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Puberty and Adolescent Health in Post-Medieval England (1550-1850)

Submitted for the Degree of Doctor of Philosophy

DEPARTMENT OF ARCHAEOLOGY – SCHOOL OF ARCHAEOLOGY, GEOGRAPHY AND ENVIRONMENTAL SCIENCE

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DECLARATION OF ORIGINAL AUTHORSHIP

"I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged."

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ABSTRACT

Adolescents are a dynamic and underrepresented part of the archaeological record. Through the use of osteological, historical, and archaeological sources this project aims to assess the health of post-medieval adolescents, aged 10 to 25 years. While there has been recent research into puberty in medieval and roman England, the post-medieval period has been largely untouched. This study sets out to fill in this gap in research by providing the first large scale analysis of post-medieval adolescent health and puberty and to address the changes in urbanization and industrialization, and the effects that they would have on a child growing into adulthood.

A primary sample of 460 skeletons was examined for age, sex, pubertal stage, stress, and pathology. While a secondary reference database was established with 424 adolescent aged individuals from published and unpublished sources. An examination of the 6 pubertal stages indicated that there was an average overall delay in pubertal growth in both boys and girls of 2 years to modern studies. Additionally, the average age of menarche for post-medieval females (16.2 years) to Modern (12.6 years), Medieval (15 years), and Roman (14.1 years) time periods were recorded. In support of historical sources, London was found with the highest rates of rickets reflecting the worsening air pollution. Naval sailors were found with the highest rates of tuberculosis and maxillary sinusitis suggesting that ship based life was more dangerous than commonly expected. The results indicated that the semi-urban cohort had the least exposure to pathology and ultimately are an unexplored demographic in the population that is beginning to arise in the period. Overall adolescents in the post-medieval period had more pathology than the medieval period and the stresses indicated that while DEH was present that these adolescents were likely well enough to survive childhood before encountering further environmental difficulties.

This research provides the most comprehensive study of adolescent morbidity and mortality in post-medieval England to date and it has provided new insights into post-medieval puberty and health while presenting suggestions for further work.

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Chapter 1 Introduction

Humans are defined by their interactions with the environment around them and the effects that it has upon their health. Through a combination of cultural and biological data, or the 'biocultural approach' bioarchaeologists investigate how humans adapted in the past to their changing environment (DeWitte and Stojanowski, 2015). Rarely though are adolescents a focus of examination in regards to changing social and environmental patterns, despite being the most likely individuals to be mobile in any given community. This is partly due to the previous lack of standards to identify puberty.

The term "post-medieval" is most often used by archaeologists to define the time period after AD 1500 and ending in the 1750s. In contrast, historians refer to AD 1600-1850 as the early modern period. In this project, the term 'post-medieval' will be used to identify the time period between AD1530 to 1850. The starting date of AD1530 was chosen because it signals the start of the Reformation which had a profound impact on the health of individuals as the overall social environment declines without the presence of religious hospitals and alms-houses that were responsible for the management of the majority of poor.

The post-medieval period is marked by the large increase in urbanization and the birth of industry. This rise in urbanization changed the landscape of the country with a consolidation of the population into cities that continued to grow larger and more densely populated (Wrigley and Schofield, 1981). The emergence of semi-urban settlements and specialized hospitals in the post- medieval period have not been fully explored in bioarchaeology, but will be considered as part of the unique environment the adolescents in this study were exposed to. All of these changes in the living environment that characterise this period would have had significant and lasting impacts on the health, and by association, the timing of puberty in adolescence.

The mobility of adolescents increased throughout the post-medieval period and was originally based in the medieval system of apprenticeships (see Chapter 2.4.1). As urbanization increased and industrialization developed, the old apprenticeship system declined and the younger adolescents would find themselves in a new workhouse environment (Humphries 2010). The timing and duration of the apprenticeships would be unique for each adolescent, but normally spanned the ages of 12 to 20 years.

1.1 PREVIOUS RESEARCH INTO ADOLESCENT HEALTH

Adolescence can be described from three different perspectives, a social perspective that regards the individual's transition into adulthood from a cultural viewpoint, a psychological perspective that encompasses the changes in emotions and behaviour, and a biological perspective that focuses on the timing and duration in which the individual undergoes pubertal changes. Puberty encompasses the timing of the growth spurt, sexual maturation, and the completion of physical development as well as the social transition between a childhood dependence and becoming an independent adult (Hochberg and Belsky 2013).

The study of adolescence and puberty is new and relatively unexplored in bioarchaeology. Research into puberty in the post-medieval period is especially limited, with most research focused on adults and non-adults. Adolescents as an age group studied in their own right has only recently been possible with the introduction of new techniques to map pubertal development, and their sexual maturation and health has since been explored for the Roman (Arthur et al. 2016) and medieval periods (Shapland and Lewis 2013, 2014; Lewis et al. 2015, 2016). While the children from any population indicate the most demographically sensitive and variable index for biocultural change, adolescence is a particularly vulnerable time in a developing individual's life, characterized by changes in their immune status, physiology and mental wellbeing. Often converging with major with social changes, it is also a time in an individual's life when their body is undergoing significant psychological and physiological change. These changes often converge with a major shift in their identity from child to adult, and may also represent a time when they begin work, marry, or have children (Lewis 2016). Hence, the age at which an individual undergoes puberty is essential not only in understanding how they would be perceived in their broader social context, but also in understanding the impact their health would have had on future generations.

Throughout history, the age of the onset in puberty has increased and decreased as a result of environmental factors and within different geographical locations (Sorenson et al. 2011). While there can be considerable variation in the onset of puberty, adolescents in modern Europe normally commence puberty approximately between 10-12 years of age (Aksglaede et al. 2008), with maturation often completing between 13-17 years in females and 15-18 for males (Hägg and Taranger, 1982). Menarche is often used as a clear indicator that puberty has begun in females, and has been used to document the age of puberty in historical contexts. The downward shift in the age of onset of puberty in modern populations has been attributed to better nutrition, health, and environmental conditions (de Muinck Keizer-Schrama and Mul, 2001).

The impact of pathology on puberty in medieval adolescents (Lewis, 2016) has provided the groundwork for further research into the shifting adolescent immune system and the effects of diseases such as tuberculosis (TB) on maturation. For the first time, this approach will be applied to post-medieval adolescents to explore whether immunological transitions and environmental conditions played a part in the delay of the timing of puberty often reported in historical accounts of the post-medieval period. How such a delay affected the identity and treatment of teenagers in post-medieval England will also be explored.

1.2 PREVIOUS RESEARCH INTO POST-MEDIEVAL ADOLESCENTS

There was little archaeological research conducted on the health differences of children in rural and urban environments until Lewis (2002) conducted her research on non-adult skeletons from medieval England. Lewis' (2002) findings indicate that stress markers and deprivation were much higher in post-medieval urban populations than in non-urban populations. Roberts and Cox (2003) assembled a mass of historical, demographic, and skeletal data to explain the shifting developments in health and disease throughout Britain. It is the first dataset to deal in depth with the full extent of health in relation to changing urban environments, but did not include data on children and adolescents.

Lewis, (2002) investigated the health and mortality of infants in urban and rural environments followed by research (Lewis and Gowland, 2007, Penny-Mason and Gowland 2014) into adolescents. This project builds upon a now developing area of research by Shapland and Lewis (2013, 2014) in the identification of adolescents and the assessment of the health in urban and semi-urban environments. Adolescents as a subset of the population are now included in numerous bioarchaeological studies (Mays, 2008; Redfern et al. 2015; Newman and Gowland, 2016; Roberts et al. 2016; Gowland, 2018).

1.3 THE POST-MEDIEVAL ENVIRONMENT AND THE IMPACT ON HEALTH

Urbanization is one of the most fundamental changes in the history of human settlement. Historical sources allude to a negative impact on population growth (Steckel, 1994). Such sources include parish records which in 1538 were mandated to record the births (by baptisms), marriages, and deaths of all who live in their parish (Ben-Amos, 1994). The London the Bills of Mortality, which began in 1592 but did not become continuous until 1603, provides details on the number and causes of death per year.

Bioarchaeological studies have demonstrated that individuals from urban populations exhibit higher rates of stress and disease than their rural counterparts (Storey, 1992; Lewis, 2002; Morfin et al., 2002; Lewis 2007; Mant and Roberts 2015). Differences in housing (Awadalla 2013), sanitation (Woods and Shelton 2010), trade (Roberts et al. 2016), industry (Brimblecombe, 1978), population density (Jorgenson and Rice 2010), diet (Carballo et al. 1998), and pollution (Satterthwaite, 1993) between rural and industrialized centres are cited as significant factors in the exposure and proximity to pathogens. In order to fully explore the lives of adolescents in post-medieval England it is necessary to understand the changing environment in which they lived and the possible health disadvantages they would have been subjected to.

