinate element of Higham and perhaps regarded as a distant manor (Courtney 2009a). Furnells manor was held by Burgred, a King's thegn, in 1066 who perhaps had it rented (Courtney 2009b).

## 3.3 Methods

Growth profiles were constructed using dental age and diaphyseal lengths of femora and tibiae. The femora and tibiae were chosen because they directly contribute to stature and are perhaps more sensitive than other long bones to periods of growth faltering (Bogin and Varela-Silva 2010). An osteometric board was used to measure the maximum diaphyseal lengths in millimetres (mm). Age-at-death estimates were based on dental development and eruption stages developed from modern and historical English children (AlQahtani, Hector and Liversidge 2010). Teeth were examined macroscopically or radiographically when radiographs were available. On account of this study examining diaphyseal lengths of the femora and tibiae, individuals with fused epiphyses and apophyses (estimated to be over 14 years of age) were excluded from this study. Thus, non-adults 0 to 13.5 years of age were analysed for this research.

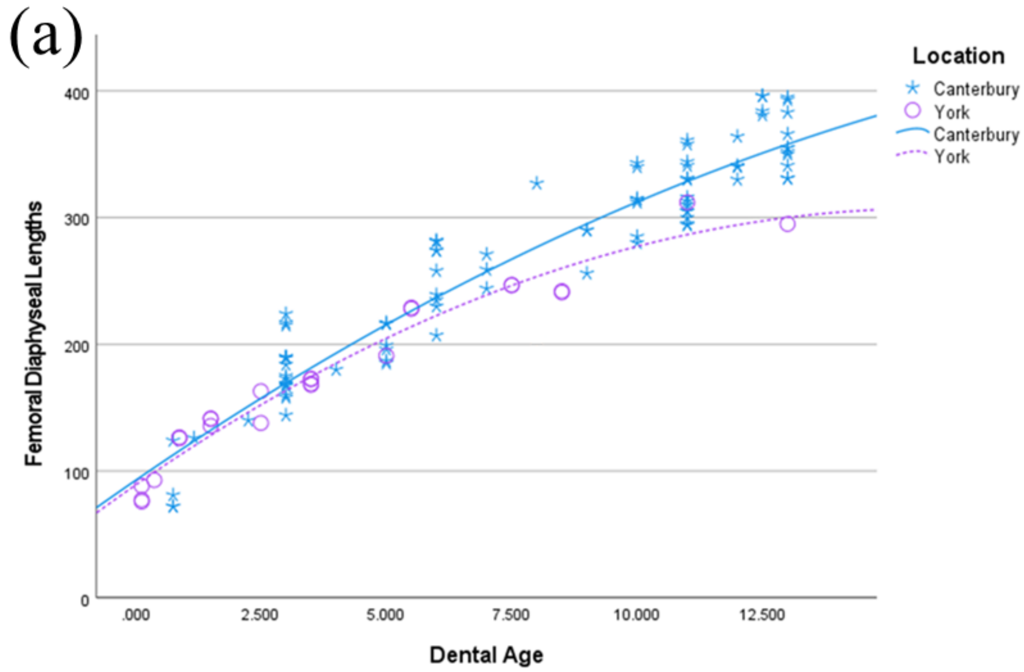
Age-at-death estimates were plotted against the diaphyseal lengths using quadratic polynomial curves to display the distribution of the growth profiles. Cox regression was conducted to compare the growth patterns between St. Gregory's Priory and the other sites. It is commonly used as a survival analysis; however, it can be adapted for estimating relative risk (risk ratios) (Breslow 1974; Stel *et al.* 2011b; Nijem *et al.* 2005). Cox regression identifies the estimate of the size difference between groups (Stel *et al.* 2011b; Stel *et al.* 2011a). Outliers tend to greatly effect regression coefficients (Sokal and Rohlf 1969). Hence, the maximum diaphyseal lengths (mm) were transformed into $Log_{10}$ to reduce the distribution's skewness. $Log_{10}$ transformation makes the data more normally distributed and reduces the influence of outliers (West 2022). Log transformation is often used in biological anthropology studies concerning allometric scaling (Perzigian 1981; Kieser, Groeneveld and Preston 1986; Jungers 1988; Holliday and

Franciscus 2012; Harris *et al.* 2017; Pomeroy *et al.* 2018). Box plots were used to show the $Log_{10}$ distribution of the diaphyseal lengths between the sites. Separate cox regression tests were performed for individuals 3 years of age and younger and 4 years of age and older to identify growth deficit patterns. From birth to 3 years of age is a period of rapid growth (Larsen 2015; Lejarraga 2012; Lewis 2007; Humphrey 2003). After 3 years of age, growth velocity slows down and becomes stable (Lejarraga 2012), thus reflecting the development transition period from infancy to childhood (Bogin 2021).

$Log_{10}$ diaphyseal lengths were used as the time variables, death (coded as 1) was used as the status of the non-adults, and St. Gregory's Priory and the other sites were the covariates. Thus, it calculates the risk of growth deficit patterns between the sites. Six Cox regression tests were performed: St. Gregory's Priory compared to All Saint's Church (femora and tibiae), St. Gregory's Priory compared to Black Gate (femora and tibiae) and St. Gregory's Priory compared to Raunds Furnells (femora and tibiae). Also, variance inflation factor (VIF) tests were carried out to identify if the coefficients and p-values in the cox regression output are reliable.

## 3.4 Results

The growth profiles of Canterbury compared to the other sites for femoral and tibial diaphyseal lengths (mm) are displayed in figures 3.2 to 3.4. The femoral diaphyseal lengths (figure 3.2a) show that the quadratic polynomial curve for non-adults from Canterbury begins to diverge higher than those from York around 3 years old. In figure 3.3a, the quadratic polynomial curve for the femoral diaphyseal lengths of non-adults from Canterbury stays above those from Newcastle and increases around 4 years. The femoral diaphyseal lengths (figure 3.4a) display that the quadratic polynomial curve for non-adults from Canterbury stays above those from Raunds. The tibial diaphyseal lengths (figure 3.2b) display the quadratic polynomial curve for non-adults from Canterbury stays above those from York. In figure 3.3b, the quadratic polynomial curve for tibial diaphyseal lengths of non-adults from Canterbury diverges higher than non-adults from Newcastle around 4 years of age. The tibial diaphyseal lengths (figure 3.4b) display the quadratic polynomial curve for non-adults from Canterbury stays above those from Raunds.



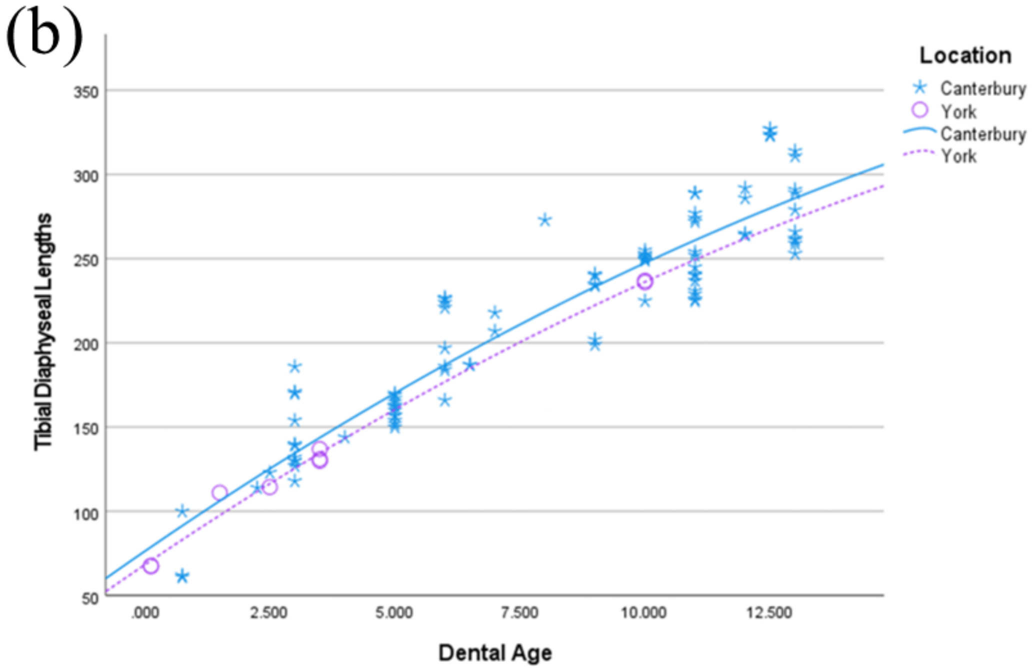




**Figure 3.2** Scatter plot of femoral (a) and tibial (b) diaphyseal lengths plotted against dental age for non-adults from Canterbury (St. Gregory's Priory) and York (All Saint's Church) outlined by quadratic polynomial curves

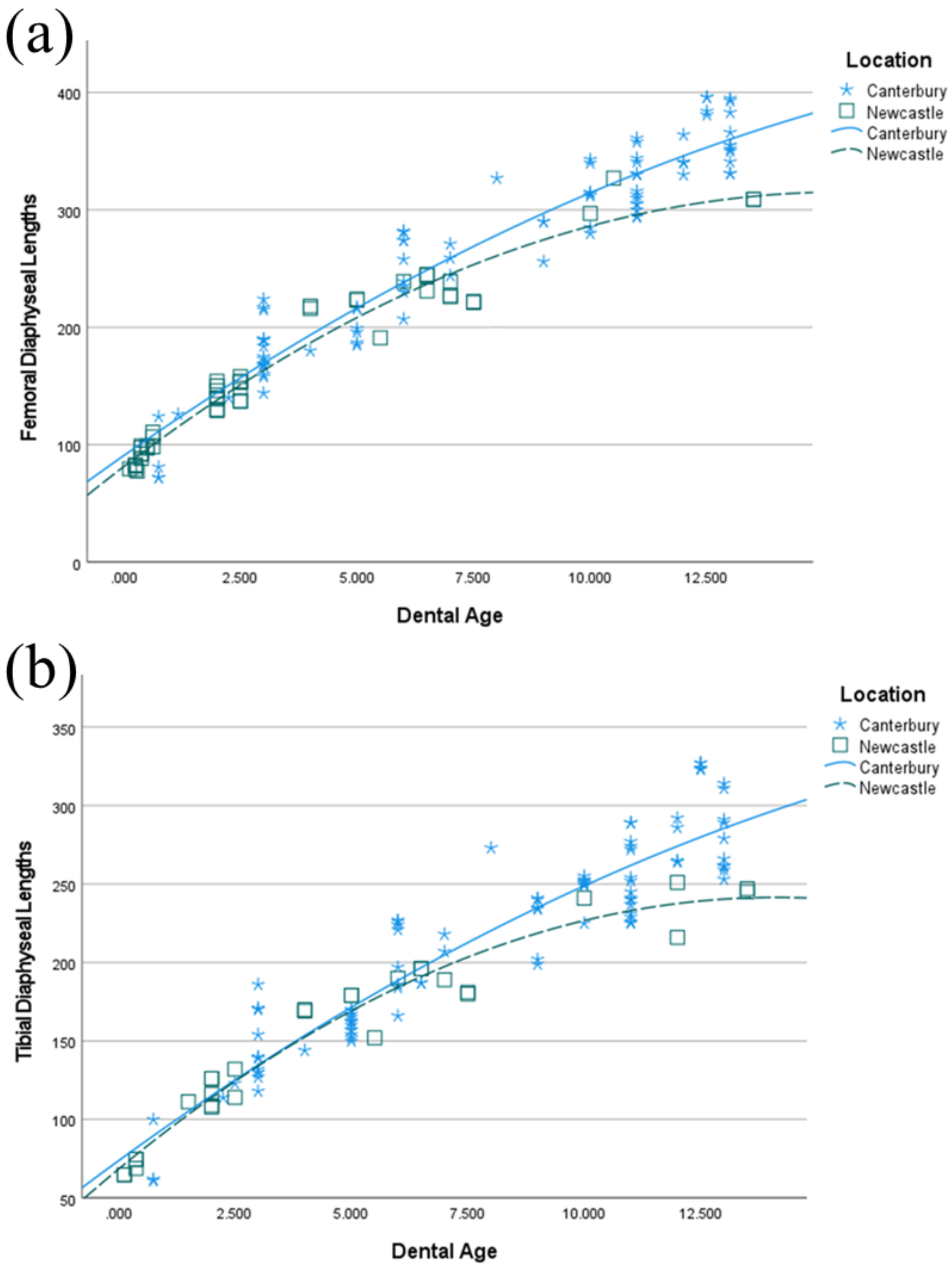



**Figure 3.3** Scatter plot of femoral (a) and tibial (b) diaphyseal lengths plotted against dental age for non-adults from Canterbury (St. Gregory's Priory) and Newcastle (Black Gate) outlined by quadratic polynomial curves

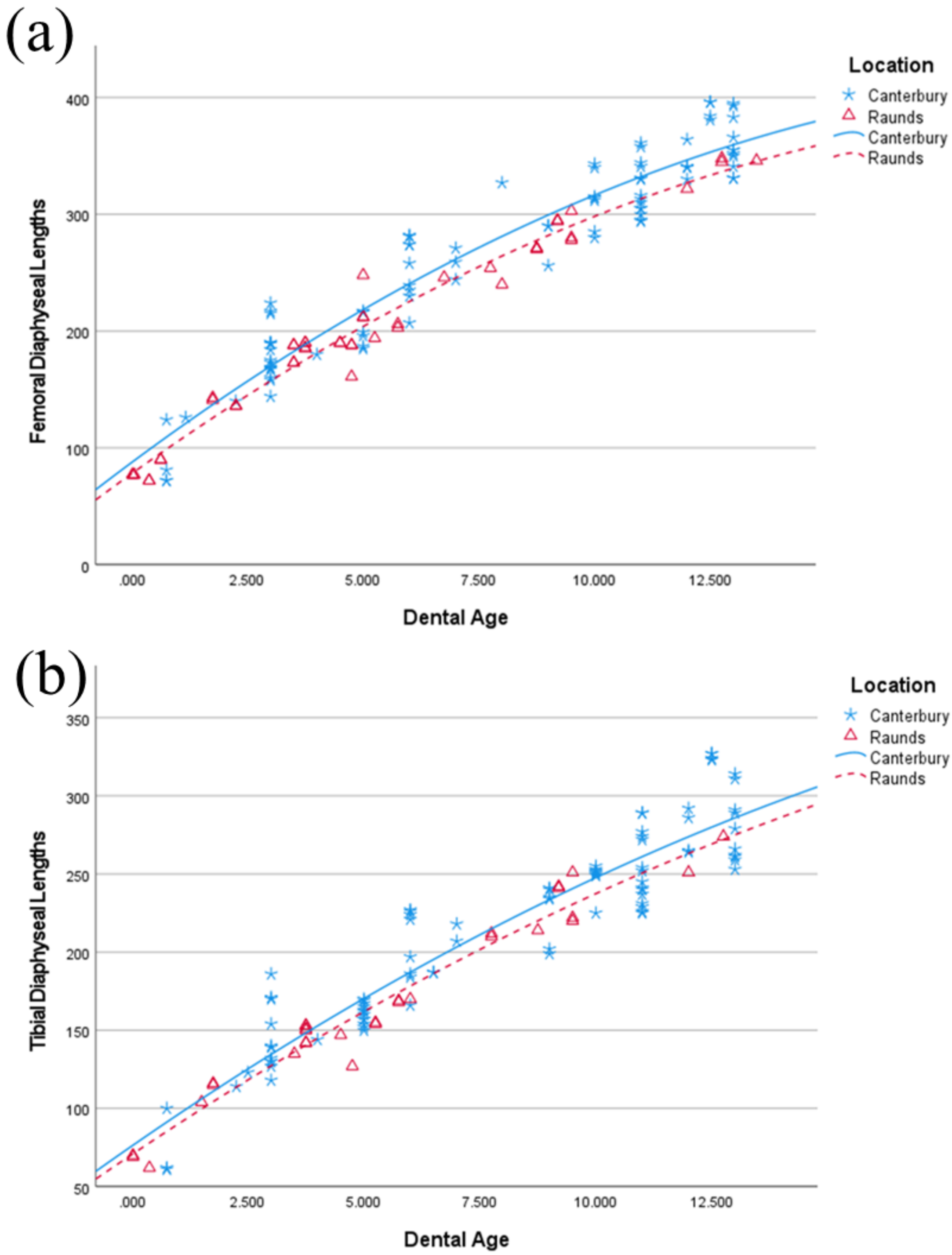



**Figure 3.4** Scatter plot of femoral (a) and tibial (b) diaphyseal lengths plotted against dental age for non-adults from Canterbury (St. Gregory's Priory) and Raunds (Raunds Furnells) outlined by quadratic polynomial curves

Figures 3.5 to 3.10 illustrate the femoral and tibial diaphyseal lengths $Log_{10}$ distributions between non-adults 3 years and younger and 4 years and older from Canterbury and the other sites. The box plots of non-adults 3 years and younger $Log_{10}$ femoral and tibial diaphyseal lengths from Canterbury are higher than York and Newcastle (figures 3.5 and 3.6). The $Log_{10}$ distribution of non-adults 3 and younger from Raunds displays a broader range in distribution (i.e., more scattered data) than those from Canterbury (figure 3.7). Figure 3.8a shows that the $Log_{10}$ distribution of non-adults 4 and older from Canterbury is higher than York. Figure 3.8b display the $Log_{10}$ distribution of non-adults 4 and older from Canterbury has a broader range in distribution than those from York. The $Log_{10}$ distribution of non-adults 4 and older from Canterbury is higher than Newcastle and Raunds (figures 3.9a and 3.10a). The box plots display that the $Log_{10}$ distribution of Canterbury is slightly higher than Newcastle and Raunds (figures 3.9b and 3.10b).

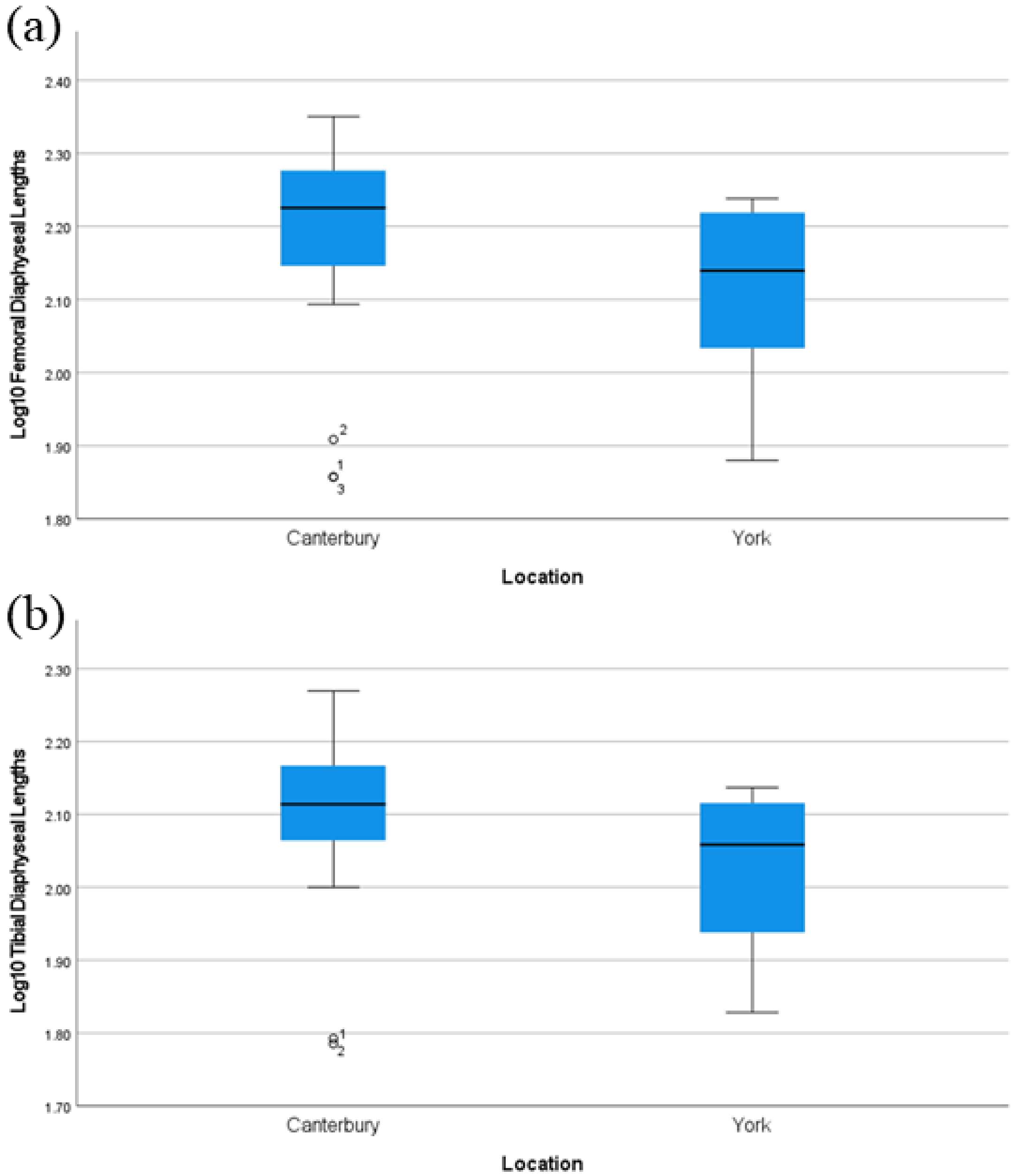



**Figure 3.5** Boxplot displaying the median and quartiles for femoral and tibial diaphyseal lengths transformed to $Log_{10}$ for non-adults 3 years and younger from Canterbury (St. Gregory's Priory) and York (All Saint's Church)

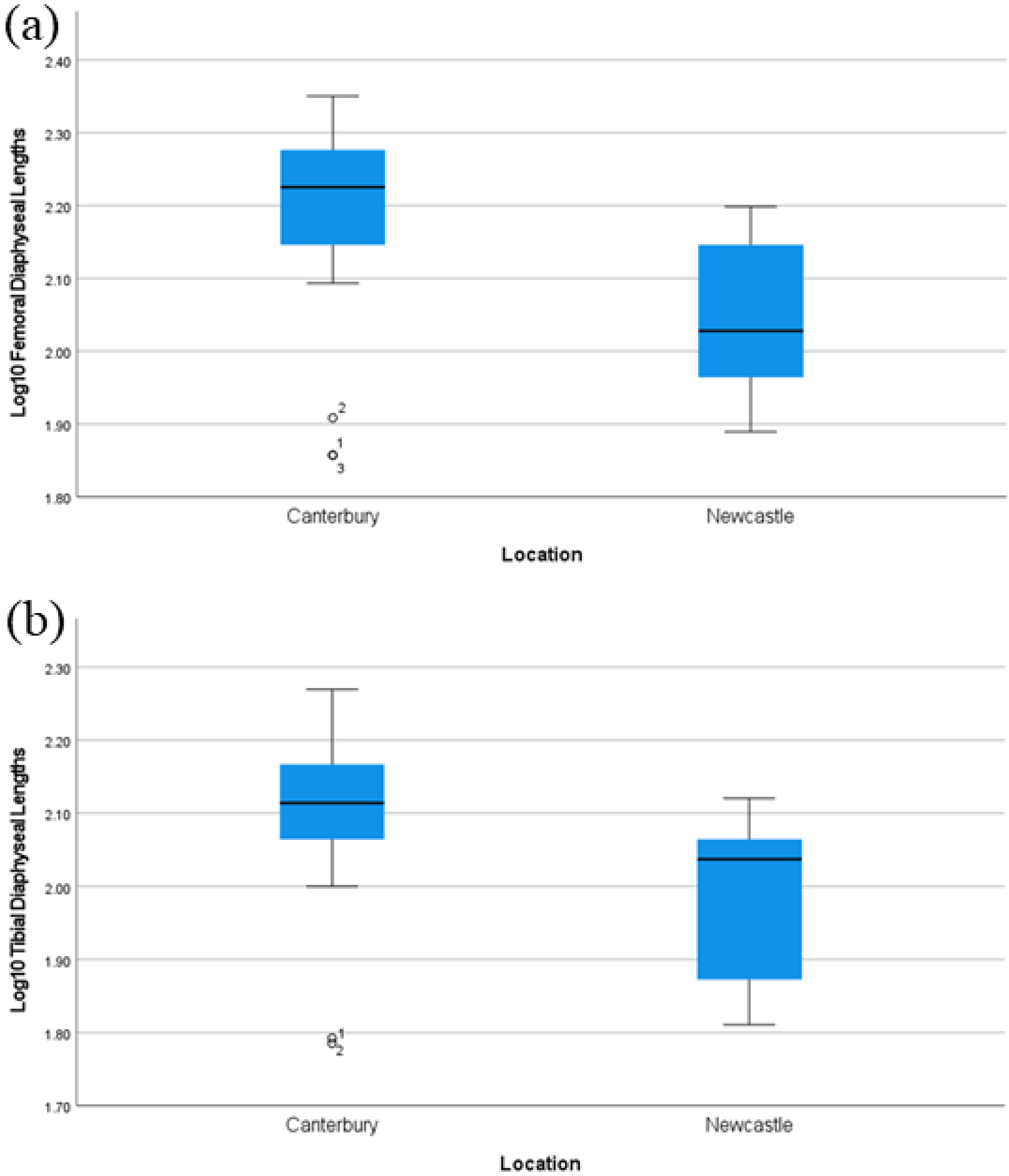



**Figure 3.6** Boxplot displaying the median and quartiles for femoral (a) and tibial (b) diaphyseal lengths transformed to $Log_{10}$ for non-adults 3 years and younger from Canterbury (St. Gregory's Priory) and Newcastle (Black Gate)

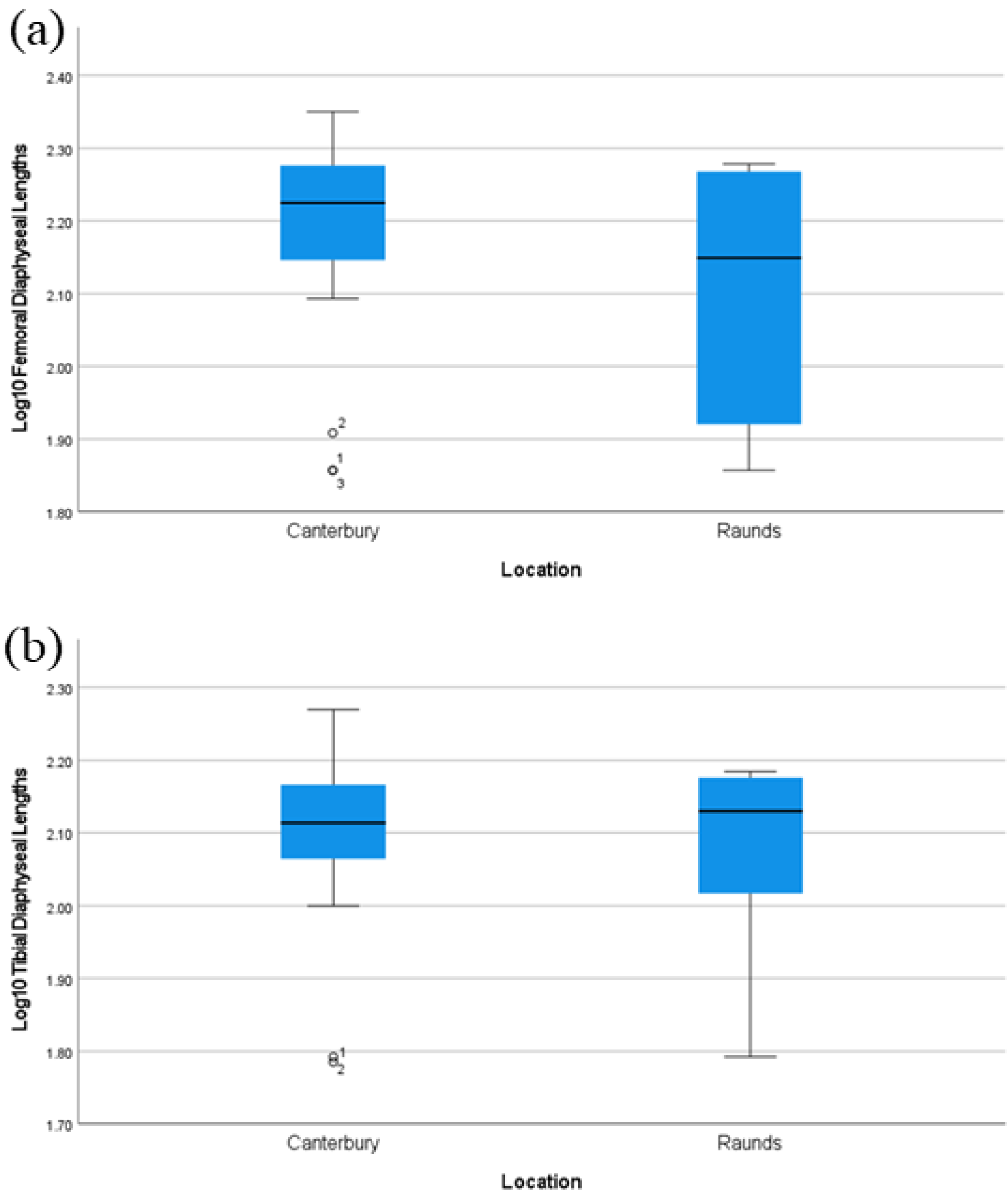



**Figure 3.7** Boxplot displaying the median and quartiles for femoral and tibial diaphyseal lengths transformed to $Log_{10}$ for non-adults 3 years and younger from Canterbury (St. Gregory's Priory) and Raunds (Raunds Furnells)

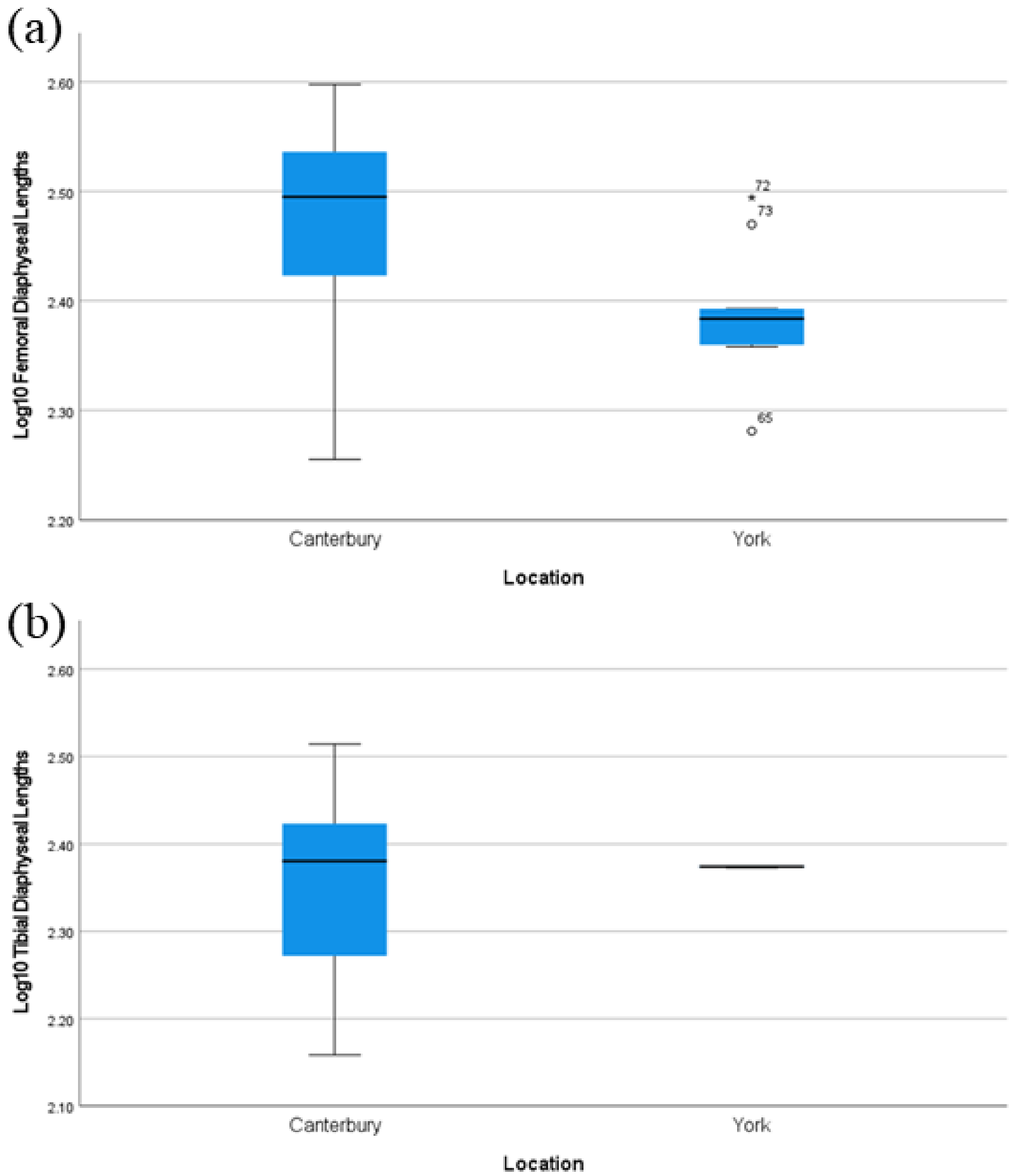



**Figure 3.8** Boxplot displaying the median and quartiles for femoral and tibial diaphyseal lengths transformed to $Log_{10}$ for non-adults 4 years and older from Canterbury (St. Gregory's Priory) and York (All Saint's Church)

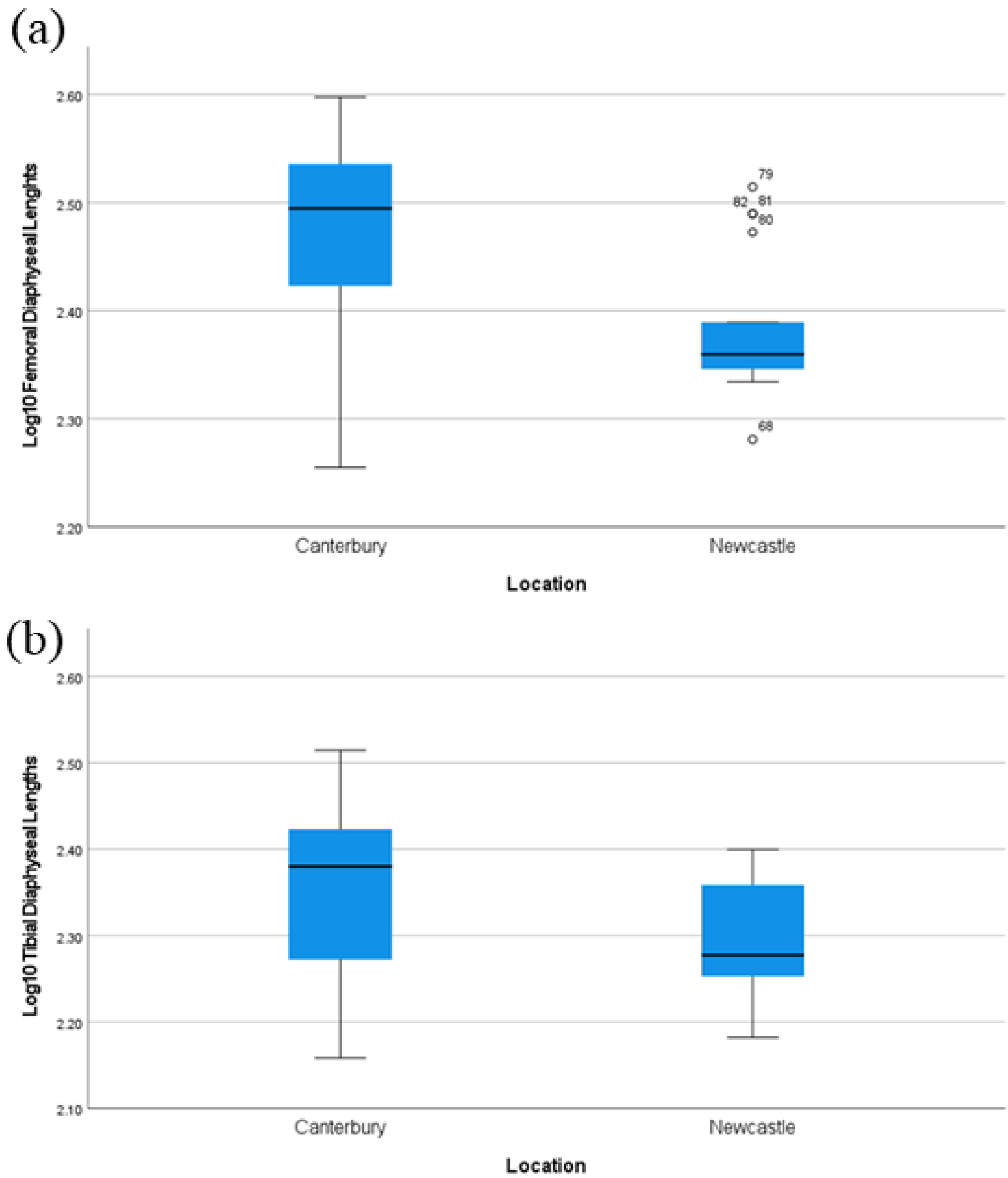



**Figure 3.9** Boxplot displaying the median and quartiles for femoral and tibial diaphyseal lengths transformed to $Log_{10}$ for non-adults 4 years and older from Canterbury (St. Gregory's Priory) and Newcastle (Black Gate)

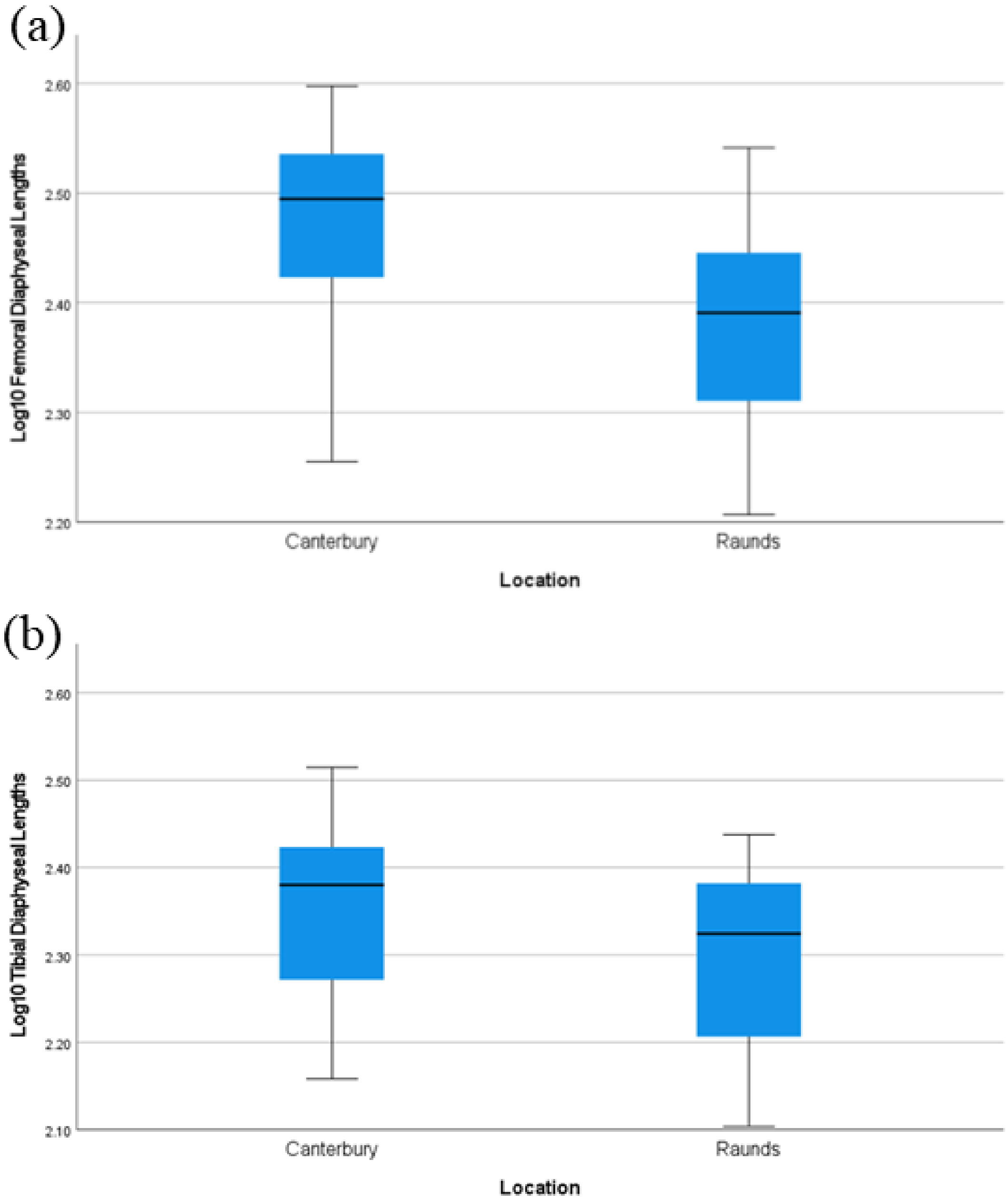



**Figure 3.10** Boxplot displaying the median and quartiles for femoral and tibial diaphyseal lengths transformed to $Log_{10}$ for non-adults 4 years and older from Canterbury (St. Gregory's Priory) and Raunds (Raunds Furnells)

The femoral diaphyseal lengths $Log_{10}$ (tables 3.2) reveals there are no significant differences between Canterbury's and Raunds's non-adults 3 years and younger growth values. However, it shows there are significant differences between Canterbury's and Newcastle's non-adults 3 years and younger and 4 years and older, Canterbury's and York's non-adults 3 years and younger and 4 years and older, and Canterbury's and Raunds's non-adults 4 years and older growth values. York's non-adults 3 years and younger had a 62.3% risk of delayed growth compared to those from Canterbury. Additionally, non-adults from York 4 years and older had a 73.5% risk of delayed growth compared to those from Canterbury. Non-adults 3 years and younger from Newcastle had an 83.3% risk of delayed growth compared to those from Canterbury. Also, Newcastle's non-adults 4 years and older had a 73.4% risk of delayed growth compared to those from Canterbury. Non-adults 4 years and older from Raunds had a 63.7% risk of delayed growth compared to those from Canterbury. The variance inflation factors express that the coefficients and p-values of the binary logistic regression are reliable.

**Table 3.2** Cox regression analysis of femoral diaphyseal lengths $Log_{10}$ of non-adults from Canterbury compared to the other sites by age group

| **Variables** | **B** | **df** | **P-value** | **Risk Ratio (95% CI)** | **VIF** |
|---|---|---|---|---|---|
| **Canterbury x York** | | | | | |
| **3 and younger** | -0.976 | 1 | 0.012[1] | 0.377 (0.175-0.809) | 1.000[2] |
| **4 and older** | -1.326 | 1 | 0.001[1] | 0.265 (0.124-0.568) | 1.000[2] |
| **Canterbury x Newcastle** | | | | | |
| **3 and younger** | -1.788 | 1 | 0.000[1] | 0.167 (0.072-0.386) | 1.000[2] |
| **4 and older** | -1.324 | 1 | 0.000[1] | 0.266 (0.148-0.480) | 1.000[2] |
| **Canterbury x Raunds** | | | | | |
| **3 and younger** | -0.416 | 1 | 0.210 | 0.660 (0.344-1.264) | 1.000[2] |
| **4 and older** | -1.014 | 1 | 0.000[1] | 0.363 (0.244-0.588) | 1.000[2] |

[1]Significant
[2]No correlation

The tibial diaphyseal lengths $Log_{10}$ (table 3.3) show no significant differences between non-adults from Canterbury and York 3 years and younger and 4 years and older and non-adults from Canterbury and Raunds 3 years and younger. Additionally, it exhibits that there are significant differences between non-adults from Canterbury and Newcastle 3 years and younger and 4 years and older and non-adults from Canterbury and 4 years and older. Non-adults 3 years and younger from Newcastle had a 71.8% risk of delayed growth compared to those from Canterbury. Further, Newcastle's non-adults 4 years and older had a 62.1% risk of delayed growth compared to those from Canterbury. Non-adults 4 years and older from Raunds had a 55.9% risk of delayed growth compared to those from Canterbury. The variance inflation factors signifies that the coefficients and p-values of the binary logistic regression are reliable.

**Table 3.3** Cox regression analysis of tibial diaphyseal lengths $Log_{10}$ of non-adults from Canterbury compared to the other sites by age groups

| Variables | B | df | P-value | Risk Ratio (95% CI) | VIF |
|---|---|---|---|---|---|
| **Canterbury x York** | | | | | |
| **3 and younger** | -0.783 | 1 | 0.116 | 0.457 (0.172-1.214) | 1.000[2] |
| **4 and older** | -0.416 | 1 | 0.567 | 0.660 (0.159-2.743) | 1.000[2] |
| **Canterbury x Newcastle** | | | | | |
| **3 and younger** | -1.265 | 1 | 0.005[1] | 0.282 (0.118-0.677) | 1.000[2] |
| **4 and older** | -0.971 | 1 | 0.001[1] | 0.379 (0.211-0.680) | 1.000[2] |
| **Canterbury x Raunds** | | | | | |
| **3 and younger** | -0.279 | 1 | 0.489 | 0.756 (0.343-1.670) | 1.000[2] |
| **4 and older** | -0.819 | 1 | 0.003[1] | 0.441 (0.257-0.756) | 1.000[2] |

[1]Significant
[2]No correlation

## 3.5 Discussion

In summary, the femoral diaphyseal lengths of non-adults from York (urban) from birth to 3 years and 4 years and older exhibited a higher risk of delayed growth compared to those from Canterbury (urban). However, the risk of delayed growth of tibial diaphyseal lengths of non-adults from Canterbury and York showed no significant differences. Although, the risk of delayed femoral and tibial diaphyseal growth of non-adults from Newcastle (proto-urban) is higher than those from Canterbury. Further, the risk of delayed growth of tibial and femoral diaphyseal lengths of non-adults from Canterbury and Raunds from birth to 3 years showed no significant differences. Conversely, the risk of delayed femoral and tibial diaphyseal growth of non-adults 4 years and older from Raunds is higher than those from Canterbury. Our findings differ from previous research that found similar growth profiles (Lewis 2002) and no significant differences (Pinhasi *et al.* 2006) of non-adults from urban and rural populations (9$^{th}$ to 16$^{th}$ century). Thus, the current study suggests that differences in childhood growth may have been present during the medieval period.

### 3.5.1 Urban vs Urban

It can be assumed that the higher risk of delayed growth in femoral diaphyseal lengths of non-adults from York from birth to 3 years compared to Canterbury reflects the sensitivity of the rapid growth stage of infancy. Nutrition is crucial during the rapid growth period during infancy (birth to 3 years) (Lejarraga 2012). The brain requires a substantial amount of essential nutrients and energy (kilocalories) to allow its structures to engage in rapid growth, including the endocrine system (Bogin, 2021). The endocrine system releases and controls the secretion of hormones such as the growth hormone and thyroid hormone (Hiller-Sturmhöfel and Bartke 1998; Saper and Lowell 2014). Adequate nutrition plays an essential role in regulating hormones that engage in skeletal growth (Bonjour *et al.* 2004; Leathem 1966). Poor nutrition influences the secretion of hormones that promote bone growth to decrease while those that inhibit growth increase (Campisi *et al.* 2018). However, there is no significant difference between tibial diaphyseal lengths of non-adults from Canterbury and York from birth to 3 years. During these ages, the form of the femoral bicondylar angle is driven by biomechanical loading while children begin to walk (Shrivastava *et al.* 2020). The differences between the femoral diaphyseal lengths growth values of non-adults from Canterbury and York from birth to 3 years may possibly be from differences in the development of the femoral bicondylar angle. The analysis of the bicondylar angle development according to age of non-adults is beyond the scope of this study. Similarly, it can be speculated for the higher risk of delayed growth of non-adults 4 years and older for femoral diaphyseal lengths from York compared to Canterbury; while simultaneously, there were no significant differences between the tibial diaphyseal lengths between the populations. Thus, perhaps there are differences between the femoral bicondylar angle for non-adults 4 years and older.