The eighteenth century in England saw the origin and development of highly industrialized centres that were heavily dependent on external sources for food and fuel due to much higher population densities (Wrigley 2014). The lack of gardens meant that urban populations could not produce their own food resources and had to buy them resulting in a greater social demand and divisions between the rich and the poor. High population density presented new difficulties. The disparity between individuals and social groups became more distinct and there was an increase in negative health effects (Storey, 1992; Barker, 2005; DeWitte et al. 2015). Pollutants to the air would come primarily in the form of smoke from the burning of fuel in home for heating (Roberts and Cox, 2003) and industrial pollutants as a result of metal smelting and casting (Brimblecombe, 1978). This air pollution would have multiple health effects from sinusitis and respiratory infections as a result of smoke inhalation to rickets, as a result of reduced access to sunlight necessary for vitamin D production (Brimblecombe, 1978). Throughout the country and in particular, London, the overcrowding of slum tenements due to rapid urbanization was spreading and placing constant pressures upon health as the population. These “slums” were squalid overcrowded urban districts inhabited by the poorest of the population and they were fraught with health risks. People were faced with a lack of consistent water supply, or proper sewage disposal (Haines 2004; Porter 2000) making them susceptible to disease due to poverty and malnutrition, sanitation, and pollution (Awadalla 2013).

The extent and proliferation of urbanization in England would not have been possible without extensive regional migration from the rural countryside. This theory was first developed by Wrigley and Schofield (1981). Later, Davenport et al. (2010) identified more specifically that the size of the young adult population of London was higher than the national average and correlated to the decline of young-adults in more rural areas of the country due to migration to industrializing cities. This migration began in the medieval period as a continued economic and social response with individuals on the periphery seeking opportunities to work (Patten, 1976; Ben-Amos 1994). With the increase of population density due to migration, large towns became the perfect incubators for infectious diseases like TB and leprosy that rely upon close communication between their hosts to spread, and treponemal diseases such as venereal syphilis that spread through ports with prostitution (Manchester, 1992). Migratory individuals like adolescents would also be prime carriers of disease to new locations as well as the prime targets for infection (McNeill et al., 1979; Luckin and Mooney, 1997).

These smaller towns would be larger than their rural counterparts and would often be in relatively close proximity to a large urban city (Tacoli 2003). While they would not be as densely populated they would still have some small scale local production and depending on the size and location, access to trade and some industry (Beauchesne and Bryant, 1999). These first semi-urban environments, while not wholly urban were capable of self-sustainment. The extent of differentiation between the urban and semi-urban adolescents in regards to pubertal development and pathology will help to determine if regional differences of urbanization are distinct or if the entire population can be considered a consolidated English group.

Poverty and socio-economic status are two of the most powerful predictors of mortality (Cavigelli and Chaudry 2012) because they control the access to resources and adequate nutrition that are essential for growth, development, tissue maintenance and immune response. The diet of migrants could be affected due to potential changes in the access to food and differing cultural customs (Carballo et al. 1998). The development of an urban and industrialized society created an increasing gap between social classes that grew more distinct as the period developed and had significant impacts on people's health (Cavigelli and Chaudry 2012). This social stratification would have been felt in different ways throughout the post-medieval period, but a prime example of the increasing change in the social make-up of London shows the broadening disparity. In 1780, the top 1% of metropolitan households held 21% of the wealth, and the top 20% of households held just over 75% of the total wealth (Sheppard 1998). Skeletally, status can be identified through the examination of diet, burial type, and location; while historical sources can assist with direct mentions about the status of individuals or their burials.

The examination of malnutrition and infection that individuals potentially experienced can be explored through the investigation of metabolic bone disease and dental enamel hypoplasia. Metabolic diseases are used to indicate conditions in which the process of bone modelling and remodeling is specifically disrupted, as the result of a deficiency in certain nutrients, such as vitamin D, Vitamin C and iron (Brickley, 2008). The development of rickets is the result of a deficiency in vitamin D that is normally absorbed through the skin from sunlight. The pervasiveness of air pollution in urban centres that has been commented upon by several sources (Storey, 1992; Brimblecomb, 2011) during the time period would have been the primary cause for rickets. The skeletal presence of scurvy due to a deficiency in vitamin C and is indicative of malnutrition. Cribra orbitalia and porotic hyperostosis are some of the most common cranial vault lesions and while it had been widely accepted that the cause of these lesions is chronic iron deficiency anaemia, new research by Walker and his colleagues (2009) has suggested that this porosity is most likely a result of haemolytic or megaloblastic anaemia and that there is often a co-occurrence of the diseases. Dental enamel hypoplasia indicates more general experiences of fever and malnutrition at an early age (Amoroso et al. 2014). The direct effects of metabolic diseases upon the onset and duration of puberty has not been directly examined until now, but it is logical to suggest that a lack of essential vitamins and calories may result in later maturation (Belsky et al. 2015).

The post-medieval period saw a rise in chronic infections such as smallpox, treponematosis (more specifically venereal syphilis), and TB, as well as more general infections like osteomyelitis and sinusitis (Roberts and Cox, 2003). Despite having declined considerably from the medieval period, leprosy was still present in Britain (Roberts, 2002), and given the modern vector of transference, it would be expected to be identified in more rural environments. Tuberculosis or *Mycobacterium tuberculosis* was present and prevalent during the post-medieval period in both the pulmonary and gastrointestinal forms. It is spread in two different ways: through the consumption of infected meat and milk from dairy cows, and through airborne droplets that were released through coughing of an infected individual (Roberts and Buikstra 2003). Pulmonary tuberculosis was significant in post-medieval England as a result of poor sanitation and increased population density in urbanized cities. The effect of tuberculosis upon the puberty in archaeological adolescents has been examined by Lewis (2016) and the research indicates that there is a delay in the onset and an increase in the duration of puberty.

1.4 RESEARCH AIMS AND OBJECTIVES

The post-medieval period was a time in which shifts in mobility and urbanization greatly impacted the health of the population. Through the use of osteological, historical, and archaeological sources this project aims to assess the health of post medieval adolescents, specifically between the ages 10 to 25 years in which puberty is expected to have commenced and reached completion.

The post medieval period will be defined as the years AD 1550 to 1850. AD 1550 has been specifically chosen to explore the impact that the Reformation and the series of repetitive outbreaks of plague that occurred at the beginning this time period may have had on the state of health. In addition, the increase in poverty (Penny-Mason and Gowland 2014) that occurred due to the Reformation exacerbated changes in the health systems. While there is greater access during this time frame to both cemetery and historical data it must be acknowledged that there is a difficulty in establishing cut off points due to the variable nature of burial patterns and deposition. As such, historical documents will be utilized whenever applicable to insure that the date range is accurate.

The historical increase in the age of onset of puberty in both sexes during the post-medieval period will be explored with focus on the possible effects that a delay in the age of menarche would have physically in females. As vulnerable members of society, it is hypothesized that adolescents suffered from a high prevalence of diseases and that these diseases contributed to a delay in skeletal maturation.

While there has been some recent research on health and diet during the post-medieval period (e.g. Mant and Roberts 2015; Gowland 2018), these are confined to particular sites or contexts. This project will collate a large dataset for the sex, age-at-death and pathological conditions identified in 10-25 years old from 12 primary post-medieval sites and 14 secondary sites from published reports and the gray literature to provide the first comprehensive review of post-medieval adolescent health. As such, this thesis will address this gap in scholarship through the physical analysis and evaluation of adolescent remains from throughout England to identify trends and differences in health among the population during puberty.

The objectives of this research are:

- To examine the age, sex, stature, pubertal stage and any common pathologies in individuals aged between 10-25 years old.
- To assess the prevalence of infectious and metabolic diseases on adolescent skeletons
- To establish the average age for each of the six stages of puberty in order to accurately identify if and when there is a delay in puberty and maturation; and to assess the impact of active pathological conditions on the differential stages of puberty
- Compare and contrast prevalence rates of trauma and pathology in semi-urban, hospital and industrial sites to identify the impact of environmental stress on adolescent health
- To address whether or not there is homogeneity between urban and semi-urban locations in England as a result of increased mobility and regional movement.

Chapter 2 Health and Development in post-medieval England

The exposure to stress insults for adolescents in the post-medieval period (AD 1530-1850) was highly dependent upon the environment in which they lived. Rural, urban or industrial environments influenced the nature and extent of exposure to infection and pollution, and played a vital role in the health of the adolescent. This chapter focuses on the distinct characteristics of rural, urban, semi-urban, industrial, and infirmary spaces, exploring the way the urban landscape developed and the impact of industrialization on migration, social status, and diet in post-medieval England. While the current study sample does not include individuals from rural settlements, understanding the nature of the post-medieval rural environment is vital when contextualising urbanisation and industrialisation from the 1700s onward. In addition, the importance and pervasiveness of a mobile migratory work force means that many of the adolescents under study would have spent their early life in a rural environment, reflecting the conditions they were exposed to. This chapter provides the broader changes over time during the period and the shift to urbanization and industrialization that are integral to the understanding the living background of adolescents. Age-specific experiences and first-hand accounts of adolescence are provided in Chapter 3 (Section 3.3).