The lack of a significant difference in delayed tibial diaphyseal growth risk may reflect similarities in York's and Canterbury's detrimental environments or differences in their affluent atmosphere. In Canterbury, the affluent atmosphere, influenced by the pilgrimage culture, perhaps allowed individuals to obtain adequate nutrition for growth development. In York, income from the popular cloth and trading industry may have permitted non-adults to obtain adequate nutrition for growth development. However, non-adults from Canterbury and York were susceptible to nutritional deficiencies and infectious diseases due to dense populations, disposal of household and industrial waste into water resources, famines, insufficient ventilation for controlled fires within homes and businesses, and superfluous usage of toxic chemicals for businesses (Roberts and Manchester 2005; Rawcliffe 2013; Roberts and Cox 2003; Lincoln 1955; Palliser 2014).

### 3.5.2 Urban vs Proto-Urban

The higher risk of delayed tibial and femoral diaphyseal growth of non-adults from Newcastle (proto-urban) than Canterbury (urban) from birth to 3 years perhaps reflects the weaning process. Growth deficit patterns between 1 and 3 years of age have been viewed as the impact of onset weaning and cessation of weaning during this period (Lewis 2002; Newman, Gowland and Caffell 2019). Isotopic analysis suggests that non-adults from Black Gate (Newcastle) were weaned approximately after 9 months until 1 year (Macpherson 2005). In contrast, microwear texture analysis of non-adults from St. Gregory's Priory (Canterbury) suggest that mixed feeding could have started during or after the 1st year and cessation of weaning started around 2 years (Mahoney *et al.* 2016). These differences in weaning processes demonstrate the sensitivity of the rapid growth stage during infancy. Thus, this perhaps influenced the significant difference in growth values between non-adults from Newcastle and Canterbury from birth to 3 years.

The higher risk of delayed growth in femoral and tibial diaphyseal lengths of non-adults 4 years and older from Newcastle compared to Canterbury may reflect the relationship between the developing immune system and nutrition. During childhood, the immune system is weak and requires a substantial amount of energy acquired by adequate nutrition to promote the cells in the immune system to function (Childs, Calder and Miles 2019; Nobs, Zmora and Elinav 2020; Ygberg and Nilsson 2012). In addition, an adequate diet is essential for a robust immune system and protection against nutritional and infectious diseases. Infectious diseases such as smallpox, plague, tuberculosis, leprosy, and respiratory diseases were common during the medieval period (Rawcliffe 2013; Roberts and Manchester 2005; Roberts and Cox 2003; Robb *et al.* 2021; Barnes 2005). Infectious diseases and chronic conditions that compromise the immune system cause the body to require twice as much of essential nutrients (Barnes 2005; Law 2005; Patel 2008). Therefore, infections cause individuals to lack adequate nutritional intake (Lejarraga 2012), which in turn slow the process of normal long bone growth. Adequate nutrition would have been challenging to acquire in early medieval Newcastle due to the frequent invasions of Scottish and English kingdoms and Vikings. In Canterbury, adequate nutrition could have been obtained based on the stable income from the pilgrimage culture and weekly markets that sold national and international foods. Accordingly, Canterbury essentially was a hub for international merchants and crafters to sell their products at the weekly markets (Lincoln 1955).

### 3.5.3 Urban vs Rural

Isotopic analysis of non-adults from Raunds suggests that infants were exclusively breastfed until about 1 year and mixed-fed from 2 to 3 years (Beaumont *et al.* 2018; Haydock *et al.* 2013). Non-adults from Canterbury exhibited similar weaning patterns (Mahoney *et al.* 2016). Similarities in weaning processes for non-adults from Canterbury and Raunds from birth to 3 years perhaps reflect the lack of significant difference in delayed femoral and tibial diaphyseal growth risk. The higher femoral and tibial diaphyseal growth risk of non-adults 4 years and older from Raunds compared to Canterbury may reflect the relationship between the developing immune system and nutrition. As previously mentioned, the developing immune system requires adequate nutrition to protect non-adults from obtaining nutritional and infectious diseases that prevent the normal bone growth process from becoming slow. The stable income gained from the pilgrimage culture in Canterbury may have allowed non-adults to obtain adequate nutrition. Conversely, non-adults from Raunds relied on limited food production (i.e., the lack of continuous food surplus).

### 3.5.4 Limitations

It must be considered that the growth patterns seen in this study are not reflective of those who survived to adulthood in medieval England, due to biological mortality bias (Wood *et al.* 1992). However, Saunders and Hoppa (1993) state that the biological mortality bias is likely small because accidental deaths and short stature do not directly correlate with high mortality. Also, Spake and colleagues (2022) suggest that the impact of biological morality bias depends on the type of societies being analyzed for comparison. This study focuses on growth patterns across medieval England, but Black Gate (AD c. 700-1168) and Raunds Furnells (AD 900-1040) skeletal collections represents early medieval populations compared to the other sites, potentially producing an increased biological mortality bias. Other factors such as the small sample size of the sites should also be considered (Saunders and Hoppa 1993). However, the data presented here still provides valuable insight into environmental influences on child health in medieval England.

## 3.6 Conclusion

In conclusion, the lack of differences in femoral and tibial diaphyseal delayed growth risk between non-adults from Canterbury and Raunds from birth to 3 years possibly demonstrates similar weaning practices between the groups. Additionally, the higher risk of delayed femoral and tibial diaphyseal growth of non-adults from Newcastle than Canterbury from birth to 3 years perhaps exhibits differences in weaning practices between the groups. This research shows the sensitivity of the infancy rapid growth stage to weaning. A substantial amount of nutrients is required during the infancy rapid growth stage to allow hormones to promote bone growth (Bogin 2021; Bonjour *et al.* 2004; Campisi *et al.* 2018). Also, this research shows the relationship between the developing immune system and nutrition. Adequate nutrition limits non-adults from obtaining diseases that encourage the normal bone growth process to become delayed. The higher risk of femoral and tibial diaphyseal delayed growth of non-adults 4 years and older from Raunds than those from Canterbury suggest that those from Canterbury were perhaps more likely to obtain adequate nutrition than those from Raunds.

The higher risk of femoral and tibial diaphyseal delayed growth of non-adults 4 years and older from Newcastle than those from Canterbury was probably influenced by Newcastle's lack of stability and continuous resources. Interestingly, non-adults from York from birth to 3 years and 4 years and older had a higher femoral diaphyseal delayed growth than those from

Canterbury; however, there was no significant difference between tibial diaphyseal delayed growth. This potentially reflects differences in the development of the bicondylar angle or similar deleterious environment levels. For York and Canterbury, this also likely reflects differences in the affluent nature of both environments or similarities of both hazardous environments.

# Chapter 4 Patterns of Periosteal New Bone Concerning Infectious Diseases in Medieval Canterbury


## Abstract

Periosteal new bone on the tibia is commonly found on human skeletal remains that exhibit infectious diseases. The adverse urban environment of medieval Canterbury perhaps influenced infectious diseases. High and low-status people lived different lifestyles but encountered the adverse environment in similar ways. This study examines patterns of periosteal new bone on the tibiae as a proxy for health, along with other skeletal lesions, to identify specific infectious diseases between high and low-status adults. Periosteal new bone on the tibiae was examined on 133 adults (26 high-status and 107 low-status) from St. Gregory's Priory skeletal collection. Periosteal new bone on the tibiae was analysed with other skeletal lesions specific to tuberculosis, leprosy, venereal syphilis, and parasitic infections. Cox regression analyses were used to estimate the risk of obtaining infectious diseases between the social status groups. There was no evidence of tuberculosis, leprosy, and venereal syphilis associated with periosteal new bone on the tibiae. Although, there was evidence of parasitic infections in association with periosteal new bone on the tibiae. The results reveal no significant differences between social status groups with periosteal new bone on the tibiae, with periosteal new bone on the tibiae and biological sex, and with periosteal new bone on the tibiae and cribra orbitalia. As a result of periosteal new bone on the tibiae being associated with multiple conditions, conclusions about the risk of obtaining it were not made to avoid misinterpretations. Living conditions in medieval Canterbury may have led social status groups to have an equal chance of encountering parasitic infections.


## 4.1 Introduction

Pathological conditions, such as trauma and infections, can cause inflammation of the periosteum, known as periostitis (Roberts 2019; Weston 2012). This results in porous, longitudinal striation, and plaque-like new bone formation between the periosteum and the cortical surface of the bone (Roberts and Manchester 2005; Ortner 2003; Weston 2012). This newly formed bone is called periosteal new bone (PNB). PNB tends not to be restricted to one area of the bone's surface, thickness is variable, and can be unilateral or bilateral (Ortner 2003;

Roberts 2019). It is commonly found on the tibiae of human remains from archaeological sites (Waldron 2009; Roberts 2019; Weston 2012). This is potentially due to the tibiae's periosteum being close to the skin, making it more exposed to direct trauma and not protected by a mass of muscle and fat (Roberts 2019; Weston 2012). Various infectious diseases can cause PNB to develop on the tibiae.

### 4.1.1 Infectious Diseases

Infections frequently cause inflammatory responses in which the body neutralises the pathogenic organism and repair or heal damaged tissues (Weston 2012). It has been suggested that periostitis is an inflammatory response to chronic infections (Crespo *et al.* 2017). Chronic infections such as tuberculosis (Kelly *et al.* 1994; Roberts, Lucy and Manchester 1994; Ortner 2003), leprosy (Roberts and Manchester 2005; Lewis, Roberts and Manchester 1995b; Schultz and Roberts 2002; Slim, Faber and Maas 2009), treponemal diseases (Mays, Crane-Kramer and Bayliss 2003; Walker *et al.* 2015; Ortner 2003; Powell and Cook 2005), and parasitic infections (Smith-Guzmán 2015; Grauer 1993) are often recognised as the influence for PNB to develop on the tibiae.

Tuberculosis (TB) is, most often in humans, caused by bacteria *Mycobacterium tuberculosis* and *Mycobacterium bovis* (Roberts 2012; Ortner 2003). It's often associated as a respiratory condition due to its affect on the lungs (*Mycobacterium tuberculosis*), but it can also impact the intestinal tract (*Mycobacterium bovis*) (Roberts 2012). Leprosy, also known as Hansen's disease, is caused by *Mycobacterium leprae* (Ortner 2003; Lynnerup and Boldsen 2012). Leprosy produces skin ulcers, weakens muscles supplied by the peripheral nerve, and enlarges or thickens the peripheral verve (WHO 2023). Venereal treponemal disease (i.e., syphilis) is caused by some form of the pathogenic bacterium *Treponema pallidum* (Cook and Powell 2012; Ortner 2003). Venereal syphilis causes individuals to develop neuropathic arthropathy, granulomatous lesions with coagulated necrotic centres on the skin, and may cause aortic aneurysm, dementia, or paresis (Cook and Powell 2012). Parasites such as *Ascaris lumbricoides* (roundworm) and *Trichuris trichiura* (whipworm) are intestinal parasites (Else *et al.* 2020). Intestinal parasites can cause severe abdominal pain, malnutrition, anaemia, dysentery, and diarrhoea (Mahmud, Lim and Amir 2018; Else *et al.* 2020).

Advanced stages of parasitic infections, venereal syphilis, leprosy, and TB that caused characteristic changes to the skeleton such as PNB on the tibia are often examined in osteoarchaeological studies on health in the past (Grauer 1993; Roberts and Cox 2003; Boldsen and Mollerup 2005; Wang *et al.* 2022; Sullivan 2005; Godde and Hens 2021; Robb *et al.* 2021; Kelmelis and Dangvard Pedersen 2019; Kelmelis *et al.* 2020; Betsinger and DeWitte 2017). These studies are often associated with detrimental environment conditions such as water pollution, unhygienic waste management, dense housing and structural communities, and shared living conditions with non-human animals.

### 4.1.2 Periosteal New Bone as an Indicator of Health

Osteoarchaeological studies have examined periosteal new bone on the tibiae to identify frailty with reference to physiological stress (Yaussy, DeWitte and Redfern 2016; DeWitte 2010; DeWitte 2014a; DeWitte 2014b; Betsinger and DeWitte 2017; Betsinger *et al.* 2020) and its relationship with specific diseases (Lewis, Roberts and Manchester 1995b; Christensen, Martínez-Lavín and Pineda 2013; Kjellström 2012; Kelmelis *et al.* 2020). DeWitte (2014b) found higher frequencies of periosteal new bone in the post-Black Death sample compared to the pre-Black Death and suggest a decline in health after the Black Death in medieval London. DeWitte (2014a) found that individuals with healed PNB had higher survivorship than those with active lesions and those without any lesions in medieval London. Yaussy and colleagues (2016) found higher periosteal new bone frequencies in non-famine burials compared to famine burials in medieval London. These studies suggest that those with active and without PNB were more susceptible to diseases and died before it could develop or heal (DeWitte 2014a; Yaussy, DeWitte and Redfern 2016). Lewis and colleagues (1995) found that 76% of the individuals with leprosy displayed PNB on their long bones and 19% of individuals without leprosy showed PNB on their long bones from St. James and St. Mary Magdalene hospital. They suggest that some people were suffering from leprosy but died before the disease developed across the skeleton, some suffered from tuberculosis, and some experienced trauma before contacting leprosy (Lewis, Roberts and Manchester 1995b). However, there is a lack of osteoarchaeological research on the use of PNB on the tibia for identifying the relationship between multiple pathological conditions and determinates of health. As mentioned above, PNB on the tibia is influenced by various pathological conditions such as TB, leprosy, treponemal diseases, and parasitic infections. Therefore, this study aims to identify patterns of periosteal new bone by examining infectious diseases.

### 4.1.2 Expectations

Urbanisation and social status can influence infectious diseases. Medieval English urban centres are frequently considered hazardous to individuals' health (Rawcliffe 2013). Close compact housing and structural communities, shared gardens, latrines, and cesspits, crowded markets, rented rooms, and multiple people living in one household are all hazards that can influence the spread of infectious diseases. Thus, osteoarchaeological studies have identified pathological conditions such as leprosy, TB, venereal syphilis, and parasitic infections in urban centres of medieval England (Roberts and Cox 2003).

Like other medieval English urban centre, Canterbury had dense housing and structural communities, a heavy population, and unhygienic waste management (Lyle 2002). Thus, transmission of infectious diseases would have been quick and easy. Pathological conditions such as leprosy and TB (*Mycobacterium tuberculosis*) are suggested to be transmitted through the air (via sneezing, coughing, and breathing) (Roberts 2012; Lynnerup and Boldsen 2012). Additionally, leprosy can be obtained from close contact with an infected person (via touching hands covered with mucus) (Lynnerup and Boldsen 2012). Thus, those of low-status would have obtained leprosy and/or TB from shared gardens and cesspits, renting beds and rooms to pilgrims who might have been infected, or encountering an infected person from the market. Contrarily, high-status people would interact less with other people than low-status people but still were at a disadvantage. For example, high-status people may have encountered infected people from conducting business, such as administrative duties or meetings at home or another space, and sharing homes with employees such as servants. However, their servants gathering essential needs such as food, beverages, and clothing from farmers and traders and their administrative assistants collecting financial obligations allowed high-status people to interact less with an abundance of people (Dyer 2002).

Another infectious disease that would have been easily spread is venereal syphilis. It is transmitted through sexual contact (Perine *et al.* 1984; Cook and Powell 2012). Regardless of status, this would have been spread by having multiple sex partners, rape, and unhygienic practices such as bathing with water from the River Stour (which was polluted with waste from households and businesses, including excretion waste). In addition, the polluted River Stour would have been a breeding ground for parasitic larvae. Common parasites recognised in medieval Europe are roundworms and whipworms (Mitchell 2015). Roundworm and whipworm are faecal-oral parasites obtained through ingestion (via contaminated drinking water and crops) (Mitchell 2015). Thus, high and low-status people would have encountered these parasites from consuming water from the river and tainted crops (caused by human faeces used as fertiliser). Another infectious disease that is obtainable through ingestion is TB (*Mycobacterium bovis*). *Mycobacterium bovis* is transmitted by consuming animal products that are contaminated with it (Roberts 2012). High- and low-status people consumed animal products (Dyer 2002; Dyer 1989). However, high-status people consumed significantly more than low-status people. Low-status people had a limited supply of meat and dairy products, whereas high-status people regularly brought meat and dairy products (Dyer 1989; Dyer 2002; Roberts and Cox 2003). For further discussion on social status groups see section 1.3.2 Social Status in chapter 1.

As a result of these conditions, it can be hypothesised that high-status people had a lower risk of obtaining leprosy and TB (*Mycobacterium tuberculosis*) compared to low-status people, high-status people had a higher risk of obtaining TB (*Mycobacterium bovis*), and both high and low-status people had equal chances of obtaining venereal syphilis and parasitic infections.

## 4.2 Materials and Methods

133 adults (26 high-status and 107 low-status) from St. Gregory's Priory skeletal collection were examined for this study (see chapter 2 for more details on St. Gregory's Priory) (see Appendix table 7.2 for data used). Biological sex was assessed using pubic bone characteristics formulae (Klales, Ousley and Vollner 2012) and morphological traits of the greater sciatic notch, nuchal crest, mastoid process, supra-orbital margin, glabella, and mental eminence (Buikstra and Ubelaker 1994). Age at death was estimated using the transition analysis method (Boldsen *et al.* 2002) conducted on the Anthropological Database, Odense University (ADBOU 2.1) age estimation software. For this study, periosteal new bone was examined on the tibiae (figure 5.1) as the primary indicator of health in association with other skeletal lesions. Cox Regression was used to identify the risk of obtaining pathological conditions between high and low-status groups. Variance inflation factor (VIF) test were performed to determine if the coefficients and p-values in the Cox Regress output are reliable. High-status individuals with skeletal lesions were compared to low-status people with skeletal lesions. By doing this reduces the issue of hidden heterogeneity and its relationship with selective mortality.

Hidden heterogeneity refers to aspects of individuals that are not observable in skeletal collections such as immune system functions, differences in exposure to disease vectors, and differences in behavioural and cultural factors (Wood *et al.* 1992; DeWitte and Stojanowski 2015; Milner and Boldsen 2018). Hidden heterogeneity influences selective mortality in which individuals with the highest susceptibility to disease and death at a specific age are selected to die out of the population (Wood *et al.* 1992; DeWitte and Stojanowski 2015; Milner and Boldsen 2018). Thus, comparing individuals with and without skeletal lesions would indicate that those without were healthier than those with skeletal lesions (Ortner 1991; Wood *et al.* 1992). However, skeletal lesions such as periosteal new bone typically take time to form (DeWitte and Stojanowski 2015; Milner and Boldsen 2018). Therefore, it is suggested that individuals with skeletal lesions may have been healthier than those without them because they were able to survive long enough for the lesion to form (DeWitte and Stojanowski 2015; Milner and Boldsen 2018). In contrast, individuals without skeletal lesions may have not interacted with the same pathological conditions or had different biological immune responses as individuals with them.

### 4.2.1 Indicators of Pathological Conditions

For this study, the pathological conditions that were examined on the skeletal remains in association with periosteal new bone on the tibia are leprosy, TB, venereal syphilis, and parasitic infections (table 4.1). The primary skeletal lesion that is associated with venereal syphilis is caries sicca (Roberts and Manchester 2005; Cook and Powell 2012; Powell and Cook 2005). Caries sicca is caused by multiple gummata, chronic inflammatory lesions with coagulated necrotic centres (Cook and Powell 2012). Caries sicca appear as a large area of pits with irregular cavitation (Roberts and Manchester 2005). They are often seen on the frontal, parietal, and long bones (Roberts and Manchester 2005). Other lesions associated with venereal syphilis are periosteal new bone and facial destruction (Roberts and Manchester 2005; Cook and Powell 2012; Powell and Cook 2005). Periostitis causes periosteal new bone on the long bones and gummata damages the palate and maxilla (Roberts and Manchester 2005; Cook and Powell 2012; Powell and Cook 2005). The skeletal changes primarily associated with TB are osteolytic lesions (destructive hole-like lesions) on the anterior section of the vertebral bodies (Ortner 2003; Roberts 2012). Other lesions include periosteal pitting and new bone formation on visceral rib surfaces, periosteal new bone on long bones and the endocranial surface of the skull, and septic arthritis of the hip and knee (Ortner 2003; Roberts 2012). The primary skeletal lesions associated with leprosy are loss of the anterior nasal spine, recession of the alveolar process of the maxilla, periosteal new bone on the palatine process of the maxilla, resorption and remodelling of the margins of the nasal aperture (Ortner 2003; Roberts and Manchester 2005; Lynnerup and Boldsen 2012). Other skeletal lesions include periosteal new bone on the tibiae and fibulae and shrinkage of the feet and hands phalanges (Ortner 2003; Lynnerup and Boldsen 2012). PNB on the tibia is not a primary indicator for leprosy, TB, and venereal syphilis. Thus, evidence of PNB on the tibia and the primary skeletal lesions of leprosy, TB, and venereal syphilis were used for diagnosis. Individuals who did not display the primary skeletal lesions of leprosy, TB, and venereal syphilis were not used for this study.

It Is difficult to Identify skeletal changes that are directly related to parasitic Infections. However, advanced stages of parasitic infections cause anaemia. Anaemia occurs when the body does not have enough red blood cells (Uthman 2009). Hookworms are blood suckers and whipworm causes blood to ooze while attached to intestines; thus, leading to anaemia (Mahmud, Lim and Amir 2018). There are various types of anaemia (Dugdale 2001); however, it is difficult to determine the specific types that affect the skeleton (Waldron 2009). Anaemia is often associated with the skeletal lesion cribra orbitalia (Waldron 2009; Brickley 2018). Cribra orbitalia (CO) is described as porous lesions on the orbital roofs (Ortner 2003; Waldron 2009; Steyn *et al.* 2016). This is due to anaemia causing the expansion of red bone marrow to promote the production of red blood cells (Brickley 2018). It is suggested that CO only forms during childhood and early adulthood due to the developing skeleton (Stuart-Macadam 1987; Mittler and Van Gerven 1994; Walker *et al.* 2009). A study on a parasitic infection, malaria, found CO and PNB on the tibia present in all adult age groups (Smith-Guzmán 2015). Thus, the current study uses Smith-Guzmán (2015) study as a proxy for identifying skeletal lesions associated with parasitic infections. Individuals who did not display any of the skeletal lesions mentioned above were not examined for this study.

**Table 4.1** Diagnostic criteria for the pathological conditions: leprosy, TB, venereal syphilis, and parasitic infections

| Pathological Condition | Skeletal Lesions | Reference |
|---|---|---|
| **Venereal Syphilis** | Primary:<br>- Caries sicca (large pits with irregular cavitation)<br>Other skeletal lesions:<br>- Facial destruction (destruction of the alveolar process of the maxilla and palate)<br>- Periosteal new bone on the long bones | (Powell and Cook 2005)<br>(Roberts and Manchester 2005)<br>(Cook and Powell 2012) |
| **Tuberculosis** | Primary:<br>- Osteolytic lesions on the anterior section of the vertebral bodies<br>Other skeletal lesions: | (Ortner 2003)<br>(Roberts and Manchester 2005)<br>(Roberts 2012) |

| | | |
|---|---|---|
| | - Periosteal pitting and new bone formation on visceral rib surfaces<br>- Periosteal new bone on long bones<br>- Periosteal new bone on the endocranial surface of the skull<br>- Septic arthritis of the hip and knee | |
| **Leprosy** | Primary:<br>- Loss of the anterior nasal spine<br>- Recession of the alveolar process of the maxilla<br>- Periosteal new bone on the palatine process of the maxilla resorption<br>- Remodelling of the margins of the nasal aperture<br>Other skeletal lesions:<br>- Periosteal new bone on the tibiae and fibulae<br>- Shrinkage of the feet and hands phalanges | (Ortner 2003)<br>(Roberts and Manchester 2005)<br>(Lynnerup and Boldsen 2012) |
| **Parasitic Infections** | Primary:<br>- Cribra orbitalia<br>- Periosteal new bone on the tibia | (Smith-Guzmán 2015) |

#### 4.2.1.1 Differential Diagnosis

This section discusses a similar pathological condition to periostitis and similar skeletal lesions to primary skeletal lesions of venereal syphilis, tuberculosis, leprosy, and parasitic infections. Osteomyelitis, similar to periostitis, develops periosteal new bone (Roberts 2019). However, the development of periosteal new bone in osteomyelitis surrounds a sequestrum (Roberts 2019). A sequestrum is a devascularised bone that separates from the bone (Roberts and Manchester 2005). Additionally, osteomyelitis develops cloacae, allowing pus and other materials to drain from the bone (Roberts and Manchester 2005; Roberts 2019). In contrast, periostitis only develops periosteal new bone (Roberts and Manchester 2005; Roberts 2019).

Primary skeletal lesions are solid indicators of specific pathological conditions. Carries sicca is a primary skeletal lesion for venereal syphilis (Roberts and Manchester 2005). Carries sicca can be misinterpreted as the skeletal lesion called porotic hyperostosis, as both affect the skull. However, carries sicca is a destructive lesion resulting in large pits on the frontal and/or parietals, while porotic hyperostosis is displayed as porous lesions on the parietals (Roberts and Manchester 2005; Ortner 2003). Furthermore, carries sicca may be mistaken for cribra orbitalia, an indicator for parasitic infections, as they also both affect the skull. Although, cribra orbitalia are porous lesions that only exhibit on the orbital rooves (Ortner 2003; Waldron 2009). In addition, similar to venereal syphilis, leprosy causes the destruction of the face (Roberts and Manchester 2005). However, facial destruction is a primary indicator of leprosy, not venereal syphilis (Roberts and Manchester 2005; Lynnerup and Boldsen 2012). Also, remodelling of the margins of the nasal aperture and periosteal new bone on the palatine process of the maxilla resorption are not exhibited in facial destruction cases of venereal syphilis (Roberts and Manchester 2005; Cook and Powell 2012).

In the case of tuberculosis, osteolytic lesions on the anterior section of the vertebral bodies are its primary indicator (Ortner 2003). A skeletal lesion that could be misinterpreted as being related to tuberculosis is Schmorl's node, as they both affect the vertebral bodies (Roberts and Manchester 2005). Contrarily, Schmorl's nodes are a spinal disc herniation that causes the intervertebral disc to bulge into the intervertebral bodies (Roberts and Manchester 2005).

## 4.3 Results

The distributions of high and low-status adult males and females with PNB on the tibiae are shown in table 4.2. Low-status adults exhibited the highest distribution of PNB on the tibiae, and females from the low-status group displayed the highest distribution of PNB on the tibiae (table 4.2). The distributions of high and low status adults with PNB on the tibiae and cribra orbitalia are shown in table 4.3. There were no evidence of leprosy, TB, and venereal syphilis on individuals with PNB on the tibiae. Low-status individuals with PNB on the tibia displayed higher distributions of CO (table 4.3). Low-status females displayed the highest distribution of CO with PNB on the tibiae (table 4.3).

Small sample sizes do not allow statistical tests to be conducted based on their requirements (Weaver *et al.* 2017). Thus, as a result of the small sample size for biological sex and CO, examinations of the risk of obtaining parasitic infections between males and females by the status groups were not conducted. The cox regression analyses were able to perform risk of obtaining PNB on the tibiae by social status, social status and biological sex, social status of individuals with CO.

The cox regression analysis did not determine any significant differences between high and low-status adults with PNB on the tibia, high and low-status adult males and females with PNB on the tibia, high and low-status adults with PNB on the tibia and cribra orbitalia. The variance inflation factors demonstrates that the coefficients and p-values of the Cox regression are trustworthy.

**Table 4.2** Distribution of males and females by status groups with periosteal new bone formation on the tibiae

| Status Category | Males | Females | Total by Status |
|---|---|---|---|
| **High** | 18 | 8 | 26 |
| **Low** | 51 | 56 | 107 |

**Table 4.3** Distribution of individuals with PNB on the tibia, PNB on the femur, and cribra orbitalia by SES group

| SES Group | CO (Males \| Females) | | Total by Status |
|---|---|---|---|
| **High** | 1 | 1 | 2 |
| **Low** | 2 | 4 | 5 |

**Table 4.4** Cox regression analysis of high and low status adults with PNB on the tibiae and their association with biological sex, and cribra orbitalia

| Variables | B | df | P-value | Risk Ratio (95% CI) | VIF |
|---|---|---|---|---|---|
| **SES** | 0.169 | 1 | 0.451 | 1.184 (0.763-1.836) | 1.000[1] |
| **SES and biological sex** | -0.265 | 1 | 0.138 | 0.767 (0.541-1.089) | 1.000[1] |
| **SES and CO** | 0.809 | 1 | 0.465 | 2.245 (0.257-19.633) | 1.000[1] |

[1]No correlation

## 4.4 Discussion

The results display that low-status individuals, specifically low-status females, had a higher distribution of PNB on the tibia. This finding is similar to previous research on patterns of PNB on the tibia in 18th to 19th century London (Yaussy 2019) . Yaussy (2019) found PNB on the tibia more common in the low SES groups than the high SES groups and suggested that the hazardous conditions of the urban environment were more detrimental for low SES groups in industrial London. In contrast to the current study, Yaussy and colleagues (2016) found higher frequencies of PNB on the tibia of males in medieval London. They suggested that some aspects of life differed for males and females, resulting in different exposures to traumas, infections, or other stressors (Yaussy, DeWitte and Redfern 2016). However, for the current study, the Cox regression revealed no significant differences between the status groups and the biological sex of the status groups. Ultimately, because PNB on the tibia can result from multiple conditions, it is difficult to make inferences about the results without over or underestimating them.

### 4.4.1 Parasitic Infections

The results revealed no significant difference between individuals from the social status groups with CO and PNB on the tibiae. Similarly, a previous study used CO as a proxy for parasitic infections in medieval London and found no significant differences between social status groups (Godde and Hens 2021). Godde and Hens (2021) mention that parasites and not diet influenced anaemia in medieval London, as iron cooking pots were common in the medieval period. They suggest no significant differences between social status groups due to population crowding, water contamination, and food contamination (Godde and Hens 2021). Thus, this perhaps had the same influence on people in medieval Canterbury.

In medieval Canterbury, various factors influenced low and high-status adults to have a similar, if not the same, chance of obtaining parasitic infections. The river Stour, unoccupied plots, and cesspits were frequently used to dispose of household and bodily waste (Lincoln 1955; Miller and Hatcher 1995; Rawcliffe 2013; Roberts and Cox 2003). Low-status people would have used private or public cesspits, private or public latrines placed over the river Stour and streams, or private or public latrines placed over designated unoccupied plots or neighbouring properties to dispose of human excretion waste (Dyer 1989; Miller and Hatcher 1995; Rawcliffe 2013). High-status people would have primarily used private latrines placed over the river or designated unoccupied plots, but when they were not in the comfort of their own homes, they would have used public latrines (Dyer 1989; Rawcliffe 2013). High and low-status people would have used the river Stour and nearby streams to dispose of household and non-human animal waste (Lincoln 1955). In addition to the people who lived in medieval Canterbury, pilgrims and travellers would have used public latrines and cesspits and disposed of waste into the river (Lincoln 1955). These waste deposits provided breeding grounds for flies and parasites (Barnes 2005). For example, whipworm and roundworm eggs were found in cesspits of medieval York (Jones 1985). Thus, people who encountered designated waste disposal areas would have obtained parasitic infections.

Additionally, high and low-status adults would have become easily infected by drinking water from the river or rainwater, collected by buckets near waste disposal areas, contaminated with animal and human faecal matter (Barnes 2005). Also, contaminated fingers from an itchy butt or building a house with animal manure, wet soil, and straw would have transferred infective larvae to people's mouths, especially when eating (Barnes 2005). Plus, Animals often roamed the city and shared living spaces with low-status people (Dyer 1989; Rawcliffe 2013). Close contact with animals such as pigs and dogs may have allowed parasites such as roundworm and whipworm to adapt to humans (Barnes 2005; Little 1985).

It can be assumed that high-status people had access to clean drinking water through wells, fresh food, and better hygienic practices; thus, allowing them to avoid parasitic infections. Although, archaeological evidence of roundworm and whipworm were recovered with King Richard III (Mitchell *et al.* 2013) and 8 Augustinian friars in medieval Cambridge (Wang *et al.* 2022). A common way that high and low-status people would have obtained parasitic infections would have been through contaminated food. Human faeces were used as fertiliser to increase crops yields (Jones 2012; Magnusson 2013). Waste from cesspits were collected and sold to farmers as fertiliser (Taylor 2015). Thus, crops would have been contaminated with parasites. In summary, high and low-status people would have similarly obtained parasitic infections through water and food contamination and unhygienic practices.

Intestinal parasites such as roundworm and whipworm release anti-clotting (i.e., preventing blood clots) factors that ensures continuous blood flow which causes chronic intestinal blood loss, that leads to anaemia (Anumudu *et al.* 2007; Hotez and Molyneux 2008; Osazuwa, Ayo and Imade 2011). Anaemia is a condition that develops when the body does not produce enough red blood cells causing systemic deficiency of oxygen (Brickley 2018; National Heart Lung and Blood Institute 2022; Osazuwa, Ayo and Imade 2011; Penn Medicine 2022).There are various types of anaemias such as anaemia due to vitamin B12 deficiency, anaemia due to folate deficiency, anaemia due to iron deficiency, anaemia od chronic disease, haemolytic anaemia, idiopathic aplastic anaemia, megaloblastic anaemia, sickle cell anaemia, and thalassemia (National Heart Lung and Blood Institute 2022; Penn Medicine 2022; Waldron 2009). Cribra orbitalia has been recognised on the skeleton to develop as a response to anaemia (Stuart-Macadam 1987; Carlson, Armelagos and Van Gerven 1974; Walker *et al.* 2009; Steyn *et al.* 2016; Waldron 2009; Ortner 2003; Roberts and Manchester 2005). Paleopathologists have long debated the type of anaemia that causes cribra orbitalia to develop (Stuart-Macadam 1987; Carlson, Armelagos and Van Gerven 1974; Walker *et al.* 2009; Steyn *et al.* 2016). Few studies have shown a relationship between a parasitic infection (malaria) and cribra orbitalia (Smith-Guzmán 2015; Gowland and Western 2012). Smith-Guzmán (2015) recognised a pattern of cribra orbitalia and periosteal new bone and suggest that PNB is an inflammatory response likely arises due to the systemic infection.

### 4.4.2 Limitations

It can be argued that the sample size for this study is exceptionally small. Additionally, using periosteal new bone on the tibiae as a proxy for health to identify diseases could be misleading (See chapter 1 section 1.5.2 Pathological Conditions for more details on non-specific skeletal lesions). However, because other skeletal lesions were analysed with PNB on the tibiae to identify specific diseases; thus, the data provides perceptions on environmental influences on parasitic infections in medieval Canterbury. Although, the absence of evidence of other pathological conditions that affect the skeleton is an issue because it continues the lack of understanding of diseases in medieval Canterbury.

## 4.5 Conclusion

In summary, this study demonstrates that high and low-status adults had a similar, if not the same, risk of having periosteal new bone on the tibiae and obtaining parasitic infections. It is difficult to discuss the reasoning for the similar risk of periosteal new bone without misinterpretation because various pathological conditions can cause it. Contrarily, the risk of obtaining parasitic infections can be discussed. High and low-status people polluted the river with waste disposal and used the water from the river for drinking, bathing, and cleaning. Also, using human faeces as fertilizer for crop yields placed high and low-status people at risk of parasitic infections. Thus, unhygienic practices and consuming polluted water and contaminated food placed high and low-status people at risk of acquiring parasitic infections.

# Chapter 5 Survivorship and Mortality of Social Status Groups in Medieval Canterbury


## 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.


## 5.1 Introduction

Social status is used in osteoarchaeological studies to recognise potential health inequities in past societies. Studies often use age-at-death distributions to identify mortality patterns of social status groups (Sullivan 2004; Sullivan 2005; Miszkiewicz 2015; Cook 1981; Grauer 1989; Powell 1988). 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 (Wilson 2014; Boldsen 2007; Redfern and Dewitte 2011; Redfern *et al.* 2015; Dewitte, Boulware and Redfern 2013; Godde, Pasillas and Sanchez 2020; Betsinger *et* *al.* 2020; Kelmelis and Dangvard Pedersen 2019). Many studies of survivorship and mortality risk patterns in England predominantly focus on London (DeWitte 2015; Yaussy and DeWitte 2018; DeWitte 2014c; Yaussy, DeWitte and Redfern 2016; DeWitte 2010; DeWitte *et al.* 2015; DeWitte 2017; Dewitte, Boulware and Redfern 2013; Godde and Hens 2021; Godde, Pasillas and Sanchez 2020) which leads to less understanding of other areas in England.

Canterbury was delegated the southern province of England for the Church, establishing it as an eminent place for theology from the 11th to 15th centuries (Clegg 2003). Shrines were established for saints in Churches to encourage pilgrims to provide donations in exchange for miracles performed by the saints and indulgences received by the Church (Ekelund *et al.* 1996; Lyle 2002; Hopper 2002; Clegg 2003; Sorabella 2011). In addition, pilgrims would have donated monetary assets to hospitals and beggars while on their journey (Webb 2000; Hopper 2002; Lyle 2002). As a result, the pilgrimage culture inspired people in Canterbury to provide souvenirs, accommodation, food, and drinks for pilgrims (Lincoln 1955; Hopper 2002). This influenced job opportunities and migration, thus, promoting a dense population, compact structural and housing communities, narrow streets, unhygienic waste management, and inadequate ventilation (Dyer 1989; Lyle 2002). Hence, these adverse conditions influence the spread of infectious diseases such as the Black Death, tuberculosis, pneumonia, and typhus (Talbot 1967; Lyle 2002; Rawcliffe 2013). Furthermore, the sporadic warm and cold weather negatively affected the crops, which caused irregular famines that caused people to develop nutritional deficiencies (Rubin 1974; Rawcliffe 2013; Pribyl 2017). Previous anthropological studies on medieval Canterbury have focused on health between social status groups. However, less is known about the effects of medieval Canterbury's urban 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.

### 5.1.1 Osteoarchaeological Studies of Survivorship and Mortality Risk Patterns

Previous studies compare rural and urban areas (Redfern *et al.* 2015; Walter and Dewitte 2017), pre-, post-, and during black death periods (DeWitte 2014c; DeWitte 2015; DeWitte 2017; Godde, Pasillas and Sanchez 2020), famine and non-famine periods (Yaussy, DeWitte and Redfern 2016; Yaussy and DeWitte 2018), and individuals with skeletal lesions (DeWitte 2010; Godde and Hens 2021; Godde, Pasillas and Sanchez 2020) 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 social status 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 2015; DeWitte 2017). 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 skeletal lesions 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 skeletal lesion had a 1.67-fold increase hazard for dying of the Black Death compared to those without skeletal lesions. They suggest that mortality was selective towards individuals whose health was compromised due to early life adverse exposures (Godde, Pasillas and Sanchez 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, DeWitte and Redfern 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, DeWitte and Redfern 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.

## 5.1.1 Biological Anthropological Studies of Social Status in Medieval Canterbury

### 5.1.2.1 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 social status backgrounds. They suggest that childhood physiological stress predisposed the skeleton to become robust in adulthood for the high social status group (Walker *et al.* 2019). However, low social status 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).

### 5.1.2.2 Non-Adults

Studies have found differences between infancy stress and physical activity of high- and low-status non-adults (Miszkiewicz *et al.* 2019; Pitfield, Deter and Mahoney 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, Deter and Mahoney 2019).

#### 5.1.2.3 Expectations

These studies of social status 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. For further discussion on social status groups see section 1.3.2 Social Status in chapter 1. 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.

## 5.2 Materials and Methods

Previous studies on social status in medieval Canterbury have analysed individuals from St. Gregory's Priory (see chapter 2 for more details on St. Gregory's Priory) skeletal collection because of the burial nature of social status groups (Miszkiewicz 2015; Miszkiewicz *et al.* 2019;Walker *et al.* 2019; Pitfield, Deter and Mahoney 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 2001b; 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 and gold thread, 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 2001b; 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 (see Appendix tables 7.3 and 7.4 for data used).

**Table 5.1** Distribution of high-status and low-status adults and non-adults

| | | **High-Status** | **Low-Status** |
|---|---|---|---|
| **Adult** | Males | 30 | 262 |
| | Females | 17 | 283 |
| **Non-adults** | | 27 | 251 |

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, Hector and Liversidge 2010) and the long bone length linear regression formulae (Primeau *et al.* 2015; Scheuer, Musgrave and Evans 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 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 (Ranstam and Cook 2017; Benítez-Parejo, Rodríguez del Águila and Pérez-Vicente 2011). 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.

### 5.2.1 Fertility Proxy

Age-at-death distributions have a stronger association with fertility patterns than mortality patterns (Sattenspiel and Harpending 1983). There are various fertility proxy methods that can be used to determine whether differences in mortality patterns of past groups reflect variation in fertility patterns (Buikstra, Konigsberg and Bullington 1986; Paine and Harpending 1996; Bocquet-Appel 2002; Robbins 2010; Schug 2012; McFadden and Oxenham 2018; Taylor, Oxenham and McFadden 2023). However, there are a lack of trial-and-error studies of these methods on populations with known age-at-death and fertility rate. The most commonly used fertility proxy is the $D_{30+}/D_{5+}$ method described by Buikstra and colleagues (1986) (Larsen 2001; Schurr and Powell 2005; Nagaoka and Hirata 2007; Klaus and Tam 2009; DeWitte 2014c; Walter and Dewitte 2017; Betsinger and DeWitte 2017; Smith *et al.* 2017; Garland, Turner and Klaus 2016; Kelmelis and DeWitte 2021; DeWitte 2015). Thus, this study controls for fertility by using the $D_{30+}/D_{5+}$ method, 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, Konigsberg and Bullington 1986). Comparison intervals are different from confidence intervals in which it controls for the overall level of significance for multiple comparisons of proportions rather than establish interval estimates for the location of true means (Buikstra, Konigsberg and Bullington 1986; Zoeller *et al.* 2021). The use of Buikstra and colleagues (1986) 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.

## 5.3 Results

The survival curve (figure 4.1) 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 (figure 4.2) 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.

### 5.3.1 Adults

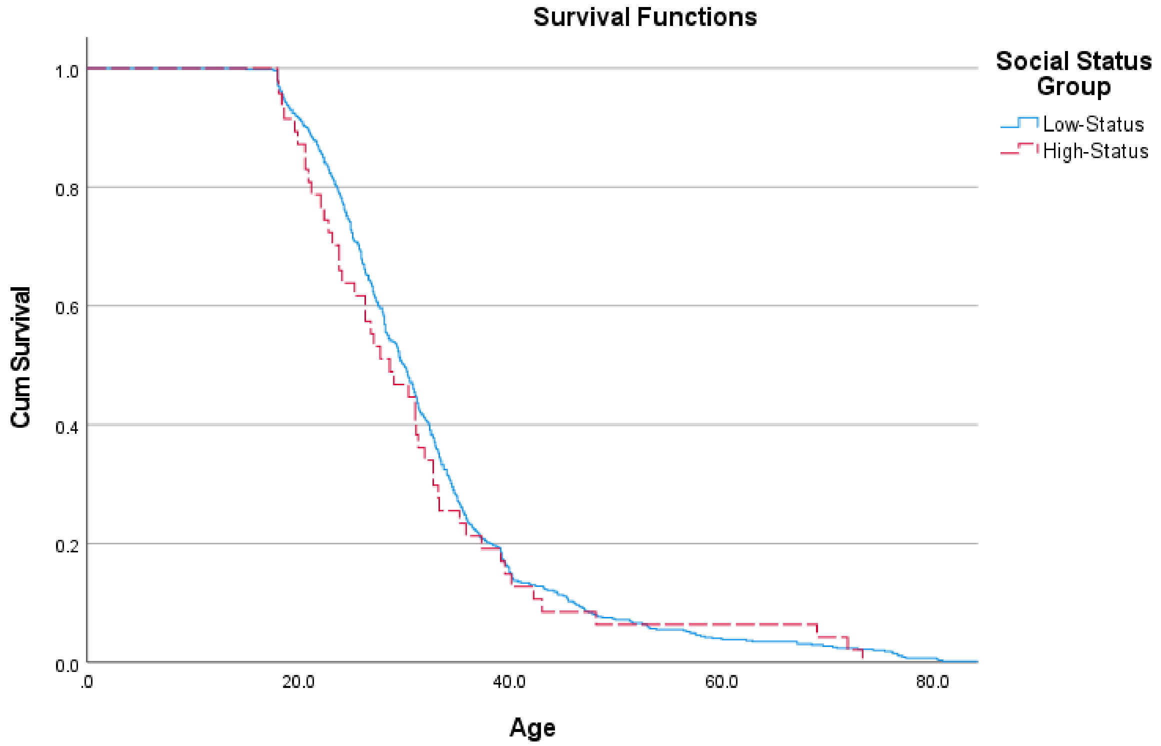



**Figure 5.1** Kaplan-Meier survival curve of high- and low-status adults

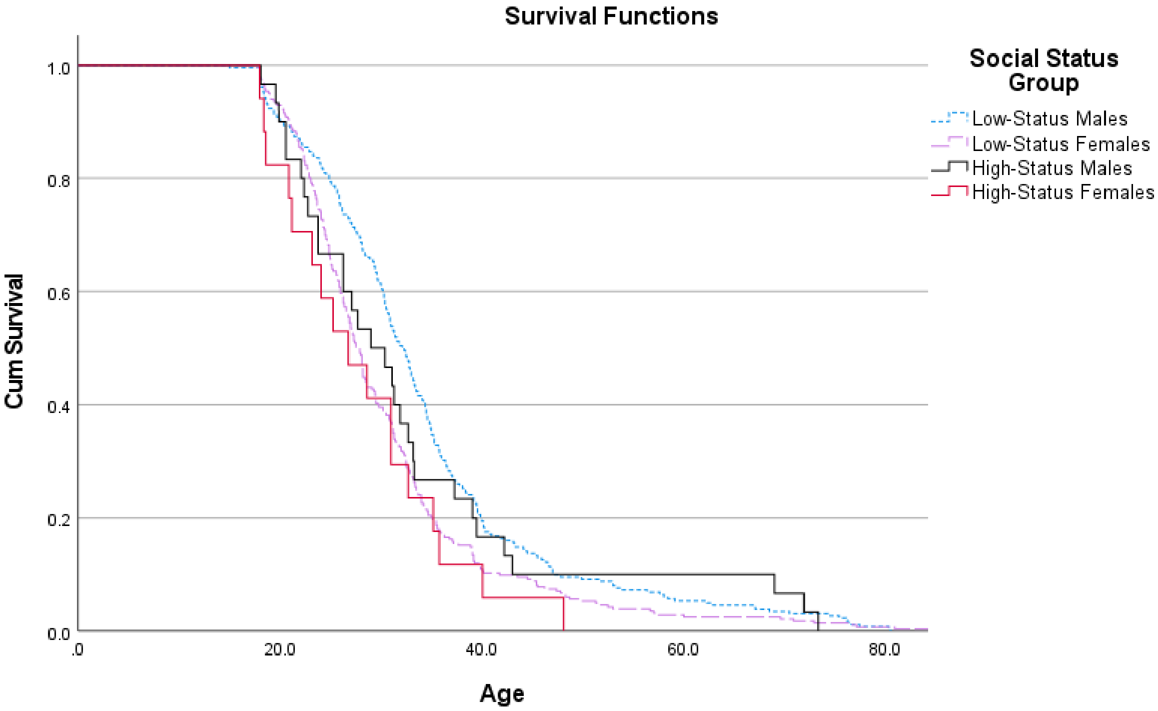



**Figure 5.2** Kaplan-Meier survival curve of high- and low-status adult males and females

However, the log rank test (Table 5.2) 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 5.3. 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 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.

**Table 5.2** Log Rank (Mantel-Cox) test of high- and low-status adults

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

[1]Significant

**Table 5.3** Cox regression analysis of high- and low-status adults

| Covariates | B | df | P-value | Hazard ratio (95% CI) | VIF |
|---|---|---|---|---|---|
| **High- x Low-Status Adults** | -0.108 | 1 | 0.480 | 0.898 (0.666-1.210) | 1.000[2] |
| **High- x Low-Status Males** | -0.145 | 1 | 0.454 | 0.865 (0.592-1.264) | 1.000[2] |
| **High- x Low-Status Females** | -0.173 | 1 | 0.489 | 0.841 (0.515-1.374) | 1.000[2] |
| **High-Status Males x Low-Status Females** | 0.160 | 1 | 0.408 | 1.173 (0.804-1.712) | 1.000[2] |
| **High-Status Females x Low-Status Males** | -0.527 | 1 | 0.036[1] | 0.590 (0.360-0.966) | 1.000[2] |

[1]Significant
[2]No correlation

## 5.3.1 Non-Adults

The Kaplan-Meier survival curve (figure 4.3) shows higher survivorship of low-status nonadults compared to those of high-status. The log rank test (table 4.4) 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 4.5. 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.