2.1 FRAMING THE POST-MEDIEVAL PERIOD

The political instability of the post-medieval period had a profound effect on the health of people living in England. The most substantial political occurrences were the English Reformation in AD 1534 that led to the reshaping religious framework throughout the country; and the English civil wars in the mid-1600s, most notably the Civil War of AD 1648 that led to the abolishment of the monarchy under Cromwell and changed the political landscape until the monarchy was restored in AD 1660. In addition to the shifting social landscape, there was rapid population expansion in the country from a total population of approximately 2.7 (AD 1541) million people to 16.7 (AD 1851) million people (Wrigley and Schofield, 1981:208-209).

The English Reformation of AD 1534 restructured the religious system and had a profound impact on the institutions that were directly responsible for the support and feeding of the poor, an ever growing proportion of the population. Penny-Mason and Gowland (2014) identified that by AD 1500, 120,000 people were living in poverty whose survival relied on alms from the Catholic Church. The primary recipients of these alms were the young, ill and impoverished. Monastic alms contributed 7- 9% of the monastic expenditures (Dyer 2012). The Suppression of Religious Houses Act of AD 1536/7 ordered royal commissioners to suppress and 'pull down to the ground the walls of any church… and the like' (Dogget, 2001:166) of any lesser religious house that did not have a revenue that exceeded £200 a year (Cook 1965). As a result of this 'dissolution' of the monasteries, alms ceased and access to food for the most impoverished declined. As religious institutions run by the church to care for the sick, poor and elderly, medieval hospitals were also affected. The Dissolution halved hospital provisions, and closed colleges and fraternities that established and managed alms-houses. Between the 1530s and 1540s the crisis of the sick and poor was so extensive that the Lord Mayor and citizens of London petitioned the King to re-establish the hospitals (Fowler and Powers 2012).

At the start of the post-medieval period, specifically AD 1530, a combination of plague and poor harvests saw a net decrease in the estimated total population in England by 174,008 (5.51%) people from the years of 1556-1561 (Wrigley and Schofield, 1981:208-209). This trend continued with the further meagre harvests in 1564 and outbreaks of the plague that continued until AD 1666. These events plunged more people into poverty, now with no assistance from the church (Gowland, 2014).

Poverty became a critical issue with numerous Acts (the English Poor Laws) introduced to try and combat its effects (Penny-Mason and Gowland, 2014). There had been several Acts that focused on beggars in the medieval period, and the government continued with a regime of harsh punishment of those who begged and were deemed vagrants (e.g. Vagabonds Acts of 1531 and 1547). In 1597 the English parliament enacted a unified Poor Relief Act. It was later amended in AD 1601 and included the first provisions for the 'deserving poor' which were the first to directly address poverty in children (Dyer, 2012). The 1601 Act gave parish overseers the power, not only to bind poor orphans and young vagrants, but also the offspring of parents overburdened with children (Dyer, 2012). It is argued that the high level of poverty in children during this period, and the interventions made by parishes and the government were important factors in the social position, health and development of many adolescents in post-medieval England.

2.2 THE DYNAMICS OF THE DEMOGRAPHIC NETWORK

The following sections discuss the different environmental factors in rural and urban settings that would have an impact the overall health of developing adolescents. It draws on modern evidence from developing countries and historical records to explore factors such as hygiene, pollution, climate, and mortality.

Large urbanizing cities would be distinct in their own industrial capacity, high urbanization and population of 5-10 thousand people. Smaller towns in 1700, as defined by Dyer (2000) came in a wide range of settlement types with the upper end comprising of perhaps 2000 people with a modest administrative role or an unusual commercial role like a river port. Below the upper range would be the majority of thriving towns that comprised anywhere from 1000 to 1,500 inhabitants and the lesser towns of 800 or fewer residents that only serviced their immediate locality. These towns may seem small by modern standards but they represented 50% of the population. It is the thriving upper and middle towns that are in close proximity to other large urban cities that would be "semi-urban".

2.2.1 Defining "Urban" and "Rural"

There is no standard definition for 'urban' and 'rural' in the historic and archaeological literature and it often involves consideration of a wide range of criteria. These criteria include: population size, population density, distance between built areas, predominant economic activity, legal or administrative status, and services and facilities that are provided by the location (Clark 2003, Wrigley and Schofield 1989). The vast majority of sources use population statistics to define "rural" versus "urban" although agricultural productivity, social and economic factors are also considered. Here, a post-medieval rural environment is defined as a town with fewer than 800 residents that engaged primarily in agricultural activity. This is in contrast to small towns that had anywhere from 1000 -2000 people and urban centres with anywhere from 5,000-10,000 people that characterized the early part of this period. Urbanization is the process of small settlements or rural areas developing into a city that is marked by increases in population size as people migrate to the burgeoning location. Previous research indicates that urbanization negatively impacts the health of populations (e.g., Storey, 1992; Pearson et al., 1993; Matalas et al., 1999; Lewis, 2002; Khumalo, 2004). Additionally, urbanization involves the acquisition of urban features, such as the development of political and social infrastructure (Adejugbe, 2004).

2.2.2 The post-medieval urban environment

In the post-medieval period, clear distinctions between urban and rural settlements did not exist as growth and maintenance of urban centres was heavily dependent upon rural spaces for the production of food, fuel and the housing of its migrant populations (Wrigley 2014). As such, the potential for growth within a city would have been dictated by transportation links for movement of resources, and constrained by the cost of such supplies that rose the further the distance from rural production centres (Von Thünen, 1966). Increases in agricultural production during the Agricultural Revolution also a increased the available labour to work in the up and coming urban centres without a measurable decline in overall production of grain. This trend is evident between 1600 and 1850 as there was less than a 50% increase in land based agricultural employment despite the fourfold increase in population during that time (Wrigley and Schofield, 1989).

Modern evidence suggests that urban centres are attractive to large numbers of migrants from rural settlements, but that this group includes a disproportionate number of disadvantaged members (Humphries and Weisdorf 2016). It is likely that, just as today it was the more impoverished members of the rural communities who travelled to the urbanising centres to find work in the seventeenth and eighteenth centuries.

As the period progressed, urban centres increased significantly. The largest and most influential urban space was that of London.

Between 1700 and 1800, England experienced a near tripling of its population and this figure had then doubled again by 1841. As individuals moved to denser urban landscapes, towns began to decline. In 1701, 50% of the population lived within towns, but this declined to 25% in 1801, and just 9% by 1841 (Langton 2000). This decline in smaller towns is equal to the increase of those living in larger towns.

The post-medieval period also saw the development of 'semi-urban' contexts which functioned as transitional spaces between urban and rural centres (Tacoli 2003). These were hybrid landscapes with both urban and rural characteristics, but also their own specific identity (Beauchesne and Bryant, 1999). These semi-urban environments were often self-sustaining with some small scale local production and access to trade in the larger urban centre, and some went on to develop their own fledgling industries (Meeus and Gulinck, 2008).

The post-medieval urban environment was marked by a high population density, high migration levels and increasing dependence of external resources to feed the population and sustain its workforce. The main mode of employment in England was no longer agriculture, with people involved in manufacturing, handicrafts and retail increasing from 1.4 million in 1811, to 3.09 million in 1851 (Wrigley 1986). Thirty-two percent of the population worked in the retail trade and handicraft, compared to 10% of the total adult population working in manufacturing (Wrigley 1989).

The negative effects of urban overcrowding on overall human health have been well-documented (Jorgenson and Rice, 2010; Ekblad, 1993; Epstein 1982). As urbanizing societies rapidly expanded they would produce further increases in noise, overcrowding, air and chemical pollutants which have an impact on the physical and psychological health of the people residing in them (Ekblad, 1993). An aggregated dense urban settlement is ideal for pathogen propagation because poor sanitation and high population density provide ideal conditions for the transmission of many varieties of pathogens. This is particularly the case with pathogens whose transmission is characterized by direct transfer to new hosts in an environment in which new susceptible individuals are always accessible in the form of both new-born infants and immigrants (McGrath 1992).

2.2.3 Infirmaries

Infirmaries and hospitals in post-medieval England were quite different from their medieval counterparts that had functioned as places of refuge for those with a wide range of curable and incurable diseases (Fowler and Powers 2012). The 18th century saw a boom in the establishment of new voluntary hospitals that were maintained by charitable gifts and subscriptions. Post-medieval hospitals all had strict rules of admittance and with limited funds many of them were careful to restrict admittance to the most deserving and curable (Fowler and Powers 2012).

The creation of infirmaries arose through humanitarian concerns for the poor, inspired by the Enlightenment and by the wealthy upper classes (Granshaw 1992). Given that the working classes were the bedrock of a functioning and wealthy society, keeping them healthy also guaranteed affluence and stability for the upper classes. Therefore, it was in the interest of the upper classes to keep urban labourers healthy by sponsoring them for admittance to the Infirmaries (Granshaw 1992; Tröhler and Prüll 1997). As the largest and most urbanized city in the country, London had seven hospitals for the sick. The oldest, St. Bartholomew's and St Thomas' were re-established in 1544 and 1551 respectively, through royal endowments by Henry VIII and Edwards VI (Fowler and Powers 2012). Five new hospitals were only founded after 1720. Less extensive urban centres would follow with their own hospitals, and the end of the 19th century saw the construction of hospitals such the Worchester Royal Infirmary, Radcliffe Infirmary in Oxford, or the Bristol and Newcastle Infirmaries.

2.2.4 Coastal and river cities

The rise and importance of coastal towns and ports cannot be understated when discussing an island nation. Coastal cities with ports and access to water were some of the fastest growing locations throughout this period (Langton, 1979). The growth of these locations was a direct result of an increase in cross national trade and internal transportation that were dependent upon water as a transportation medium (Schmal, 1981). These internal national waterways that were the foundation of growth were the great tidal rivers of the Thames, Severn, Great Ouse, Trent, Humber and Yorkshire Ouse. What made these rivers so important was their good access to the hinterland through systems of smaller tributaries and that they were navigable without obstructions from the sea (Sacks and Lynch, 2000). In addition, towards the end of the 1600s the increase in the need for a strong naval presence and growing international trade further encouraged the growth and development of these locations.

Throughout the first half of the period there is substantial and rapid increase in the total population of the country with the majority of growth in coastal cities with ports. The most important of these is London but the extent to which other such cities grew must be noted. In 1520 there were approximately ten towns within the country that had a total population of 5,000 or more individuals, half of which were port cities (Sacks and Lynch 2000). This number increased to approximately twenty towns of which twelve were seaports, but 13 including York which had a quasi-port status. In the span of only 80 years, some of these coastal towns saw as a two-fold increase in their population. Regionally this growth shows an increase in Baltic trade with the addition of Hull and further population increase in Newcastle, while in the south east the concentration of growing districts in East

Anglia focused on clothing production suggests that the international trade between the Low Countries had further increased. The increase in population of Liverpool during the 1700s is indicative of the shifting trends in trade and a focus across the Atlantic.

The size of these coastal cities and the requirements of migration to sustain them must be acknowledged. In addition to the physical and environmental differences between ports and those without them, these sites would be the first point of arrival for immigrants and as such, would have been the first to be exposed to new diseases like tuberculosis coming into the country (Ekblad 1993).

2.3 THE RISE OF INDUSTRIALISATION

The industrial revolution which began in the late eighteenth century was one of the primary transformations in British history. This technological shift contributed to rapid social change in which a predominantly rural society, wherein the majority of labour was directed towards survival and the production of food, was increasingly transformed into an urban society whose economy was greatly reliant upon factory based manufacturing industry (Wrigley 1986). This industry was generated through the development of mechanization and new manufacturing processes (Mays, et al. 2008). The bulk of the manufacturing was very heavily concentrated in Lancashire and the West Riding of Yorkshire which had over half of all manufacturing jobs in the country (Wrigley 1986).

Based upon Clark and Slacks (1976) findings, Schmal (1981:196) proposed that:

> "A definition of urbanism before the industrial revolution should come under four headings: a specialist economic function, a peculiar concentration of population, a sophisticated political superstructure and a more than logical role in the economy and society of the day. The English towns could be grouped into three major tiers: an upper tier including London and the major provincial capitals, a middle tier of incorporated towns as well as developing market towns and industrial centres."

Large scale urban growth in non-coastal towns was predominantly a result of the expansion and intensification of industry. The industrial revolution had its underpinnings in the eighteenth century and was typified by population growth, rural depopulation, rural to urban migration, and the establishment of new urban centres (Storey 1992). The post-medieval period is not contiguous in its progress and industrialization and the extent that areas were growing was wholly dependent upon the regional location of the town in relation to access to water, fuel and population. Nottingham for example increased its population from 5,000 to over 10,000 people by 1739, while only 300 of these individuals were naturally born there, indicating that the rate of immigration was very high at over 90% of the population growth (Pickles, 1996).

By the nineteenth century industrial specialization became a crucial feature of many new urban centres. These industrial specializations often existed as centralized production centres and early 'Factories' that were often little more than large workshops by today's standards (Honeyman, 2013). Birmingham became famous for its toys and glass work while Sheffield was known for its production of fine cutlery (Jones, 2017). Manchester and Bolton were known for their linens like their cotton fustians, calicoes and muslins while Burslem was renowned for its China ware (Clark, 1984). Such specialized products would create health risks unique and common to each town and help to differentiate distinct vulnerabilities in health. While the entirety of textile trades during the last quarter of the eighteenth century experienced increased expansion; the cotton industry had the greatest change to the manufacturing process with adjustments that increased the rate of expansion, productivity gains, and working practices (Chapman, 1965).

Rapid population growth during this time lead to issues of housing and quickly gave rise to slum tenements. These locations were prone to overcrowding due to urbanization and there were constant strains upon health as a result of a lack of adequate public sanitation or consistent water supply and sewage disposal (Mants and Roberts, 2015; Haines, 2004; Porter 2000; Whol 1983). This consistent lack of water from communal taps or pipes continued into the 1840s for over 30,000 people (Whol, 1983).

As industrialization increased throughout the country there was a significant shift in the use and direction of children's work. The industrialization of the towns utilized the apprenticeship system established by the poor laws to supply the new parish manufacturing establishments with free child labour that would last for nearly a decade.

2.3.1 Environmental impact on health

The effects of pollutants in the air and water, as well as a lack of hygiene and sanitation would have a profound effect on the health of both adults and adolescents during this time period. Satterthwaite (1993) identified seven kinds of health hazard that are associated with modern urban environments. Four of these have direct impacts on the health of an individual: biological diseases agents (pathogens), chemical pollutants, a shortage or lack of access to particular natural resources such as food or water, and physical hazards (flooding etc.). The other three factors that affect health less directly are negative aspects of the built environment, natural resource degradation, and global environmental degradation (Satterthwaite, 1993). While important in a modern context, global environmental degradation had little to no impact during the post medieval period.

Biological pathogens exist throughout the human environment in food, water, the air, and the soil and will be the most focused upon of all the environmental problems. Two specific pathogens that are a focus in this project are tuberculosis and syphilis due to their association with urbanization and because they manifest osteologically (Roberts and Cox, 2003). Chemical pollutants during the post medieval period predominantly came about in the form of air pollutants. The vast majority of indoor air pollution was the result of the burning of organic biomass and later fuel for the heating of homes and cooking of food (Barker, 2005). Air pollution has had an impact both in present and past urban populations, it affects every breath taken and can in indoor environments lead to respiratory and sinus problems. In the past heavy ambient air pollution had additional detrimental health effects as dense smoke in urban communities combined with an already low amount of daily sunlight led to the development of rickets (Barker, 2005).

The primary source of fuel during this time period became coal especially among the poorer households. The burning of these fuels led to irritant gases and fumes which reduced resistance to acute respiratory infection and in turn further increases a person's susceptibility to the inflammatory effects of smoke and fumes.

The extent of the demand for coal in the 1780s can be seen in the 2.5 times increase of London's import of the product to over a million tons per year in the span of just a century (Wrigley 1986). Despite the heavy demand for the fuel, air pollution legislation did not first come about until 1814 yet still had little effect. The extent of the air pollution in London was acknowledged much earlier. In 1658, Digby remarked that those who had "weak lungs, but ample income, should avoid the London air and live in Paris where the air was not so polluted". These were not only recommendations but actual practice as in Dublin, where physicians commonly removed patients to the outskirts of the town where purer air could be found (Brimblecombe 1978).

Air pollution was not only derived from the burning of coal but also from the smelting and casting of metals that caused highly toxic elements to be dispersed into their neighbouring surroundings. This pre-industrial air pollution was felt most acutely in the large manufacturing towns of the north and midlands and caused locals to acquire diseases such as lap calamine and belland (Barker, 2005).