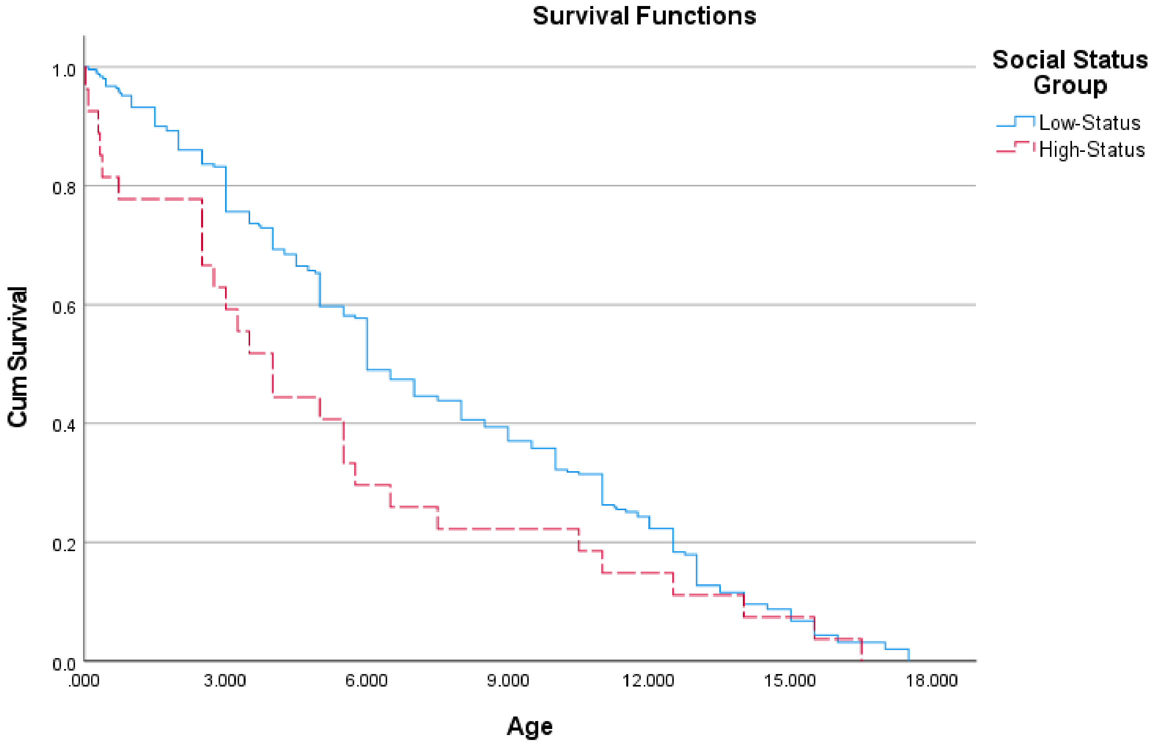



**Figure 5.3** Kaplan-Meier survival curve of high- and low-status non-adults

**Table 5.4** 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 5.5** Cox regression analysis of high- and low-status non-adults

| Covariates | B | df | P-value | Hazard ratio (95% CI) | VIF |
|---|---|---|---|---|---|
| **High- x Low-Status** | -0.385 | 1 | 0.058 | 0.681 (0.457-1.014) | 1.000[2] |

[2]No correlation

## 5.3.3 Fertility Proxy

The fertility proxies and their 95% comparison intervals for the low- and high-status groups are outlined in Table 4.6. 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.

**Table 5.6** $D_{30+}/D_{5+}$ 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 |

# 5.4 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 travelled to Canterbury for protection from anything harmful or to become cured from ailment (Webb 2000; Hopper 2002; Lyle 2002; Lincoln 1955). 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 social status due to the pilgrimage culture, resulting in similar survivorship and morality risk as high social status 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 (Tatton-Brown 1995; Sparks 2001). 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 (Micha, Wallace and Mozaffarian 2010; Feskens, Sluik and van Woudenbergh 2013). 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 (Martin 1950; Lincoln 1955). A study found that individuals who were buried in the priory had a higher average $\delta15N$ 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 social status 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; Moradi *et al.* 2018; Lee and Pearce 2018). Furthermore, pregnancy complications such as pre-existing disease or disease that developed during pregnancy (Lee and Pearce 2018; O'Brien and Thomas 2018; Hollis and Wagner 2018), high blood pressure (Moser 2007; Hedderson and Ferrara 2008), haemorrhage (Shahbazi *et al.* 2012; Mhyre 2012; Goodwin and Breen 1990), and blood clots in the veins (Mhyre 2012; Stone and Morris 2005; Bourjeily *et al.* 2010) 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 less 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, Stroop and Greene 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; Stel *et al.* 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 18$^{th}$ to mid-19$^{th}$ 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; Wood *et al.* 1992; Vaupel, Manton and Stallard 1979). 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.

### 5.4.1 Limitations

It can be assumed that migration affected the results of survivorship and mortality risk of both social status groups. Canterbury was a thriving urban centre resulting from theology and the pilgrimage culture that influenced migration (Lyle 2002; Lincoln 1955). 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 (Miller and Hatcher 1995; Dyer 2002). Hence, both social status 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 social status groups effects mortality and survivorship in medieval Canterbury.

## 5.5 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 social status 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.

# Chapter 6 Discussion and Conclusions

The data chapters (chapters 3, 4, and 5) of this thesis has assisted with addressing the aim of this thesis, identifying urban health in medieval Canterbury. This chapter discusses the outcomes of the data chapters and their relationship with the physical and social environment. Additionally, this chapter provides a brief discussion on the limitations of the research and future recommendations of this research topic. This chapter concludes with the inferences of the thesis's aim with the aid of the results from the data chapters.

## 6.1 Childhood Growth

The objective 'to compare and assess childhood growth profiles of Canterbury to other medieval English towns' was carried out in Chapter 3. This chapter examines the femoral and tibial diaphyseal lengths, as a proxy of height in relation to health, of non-adults from Canterbury and compares them against non-adults from urban York, proto-urban Newcastle, and rural Raunds. This was done to identify the difference between Canterbury's urban environment influence on childhood growth and the other settlement types. The results revealed that non-adults from birth to 3 years and 4 years and older from Canterbury had a lower risk of delayed tibial and femoral diaphyseal growth than those from Newcastle. Furthermore, non-adults 3 years and younger and 4 years and older from Canterbury had a lower risk of delayed femoral diaphyseal growth than those from York. Alternatively, there were no significant difference between the risk of delayed tibial diaphyseal growth of non-adults from Canterbury and York and the risk of delayed tibial and femoral diaphyseal growth of non-adults from birth to 3 years from Canterbury and Raunds.

The higher risk of delayed femoral and tibial diaphyseal growth of non-adults 3 years and younger from Newcastle than those from Canterbury and the lack of differences between those from Canterbury and Raunds reflects the sensitivity of growth disruption during the rapid growth stage of infancy. It has been suggested that onset weaning and cessation of weaning influence delayed growth patterns between 1 and 3 years of age (Lewis 2002; Newman, Gowland and Caffell 2019). The difference in weaning patterns include non-adults from Newcastle were weaned approximately after 9 months until 1 year of age (Macpherson 2005) and those from Canterbury started mixed feeding during or shortly after the 1st year and cessation of weaning started around 2 years of age (Mahoney *et al.* 2016). However, weaning patterns of non-adults from Raunds Furnells (Beaumont *et al.* 2018; Haydock *et al.* 2013) are similar to those from Canterbury. Thus, similarities in the risk of delayed femoral and tibial diaphyseal growth may reflect similarities in the weaning diet of non-adults from Raunds and Canterbury. In the case of non-adults, 3 years and younger, from York risk of delayed femoral diaphyseal growth being higher than those from Canterbury may reflect differences in the formation of the femoral bicondylar angle and/or pathological conditions that affect the femoral neck for the reason that there is no significant difference between non-adults 3 years and younger from Canterbury and York risk of delayed tibial diaphyseal growth.

Similar inferences can be made for the higher risk of delayed femoral diaphyseal growth of non-adults 4 years and older from York than those from Canterbury; while at the same time, non-adults 4 years and older from York and Canterbury showed no significant difference in the risk of delayed tibial diaphyseal growth. Contrarily, the higher risk of delayed femoral and tibial diaphyseal growth of non-adults 4 years and older from Newcastle and Raunds than those from Canterbury reflects the relationship between the developing immune system and nutrition. Adequate intake of essential nutrients would have been difficult to obtain in early medieval Newcastle due to the frequent invasions of Vikings and Scottish and English kingdoms, which would have left them with little to no resources to sustain an adequate diet. Those from Raunds would have depended on agricultural practices to produce food for their own consumption. In contrast, those from Canterbury would have gained an adequate nutritional intake based on the stable income from the pilgrimage culture that allowed them to purchase national and international food from the markets.

A previous study comparing medieval growth profiles of non-adults from rural Raunds to urban York found that non-adults from York had higher growth values than those from Raunds (Pinhasi *et al.* 2006). It is suggested that differences in York's and Raunds' social environments impacted growth due to differences in health practices, infant feeding practices, and food availability (Pinhasi *et al.* 2006). Osteoarchaeological studies on childhood growth in urban areas in the past have found no differences between growth patterns (Cardoso *et al.* 2018; Newman, Gowland and Caffell 2019; Newman and Gowland 2017). A study focused on health inequities in childhood growth in industrial-era London, Newman and Gowland (2017) found no differences between tibial lengths of socioeconomic status groups. They suggest that the urban environment influenced stress in early life and had implications for future adult health (Newman and Gowland 2017). Cardoso and colleagues (2018) found a lack of differences between the growth of 15th to 17th century enslaved African children from Lagos, Portugal and early 20th century African descent children from Cleveland, Ohio, USA and Gauteng Province, South Africa. They suggest the consequences of institutionalised racial discrimination in urban centres compare well to the impacts of institutionalised slavery (Cardoso *et al.* 2018).

The current study contributes to knowledge of urbanisation and childhood growth in medieval England. It contributes to the suggestion that there are differences in childhood growth between medieval rural and urban environments. It also introduces differences between medieval urban and proto-urban environments.

# 6.2 Pathological Conditions

The objective 'to identify potential pathological conditions people obtained by investigating periosteal new bone patterns of adults' was conducted in Chapter 4. This chapter analysed periosteal new bone to recognise potential patterns of advanced stages of infectious diseases to identify potential social and health inequities within medieval Canterbury. The results revealed that there was only macroscopic evidence of parasitic infections. However, no significant difference existed between adult individuals with parasitic infections from high and low status groups. The urban environmental conditions would have equally or similarly caused people to encounter parasitic infections. As a result of disposing of waste into the river, cesspits, and onto unoccupied plots, dense housing conditions, close contact with animals, and unhygienic practices may have easily spread parasitic infections. Paleoparasitological evidence suggest that parasites were common in medieval Europe (Mitchell 2015).

As mentioned in chapter 4, many osteoarchaeological studies examine periosteal new bone as an indicator of specific diseases along with other skeletal lesions (Farley and Manchester 1989; Mays, Crane-Kramer and Bayliss 2003; Lewis, Roberts and Manchester 1995b; Walker *et al.* 2015). For example, Farley and Manchester (1989) recognized periosteal new bone on the tibia and other skeletal lesions that indicated leprosy on individuals from the Leper Hospital of St. Margaret in medieval High Wycombe. Mays and colleagues (2003) examined a range of skeletal lesions, including periosteal new bone on the tibia, that indicated treponemal disease in medieval Essex and Suffolk. Additionally, osteoarchaeological studies examine age-related patterns of periosteal new bone on the tibia as an indicator of physiological stress (DeWitte 2014a; Yaussy, DeWitte and Redfern 2016; DeWitte 2010). Yaussy and colleagues (2016) found more older adults with periosteal new bone from the non-famine burials than the famine burials in medieval London. It is suggested that those from the non-famine burials were less frail compared to those from the famine burials (Yaussy, DeWitte and Redfern 2016). DeWitte (2014) found more older adults with periosteal new bone from the post-Black Death period

(AD 1350-1538) than the pre-Black Death period (AD 1000-1300) in London, and it is suggested that the health may have improved after the Black Death.

This study attempts to examine periosteal new bone during the advanced stages of infectious diseases, but more macroscopic evidence of other skeletal lesions was needed on the skeletal remains. On a high note, macroscopic evidence of parasitic infections was identified, thus providing insight into the relationship between individuals obtaining parasitic infections and the urban environment in medieval Canterbury.

## 6.3 Survivorship and Mortality Risk Patterns

The objective 'to explore survivorship and mortality risk patterns of adults and non-adults' was carried out in chapter 5. This chapter examined survivorship and mortality risk to recognise potential social and health inequities within medieval Canterbury. The results revealed only a significant difference between survival and mortality risk patterns of low-status adult males and high-status adult females, thus, demonstrating that low-status adult males had an increased survivorship and lower mortality risk than high-status adult females. The results also revealed that low-status non-adults had an increased survivorship compared to high-status non-adults, but there is no significant difference in mortality risk. However, the significant difference in survivorship may be minor because there is no significant difference in risk of mortality between high- and low-status non-adults. This is due to differences in the statistical methodology between the Kaplan-Meier and Cox regression tests. In the case of differences in survival and mortality risk patterns between low-status adult males and high-status females, high-status females would have had a high intake of meat in their diet and, additionally, would have rationed their food to provide more for their husbands and children. Also, due to the pilgrimage culture allowing people to have higher wages than average, low-status adult males had access to various types of fruits and vegetables because the markets were a national and international hub.

A study conducted by DeWitte and colleagues (2015) found a lack of significant differences in survivorship and mortality risk between social status groups of adults in industrial-era London and suggest the relationship between selective mortality and heterogeneity during childhood may be the reason for it. However, the current study differs from DeWitte and colleagues (2015) because it examined adult males and females based on SES groups. Therefore, finding a difference between high-status adult females and low-status adult males. This study provides insight into the potential nutritional intake between medieval Canterbury's high and low status groups. Notably, it suggests that low-status adult males were less at risk of mortality and had a higher chance of surviving the urban environment because of the stable income gained by the pilgrimage culture. Thus, this allowed low status adult males to have frequent access to various nutritious foods that allowed their immune systems to combat nutritional and infectious diseases.

## 6.4 Limitations

It may be suggested that sample size, time period, and migration may not contribute sufficient information for this research. The sample size for this research is influenced by the preservation of the skeletal remains. Decomposition, taphonomy, and the manner in which the remains were preserved during excavation and curation (Larsen 2015) may have caused specific skeletal elements required for analysis to become deteriorated, misplaced, or fragmented. Also, time restrictions and the lack of financial resources of archaeological excavations (O'Neil 1993) may have influenced the sample size of St. Gregory's Priory skeletal collection. In addition, St. Gregory's Priory skeletal collection consists of individuals from a wide time range. Also, the lack of archaeological evidence for specific dates of individuals who were buried in the cemetery outside of the priory (besides the standard late medieval matrix) does not help. Furthermore, migrants to Canterbury may have been buried at St. Gregory's Priory, thus leading to additional interpretations of data analysis as seen in chapters 4 and 5. However, this research's results still provide useful information regarding urban health in medieval Canterbury concerning childhood growth, pathological conditions, and survivorship and mortality patterns.

## 6.5 Future Recommendations

### 6.5.1 Isotope Analysis for Migration

It is recommended to conduct strontium and oxygen isotope analyses to identify potential migrants to Canterbury. Chenery and colleagues (2010) found, in Roman Gloucester, isotopic values of individuals born in the UK and from warmer climates. Kendall and colleagues (2013) found isotopic values in individuals born in 14th century London, London's surrounding hinterlands, and northern and western UK. Isotope analyses will recognise potential migration to Canterbury during the medieval period. As well as, understanding the possible influence Canterbury's environment had on migrants compared to those born in Canterbury.

## 6.5.2 Comparison with Other Skeletal Collections

It is recommended to examine St. Gregory's Priory with other skeletal collections of medieval Canterbury and the county of Kent. Yaussy and colleagues (2016) found, in medieval London, that individuals from famine burials had a higher frequency of linear enamel hypoplasia and individuals from non-famine burials had a higher frequency of PNB. They suggest that this may be because individuals from the non-famine burials lived long enough to develop PNB while those who were buried in the famine burials did not (Yaussy, DeWitte and Redfern 2016). It is also suggested that higher frequency of linear enamel hypoplasias of individuals from famine burials may indicate that repeated stress influenced their risk of mortality during famine (Yaussy, DeWitte and Redfern 2016). Newman and Gowland (2017) found no differences in growth profiles of non-adults' socioeconomic status groups in industrial-era London. However, Hughes-Morey (2015) found that low-status adult females from the same skeletal collections displayed shorter femoral lengths. Thus, they have suggested that inadequacies of health during early life in the 18th and 19th centuries of London impacted the health in adulthood (Newman and Gowland 2017). A study comparing urban and rural medieval Denmark, Gamble (2020) found that individuals from rural Tirup experienced more childhood stress and reduced survivorship in the early period (1050-1250 AD) compared to rural Sejet and urban Ole Wormsgade. Also, mortality patterns are similar between Sejet and Ole Wormsgade but individuals from Sejet experienced more childhood stress (Gamble 2020). Gamble (2020) mentions that urbanization was slower compared to other countries in Europe and suggest that periods of famines and disease outbreaks may have impacted the populations. Each of these studies recognise the impact of famines and disease outbreaks had on urban health as well as health inadequacies in urban societies in the past. By examining other skeletal collections with St. Gregory's Priory will potentially further recognise urban health in medieval Canterbury and the county of Kent.

# 6.6 Urban Health in Medieval Canterbury: Conclusion

Based on the results from the data chapters of this thesis, the social and physical environments influenced health outcomes in medieval Canterbury, with the social environment being the primary influence (table 6.1). The pilgrimage culture dominated the social environment. Pilgrims consistently travelled to various shrines in Canterbury with the hopes of receiving miracles or indulgences. The people and organisations of Canterbury would have gained a stable income by offering resources to pilgrims such as accommodation, food, beverages, and souvenirs. A stable income allowed people to access various food for a well-balanced diet. A varied diet is essential during the development of the immune system in childhood to protect against nutritional and infectious diseases. The lower risk of delayed femoral and tibial diaphyseal growth of non-adults 4 years and older from Canterbury compared to Newcastle and Raunds may reflect the abundant access to food, to provide a well-balanced diet, that people in Canterbury had through weekly markets. While people in Raunds would have depended on their own agriculture for food, and those from Newcastle would have had a difficult time having a varied diet due to being regularly invaded and left with little to no resources. Hence, the pilgrimage culture would have allowed people to obtain a well-balanced diet. However, dietary social preferences perhaps influenced high-status adult females to have a higher mortality risk and reduced survivorship compared to low-status adult males. High-status people favoured meat mostly in their diet, and women rationed out their food to provide more for their husbands and children. Thus, high-status women may have suffered from poorer health conditions due to consuming more meat and rationing their food compared to low-status men.

Furthermore, dietary social beliefs may have influenced non-adults in Canterbury to be less at risk of delayed growth from birth to 3 years old than those from Newcastle and Raunds. It has been suggested that onset weaning and cessation of weaning influence delayed growth patterns between 1 and 3 years of age (Lewis 2002; Newman, Gowland and Caffell 2019). Non-adults from Newcastle were weaned roughly after 9 months until 1 year (Macpherson 2005), in contrast, those from Canterbury were mixed feed during or after the 1$^{st}$ year, and cessation of weaning started around 2 years (Mahoney *et al.* 2016). Alternatively, non-adults from Raunds and Canterbury had similar weaning patterns. Thus, differences in the risk of delayed growth may reflect deficiencies in the weaning diet that caused non-adults from Raunds to be at a higher risk of delayed growth than those from Canterbury. Although the social environment has primarily influenced health, the physical environment also played a role in influencing health. The physical environmental conditions perhaps allowed adults from high and low social status groups to have an equal or similar chance of obtaining parasitic infections. Factors such as household and bodily waste disposal into the river Stour and streams and public and private latrines placed over the river, designated unoccupied plots, or neighbouring properties would have provided breeding grounds for flies and parasites (Barnes 2005). People would have obtained parasitic infections by using water from the river and streams for drinking, bathing, and cleaning. Additionally, parasitic infections would have been obtained by eating contaminated crops that were fertilised with human faeces.

In conclusion, the findings within this thesis recognise that urban health in medieval Canterbury was influenced by the pilgrimage culture, dietary intake, breastfeeding and weaning practices, dense housing conditions, unhygienic waste management, and polluted water resources.

**Table 6.1** Urban Health of Medieval Canterbury: Health Outcomes that were influenced by the Social and Physical Environments

| Health Outcomes | Potential Influences | Determinates of Health |
|---|---|---|
| Non-adults from birth to 3 years of age from Canterbury had a lower risk of delayed growth than those from proto-urban and rural areas | Differences in weaning practices and diet | Social environment |
| Non-adults 4 years and older from Canterbury had a lower risk of delayed growth than those from proto-urban and rural areas | Access to nutritious foods due the stable income obtained from the pilgrimage culture | Social environment |
| Equal or similar chance of obtaining parasitic infections among adults | Dense housing conditions, close contact with animals, disposal of waste into the river and cesspits, and unhygienic practices | Physical environment |
| Low-status adult males had increased survivorship and lower mortality risk compared to high-status adult females | Low-status people had access to nutritious foods due the stable income obtained from the pilgrimage culture<br><br>High-status adult females may have had an inadequate nutritional intake due to the preference for high meat consumption and rationing out food for husbands and children. | Social environment |

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# Appendix

Example Non-adult Recording Form

**Skeletal Number/Burial Location:**

**Preservation:**

**Age:**

**Pathology Diagnosis:**

*Description/Lesions:*

**Skeletal Number/Burial Location:**

**Preservation:**

**Age:**

**Pathology Diagnosis:**

*Description/Lesions:*

<<Notes/Comments**: FLIP PAGE OVER**>>

Example Adult Recording Form

**Skeletal Number/Burial Location:**

**Preservation:**

**Sex:**

*Greater Sci. Not. =* *Med. Aspect =* *Nuchal Cr.=* *Mastoid Pro. =*

*Ven. Arc. =* *Subpubic Con. =* *Supro-Orb. Mar. =* *Mental Emin =*

| L95%: | Max Lik: | U95%: |
|---|---|---|

**Age:**

**Stature:**
*Humerus =* *Femur =*
*Radius =* *Tibia =*

| Cranial | min | max | Pubic Sym. | Left Min Max | Right Min Max |
|---|---|---|---|---|---|
| Cor. P. | | | Topo. | | |
| Sag. O. | | | Texture | | |
| Lam. A. | | | Sup. Pro. | | |
| Int. S. | | | Ven. M. | | |
| Zy. S. | | | Dor. M. | | |

| Auricular Area | Left Min Max | Right Min Max | Auricular Area | Left Min Max | Right Min Max |
|---|---|---|---|---|---|
| Sup. Topo. | | | Inf. Texture | | |
| Inf. Topo. | | | Sup. Ex | | |
| Sup. Char. | | | Inf. Ex | | |
| Ap. Char. | | | Post. Ex. | | |
| Inf. Char. | | | | | |

<<**Pathology Diagnosis:** *(Description/Lesions)* **FLIP PAGE OVER**>>

**Table 7.1** Non-adults from St. Gregory's Priory Collection age-at-death and diaphyseal lengths of the femora and tibiae. Non-adults from Black Gate, All Saint's Church, and Raunds Furnells must be requested from Dr. Charlotte Primeau. Data used for statistical methods for chapter 3.