2.4 MIGRATION

Migration is presently, and has been in the past, an important process that has linked communities, nations, and continents on a cultural, social, demographic and economic level through the use of human capital. In the post-medieval period, everyone would have been affected by migration as it impacted on the very structure and organization of the communities in which people lived (Whyte 2000). Migration from 1530-1850 falls into two categories, "subsistence" which is the long distance migration of the poor and "betterment" in which the local migration is a constant feature of urban to rural contacts (Clarke, 1972). Individuals moving for "betterment" reasons, generally travelled short range distances and in the case of Norwich most apprentices came from within a radius of eight to twenty miles, while "subsistence" migrants often travelled longer distances as a result of survival or economic necessity (Griffiths et al. 2001)

It has been established over the past three decades of research by demographers (Wrigley and Schofield, 1989; Clark, 2001; Wrigley 2014) that the majority of towns in "pre-industrial" England would not have developed in size or flourished without influxes of migrant newcomers. The very survival of these large urban towns was dependent upon migration. In addition, the constant influx of labour was necessary to fulfil the continuing urban demand for labourers in manufacturing, trade crafts, and service occupations (Patten 1976) and it was identified by Wrigley (1981, 1989) that the large urban towns such as London, in order to maintain their population, required a minimum recruitment of a third of the town's population in migration. Furthermore, by the 18th century, London required and annual average of 5,000 people migrating in to maintain itself (McNeill 1979).

The primary motives for humans moving is to improve their lives or the lives of their children but the new environments that they are exposed to are often stressful and carry high risks of illness and death (Grigg, 1977). While there are many reasons for increased risks to migrants and especially their children, the primary reasons are based upon the migrant's fundamental lack of adaptation to their new living environment (Little and Baker, 1988). Large cities, like London or Norwich in the 1580s, were the primary receiving areas for immigrants and their high population growth rates was often necessary to offset the virulence that and susceptibility that they encountered there.

The trends for migration continued from 1700 onwards with the focal destinations being the rapidly growing port and industrialising cities. One such example of a rapidly growing industrial city was that of Liverpool, whose population between the years of 1790-1801 was estimated to be 70-80% migrants in a total population of 20-22 thousand people (Langton and Laxton, 1978). The urbanization that is indicative of the end of the post-medieval period was fuelled by the mobility of populations from rural to more urban settings. From the years of 1801-1901 the proportion of people living in towns increased from one fifth to four fifths (Whol 1983).

Three East Anglian towns, the provincial capital of Norwich, and the seaports of Great Yarmouth and Ipswich were examined by Patten (1976) ranging from the sixteenth and seventeenth centuries to assess the migratory patterns of large towns other than London. He identified that migration appeared to have been generally a movement to the densest immediate surroundings from smaller towns. These immediate surroundings were often smaller towns in the region and from areas that often had special commercial links such as manufacturing or mining.

In the case of Norwich, it attracted individuals from the northern and western uplands in order to maintain the economic and production capacity. Smaller towns like Great Yarmouth, despite their size had the distinct advantage of a coastal location which afforded them the opportunity to attract interested individuals from many of the coastal areas of Norfolk and Suffolk. The most notable of these were the high densities of immigrants from the North and north-eastern fishing and coastal trading ports (Paten 1976). Despite the rise of Norwich during the sixteenth and seventeenth centuries, Clark (1984) identifies that the population did not continue on its upward trend of growth, which was uncommon for cities of its size.

Due to economic prosperity and the size of the city, London had the greatest attraction for migration in the country. There is evidence this attraction did not last for the entirety of the post medieval period due to a contraction in the overall distance in the geographical distribution of the recruitment of apprentices to the London companies (Wareing, 1980). In addition the evidence suggests a more general decline in the area of migratory recruitment as the rate fell from an average distance travelled by non-apprentice migrants of 178 km in 1580-1639 to 166km in 1680 and 145km by 1775. New immigrants would often be relegated to the more impoverished areas and what would eventually become the slums in which there would not only possible negative health complications but also riskier lifestyles (Awadalla 2013).

2.4.1 Apprenticeships

During the medieval and post-medieval periods, apprenticeships were important aspects of the social and economic framework that began in adolescents and continued through young adulthood. While the use of child labour was prevalent throughout the medieval period, the full adoption of the apprenticeship model was not practiced by the majority of towns and guilds until 1450 (Dunlop, 1912). Apprenticeships encompassed the majority of post-medieval individuals' formative years (12-20 years) in which adolescents were undergoing puberty and coming into their own identities. These young developing individuals would be highly susceptible to disease and the carriers of it throughout the country (Woods and Shelton, 2000).

The significance of apprenticeships as an economic and social system waned towards the end of the 1800s, but their impact on the health of adolescents must be addressed due to the extensive time period an individual spent in them. The apprenticeship would have been most important for the wealthy who paid for their children to become apprentices while most of the young poor migrants would have been taken on to do any work they could find. The apprenticeship system was a primary source of mobility for adolescents during the beginning of this time period, moving children as early as 13 from their homes to begin work (Ben-Amos, 1994) and with 40% of the population under the age of 20 (Sharpe 1987) there was increased vulnerability to disease and epidemics.

The basic structure of an apprenticeship is a form of labour, most often of children, that combines work and learning. In modern examples, the apprenticeship involves between three to four years of training, schooling, and generally leads to a formal certification (Hansen, 2010). In post medieval England the apprenticeship encompassed approximately 7 years and was different in both structure and obligations to the modern standards. At the beginning of this period there was no set date or age for apprenticeships to begin but the average age for the start of urban apprenticeships was 14.7 years of age and falls within reasonable bounds of the Statutes of Apprentices of 1563 (Ben-Amos, 1994). In regards to agricultural apprenticeships this age was even lower at the age of 13, although this was most likely a result of proximity to the individual and the social status.

Several examples of adolescents and early adults moving away from homes in rural locations to more urban environments to learn new trades, (first hand autobiographical account by John Jay). Apprenticeship migration throughout the period began to change in the numbers of apprenticeships available as well as in the types of work that were still available to children. One of the reasons for the decline in the amount of migration during the 1600 – 1700s was due to the flow of indentured servants to the Americas increased (Whyte, 2000). As the time period progressed and manufacturing grew adolescents would spend more of their time in early factories in which, children and adolescents were found to work for '13 hours a day five days in the week, and eleven on the Saturday'(Humphries 2013).

It is noteworthy that there is a shift in the nature of apprenticeships throughout this period and that as time passed the conditions of recruitment and age range for individuals changed. The principal importance of apprenticeships was its role in the migration and movement of the developing members of the population around England and the environment that the work placed these vulnerable youths.

2.5 THE DEMOGRAPHICS OF SOCIAL STATUS

Throughout the post medieval period, the demographic representation of social status changed with the rise of urbanization and industrialization in the cities. It has been argued by Sjoberg (1960) and generally agreed upon by urban social geographers that urban society was segregated by wealth or status, with the rich and powerful living near the centre of towns with the poor and powerless relegated to the periphery of cities before industrialization (Langton 1979). This distribution of population based upon social status would eventually reverse with the increase in industrialization and urbanization as the wealthy elites of society fled the now densely packed cities for the open air and freedom of the countryside.

In 1780 London, the top 1% of the metropolitan households boasted 21% of the total wealth in the city, and the top 20% of the social strata held 75 % of the total wealth (Sheppard 1998). The middle class of the time known as the "middling sort," made up between 20–30 % of London's population during this time and were paid, on average, between £60 and £200 per year (Sheppard 1998). The discrepancy was between the classes was most pronounced with the working class, or "inferior sort," who despite comprising of nearly 75% of London's population were paid, on average, less than £60 per year (Sheppard 1998). These working class individuals were, on the whole, not banished to exclusively working-class districts, but were instead crammed into slum tenements.

2.5.1 The effects of social status on health

Social status impacts the health of individuals in multiple ways, from where they live, to the quality of the food they eat and water that they drink, to the environmental hazards that they are exposed to and ultimately, the quality of the air that they breathe. There is a strong relationship between the socioeconomic status and poverty of an individual and their disease burden (Cavigelli and Chaundhry, 2012). In addition, inflammatory responses are influenced by social status based stress factors (Owen et al. 2003).

Modern samples have shown that despite their current social status, adults who spent their childhood in a lower socioeconomic environment displayed higher cortisol levels and IL – 6 gene expressions, which suggests that there was a greater stress response to these individuals (Cavigelli and Chaudhry, 2012).

Sullivan (2004) found that status and mortality were linked in a medieval sample from St Andrew's priory in Fishergate, York, but that the associations were not always in the direction one might expect. In this case it was middle status females, rather than high status males or females, whose lifespan matched that of the longest-lived religious males. High status males often died young from violent injuries in Sullivan's sample, highlighting that the relationship between mortality and social status may be more nuanced and, once again, context-specific, than is typically assumed. Miszkiewicz (2015) also identified a relationship between social status and longevity in the sample from St Gregory's priory, where liner enamel hypoplasia in adults was significantly lower for those buried in the priory than in the cemetery. The individuals from the priory, a reflection of high social status, lived significantly longer than those buried in the associated cemetery, which was reserved for the lower social strata.

In an attempt to understand the lack of difference in mortality between high and low status adults in industrialized England, DeWitte et al. (2015) identified that migrants to London during this time period were in fact at least as healthy, if not healthier than their native borne London counterparts, and that their research could be an indication of migrant selectivity. They posit that the pattern could be a result of reduced survival chances for lower socioeconomic children and the influx of healthy young migrants.

2.5.2 Diet

The quantity and quality of food that is eaten plays an integral role in the health of an individual and getting adequate nutrition plays a significant role in the adolescent's pubertal growth and development especially when combined with other possible health factors in their environment.

The diet of the urban working class during the post-medieval period generally consisted of bread, butter, cheese, beer, and tea, with the irregular addition of carrots, cabbage, and potatoes. This working class diet was usually low in proteins and deficient in vitamins and minerals while heavily dependent upon carbohydrates and fats (Wohl 1983). Meanwhile, the middle and especially higher-class families would have been consuming even higher calorie diets due to their propensity to supplement their consumption with luxuries like chocolate, sweets, eggs, and cream (Drummond and Wilbraham 1957).

The impact of the industrial revolution was not confined to the urban setting, but was accompanied by agricultural improvements on farms in grain processing. This resulted in the production of cheaper refined flour that would come to dominate the diet of all classes during the 1800s. In contrast, the consumption of healthier rye and barley bread declined as a direct result of its increasing popularity among all of the social classes (Pelizzon, 2000).

The difference in diet between rural and urban locations was noted by Quarinonius in (1610) that:

> "The peasant girls in this landschaft in general menstruate much later than the daughters of the townsfolk or the aristocracy, and seldom before their 17th, 18th, or 20th year. For this reason they also live much longer than the townsfolk and aristocratic children and do not become old so early. The townsfolk have usually borne several children before the peasant girls have yet menstruated. The cause seems to be that the inhabitants of the town consume more fat food and drink and so their bodies become soft, weak and fat and come early to menstruation in the same way as a tree which one waters too early produces earlier but less well-formed fruit than another."

This theory was examined by Tanner and Eveleth (1976) and they determined, through the use of height and weight ratios, that most if not all of the urban to rural differences are due to the economic differential between town and country dwellers, resulting in the better nutrition for the wealthier in some rural communities.

Infants being the most susceptible age group were the first to suffer the negative effects of changing diets. The first negative dietary practice during this period that affected infants was the decrease in weaning age from 18 months to only 7.25 months and coincided with the increase in women moving into cities to find work (Fildes, 1986; Lewis 2007). The second change was the shift to feeding breast-fed babies a mixture of bread, water, sugar, treacle, and milk, or at times flour and donkey's milk called pobs (Fildes 1986; Lanphear 1990). These feeding practices would impact the health of the growing infants and could lead to stunted stature due to malnutrition, should it continue throughout the individual's formative pubertal years.

Dietary habits are often unstable due to being strongly defined by cultural behaviours and can be often be disrupted through migration to a new location by forcing the adaptation to new life styles. These changes to customs and nutritional habits as a result of migration often necessitate fundamental changes in both the preparation and substantive quality of the food consumed. In a modern example, breast-feeding while common in more traditional societies is uncommon in modern industrial or post-industrial societies as a result of the abundance of formula foods and a demanding work schedule (Carballo et al. 1998).

2.6 SUMMARY

This chapter has provided an overview of the overall changing demographic systems within England during the post-medieval period. While there is an overall lack of information on health in post-medieval England in the palaeopathological and archaeological record, the research available has been presented. Rural England while still present decreases significantly during this period and the archaeological evidence for it is sparse. While some specific effects like migration have been mentioned, further personal accounts of adolescent life and autobiographical information can be seen in Chapter 3.

Post-medieval England changed greatly over the 320 years that this project covers. The growth of new towns was fuelled by a bourgeoning new industrial landscape that leads to significant urbanization. It is this urbanization that would lead to increases in disease and social conflicts. While this change took time it had a significant effect on the health and lives of the people who lived in them. Adolescents being some of the most mobile people of the population would have been greatly affected. The fact that they would be moving to more urban and industrializing towns makes the archaeological examination of adolescents in post-medieval England crucial to the changing environment and their own living conditions.

Chapter 3 Puberty and Adolescent development

3.1 THE ADOLESCENT PERIOD

"Age" is a multi-dimensional construct. It can be organized into three distinct categories beneficial for bioarchaeological studies: chronological age, biological age, and social age (Penny-Mason and Gowland, 2014, Arber and Ginn 1995, Halcrow and Tayles 2008a). The modern western interpretation of childhood is based on chronological age (Perry, 2006) but, as we age we are influenced by the societal, economic, and political changes that shape the most important biological stages of development, including puberty. Chronological age measures the number of years a person has experienced since birth and may influence roles and social identity as the individual ages. Chronological age can have an impact on the expectations, privileges, and restrictions that the individual will be subjected to (Penny-Mason and Gowland, 2014). Biological or physiological age is based upon the physical growth and functional ability of an individual, and varies based upon the individual and genetics. This growth can be impacted and influenced by physical and emotional stressors that are in the environment and as such, is often used to compare status, social background, and gender in individuals from different periods and places (Ginn and Arber 1995, 5-10; Redfern and Gowland 2011). Social age is a cultural construct of age-appropriate behaviours and subjective perceptions that are influenced by gender differences. There is an interdependent relationship between the categories of age with an easily identifiable link between biological and chronological age, while social age is more variable and dependent upon the cultural perceptions of the time and location (Halcrow and Tayles, 2008).

As males and females mature at different rates, the identification of biological sex of an individual is especially important in bioarchaeology. For pre-pubescent individuals and younger adolescents, sex assessment can be more difficult as they lack the secondary sexual characteristics that differentiate males from females (Scheuer and Black, 2000). However, when identified correctly it can aid in the accurate determination of an individual's estimated age. With this information it is possible to explore the patterns of mortality and morbidity that are present in a socio-cultural context in relation to children and even more specifically in relation to sex-specific variables (Koziel et al. 2001; Lewis 2007, 48).

When comparing non-adults to adults in palaeopathology it is necessary to acknowledge specific complexities between both groups. These factors are rapid bone remodeling, bone plasticity, the presence of a cartilaginous growth plate, a looser, thicker, and more active periosteum, and large amounts of red bone marrow (Lewis 2018). Due to the rapid rate of growth and change in sub-adults, the diagnostic criteria for certain pathologies were different for the youngest individuals in the project.

In regard to scurvy the active presence of the disease would be easier to observe macroscopically, as sub-periosteal changes due to the periosteum being less firmly attached in children or bone surface porosity due to inflammation (Brickley and Ives 2008). While the presence of rickets in older individuals tend to be as a result of a residual bowing of the long bones, the presence of bowing long bone limbs in younger individuals was also used to determine those who had the disease. There were additional complexities in regards to the presence of lesions indicative of venereal syphilis in the youngest ages of the sample due to the average duration before osteological symptoms tend to occur.

The presence of pathological or nutritional deficiencies in early childhood and in *utero* could potentially have an impact on adolescent survivorship due to past health insults. While the focus of this project is not on early childhood and juvenile health, it is important to be aware of the impact that negative health insults may have upon both puberty and the later development of the adolescent. It is a possibility that the adolescents that were included in this project are those that were resilient enough survive the presence of negative health impacts during early childhood but were ultimately affected by the experiences which resulted in a weakened immune system that led to an early death during adolescence.

Adolescence is best described as a transitionary period in which the male or female is no longer a child, but yet not an adult. In modern day this period of an individual's development is one of great physical and psychological changes, including a period of sexual maturation, or puberty (Hochberg and Belsky 2013). It is often a turbulent time. The average adolescent encounters new situations that they may struggle to cope with as the result of significant hormonal and physical changes and changes in their thinking and social standing. They begin to compare themselves against their peers and establish their own place in the world (Angold and Costello 2006; Patton and Viner, 2007). This transformation occurs over many years and shapes the type of adult the adolescent will grow to be, both psychologically and physically (Mensah et al. 2012) and caused both males and females to expose themselves to different levels of risky behaviour.

The mechanism and timing of pubertal maturation has been explored hormonally (Gluckman and Hanson 2006; Hochberg and Belsky 2013), environmentally (Buck Louis et al. 2007), psychologically (Belsky et al. 1991; Walker et al., 2006) and from an evolutionary perspective (Rickard et al. 2014). Here, adolescent development will be explored in relation to the social significance of puberty, as well as the psychological, physiological and biological changes these individuals experience. The chapter ends with a review of bioarchaeological research into puberty and adolescents in the archaeological record.