| Skeletal Number | Average Dental Years | Left Femur | Right Femur | Left Tibia | Right Tibia |
|---|---|---|---|---|---|
| **NGA88 SK184** | 7 | 259 | | 207 | |
| **NGA88 SK889** | 12.5 | | | | |
| **NGA88 SK823** | 8 | 203 | | 158 | |
| **NGA88 SK1061** | 7 | | | | |
| **NGA88 SK716** | 6 | | | | |
| **NGA88 SK661** | 2.5 | | | 123 | |
| **NGA88 SK1139** | 11 | | | | |
| **NGA88 SK363** | 3 | | 224 | 186 | |
| **NGA88 SK364** | 11 | 341 | 344 | 274 | 277 |
| **NGA88 SK812** | 0.5 | | | | |
| **NGA88 SK620** | 12 | 330 | | | |
| **NGA88 SK621** | 5 | | | | |
| **NGA88 SK219** | 13 | 355 | 350 | | 279 |
| **NGA88 SK389** | 11 | 310 | 214 | 254 | 252 |
| **NGA88 SK233** | 12.5 | 381 | 384 | 324 | 323 |
| **NGA88 SK232** | 6 | 235 | 239 | 184 | 186 |
| **NGA88 SK107** | 5.5 | | | | |
| **NGA88 SK235** | 6 | 230 | | | |
| **NGA88 SK417** | 6 | | | | |
| **NGA88 SK789** | 13 | | | | |
| **NGB89 SK61** | 0.75 | 72 | 72 | 61 | 62 |
| **NGA88 SK447** | 13 | 366 | | 291 | 289 |
| **NGA88 SK688** | 2 | | | | |
| **NGA88 SK800** | 6 | 258 | 254 | | 197 |
| **NGA88 SK261** | 6 | 274 | 274 | 227 | 226 |
| **NGA88 SK260** | 3 | | | | |
| **NGA88 SK49** | 10 | | | | |
| **NGA88 SK150** | 6 | | | | |
| **NGA88 SK82** | 10 | 285 | 280 | 225 | |
| **NGA88 SK802** | 3 | | | 130 | |
| **NGA88 SK230** | 10 | 315 | 312 | 250 | 249 |
| **NGA88 SK1095** | 8.5 | | | | |
| **NGA88 SK558** | 14 | | | | |
| **NGA88 SK885** | 3 | | 184 | | |
| **NGA88 SK201** | 3 | | 189 | 154 | |
| **NGA88 SK111** | 3 | | 158 | | 127 |
| **NGA88 SK110** | 0.25 | | | | |
| **NGB89 SK17** | 3 | 215 | 217 | 170 | 171 |

| | | | | | |
|---|---|---|---|---|---|
| **NGA88 SK946** | 11 | 330 | 331 | 241 | 245 |
| **NGA88 SK80** | 3 | | | | 118 |
| **NGA88 SK665** | 3 | | | | |
| **NGA88 SK127** | 11 | 316 | 313 | 240 | 237 |
| **NGA88 SK126** | 3 | 175 | | 139 | 140 |
| **NGB89 SK21** | 6.5 | | | 187 | 187 |
| **NGA88 SK516** | 3 | | | | |
| **NGA88 SK631** | 5 | | | 162 | 160 |
| **NGA88 SK79** | 3 | | | | |
| **NGA88 SK373** | 5 | 199 | 196 | 157 | 154 |
| **NGA88 SK374** | 5 | 217 | 216 | 169 | 167 |
| **NGB89 SK57** | 3 | | 160 | | 130 |
| **NGA88 SK102** | 2 | | | | |
| **NGA88 SK142** | 11 | 305 | | 231 | |
| **NGA88 SK168** | 13 | 393 | 395 | 311 | 314 |
| **NGA88 SK253** | 10 | 343 | 340 | 251 | 252 |
| **NGB89 SK83** | 5 | | | 170 | |
| **NGB89 SK26** | 5 | 185 | 187 | 150 | 152 |
| **NGB89 SK40** | 6 | | | 166 | |
| **NGB89 SK29** | 5 | | | 163 | 165 |
| **NGB89 SK78** | 9 | | | 235 | 234 |
| **NGB89 SK32** | 3 | | | | |
| **NGB89 SK31** | 3 | 167 | 168 | | 132 |
| **NGA88 SK85** | 3 | 173 | | | |
| **NGA88 SK31** | 1.167 | | 126 | | |
| **NGA88 SK779** | 7 | 271 | | 218 | |
| **NGA88 SK781** | 3 | 190 | 190 | | |
| **NGB89 SK42** | 11 | | | 272 | |
| **NGA88 SK360** | 6 | 282 | 281 | 224 | 221 |
| **NGB89 SK43** | 0.5 | | | | |
| **NGA88 SK207** | 0.75 | | 124 | | 100 |
| **NGA88 SK960** | 6 | | 207 | | |
| **NGA88 SK269** | 9 | 290 | 290 | 240 | 241 |
| **NGA88 SK796** | 11 | 295 | 294 | 229 | 225 |
| **NGA88 SK1236** | 3 | 169 | | | |
| **NGA88 SK760** | 13 | 341 | | 253 | |
| **NGA88 SK782** | 7 | 244 | | | |
| **NGA88 SK214** | 8 | | 327 | | 273 |
| **NGA88 SK753** | 5 | | | | 157 |
| **NGA88 SK97** | 12 | 341 | 340 | 264 | 265 |
| **NGA88 SK492** | 4 | | 180 | | 144 |
| **NGA88 SK708** | 13 | | 383 | | |
| **NGA88 SK73** | 2.25 | 140 | | 114 | |
| **NGA88 SK17** | 13 | 331 | 331 | 259 | 261 |
| **NGA88 SK123** | 11 | 358 | 361 | 289 | 289 |
| **NGA88 SK801** | 9 | | 256 | 202 | 199 |
| **NGA88 SK178** | 3 | | 144 | | |

| | | | | | |
|---|---|---|---|---|---|
| **NGA88 SK860** | 13 | 352 | 355 | 266 | 262 |
| **NGA88 SK326** | 0.75 | 81 | | | |
| **NGA88 SK145** | 12 | 364 | | 292 | 286 |
| **NGA88 SK84** | 15 | | | | |
| **NGA88 SK137** | 10 | | 314 | 255 | 253 |
| **NGA88 SK339** | 11 | 300 | 305 | 226 | |
| **NGA88 SK376** | 12.5 | 396 | 396 | 327 | 327 |
| **NGA88 SK1242** | 6 | | | | |

Blank = no data available/skeletal element not available or not preserved well

**Table 7.2** Adults' burial location, age-at-death, and biological sex with periosteal new bone on a tibia and with or without cribra orbitalia. Data used for statistical methods for chapter 4.

| **Skeletal Number** | **Location** | **Sex** | **Age** | **Periosteal New Bone on Tibia** | **CO** |
|---|---|---|---|---|---|
| **NGB89 SK45** | Priory | Male | 73.3 | 1 | |
| **NGA88 SK273** | Cemetery | Male | 80.3 | 1 | |
| **NGA88 SK172** | Cemetery | Female | 34 | 1 | |
| **NGA88 SK879** | Cemetery | Male | 22 | 1 | |
| **NGA88 SK200** | Cemetery | Male | 35.7 | 1 | |
| **NGA88 SK53** | Cemetery | Male | 31 | 1 | |
| **NGA88 SK994** | Cemetery | Female | 40.2 | 1 | |
| **NGA88 SK229** | Cemetery | Female | 24.9 | 1 | |
| **NGA88 SK158** | Cemetery | Female | 25 | 1 | |
| **NGA88 SK309** | Cemetery | Female | 24.1 | 1 | |
| **NGA88 SK906** | Cemetery | Male | 33.7 | 1 | |
| **NGA88 SK757** | Cemetery | Male | 17.3 | 1 | |
| **NGA88 SK685** | Cemetery | Male | 22.8 | 1 | |
| **NGA88 SK30** | Cemetery | Female | 29.5 | 1 | |
| **NGA88 SK217** | Cemetery | Male | 25 | 1 | |
| **NGA88 SK824** | Cemetery | Female | 25.2 | 1 | 1 |
| **NGA88 SK320** | Cemetery | Female | 33.4 | 1 | |
| **NGA88 SK25** | Cemetery | Female | 25.2 | 1 | |
| **NGA88 SK136** | Cemetery | Female | 17.1 | 1 | |
| **NGA88 SK243** | Cemetery | Male | 18.7 | 1 | |
| **NGB89 SK79** | Priory | Female | 48.1 | 1 | |
| **NGB89 SK39** | Priory | Female | 31 | 1 | 1 |
| **NGB89 SK18** | Priory | Male | 20.6 | 1 | 1 |
| **NGB89 SK53** | Priory | Male | 37.3 | 1 | |

| | | | | | |
|---|---|---|---|---|---|
| **NGB89 SK72** | Priory | Male | 42.2 | 1 | |
| **NGB89 SK19** | Priory | Female | 40.1 | 1 | |
| **NGB89 SK7** | Priory | Male | 33.3 | 1 | |
| **NGB89 SK80** | Priory | Male | 22.8 | 1 | |
| **NGB89 SK65** | Priory | Female | 26.8 | 1 | |
| **NGB89 SK64** | Priory | Female | 24.1 | 1 | |
| **NGB89 SK54** | Priory | Male | 27.7 | 1 | |
| **NGB89 SK23** | Priory | Male | 22.1 | 1 | |
| **NGB89 SK37** | Priory | Male | 29 | 1 | |
| **NGB89 SK8** | Priory | Male | 31.1 | 1 | |
| **NGB89 SK50** | Priory | Female | 23.2 | 1 | |
| **NGB89 SK28** | Priory | Male | 69 | 1 | |
| **NGB89 SK71** | Priory | Female | 17.4 | 1 | |
| **NGB89 SK22** | Priory | Male | 22.4 | 1 | |
| **NGB89 SK55** | Priory | Male | 30.4 | 1 | |
| **NGB89 SK2** | Priory | Male | 23.8 | 1 | |
| **NGA88 SK735** | Cemetery | Female | 39.1 | 1 | |
| **NGB89 SK51** | Priory | Male | 31.9 | 1 | |
| **NGA88 SK287** | Cemetery | Female | 28.5 | 1 | 1 |
| **NGA88 SK992** | Cemetery | Male | 27.9 | 1 | |
| **NGA88 SK1043** | Cemetery | Female | 26.2 | 1 | |
| **NGA88 SK331** | Cemetery | Female | 26.6 | 1 | |
| **NGA88 SK1216** | Cemetery | Male | 28.5 | 1 | |
| **NGA88 SK529** | Cemetery | Female | 28.2 | 1 | |
| **NGA88 SK917** | Cemetery | Male | 28.1 | 1 | |
| **NGA88 SK485** | Cemetery | Female | 28.6 | 1 | |
| **NGA88 SK748** | Cemetery | Male | 19.4 | 1 | |
| **NGA88 SK747** | Cemetery | Male | 23.2 | 1 | |
| **NGA88 SK726** | Cemetery | Male | 28.4 | 1 | 1 |
| **NGA88 SK312** | Cemetery | Female | 20.6 | 1 | |
| **NGA88 SK478** | Cemetery | Male | 46.5 | 1 | |
| **NGA88 SK62** | Cemetery | Male | 34.5 | 1 | |
| **NGA88 SK765** | Cemetery | Female | 57 | 1 | |
| **NGA88 SK1230** | Cemetery | Male | 30.5 | 1 | |
| **NGA88 SK910** | Cemetery | Male | 29.4 | 1 | |
| **NGB89 SK16** | Priory | Female | 35.2 | 1 | |
| **NGA88 SK534** | Cemetery | Male | 29.4 | 1 | |
| **NGA88 SK515** | Cemetery | Female | 27.6 | 1 | |
| **NGA88 SK792** | Cemetery | Male | 33.5 | 1 | |
| **NGA88 SK1212** | Cemetery | Male | 34.5 | 1 | |

| | | | | | |
|---|---|---|---|---|---|
| **NGA88 SK622** | Cemetery | Female | 20.5 | 1 | |
| **NGA88 SK445** | Cemetery | Female | 25.7 | 1 | |
| **NGA88 SK743** | Cemetery | Female | 34 | 1 | |
| **NGA88 SK177** | Cemetery | Female | 20.9 | 1 | |
| **NGA88 SK239** | Cemetery | Male | 36 | 1 | |
| **NGA88 SK613** | Cemetery | Male | 38.7 | 1 | |
| **NGA88 SK272** | Cemetery | Female | 27 | 1 | |
| **NGA88 SK143** | Cemetery | Female | 21.7 | 1 | |
| **NGA88 SK541** | Cemetery | Female | 21.8 | 1 | 1 |
| **NGA88 SK609** | Cemetery | Female | 43.5 | 1 | |
| **NGA88 SK957** | Cemetery | Female | 19 | 1 | |
| **NGA88 SK1053** | Cemetery | Female | 27.3 | 1 | |
| **NGA88 SK766** | Cemetery | Female | 31.8 | 1 | |
| **NGA88 SK810** | Cemetery | Male | 35.8 | 1 | |
| **NGA88 SK335** | Cemetery | Male | 39.2 | 1 | |
| **NGA88 SK148** | Cemetery | Male | 36 | 1 | |
| **NGA88 SK1057** | Cemetery | Female | 28.1 | 1 | |
| **NGA88 SK770** | Cemetery | Female | 32.4 | 1 | |
| **NGA88 SK1159** | Cemetery | Male | 31.2 | 1 | |
| **NGA88 SK416** | Cemetery | Male | 34.4 | 1 | |
| **NGA88 SK691** | Cemetery | Male | 34.4 | 1 | |
| **NGA88 SK557** | Cemetery | Female | 51.4 | 1 | |
| **NGA88 SK632** | Cemetery | Female | 27.9 | 1 | |
| **NGA88 SK655** | Cemetery | Female | 25.1 | 1 | |
| **NGA88 SK987** | Cemetery | Female | 22.8 | 1 | |
| **NGA88 SK711** | Cemetery | Female | 24.5 | 1 | 1 |
| **NGA88 SK1019** | Cemetery | Female | 32.4 | 1 | |
| **NGA88 SK742** | Cemetery | Male | 41 | 1 | |
| **NGA88 SK1112** | Cemetery | Male | 33.5 | 1 | |
| **NGA88 SK677** | Cemetery | Male | 53 | 1 | |
| **NGA88 SK1110** | Cemetery | Male | 25.1 | 1 | |
| **NGA88 SK693** | Cemetery | Female | 31.1 | 1 | |
| **NGA88 SK839** | Cemetery | Female | 21.9 | 1 | |
| **NGA88 SK212** | Cemetery | Female | 32.5 | 1 | |
| **NGA88 SK767** | Cemetery | Male | 34.7 | 1 | |
| **NGA88 SK1000** | Cemetery | Female | 23.7 | 1 | |
| **NGA88 SK998** | Cemetery | Female | 23.8 | 1 | |
| **NGA88 SK979** | Cemetery | Female | 24.8 | 1 | |
| **NGA88 SK763** | Cemetery | Female | 48.3 | 1 | |
| **NGA88 SK468** | Cemetery | Male | 27 | 1 | |

| | | | | | |
|---|---|---|---|---|---|
| **NGA88 SK705** | Cemetery | Male | 18.5 | 1 | |
| **NGA88 SK1187** | Cemetery | Female | 22.7 | 1 | |
| **NGA88 SK758** | Cemetery | Female | 48.1 | 1 | |
| **NGA88 SK489** | Cemetery | Female | 35.6 | 1 | |
| **NGA88 SK503** | Cemetery | Female | 31.3 | 1 | |
| **NGA88 SK109** | Cemetery | Female | 35 | 1 | |
| **NGA88 SK1246** | Cemetery | Male | 30 | 1 | |
| **NGA88 SK469** | Cemetery | Male | 29.6 | 1 | |
| **NGA88 SK452** | Cemetery | Male | 32.5 | 1 | |
| **NGA88 SK1161** | Cemetery | Male | 38.4 | 1 | |
| **NGA88 SK1079** | Cemetery | Female | 33.1 | 1 | |
| **NGA88 SK504** | Cemetery | Female | 37.1 | 1 | |
| **NGA88 SK1039** | Cemetery | Male | 23.4 | 1 | |
| **NGB89 SK47** | Priory | Male | 39.1 | 1 | |
| **NGB89 SK24** | Priory | Male | 32.7 | 1 | |
| **NGA88 SK170** | Cemetery | Female | 24.3 | 1 | |
| **NGA88 SK210** | Cemetery | Male | 21.4 | 1 | |
| **NGA88 SK295** | Cemetery | Male | 37.8 | 1 | |
| **NGA88 SK337** | Cemetery | Male | 30.9 | 1 | |
| **NGA88 SK66** | Cemetery | Male | 45.3 | 1 | |
| **NGA88 SK226** | Cemetery | Male | 29.6 | 1 | |
| **NGA88 SK98** | Cemetery | Male | 32.9 | 1 | |
| **NGA88 SK16** | Cemetery | Female | 28 | 1 | |
| **NGA88 SK114** | Cemetery | Male | 23.3 | 1 | |
| **NGB89 SK4** | Priory | Male | 33.2 | 1 | |
| **NGA88 SK844** | Cemetery | Male | 27.4 | 1 | |
| **NGA88 SK48** | Cemetery | Male | 24.2 | 1 | 1 |
| **NGA88 SK188** | Cemetery | Female | 28.1 | 1 | |
| **NGA88 SK128** | Cemetery | Female | 20.2 | 1 | |

1 = present
Blank = absent

**Table 7.3** Non-adults burial location and age-at-death. Data used for statistical methods for chapter 5.

| Skeletal Number | Location | Age |
|---|---|---|
| NGB89 SK21 | Priory | 7.5 |
| NGA88 SK374 | Cemetery | 5.5 |
| NGA88 SK373 | Cemetery | 4.5 |
| NGA88 SK665 | Cemetery | 3.5 |
| NGA88 SK664 | Cemetery | 1.5 |
| NGA88 SK666 | Cemetery | 12.5 |
| NGA88 SK126 | Cemetery | 2.5 |
| NGA88 SK127 | Cemetery | 11 |
| NGA88 SK168 | Cemetery | 12.5 |
| NGA88 SK671 | Cemetery | 6 |
| NGA88 SK207 | Cemetery | 0.79 |
| NGA88 SK208 | Cemetery | 17.5 |
| NGB89 SK57 | Priory | 2.5 |
| NGA88 SK79 | Cemetery | 4 |
| NGA88 SK607 | Cemetery | 9 |
| NGA88 SK516 | Cemetery | 3 |
| NGA88 SK517 | Cemetery | 9.5 |
| NGA88 SK80 | Cemetery | 3 |
| NGA88 SK102 | Cemetery | 2 |
| NGA88 SK101 | Cemetery | 4 |
| NGA88 SK631 | Cemetery | 5 |
| NGA88 SK142 | Cemetery | 11 |
| NGA88 SK730 | Cemetery | 4.5 |
| NGA88 SK729 | Cemetery | 14.5 |
| NGB89 SK90 | Priory | 14 |
| NGB89 SK83 | Priory | 5.5 |
| NGA88 SK253 | Cemetery | 10 |
| NGB89 SK41 | Priory | 15.5 |
| NGB89 SK40 | Priory | 5 |
| NGA88 SK736 | Cemetery | 5 |
| NGB89 SK29 | Cemetery | 4.5 |
| NGB89 SK78 | Cemetery | 6 |

| | | |
|---|---|---|
| **NGB89 SK26** | Priory | 4 |
| **NGB89 SK32** | Priory | 2.5 |
| **NGB89 SK31** | Priory | 2.5 |
| **NGA88 SK779** | Cemetery | 8 |
| **NGA88 SK31** | Cemetery | 2 |
| **NGA88 SK40** | Cemetery | 1.5 |
| **NGA88 SK70** | Cemetery | 0.25 |
| **NGA88 SK85** | Cemetery | 3 |
| **NGA88 SK73** | Cemetery | 1.5 |
| **NGA88 SK859** | Cemetery | 9.5 |
| **NGB89 SK42** | Priory | 11 |
| **NGA88 SK781** | Cemetery | 3.5 |
| **NGA88 SK46** | Cemetery | 2 |
| **NGA88 SK47** | Cemetery | 14 |
| **NGA88 SK359** | Cemetery | 5.5 |
| **NGA88 SK116** | Cemetery | 8 |
| **NGA88 SK115** | Cemetery | 3 |
| **NGA88 SK782** | Cemetery | 6.5 |
| **NGB89 SK44** | Priory | 5.75 |
| **NGB89 SK43** | Priory | 0.29 |
| **NGA88 SK117** | Cemetery | 2.5 |
| **NGA88 SK95** | Cemetery | 1.5 |
| **NGA88 SK576** | Cemetery | 7 |
| **NGA88 SK796** | Cemetery | 11 |
| **NGA88 SK1006** | Cemetery | 11.75 |
| **NGA88 SK360** | Cemetery | 9.5 |
| **NGA88 SK960** | Cemetery | 5 |
| **NGB89 SK25** | Priory | 2.75 |
| **NGA88 SK269** | Cemetery | 9 |
| **NGA88 SK624** | Cemetery | 11.75 |
| **NGA88 SK623** | Cemetery | 11.3 |
| **NGA88 SK214** | Cemetery | 8 |
| **NGA88 SK176** | Cemetery | 13 |
| **NGA88 SK1236** | Cemetery | 4 |
| **NGA88 SK1234** | Cemetery | 3.75 |
| **NGA88 SK753** | Cemetery | 5 |
| **NGA8 SK755** | Cemetery | 1.75 |
| **NGA88 SK760** | Cemetery | 13 |
| **NGA88 SK759** | Cemetery | 4.75 |
| **NGB89 SK35** | Priory | 0.33 |
| **NGB89 SK76** | Priory | 3.5 |
| **NGB89 SK46** | Priory | 3.25 |

| | | |
|---|---|---|
| **NGA88 SK97** | Cemetery | 12 |
| **NGA88 SK192** | Cemetery | 4 |
| **NGA88 SK492** | Cemetery | 2.5 |
| **NGA88 SK493** | Cemetery | 2.5 |
| **NGA88 SK976** | Cemetery | 11 |
| **NGB89 SK68(A)** | Priory | 0.38 |
| **NGA88 SK1210(A)** | Cemetery | 6.5 |
| **NGA88 SK1210(B)** | Cemetery | 2.5 |
| **NGA88 SK706** | Cemetery | 5 |
| **NGA88 SK708** | Cemetery | 12.5 |
| **NGA88 SK707** | Cemetery | 13.5 |
| **NGA88 SK481** | Cemetery | 6.5 |
| **NGA88 SK785** | Cemetery | 4.25 |
| **NGA88 SK1058** | Cemetery | 8 |
| **NGA88 SK819** | Cemetery | 10 |
| **NGA88 SK993** | Cemetery | 3.5 |
| **NGB89 SK68(B)** | Priory | 0.019 |
| **NGA88 SK962** | Cemetery | 12.5 |
| **NGA88 SK850** | Cemetery | 13 |
| **NGA88 SK625** | Cemetery | 17.5 |
| **NGA88 SK1030** | Cemetery | 16 |
| **NGA88 SK121** | Cemetery | 4 |
| **NGA88 SK55** | Cemetery | 1.5 |
| **NGA88 SK54** | Cemetery | 8.5 |
| **NGA88 SK56** | Cemetery | 12.75 |
| **NGA88 SK314** | Cemetery | 4.25 |
| **NGA88 SK296** | Cemetery | 4.75 |
| **NGA88 SK270** | Cemetery | 11.25 |
| **NGA88 SK915** | Cemetery | 10.5 |
| **NGA88 SK186** | Cemetery | 11 |
| **NGA88 SK739** | Cemetery | 8 |
| **NGA88 SK890** | Cemetery | 5.75 |
| **NGA88 SK130** | Cemetery | 13 |
| **NGA88 SK131** | Cemetery | 2.75 |
| **NGA88 SK1191** | Cemetery | 17 |
| **NGA88 SK307** | Cemetery | 10.25 |
| **NGA88 SK1196** | Cemetery | 5 |
| **NGA88 SK184** | Cemetery | 7 |
| **NGA88 SK1096** | Cemetery | 13 |
| **NGA88 SK889** | Cemetery | 12.5 |
| **NGA88 SK627** | Cemetery | |
| **NGA88 SK34** | Cemetery | 12 |
| **NGA88 SK823** | Cemetery | 8 |

| | | |
|---|---|---|
| **NGA88 SK1061** | Cemetery | 7 |
| **NGA88 SK282** | Cemetery | 6 |
| **NGA88 SK716** | Cemetery | 6 |
| **NGA88 SK817** | Cemetery | 0.458 |
| **NGA88 SK661** | Cemetery | 2.5 |
| **NGA88 SK154** | Cemetery | 3.5 |
| **NGA88 SK1139** | Cemetery | 11 |
| **NGA88 SK363** | Cemetery | 3 |
| **NGA88 SK364** | Cemetery | 11 |
| **NGA88 SK812** | Cemetery | 0.458 |
| **NGA88 SK620** | Cemetery | 12 |
| **NGA88 SK621** | Cemetery | 5 |
| **NGA88 SK219** | Cemetery | 13 |
| **NGA88 SK389** | Cemetery | 11 |
| **NGA88 SK657** | Cemetery | 14 |
| **NGA88 SK233** | Cemetery | 12.5 |
| **NGA88 SK232** | Cemetery | 6 |
| **NGA88 SK174** | Cemetery | 3 |
| **NGA88 SK107** | Cemetery | 5.5 |
| **NGA88 SK257** | Cemetery | 5.5 |
| **NGA88 SK235** | Cemetery | 6 |
| **NGA88 SK417** | Cemetery | 6 |
| **NGA88 SK5** | Cemetery | 17.5 |
| **NGA88 SK789** | Cemetery | 13 |
| **NGA88 SK1248** | Cemetery | 3 |
| **NGA88 SK63** | Cemetery | 0.729 |
| **NGB89 SK61** | Priory | 0.729 |
| **NGA88 SK447** | Cemetery | 13 |
| **NGA88 SK688** | Cemetery | 2 |
| **NGA88 SK800** | Cemetery | 6 |
| **NGA88 SK799** | Cemetery | 6 |
| **NGA88 SK261** | Cemetery | 6 |
| **NGA88 SK260** | Cemetery | 3 |
| **NGA88 SK50** | Cemetery | 0.458 |
| **NGA88 SK49** | Cemetery | 10 |
| **NGA88 SK150** | Cemetery | 6 |
| **NGA88 SK82** | Cemetery | 10 |
| **NGA88 SK28** | Cemetery | 3.5 |
| **NGA88 SK802** | Cemetery | 3 |
| **NGA88 SK230** | Cemetery | 10 |
| **NGA88 SK1095** | Cemetery | 8.5 |
| **NGA88 SK558** | Cemetery | 14 |
| **NGA88 SK885** | Cemetery | 3 |

| | | |
|---|---|---|
| **NGA88 SK462** | Cemetery | 17 |
| **NGA88 SK201** | Cemetery | 3 |
| **NGA88 SK111** | Cemetery | 3 |
| **NGA88 SK112** | Cemetery | 1 |
| **NGA88 SK110** | Cemetery | 0.083 |
| **NGB89 SK17** | Priory | 3 |
| **NGA88 SK946** | Cemetery | 11 |
| **NGA88 SK17** | Cemetery | 13 |
| **NGA88 SK123** | Cemetery | 11 |
| **NGA88 SK801** | Cemetery | 9 |
| **NGA88 SK860** | Cemetery | 13 |
| **NGA88 SK178** | Cemetery | 3 |
| **NGA88 SK1093** | Cemetery | 1 |
| **NGA88 SK326** | Cemetery | 0.75 |
| **NGA88 SK145** | Cemetery | 12 |
| **NGA88 SK84** | Cemetery | 15 |
| **NGA88 SK137** | Cemetery | 10 |
| **NGA88 SK339** | Cemetery | 11 |
| **NGA88 SK376** | Cemetery | 12.5 |
| **NGA88 SK1242** | Cemetery | 6 |
| **NGA88 SK1241** | Cemetery | 1 |
| **NGA88 SK495** | Cemetery | 3 |
| **NGA88 SK762** | Cemetery | 15 |
| **NGA88 SK10** | Cemetery | 13 |
| **NGA88 SK59** | Cemetery | 3 |
| **NGA88 SK1029** | Cemetery | 6 |
| **NGA88 SK319** | Cemetery | 15.5 |
| **NGA88 SK1119** | Cemetery | 15.5 |
| **NGA88 SK240** | Cemetery | 11 |
| **NGA88 SK286** | Cemetery | 7.5 |
| **NGA88 SK206** | Cemetery | 5 |
| **NGA88 SK447** | Cemetery | 6 |
| **NGA88 SK279** | Cemetery | 6 |
| **NGB89 SK57** | Cemetery | 15.5 |
| **NGB89 SK88** | Cemetery | 7 |
| **NGA88 SK401** | Cemetery | 11 |
| **NGA88 SK393** | Cemetery | 16 |
| **NGA88 SK1096** | Cemetery | 13 |
| **NGA88 SK34** | Cemetery | 12 |
| **NGA88 SK5** | Cemetery | 17.5 |
| **NGA88 SK462** | Cemetery | 17 |
| **NGB89 SK41** | Priory | 16.5 |
| **NGA88 SK319** | Cemetery | 15.5 |

| | | |
|---|---|---|
| **NGA88 SK627** | Cemetery | 13.5 |
| **NGA88 SK1006** | Cemetery | 14 |
| **NGB89 SK42** | Priory | 12.5 |
| **NGA88 SK427** | Cemetery | 12.5 |
| **NGA88 SK982** | Cemetery | 13 |
| **NGA88 SK421** | Cemetery | 12.5 |
| **NGA88 SK1090** | Cemetery | 14.5 |
| **NGA88 SK442** | Cemetery | 13.5 |
| **NGA88 SK441** | Cemetery | 3.7 |
| **NGA88 SK806** | Cemetery | 5 |
| **NGA88 SK816** | Cemetery | 0.4 |
| **NGA88 SK818** | Cemetery | 1.5 |
| **NGA88 SK1141** | Cemetery | 4.9 |
| **NGA88 SK571** | Cemetery | 12.5 |
| **NGA88 SK673** | Cemetery | 15 |
| **NGA88 SK258** | Cemetery | 6 |
| **NGA88 SK236** | Cemetery | 2 |
| **NGA88 SK1168** | Cemetery | 5 |
| **NGA88 SK1201** | Cemetery | 3 |
| **NGA88 SK649** | Cemetery | 6 |
| **NGA88 SK804** | Cemetery | 11.5 |
| **NGA88 SK803** | Cemetery | 1.5 |
| **NGA88 SK1158** | Cemetery | 15 |
| **NGA88 SK38** | Cemetery | 3 |
| **NGA88 SK562** | Cemetery | 1.75 |
| **NGA88 SK561** | Cemetery | 4.5 |
| **NGA88 SK458** | Cemetery | 2 |
| **NGA88 SK113** | Cemetery | 2 |
| **NGA88 SK181** | Cemetery | 0.68 |
| **NGA88 SK990** | Cemetery | 1 |
| **NGA88 SK517** | Cemetery | 10 |
| **NGA88 SK607** | Cemetery | 9 |
| **NGA88 SK729** | Cemetery | 15.5 |
| **NGB89 SK90** | Priory | 10.5 |
| **NGB89 SK25** | Priory | 4 |
| **NGA88 SK70** | Cemetery | 0.28 |
| **NGA88 SK95** | Cemetery | 1 |
| **NGA88 SK576** | Cemetery | 5 |
| **NGA88 SK359** | Cemetery | 7 |
| **NGB89 SK44** | Priory | 6.5 |
| **NGA88 SK46** | Cemetery | 1.5 |
| **NGA88 SK759** | Cemetery | 6 |
| **NGA88 SK755** | Cemetery | 3 |

| | | |
|---|---|---|
| **NGB89 SK46** | Priory | 5.5 |
| **NGB89 SK35** | Priory | 0.08 |
| **NGA88 SK785** | Cemetery | 6 |
| **NGA88 SK192** | Cemetery | 5 |
| **NGA88 SK706** | Cemetery | 6.5 |
| **NGA88 SK976** | Cemetery | 16 |
| **NGA88 SK481** | Cemetery | 8 |
| **NGA88 SK17** | Cemetery | 4 |
| **NGA88 SK89** | Cemetery | 15 |
| **NGA88 SK443** | Cemetery | 4 |
| **NGA88 SK943** | Cemetery | 10 |
| **NGA88 SK1091** | Cemetery | 10 |
| **NGA88 SK325** | Cemetery | 4 |
| **NGA88 SK1009** | Cemetery | 4.5 |
| **NGA88 SK1014** | Cemetery | 14 |
| **NGA88 SK264** | Cemetery | 4 |
| **NGA88 SK36** | Cemetery | 6 |
| **NGA88 SK37** | Cemetery | 6 |
| **NGA88 SK146** | Cemetery | 2 |
| **NGA88 SK161** | Cemetery | 7 |
| **NGA88 SK1244** | Cemetery | 5 |
| **NGA88 SK156** | Cemetery | 3 |
| **NGA88 SK797** | Cemetery | 8 |
| **NGA88 SK793** | Cemetery | 15.5 |
| **NGA88 SK316** | Cemetery | 6 |
| **NGA88 SK724** | Cemetery | 17.5 |
| **NGA88 SK284** | Cemetery | 5 |
| **NGA88 SK425** | Cemetery | 9 |
| **NGA88 SK203** | Cemetery | 9 |
| **NGA88 SK220** | Cemetery | 7.5 |
| **NGA88 SK164** | Cemetery | 7 |
| **NGA88 SK165** | Cemetery | 8.5 |
| **NGA88 SK877** | Cemetery | 0.33 |

**Table 7.4** Adults' burial location, age-at-death, and biological sex. Data used for statistical methods for chapter 5.

| Skeleton Number | Location | Age | Sex |
|---|---|---|---|
| **NGA88 SK669** | Cemetery | 29.1 | Female |
| **NGA88 SK78** | Cemetery | 80.5 | Male |
| **NGA88 SK728** | Cemetery | 60 | Female |
| **NGA88 SK737** | Cemetery | 33.3 | Female |

| | | | |
|---|---|---|---|
| **NGB89 SK30** | Priory | 20.9 | Female |
| **NGA88 SK118** | Cemetery | 76.2 | Male |
| **NGB89 SK34** | Priory | 35.8 | Female |
| **NGB89 SK45** | Priory | 73.3 | Male |
| **NGB89 SK70** | Priory | 71.9 | Male |
| **NGA88 SK39** | Cemetery | 28.2 | Male |
| **NGA88 SK482** | Cemetery | 24.9 | Female |
| **NGA88 SK786** | Cemetery | 24.1 | Female |
| **NGA88 SK863** | Cemetery | 18.6 | Male |
| **NGA88 SK1084** | Cemetery | 20.3 | Female |
| **NGA88 SK1171** | Cemetery | 21.2 | Female |
| **NGA88 SK117** | Cemetery | 33.2 | Male |
| **NGA88 SK1133** | Cemetery | 76.6 | Male |
| **NGA88 SK881** | Cemetery | 36.9 | Male |
| **NGA88 SK964** | Cemetery | 33.7 | Female |
| **NGA88 SK963** | Cemetery | 62.3 | Male |
| **NGA88 SK820** | Cemetery | 21.8 | Female |
| **NGA88 SK273** | Cemetery | 80.3 | Male |
| **NGA88 686** | Cemetery | 24.3 | Male |
| **NGA88 SK223** | Cemetery | 62.9 | Male |
| **NGA88 SK1208** | Cemetery | 23.5 | Female |
| **NGA88 SK506** | Cemetery | 19.9 | Male |
| **NGA88 SK703** | Cemetery | 47.1 | Male |
| **NGA88 SK294** | Cemetery | 25.9 | Male |
| **NGA88 SK173** | Cemetery | 18 | Male |
| **NGA88 SK667** | Cemetery | 23.7 | Female |
| **NGA88 SK480** | Cemetery | 72.9 | Female |
| **NGA88 SK867** | Cemetery | 28.5 | Female |
| **NGA88 SK825** | Cemetery | 18.2 | Female |
| **NGA88 SK953** | Cemetery | 31.4 | Male |
| **NGA88 SK901** | Cemetery | 23.7 | Female |
| **NGA88 SK321** | Cemetery | 80.9 | Female |
| **NGA88 SK129** | Cemetery | 24.1 | Female |
| **NGA88 SK501** | Cemetery | 19.4 | Male |
| **NGA88 SK262** | Cemetery | 28.2 | Female |
| **NGA88 SK777** | Cemetery | 31 | Male |
| **NGA88 SK172** | Cemetery | 34 | Female |
| **NGA88 SK171** | Cemetery | 18 | Female |
| **NGA88 SK263** | Cemetery | 18.9 | Female |
| **NGA88 SK308** | Cemetery | 27.9 | Male |
| **NGA88 SK567** | Cemetery | 53.2 | Male |
| **NGA88 SK612** | Cemetery | 27.2 | Female |
| **NGA88 SK897** | Cemetery | 43.1 | Male |
| **NGA88 SK896** | Cemetery | 34.8 | Male |
| **NGA88 SK861** | Cemetery | 21.3 | Female |
| **NGA88 SK879** | Cemetery | 22 | Male |
| **NGA88 SK13** | Cemetery | 67.1 | Male |

| | | | |
|---|---|---|---|
| **NGA88 SK200** | Cemetery | 35.7 | Male |
| **NGA88 SK18** | Cemetery | 32.1 | Male |
| **NGA88 SK513** | Cemetery | 31.5 | Female |
| **NGA88 SK514** | Cemetery | 76.1 | Male |
| **NGA88 SK870** | Cemetery | 35 | Male |
| **NGA88 SK53** | Cemetery | 31 | Male |
| **NGA88 SK7** | Cemetery | 34 | Female |
| **NGA88 SK994** | Cemetery | 40.2 | Female |
| **NGA88 SK518** | Cemetery | 32.7 | Female |
| **NGA88 SK942** | Cemetery | 18.3 | Male |
| **NGA88 SK941** | Cemetery | 23.4 | Female |
| **NGA88 SK710** | Cemetery | 22.9 | Female |
| **NGA88 SK1044** | Cemetery | 18 | Male |
| **NGA88 SK292** | Cemetery | 38.1 | Male |
| **NGA88 SK1204** | Cemetery | 28.6 | Female |
| **NGA88 SK1202** | Cemetery | 24.9 | Female |
| **NGA88 SK549** | Cemetery | 24 | Male |
| **NGA88 SK907** | Cemetery | 27.2 | Male |
| **NGA88 SK508** | Cemetery | 26.2 | Male |
| **NGA88 SK509** | Cemetery | 22.9 | Male |
| **NGA88 SK93** | Cemetery | 53 | Female |
| **NGA88 SK746** | Cemetery | 27.5 | Male |
| **NGA88 SK229** | Cemetery | 24.9 | Female |
| **NGA88 SK108** | Cemetery | 32.2 | Female |
| **NGA88 SK196** | Cemetery | 31.9 | Male |
| **NGA88 SK94** | Cemetery | 24.9 | Male |
| **NGA88 SK809** | Cemetery | 15 | Male |
| **NGA88 SK899** | Cemetery | 25.7 | Male |
| **NGA88 SK1005** | Cemetery | 34.2 | Female |
| **NGA88 SK1036** | Cemetery | 18 | Male |
| **NGA88 SK1038** | Cemetery | 26.3 | Female |
| **NGA88 SK1072** | Cemetery | 18 | Male |
| **NGA88 SK1209** | Cemetery | 21.9 | Female |
| **NGA88 SK310** | Cemetery | 22.4 | Female |
| **NGA88 SK660** | Cemetery | 34 | Male |
| **NGA88 SK158** | Cemetery | 25 | Female |
| **NGA88 SK309** | Cemetery | 24.1 | Female |
| **NGA88 SK487** | Cemetery | 75.4 | Male |
| **NGA88 SK855** | Cemetery | 32.8 | Male |
| **NGA88 SK682** | Cemetery | 24.3 | Female |
| **NGA88 SK906** | Cemetery | 33.7 | Male |
| **NGA88 SK581** | Cemetery | 34.6 | Female |
| **NGA88 SK505** | Cemetery | 21.7 | Female |
| **NGA88 SK585** | Cemetery | 26.6 | Male |
| **NGA88 SK216** | Cemetery | 26.2 | Female |
| **NGA88 SK81** | Cemetery | 21 | Male |
| **NGA88 SK757** | Cemetery | 18.3 | Male |

| | | | |
|---|---|---|---|
| **NGA88 SK1088** | Cemetery | 29.2 | Male |
| **NGA88 SK713** | Cemetery | 18 | Male |
| **NGA88 SK712** | Cemetery | 18 | Male |
| **NGA88 SK587** | Cemetery | 70.5 | Male |
| **NGA88 SK544** | Cemetery | 18.9 | Male |
| **NGA88 SK1128** | Cemetery | 77.1 | Female |
| **NGA88 SK528** | Cemetery | 25.7 | Male |
| **NGA88 SK1129** | Cemetery | 18.4 | Male |
| **NGA88 SK1217** | Cemetery | 18 | Female |
| **NGA88 SK1165** | Cemetery | 22.8 | Female |
| **NGA88 SK638** | Cemetery | 19.6 | Female |
| **NGA88 SK586** | Cemetery | 28.1 | Female |
| **NGA88 SK498** | Cemetery | 20.8 | Female |
| **NGA88 SK439** | Cemetery | 21.1 | Female |
| **NGA88 SK527** | Cemetery | 31.1 | Female |
| **NGA88 SK547** | Cemetery | 76.7 | Female |
| **NGA88 SK685** | Cemetery | 22.8 | Male |
| **NGA88 SK684** | Cemetery | 24.3 | Female |
| **NGA88 SK1062** | Cemetery | 19.2 | Male |
| **NGA88 SK580** | Cemetery | 21.1 | Male |
| **NGA88 SK1025** | Cemetery | 31.2 | Male |
| **NGA88 SK869** | Cemetery | 29.3 | Male |
| **NGA88 SK868** | Cemetery | 18.5 | Female |
| **NGA88 SK905** | Cemetery | 19.1 | Female |
| **NGA88 SK940** | Cemetery | 18 | Female |
| **NGA88 SK100** | Cemetery | 27.5 | Female |
| **NGA88 SK275** | Cemetery | 18 | Male |
| **NGA88 SK30** | Cemetery | 29.5 | Female |
| **NGA88 SK237** | Cemetery | 30.5 | Female |
| **NGA88 SK928** | Cemetery | 18 | Female |
| **NGA88 SK217** | Cemetery | 25 | Male |
| **NGA88 SK833** | Cemetery | 17.6 | Female |
| **NGA88 SK938** | Cemetery | 18 | Male |
| **NGA88 SK247** | Cemetery | 18.2 | Female |
| **NGA88 SK328** | Cemetery | 18.5 | Female |
| **NGA88 SK821** | Cemetery | 28.9 | Male |
| **NGB89 SK15** | Priory | 18 | Female |
| **NGB89 SK87** | Priory | 20.6 | Male |
| **NGA88 SK69** | Cemetery | 19.7 | Female |
| **NGA88 SK991** | Cemetery | 20.4 | Male |
| **NGA88 SK824** | Cemetery | 25.2 | Female |
| **NGA88 SK611** | Cemetery | 39.1 | Female |
| **NGA88 SK300** | Cemetery | 21.4 | Male |
| **NGA88 SK320** | Cemetery | 33.4 | Female |
| **NGA88 SK24** | Cemetery | 29.5 | Female |
| **NGA88 SK25** | Cemetery | 25.2 | Female |
| **NGA88 SK977** | Cemetery | 30.3 | Male |

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| **NGA88 SK1099** | Cemetery | 18 | Female |
| **NGA88 SK884** | Cemetery | 18 | Male |
| **NGA88 SK136** | Cemetery | 18.1 | Female |
| **NGA88 SK243** | Cemetery | 18.7 | Male |
| **NGA88 SK919** | Cemetery | 38.3 | Male |
| **NGA88 SK189** | Cemetery | 19.4 | Female |
| **NGA88 SK149** | Cemetery | 25.1 | Female |
| **NGA88 SK1071** | Cemetery | 24.8 | Female |
| **NGA88 SK1073** | Cemetery | 21 | Female |
| **NGB89 SK3** | Priory | 19.9 | Male |
| **NGB89 SK89** | Priory | 26.3 | Male |
| **NGB89 SK6** | Priory | 32.7 | Female |
| **NGB89 SK79** | Priory | 48.1 | Female |
| **NGB89 SK39** | Priory | 31 | Female |
| **NGB89 SK18** | Priory | 20.6 | Male |
| **NGB89 SK53** | Priory | 37.3 | Male |
| **NGB89 SK72** | Priory | 42.2 | Male |
| **NGB89 SK48** | Priory | 21.2 | Female |
| **NGB89 SK19** | Priory | 40.1 | Female |
| **NGB89 SK13** | Priory | 25.3 | Female |
| **NGB89 SK7** | Priory | 33.3 | Male |
| **NGB89 SK20** | Priory | 31 | Female |
| **NGB89 SK80** | Priory | 22.8 | Male |
| **NGB89 SK63** | Priory | 18.1 | Male |
| **NGB89 SK65** | Priory | 26.8 | Female |
| **NGB89 SK64** | Priory | 24.1 | Female |
| **NGB89 SK91** | Priory | 23.8 | Male |
| **NGB89 SK54** | Priory | 27.7 | Male |
| **NGB89 SK61** | Priory | 19.6 | Male |
| **NGB89 SK23** | Priory | 22.1 | Male |
| **NGB89 SK37** | Priory | 29 | Male |
| **NGB89 SK73** | Priory | 26.3 | Male |
| **NGB89 SK8** | Priory | 31.1 | Male |
| **NGB89 SK14** | Priory | 18.6 | Female |
| **NGB89 SK50** | Priory | 23.2 | Female |
| **NGB89 SK28** | Priory | 69 | Male |
| **NGB89 SK71** | Priory | 18.4 | Female |
| **NGB89 SK22** | Priory | 22.4 | Male |
| **NGB89 SK55** | Priory | 30.4 | Male |
| **NGB89 SK2** | Priory | 23.8 | Male |
| **NGB89 SK49** | Priory | 31.3 | Male |
| **NGA88 SK735** | Cemetery | 39.1 | Female |
| **NGA88 SK33** | Cemetery | 23.9 | Male |
| **NGB89 SK51** | Priory | 31.9 | Male |
| **NGA88 SK287** | Cemetery | 28.5 | Female |
| **NGA88 SK871** | Cemetery | 23.6 | Female |
| **NGA88 SK992** | Cemetery | 27.9 | Male |

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| **NGA88 SK727** | Cemetery | 29.4 | Female |
| **NGA88 SK1051** | Cemetery | 18.8 | Male |
| **NGA88 SK1043** | Cemetery | 26.2 | Female |
| **NGA88 SK1024** | Cemetery | 74.3 | Male |
| **NGA88 SK1023** | Cemetery | 23 | Female |
| **NGA88 SK1067** | Cemetery | 32.7 | Male |
| **NGA88 SK952** | Cemetery | 24.2 | Male |
| **NGA88 SK331** | Cemetery | 26.6 | Female |
| **NGA88 SK1216** | Cemetery | 28.5 | Male |
| **NGA88 SK913** | Cemetery | 26.2 | Male |
| **NGA88 SK529** | Cemetery | 28.2 | Female |
| **NGA88 SK927** | Cemetery | 29.3 | Female |
| **NGA88 SK917** | Cemetery | 28.1 | Male |
| **NGA88 SK486** | Cemetery | 28.6 | Female |
| **NGA88 SK748** | Cemetery | 19.4 | Male |
| **NGA88 SK725** | Cemetery | 35.9 | Male |
| **NGA88 SK747** | Cemetery | 23.2 | Male |
| **NGA88 SK1122** | Cemetery | 22.4 | Female |
| **NGA88 SK1137** | Cemetery | 23.8 | Female |
| **NGA88 SK1156** | Cemetery | 30.2 | Female |
| **NGA88 SK726** | Cemetery | 28.4 | Male |
| **NGA88 SK840** | Cemetery | 70.9 | Female |
| **NGA88 SK312** | Cemetery | 20.6 | Female |
| **NGA88 SK540** | Cemetery | 22.7 | Female |
| **NGA88 SK830** | Cemetery | 27 | Female |
| **NGA88 SK478** | Cemetery | 46.5 | Male |
| **NGA88 SK467** | Cemetery | 29.9 | Male |
| **NGA88 SK62** | Cemetery | 34.5 | Male |
| **NGA88 SK764** | Cemetery | 20.9 | Female |
| **NGA88 SK765** | Cemetery | 57 | Female |
| **NGA88 SK704** | Cemetery | 18.6 | Female |
| **NGA88 SK1230** | Cemetery | 30.5 | Male |
| **NGA88 SK910** | Cemetery | 29.4 | Male |
| **NGA88 SK1167** | Cemetery | 21.6 | Female |
| **NGA88 SK1166** | Cemetery | 22.9 | Female |
| **NGB89 SK16** | Priory | 35.2 | Female |
| **NGA88 SK530** | Cemetery | 26 | Female |
| **NGA88 SK313** | Cemetery | 35.9 | Female |
| **NGA88 SK191** | Cemetery | 69.6 | Female |
| **NGA88 SK534** | Cemetery | 29.4 | Male |
| **NGA88 SK989** | Cemetery | 30.3 | Male |
| **NGA88 SK695** | Cemetery | 30.5 | Male |
| **NGA88 SK832** | Cemetery | 42.4 | Male |
| **NGA88 SK515** | Cemetery | 27.6 | Female |
| **NGA88 SK749** | Cemetery | 35 | Male |
| **NGA88 SK1059** | Cemetery | 77.4 | Male |
| **NGA88 SK556** | Cemetery | 23.2 | Female |