3.1.1 Social Transition

The social transition from child to adult is often marked by the onset of puberty (Boynton-Jarrett and Harville, 2012). It is the period in which an individual transitions between childhood dependency and functioning as an independent adult. These social transitions may be different for males and females depending on the cultural context. In addition to the identity imposed by society, the adolescent would be searching for their own self-identity and where they fit within the society (Carlo et al. 1999). In modern times these social transitions can be addressed as the result of the family and peer influences (Carlo et al. 1999).

The family changes are focused primarily on the relationship between the adolescent and their parents. The parent-child relationship changes during this time as both individuals deal with the shifting expectations and behaviours of the other (Collins 1997). The establishment of a peer network is an important part of adolescence and is instrumental in the development of adolescent self-esteem (Larson and Richards 1991, Simmons and Blyth 1987). Additionally, adolescence is the period in which the individual is adopting cultural norms and practices from their peers in the environment (Carlo et al. 1999). During this period the social, psychological, and biological changes are not isolated and often have effects on one another. The possible skeletal manifestations that can be observed and relate to the social transition of puberty could be trauma as a result of risky behaviour and interpersonal violence, as well as, the presence of syphilis due to sexual exploration.

3.1.2 Psychological Transition

Psychologically, adolescence is a time of great insecurity (Angold and Costello 2006; Patton and Viner, 2007; Mensah et al. 2012). Psychological complications like increased behavioural problems, anxiety, and depression can then lead to further social difficulties (Viner 2014).

Puberty is a time of distinct self-determination in which the adolescent is trying to find their own sense of self and identity (Erikson 1988). Puberty also has an impact on mental health, with early puberty linked to an increased risk for behavioural problems (Angold and Costello 2006; Patton and Viner, 2007; Viner 2015). The psychological and behavioural effects of puberty were examined in by Mensah et al. (2012) on 3491 modern Australian children aged 4-11 years in order to track early behavioural problems and the onset of puberty. Their results indicate that there was poorer psychosocial adjustment in the boys and girls that entered puberty early versus those that did not. They also observed that while the children in early puberty had different patterns of social adjustment, that poor mental health appears to result not directly from puberty and had been well on the way beforehand. It is such that the psychological effects of puberty are not isolated and many difficulties can be associated with external environmental factors. Unlike the biological and social transitions, the psychological changes that occur during puberty do not manifest skeletally but the psychological changes could have an impact on behaviour that leads to trauma and injury.

3.1.3 Physiological Transition

Puberty is the biological period that is responsible for the progression and completion of physical maturation (Belsky et al. 2015). The biochemical changes commence with the reactivation of the hypothalamic gonadotropin releasing hormone secretion system. The hormone secretion system involved in the beginning of puberty is the result of the activation of the hypothalamic-pituitary-gonadal (HPG) and hypothalamic-pituitary-adrenal (HPA) axis (Hochberg and Belsky 2013). The early effects of HPG and HPA action are invisible (Figure 3.1). HPG is active throughout the midfetal, neonatal and early infancy periods but becomes relatively dormant in childhood before reactivation due to increases in the gonadotrophin releasing hormone (GnRH) in the hypothalamus and increased secretion of the LH and FSH gonadotrophins in the pituitary gland (Buck Louis et al. 2008; Lomniczi and Ojeda 2016).

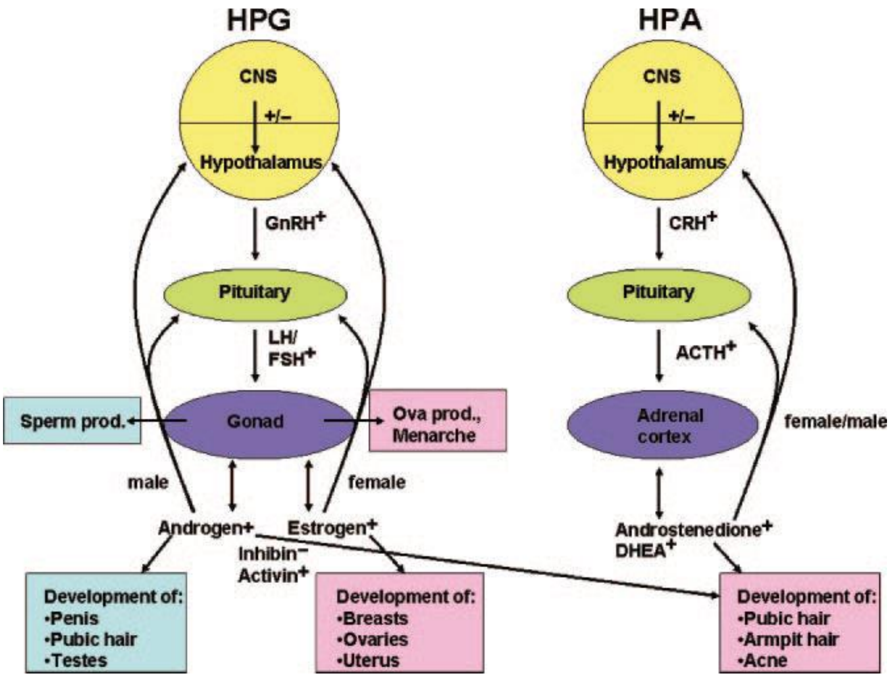

Figure 3.1 HPG and HPA regulation of hormonal release and pubertal development (taken from Buck Louis et al. 2007)

Puberty is also associated with adrenal activation, or the physiological event known as ‘adrenarche’, which today normally occurs between the ages of 6-8 years in both sexes. Adrenarche leads to ‘pubarche’ which defines the more visible secondary sexual changes that are often identified with puberty, such as pubic hair development, acne, and body odour. ‘Thelarche’ is the onset of secondary breast development in girls. ‘Gonadarche’ is the onset of gonadal endocrine function that is responsible for the production of sperm in males and ovulation in females. The first menstruation in a female, known as menarche is further explored in Section 3.1.3.2.

Sex hormones influence the immune system differently, with testosterone being more immunosuppressive, and oestrogen causing suppressed cell-mediated immunity coupled with advanced B lymphocyte activity and antibody production (McDade, 2003). The different moderating effects of androgens and oestrogens are apparent with females being more prone to autoimmune diseases and males more likely to experience chronic inflammatory disease and infections (Bupp, 2015). This shifting immune system can help explain the greater propensity for chronic tuberculosis in adolescents (Marais et al. 2005). The possible skeletal manifestations that can be observed and relate to the physiological transition of puberty are canine mineralization, development of the hamate hook, the fusion of the distal radius and phalanges, the fusion of the iliac crest, and cervical vertebrae maturation and are all further explored in Section 4.3.3 .

3.1.3.1 Stages of Puberty

Puberty can be divided into six stages based upon the timing and hormonal state of the individual namely, Initiation, Acceleration, Peak height Velocity, Deceleration, Maturation, and Completion. Nutrition and a lack of chronic disease are fundamental in maintaining the height and weight of the adolescents that is instrumental in the successful advancement through the pubertal stages (Proos and Gustafsson, 2012). Peak height velocity (PHV) is the period of greatest acceleration in the pubertal growth spurt and represents an integral biological time period. Menarche and the onset of menstruation in girls is one of the most important biological and social indicators of adulthood as it represents a girl's reproductive viability (Sun et al., 2017). In the terms of evolutionary biology and human phenotypic plasticity in favourable conditions, females are able to achieve the extremes of their genetic range for maturation. Meanwhile females in less favourable conditions may delay sexual maturation until they have reached the required body weight leading to later fertility (Hochberg and Belsky 2013).

The most visible physical manifestations of adolescence are the pubertal growth spurt that reaches its apex during peak height velocity (PHV) and the appearance of secondary sexual characteristics. An earlier timing for pubertal maturation may lead to the premature termination of long bone growth, resulting for instance, in a shorter stature as well as body disproportions (Nowak-Szczepanska and Koziel 2016).

Rickard et al. (2014: 6) argue for the "internal psychological model" for evolutionary adolescent development that is founded upon internal prediction as a possible cause of early pubertal maturation, in conjunction with an external model

(Belsky et al. 1991; Walker et al., 2006). Such that the evolutionary development and advantage of early puberty is the access to a longer reproductive period while under environmental stress, thereby allowing greater chances of reproductive success at the cost of physical growth and long term wellbeing.

Gage (2003) examined two models of human phenotypic plasticity in regards to age and reproductive maturation. During the examination of menarche in relation to the growth of children he noted that the decline in age of menarcheal onset and the rapid growth of children have both been generally been attributed to improvements in nutrition associated with modernization. These models predict that in better environments due to better nutritional status there will be acceleration in growth and a downward shift in the age of maturity.