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| **NGA88 SK965** | Cemetery | 32.4 | Male |
| **NGA88 SK1069** | Cemetery | 35.5 | Female |
| **NGA88 SK792** | Cemetery | 33.5 | Male |
| **NGA88 SK647** | Cemetery | 24.9 | Male |
| **NGA88 SK1212** | Cemetery | 34.5 | Male |
| **NGA88 SK622** | Cemetery | 20.5 | Female |
| **NGA88 SK445** | Cemetery | 25.7 | Female |
| **NGA88 SK1135** | Cemetery | 24.7 | Female |
| **NGA88 SK1146** | Cemetery | 39.1 | Female |
| **NGA88 SK743** | Cemetery | 34 | Female |
| **NGA88 SK177** | Cemetery | 20.9 | Female |
| **NGA88 SK239** | Cemetery | 36 | Male |
| **NGA88 SK613** | Cemetery | 38.7 | Male |
| **NGA88 SK1157** | Cemetery | 24 | Female |
| **NGA88 SK271** | Cemetery | 27 | Female |
| **NGA88 SK272** | Cemetery | 18.7 | Male |
| **NGA88 SK465** | Cemetery | 28.3 | Male |
| **NGA88 SK531** | Cemetery | 30.9 | Female |
| **NGA88 SK143** | Cemetery | 21.7 | Female |
| **NGA88 SK541** | Cemetery | 21.8 | Female |
| **NGA88 SK645** | Cemetery | 24.5 | Female |
| **NGA88 SK502** | Cemetery | 22.1 | Male |
| **NGA88 SK1164** | Cemetery | 24.6 | Male |
| **NGA88 SK1163** | Cemetery | 24.9 | Female |
| **NGA88 SK674** | Cemetery | 31 | Female |
| **NGA88 SK676** | Cemetery | 26.4 | Female |
| **NGA88 SK15** | Cemetery | 23.5 | Female |
| **NGA88 SK609** | Cemetery | 43.5 | Female |
| **NGA88 SK956** | Cemetery | 20 | Male |
| **NGA88 SK957** | Cemetery | 19 | Female |
| **NGA88 SK1053** | Cemetery | 27.3 | Female |
| **NGA88 SK766** | Cemetery | 31.8 | Female |
| **NGA88 SK810** | Cemetery | 35.8 | Male |
| **NGA88 SK616** | Cemetery | 37.1 | Male |
| **NGA88 SK589** | Cemetery | 21.9 | Female |
| **NGA88 SK454** | Cemetery | 23.9 | Male |
| **NGA88 SK187** | Cemetery | 35.7 | Male |
| **NGA88 SK564** | Cemetery | 37 | Male |
| **NGA88 SK335** | Cemetery | 39.2 | Male |
| **NGA88 SK148** | Cemetery | 36 | Male |
| **NGA88 SK551** | Cemetery | 33.4 | Female |
| **NGA88 SK1057** | Cemetery | 28.1 | Female |
| **NGA88 SK770** | Cemetery | 32.4 | Female |
| **NGA88 SK912** | Cemetery | 32.3 | Female |
| **NGA88 SK1159** | Cemetery | 31.2 | Male |
| **NGA88 SK416** | Cemetery | 34.4 | Male |
| **NGA88 SK691** | Cemetery | 34.4 | Male |

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| **NGA88 SK557** | Cemetery | 51.4 | Female |
| **NGA88 SK632** | Cemetery | 27.9 | Female |
| **NGA88 SK655** | Cemetery | 25.1 | Female |
| **NGA88 SK838** | Cemetery | 37.7 | Female |
| **NGA88 SK1134** | Cemetery | 27.3 | Female |
| **NGA88 SK986** | Cemetery | 20.1 | Male |
| **NGA88 SK987** | Cemetery | 22.8 | Female |
| **NGA88 SK711** | Cemetery | 24.5 | Female |
| **NGA88 SK1019** | Cemetery | 32.4 | Female |
| **NGA88 SK834** | Cemetery | 37.4 | Male |
| **NGA88 SK742** | Cemetery | 41 | Male |
| **NGA88 SK1075** | Cemetery | 24.5 | Female |
| **NGA88 SK1074** | Cemetery | 29.7 | Male |
| **NGA88 SK1112** | Cemetery | 33.5 | Male |
| **NGA88 SK678** | Cemetery | 51.3 | Female |
| **NGA88 SK677** | Cemetery | 53 | Male |
| **NGA88 SK1110** | Cemetery | 25.1 | Male |
| **NGA88 SK693** | Cemetery | 31.1 | Female |
| **NGA88 SK1143** | Cemetery | 28.1 | Male |
| **NGA88 SK839** | Cemetery | 21.9 | Female |
| **NGA88 SK605** | Cemetery | 38.9 | Female |
| **NGA88 SK552** | Cemetery | 22.1 | Female |
| **NGA88 SK212** | Cemetery | 32.5 | Female |
| **NGA88 SK1000** | Cemetery | 23.7 | Female |
| **NGA88 SK999** | Cemetery | 29.8 | Female |
| **NGA88 SK998** | Cemetery | 23.8 | Female |
| **NGA88 SK979** | Cemetery | 24.8 | Female |
| **NGA88 SK767** | Cemetery | 34.7 | Male |
| **NGA88 SK554** | Cemetery | 58 | Male |
| **NGA88 SK845** | Cemetery | 58.4 | Male |
| **NGA88 SK763** | Cemetery | 48.3 | Female |
| **NGA88 SK74** | Cemetery | 45.5 | Male |
| **NGA88 SK468** | Cemetery | 27 | Male |
| **NGA88 SK705** | Cemetery | 18.5 | Male |
| **NGA88 SK629** | Cemetery | 34.9 | Male |
| **NGA88 SK891** | Cemetery | 22.4 | Female |
| **NGA88 SK1187** | Cemetery | 22.7 | Female |
| **NGA88 SK1193** | Cemetery | 22.5 | Female |
| **NGA88 SK1126** | Cemetery | 32.8 | Male |
| **NGA88 SK758** | Cemetery | 48.1 | Female |
| **NGA88 SK968** | Cemetery | 47 | Male |
| **NGA88 SK489** | Cemetery | 35.6 | Female |
| **NGA88 SK503** | Cemetery | 31.3 | Female |
| **NGA88 SK1105** | Cemetery | 28.2 | Female |
| **NGA88 SK446** | Cemetery | 32.8 | Female |
| **NGA88 SK1145** | Cemetery | 44.1 | Male |
| **NGA88 SK72** | Cemetery | 26.3 | Female |

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| **NGA88 SK985** | Cemetery | 30.8 | Male |
| **NGA88 SK1120** | Cemetery | 39.7 | Female |
| **NGA88 SK811** | Cemetery | 52.9 | Male |
| **NGA88 SK109** | Cemetery | 35 | Female |
| **NGA88 SK700** | Cemetery | 23.6 | Female |
| **NGA88 SK701** | Cemetery | 27.4 | Female |
| **NGA88 SK1245** | Cemetery | 33.2 | Female |
| **NGA88 SK1195** | Cemetery | 25.8 | Female |
| **NGA88 SK185** | Cemetery | 31.3 | Female |
| **NGA88 SK1240** | Cemetery | 34.4 | Male |
| **NGA88 SK1146** | Cemetery | 46.8 | Male |
| **NGA88 SK1246** | Cemetery | 30 | Male |
| **NGA88 SK1229** | Cemetery | 35.2 | Male |
| **NGA88 SK1231** | Cemetery | 26.7 | Female |
| **NGA88 SK653** | Cemetery | 35.6 | Female |
| **NGA88 SK1181** | Cemetery | 25.3 | Female |
| **NGA88 SK520** | Cemetery | 45.9 | Male |
| **NGA88 SK769** | Cemetery | 29.3 | Male |
| **NGA88 SK469** | Cemetery | 29.6 | Male |
| **NGA88 SK452** | Cemetery | 32.5 | Male |
| **NGA88 SK1161** | Cemetery | 38.4 | Male |
| **NGA88 SK1079** | Cemetery | 33.1 | Female |
| **NGA88 SK721** | Cemetery | 27.1 | Female |
| **NGA88 SK720** | Cemetery | 26 | Female |
| **NGA88 SK504** | Cemetery | 37.1 | Female |
| **NGA88 SK645** | Cemetery | 30.4 | Male |
| **NGA88 SK 1188** | Cemetery | 24.4 | Male |
| **NGA88 SK1039** | Cemetery | 23.4 | Male |
| **NGA88 SK1100** | Cemetery | 56.4 | Male |
| **NGA88 SK752** | Cemetery | 34.7 | Female |
| **NGA88 SK751** | Cemetery | 45.4 | Female |
| **NGA88 SK546** | Cemetery | 25.9 | Female |
| **NGA88 SK888** | Cemetery | 44.4 | Male |
| **NGA88 SK470** | Cemetery | 28.2 | Female |
| **NGA88 SK853** | Cemetery | 44.5 | Female |
| **NGA88 SK628** | Cemetery | 30.3 | Male |
| **NGA88 SK1104** | Cemetery | 23.3 | Female |
| **NGA88 SK775** | Cemetery | 53.8 | Male |
| **NGA88 SK456** | Cemetery | 46.1 | Male |
| **NGA88 SK455** | Cemetery | 28.2 | Female |
| **NGA88 SK327** | Cemetery | 23.1 | Female |
| **NGA88 SK593** | Cemetery | 36.8 | Female |
| **NGA88 SK1107** | Cemetery | 32 | Female |
| **NGA88 SK1111** | Cemetery | 57.6 | Male |
| **NGA88 SK1218** | Cemetery | 29.5 | Female |
| **NGB89 SK69** | Priory | 43 | Male |
| **NGB89 SK47** | Priory | 39.1 | Male |

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| **NGB89 SK24** | Priory | 32.7 | Male |
| **NGA88 SK988** | Cemetery | 39.1 | Female |
| **NGA88 SK969** | Cemetery | 45.5 | Female |
| **NGA88 SK692** | Cemetery | 52.5 | Female |
| **NGA88 SK139** | Cemetery | 59.1 | Male |
| **NGA88 SK507** | Cemetery | 46.2 | Female |
| **NGA88 SK132** | Cemetery | 37.1 | Male |
| **NGA88 SK1001** | Cemetery | 26.1 | Male |
| **NGA88 SK311** | Cemetery | 30.2 | Male |
| **NGA88 SK170** | Cemetery | 24.3 | Female |
| **NGA88 SK210** | Cemetery | 21.4 | Male |
| **NGA88 SK198** | Cemetery | 28.1 | Female |
| **NGA88 SK194** | Cemetery | 35.8 | Male |
| **NGA88 SK1017** | Cemetery | 32.5 | Female |
| **NGA88 SK295** | Cemetery | 37.8 | Male |
| **NGA88 SK1046** | Cemetery | 40.2 | Male |
| **NGA88 SK337** | Cemetery | 30.9 | Male |
| **NGA88 SK615** | Cemetery | 26.6 | Female |
| **NGA88 SK510** | Cemetery | 37.6 | Male |
| **NGA88 SK66** | Cemetery | 45.3 | Male |
| **NGA88 SK226** | Cemetery | 29.6 | Male |
| **NGA88 SK98** | Cemetery | 32.9 | Male |
| **NGA88 SK125** | Cemetery | 22.4 | Male |
| **NGA88 SK16** | Cemetery | 28 | Female |
| **NGA88 SK822** | Cemetery | 32 | Female |
| **NGA88 SK1184** | Cemetery | 36.4 | Male |
| **NGA88 SK483** | Cemetery | 28.1 | Female |
| **NGA88 SK1186** | Cemetery | 39.5 | Male |
| **NGA88 SK808** | Cemetery | 25.9 | Female |
| **NGA88 SK815** | Cemetery | 35.2 | Male |
| **NGA88SK155** | Cemetery | 39.8 | Male |
| **NGA88 SK436** | Cemetery | 47.4 | Female |
| **NGA88 SK658** | Cemetery | 45.4 | Female |
| **NGA88 SK106** | Cemetery | 40.7 | Male |
| **NGA88 SK259** | Cemetery | 33.3 | Male |
| **NGA88 SK788** | Cemetery | 40.3 | Male |
| **NGA88 SK4** | Cemetery | 39.6 | Male |
| **NGB89 SK60** | Priory | 27.1 | Male |
| **NGA88 SK1200** | Cemetery | 27.9 | Female |
| **NGA88 SK650** | Cemetery | 36.1 | Female |
| **NGA88 SK524** | Cemetery | 30 | Male |
| **NGA88 SK152** | Cemetery | 47.8 | Male |
| **NGA88 SK22** | Cemetery | 39.2 | Female |
| **NGA88 SK448** | Cemetery | 28 | Male |
| **NGA88 SK1197** | Cemetery | 25.1 | Female |
| **NGA88 SK1198** | Cemetery | 30.2 | Female |
| **NGA88 SK1199** | Cemetery | 37.2 | Female |

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|---|---|---|---|
| **NGA88 SK1160** | Cemetery | 40.3 | Male |
| **NGA88 SK1174** | Cemetery | 30.4 | Male |
| **NGA88 SK1136** | Cemetery | 26.3 | Male |
| **NGA88 SK457** | Cemetery | 29.5 | Male |
| **NGA88 SK473** | Cemetery | 34.2 | Male |
| **NGA88 SK599** | Cemetery | 40.1 | Female |
| **NGA88 SK597** | Cemetery | 67.1 | Male |
| **NGA88 SK1219** | Cemetery | 25.7 | Male |
| **NGA88 SK1222** | Cemetery | 47 | Male |
| **NGA88 SK202** | Cemetery | 56.7 | Female |
| **NGA88 SK114** | Cemetery | 23.3 | Male |
| **NGA88 SK1238** | Cemetery | 25.5 | Male |
| **NGA88 SK866** | Cemetery | 30.8 | Male |
| **NGA88 SK124** | Cemetery | 25.6 | Female |
| **NGA88 SK435** | Cemetery | 435 | Female |
| **NGA88 SK190** | Cemetery | 24.1 | Female |
| **NGA88 SK134** | Cemetery | 35.5 | Female |
| **NGA88 SK1151** | Cemetery | 34.9 | Male |
| **NGA88 SK926** | Cemetery | 39.2 | Male |
| **NGA88 SK180** | Cemetery | 39.9 | Male |
| **NGA88 SK160** | Cemetery | 22.3 | Female |
| **NGA88 SK856** | Cemetery | 33.3 | Male |
| **NGA88 SK648** | Cemetery | 23.4 | Female |
| **NGA88 SK689** | Cemetery | 25.6 | Female |
| **NGB89 SK52** | Priory | 28.6 | Female |
| **NGA88 SK731** | Cemetery | 48.7 | Female |
| **NGA88 SK569** | Cemetery | 19.7 | Male |
| **NGA88 SK568** | Cemetery | 43.2 | Male |
| **NGA88 SK248** | Cemetery | 39.9 | Male |
| **NGA88 SK444** | Cemetery | 45 | Female |
| **NGA88 SK293** | Cemetery | 40.2 | Male |
| **NGA88 SK104** | Cemetery | 43.2 | Male |
| **NGA88 SK1116** | Cemetery | 19.1 | Female |
| **NGA88 SK1035** | Cemetery | 26.9 | Female |
| **NGA88 SK1049** | Cemetery | 25 | Female |
| **NGA88 SK86** | Cemetery | 35.8 | Female |
| **NGA88 SK944** | Cemetery | 47.8 | Female |
| **NGA88 SK213** | Cemetery | 29.6 | Male |
| **NGA88 SK1210** | Cemetery | 39.4 | Male |
| **NGA88 SK967** | Cemetery | 32.8 | Male |
| **NGA88 SK265** | Cemetery | 40 | Male |
| **NGA88 SK1016** | Cemetery | 46.6 | Male |
| **NGA88 SK1037** | Cemetery | 32.4 | Female |
| **NGA88 SK1125** | Cemetery | 28.4 | Female |
| **NGA88 SK1178** | Cemetery | 33.5 | Female |
| **NGA88 SK1205** | Cemetery | 30.8 | Female |
| **NGA88 SK973** | Cemetery | 35 | Male |

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| **NGA88 SK1207** | Cemetery | 39.9 | Female |
| **NGA88 SK573** | Cemetery | 30.9 | Male |
| **NGA88 SK1047** | Cemetery | 24.4 | Female |
| **NGA88 SK826** | Cemetery | 44.5 | Male |
| **NGA88 SK734** | Cemetery | 26.4 | Female |
| **NGA88 SK596** | Cemetery | 25.9 | Female |
| **NGA88 SK199** | Cemetery | 31.4 | Male |
| **NGA88 SK494** | Cemetery | 23.1 | Female |
| **NGA88 SK304** | Cemetery | 26.8 | Female |
| **NGA888 SK954** | Cemetery | 35.4 | Male |
| **NGA88 SK563** | Cemetery | 22.3 | Female |
| **NGA88 SK778** | Cemetery | 18.4 | Female |
| **NGA88 SK784** | Cemetery | 39.6 | Male |
| **NGA88 SK138** | Cemetery | 27.1 | Female |
| **NGA88 SK338** | Cemetery | 31.2 | Female |
| **NGA88 SK256** | Cemetery | 35.5 | Female |
| **NGA88 SK162** | Cemetery | 36.3 | Female |
| **NGA88 SK32** | Cemetery | 36.7 | Male |
| **NGA88 SK1085** | Cemetery | 49.7 | Female |
| **NGB89 SK4** | Priory | 33.2 | Male |
| **NGA88 SK750** | Cemetery | 32.9 | Female |
| **NGA88 SK880** | Cemetery | 32.6 | Male |
| **NGA88 SK157** | Cemetery | 68.5 | Male |
| **NGA88 SK981** | Cemetery | 26 | Male |
| **NGA88 SK761** | Cemetery | 25.9 | Male |
| **NGA88 SK844** | Cemetery | 27.4 | Male |
| **NGA88 SK798** | Cemetery | 51.6 | Male |
| **NGA88 SK169** | Cemetery | 39.2 | Male |
| **NGA88 SK461** | Cemetery | 34.1 | Male |
| **NGA88 SK1032** | Cemetery | 33 | Male |
| **NGA88 SK317** | Cemetery | 29.5 | Female |
| **NGA88 SK59** | Cemetery | 39.3 | Female |
| **NGA88 SK539** | Cemetery | 26 | Female |
| **NGA88 SK1121** | Cemetery | 26.3 | Female |
| **NGA88 SK288** | Cemetery | 39.2 | Female |
| **NGA88 SK511** | Cemetery | 33.7 | Female |
| **NGA88 SK591** | Cemetery | 25.8 | Female |
| **NGA88 SK971** | Cemetery | 33.2 | Male |
| **NGA88 SK592** | Cemetery | 34.3 | Female |
| **NGA88 SK795** | Cemetery | 29.4 | Female |
| **NGA88 SK426** | Cemetery | 28 | Male |
| **NGA88 SK848** | Cemetery | 32.3 | Male |
| **NGA88 SK205** | Cemetery | 39.9 | Female |
| **NGA88 SK221** | Cemetery | 32.4 | Male |
| **NGA88 SK1213** | Cemetery | 40.2 | Male |
| **NGA88 SK949** | Cemetery | 21.7 | Male |
| **NGA88 SK895** | Cemetery | 33.5 | Female |

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| **NGA88 SK1041** | Cemetery | 27.6 | Male |
| **NGA88 SK852** | Cemetery | 34.7 | Female |
| **NGA88 SK283** | Cemetery | 31.6 | Male |
| **NGA88 SK48** | Cemetery | 24.2 | Male |
| **NGA88 SK35** | Cemetery | 30.7 | Male |
| **NGA88 SK908** | Cemetery | 41.8 | Female |
| **NGA88 SK77** | Cemetery | 22.3 | Female |
| **NGA88 SK76** | Cemetery | 34.6 | Male |
| **NGA88 SK1027** | Cemetery | 39.5 | Male |
| **NGA88 SK188** | Cemetery | 28.1 | Female |
| **NGA88 SK939** | Cemetery | 27.1 | Male |
| **NGA88 SK334** | Cemetery | 26.6 | Female |
| **NGA88 SK336** | Cemetery | 26.8 | Male |
| **NGA88 SK1147** | Cemetery | 22.5 | Female |
| **NGA88 SK218** | Cemetery | 33.3 | Female |
| **NGA88 SK305** | Cemetery | 27 | Male |
| **NGA88 SK1085** | Cemetery | 27 | Female |
| **NGA88 SK41** | Cemetery | 36.6 | Male |
| **NGA88 SK1022** | Cemetery | 21.2 | Male |
| **NGA88 SK128** | Cemetery | 20.2 | Female |
| **NGA88 SK997** | Cemetery | 20.4 | Female |
| **NGA88 SK43** | Cemetery | 30.8 | Female |
| **NGA88 SK542** | Cemetery | 31.3 | Female |
| **NGA88 SK274** | Cemetery | 34.3 | Female |
| **NGA88 SK147** | Cemetery | 22.2 | Male |
| **NGA88 SK851** | Cemetery | 31.6 | Male |
| **NGA88 SK875** | Cemetery | 35.3 | Male |
| **NGA88 SK12** | Cemetery | 29.7 | Female |
| **NGA88 SK153** | Cemetery | 34.5 | Male |
| **NGA88 SK873** | Cemetery | 34 | Female |
| **NGA88 SK228** | Cemetery | 33 | Male |
| **NGA88 SK423** | Cemetery | 26.9 | Female |
| **NGA88 SK882** | Cemetery | 30.3 | Male |
| **NGA88 SK45** | Cemetery | 49.9 | Male |
| **NGA88 SK197** | Cemetery | 28.1 | Male |
| **NGA88 SK249** | Cemetery | 33.7 | Male |
| **NGA88 SK209** | Cemetery | 32.9 | Female |
| **NGA88 SK921** | Cemetery | 31.3 | Male |
| **NGA88 SK289** | Cemetery | 41.9 | Male |
| **NGA88 SK67** | Cemetery | 31.2 | Female |
| **NGA88 SK278** | Cemetery | 25.9 | Male |
| **NGA88 SK280** | Cemetery | 30.5 | Female |
| **NGA88 SK315** | Cemetery | 28.2 | Female |
| **NGA88 SK278** | Cemetery | 31.8 | Male |
| **NGA88 SK268** | Cemetery | 30.1 | Male |
| **NGA88 SK330** | Cemetery | 31.5 | Female |
| **NGA88 SK103** | Cemetery | 36.5 | Male |

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|---|---|---|---|
| **NGA88 SK215** | Cemetery | 57.5 | Female |
| **NGA88 SK936** | Cemetery | 24.9 | Female |
| **NGA88 SK42** | Cemetery | 31.2 | Female |
| **NGA88 SK254** | Cemetery | 35.3 | Male |
| **NGA88 SK1083** | Cemetery | 25.1 | Male |
| **NGA88 SK133** | Cemetery | 32.5 | Female |
| **NGA88 SK290** | Cemetery | 26.9 | Female |
| **NGA88 SK159** | Cemetery | 27.5 | Female |
| **NGA88 SK222** | Cemetery | 31.4 | Female |
| **NGA88 SK894** | Cemetery | 24.3 | Female |
| **NGA88 SK893** | Cemetery | 24.6 | Female |
| **NGA88 SK167** | Cemetery | 36.4 | Male |
| **NGA88 SK144** | Cemetery | 33.4 | Male |
| **NGA88 SK251** | Cemetery | 35.1 | Female |
| **NGA88 SK876** | Cemetery | 27.3 | Female |
| **NGA88 SK1** | Cemetery | 30.7 | Male |
| **NGA88 SK246** | Cemetery | 24.6 | Female |
| **NGA88 SK911** | Cemetery | 39.2 | Female |
| **NGA88 SK1172** | Cemetery | 34.6 | Male |
| **NGA88 SK227** | Cemetery | 32.9 | Male |
| **NGA88 SK578** | Cemetery | 20.4 | Female |
| **NGA88 SK1232** | Cemetery | 25.9 | Male |
| **NGA88 SK491** | Cemetery | 18.4 | Male |
| **NGB89 SK56** | Priory | 39.5 | Male |