3.1.3.2 Menarche

The timing of the onset of menarche is important as there are negative health and developmental effects that are associated with both an early and late age of onset. Females with early menarche in particular have been associated with a greater susceptibility to major chronic disease like breast and endometrial cancers (Kvåle 1992; Hamilton and Mack 2003; Dossus et al 2010), cardiovascular disease and metabolic dysfunction (Frontini et al. 2003; Remsberg et al. 2005; Lakshman et al. 2009), and even depression (Stice et al. 2010). Delayed onset of menarche has been associated with fractures (Silman, 2003; Bonjour and Chevalley 2014) and low bone mineral density in later life (Eastell, 2005). It is necessary to acknowledge that many of these associated risk factors exist even though the majority of them would not present themselves osteologically. Fractures, low bone mineral density, and metabolic dysfunction while observable to an extent osteologically on an older female would not be indicative in their own right of an early or delayed menarcheal onset nor having a direct causal association with menarche.

Jeanson et al. (2016) assessed dental mineralization in adolescent females to try and ascertain whether it could be used to predict the onset of menarche. They examined panoramic radiographs of 73 modern French girls between the ages of 6 and 17. Their findings indicated that the dental mineralization of the 1st and 2nd pre-molars were the most accurate in identifying the onset of menarche, with an 82% in correct prediction for the Pm_1 and 81% correct prediction of sex based upon the Pm_2. These standards have not been utilized in archaeological samples.

There has been evidence of environmental and lifestyle aspects playing a role in pubertal development and the onset of menarche. Most notable of these is the influence of socioeconomic status on diet and nutrition, and environment in which the person lives. It has been observed that girls with a greater body size during childhood were associated with and earlier onset of menarche and that it occurred about 6 months after the peak height velocity was achieved. Biologically the onset of puberty begins with the reactivation of the hypothalamic-gonadotropin-releasing hormone secretion system. The relationship between obesity and early menarche was recently examined by Kaplowitz (2008). This study suggested that there is an evolutionary mechanism for ensuring that pregnancy only occurs when a female has achieved the right body weight ensuring reproductive success and the critical weight hypothesis states that reaching a critical fat mass is a necessary condition for menarche to occur (Frisch 1970) This is specifically through the role and threshold of leptin (a protein released by fat cells) in stimulating the secretion of gonadotropin that is necessary for the initiation of menstruation.

Irrespective of a child's ancestry or developmental environment, the relationship between the onset or delay in menarche and poor nutrition has been well documented (Gluckman and Hanson, 2006; Goyal et al., 2012; Karapanou and Papadimitriou, 2010). Swenne (2008) noted that severe undernutrition and eating disorders in modern girls had the effect of slowing their progress through puberty by more than 2 years when compared to healthy Swedish girls and the interval between peak growth velocity and menarche as longer than the expected 1-year period of time and that it takes a long time to fully reverse the effects of starvation on puberty despite the accelerated growth from weight gain. Additionally, girls with eating disorders and severe undernutrition were slow to progress through puberty and menarcheal delays have been demonstrated in times of famine (Van Noord and Kaaks, 1991). Although carried out on a small sample of 60 North American girls, Dreizen et al. (1967) noted a delay in pubertal growth and menarche by as much as 24 months in undernourished girls compared to their well-nourished peers. The effects were most severe during the early stages of the adolescent growth spurt, after which time 'catch-up' growth allows malnourished adolescents to achieve similar adult stature to their better nourished peers.

The association between vitamin D and the onset of menarche was first explored by Villamor et al. (2000) in a study of 242 girls from Bogota, Columbia and found that the vitamin D deficient girls were three times as likely to undergo early menarche as those that were not deficient. Chew and Harris (2013) further refined this study by adjusting for the BMI-for-age and still found that vitamin D deficient girls were twice as likely than vitamin D sufficient girls to reach menarche at a younger age. The exact reason behind this association is currently unknown, but could be due to factors of adiposity body size and growth rate that were not fully measured in the use of a BMI-to-age score.

The environment that a girl lives in can also have a significant impact on the age of menarche. Villamor et al. (2009) looked at instances of generalized violence in 5577 Colombian women born between the years of 1941-1989 in relation to the homicide rate during the time. They found that there was a positive correlation between the national increase in homicide rate and the increase in the age of menarche.

3.1.3.2.1 The age of menarche

It has been noted by historical sources in the 1840s that the average age of menarche for working women of Manchester, was estimated at 15 years 7 months, (even) lower for "educated ladies" at 14 years 6 months (Whitehead, 1847; Papadimitriou 2016). In London obstetric patients from 1855, menarche was estimated to occur at 15 years and 5 months (Rigden 1869; Papadimitriou 2016). In 1880, it was estimated that the age of menarche for London middle-class females occurred at 15 years (Giles 1901). It is important to note that given the size and urbanized structure of London at the time, the ages of pubertal timings may not have been in conjunction with the overall trends throughout the rest of the country.

The basis for the social interpretation of puberty comes primarily in the form of excerpts in autobiographies of individuals from the latter half of the period. Through autobiographies there is an insight into the activities and mobility of some exceptional individual people as they were growing up (Burnett, 1984). Each individual would have varying experiences throughout the time period and ultimately the autobiographies that we have represent a portion of the population that not only survived well into adulthood but were also literate. In addition to being written disproportionally by literate males, autobiographies are written by a unique subset of the population that has a desire to get their past experiences put to paper for whatever personal reasons (Burnett, 1984). The sex distribution of autobiographies is also of important note but the best guess of historians is that the rate of literacy for men in the 1700s was about 50% in 1700, 56% in 1775 and 67% based upon the 1841 census (Humphries 2010). Puberty and menarche in particular would have been an important social signifier indicating a female's suitability for both marriage and childbirth (Philips 1999) but the presence of it in written literature at the time is subjective.

Marriage during the post-medieval period was a social landmark that occurred at the end of adolescence for many people. While the average age of marriage throughout the period varied, based upon first hand autobiographies males on average were getting married from the ages of 20-30. In contrast, despite being able to legally consent to marriage at 12, few females did so and those who did not get married young usually married in the early to mid-20s (Mendelson and Crawford 1998). While it is impossible to know the exact social perspectives on becoming an adult, many contemporary writers attributed a girl's first menstruation as a signal of physical maturity; one even saying "the onset of the flowers" marked a new stage of life (Bacon 1638). In the cases of a young wife who had not yet reached menarche, the consummation of the marriage would be postponed until she was of adequate physical development (Mendelson and

Crawford 1998). This is important as the average age of marriage would still fall within the upper age ranges of the study sample for females and would be partially included in the cases of males.

Since the 20th and early 21st century the age of menarche has steadily decreased (Boynton-Jarret and Harville, 2012) and while the exact rate in which the decline varies greatly among different populations, the average age of menarche has fallen approximately 3 years from the 1850s to the 1950s (Chew and Harris, 2013). From the 1960s onward the decrease has slowed, with a few countries even showing a small increasing trend in the age at menarche. The modern variability of the age at menarche is evident in urban and rural populations, and within small geographic areas. An earlier age of menarche could lead to more young women experiencing their first pregnancy (Reis et al., 2016) increasing the risk of premature births and other delivery complications (Jolly et al., 2000).

Modern European adolescents normally experience the onset of puberty at around 10–12 years (Aksglaede et al. 2008) with the average age of menarche being around 13 for girls in modern industrial countries (Marshall and Tanner 1986). The maturation of adolescents in these populations is usually complete by 15–18 years for boys and 13–17 years in girls (Hägg and Taranger, 1982), although there are instances of delayed or early development on an individual basis (Tanner, 1989). Eveleth and Tanner (1990) identified that at the end of this projects range of study, during the 1800s menarche is recorded as occurring between the ages of 14 year in the United States and 17 years in Finland. Meanwhile Lewis et al. (2015) estimated that the average minimum age for menarche for medieval females was 15 years.

While there are minor individual variations, females tend to achieve menarche during the deceleration phase just after PHV has been achieved (Tanner, 1989) which is approximately 2 years into the initiation of puberty. Two osteological indicators of menarche occurring are the fusion of the iliac crest and the fusion of the epiphysis of the first distal hand phalanx and the second metacarpal (Buehl and Pyle, 1942; Frisancho et al. 1969). The ossification of the iliac crest is a strong signal that menarche has recently begun but this thin ribbon of bone is rarely preserved. In instances where an ossified iliac crest is present and identified, the extent of fusion of the epiphysis can be used to indicate that menarche has been achieved.

The association between the onset of menarcheal and adult stature was examined in 2011 by McIntyre. Using the NHANES III (The Third National Health and Nutrition Survey of the United States) to examine the correlation between the pubertal timing and the final long bone length in women, McIntyre (2011) was able to observe that modern females who had an earlier menarcheal age also possessed a shorter adult stature and shorter leg length.

In an examination of 60 modern American girls, Beuhl and Pyle (1942) identified that within six months of menarche the iliac crest had begun to ossify in 66% of the adolescent girls. One issue in the use of the ossification of the iliac crest is that unfused but ossified epiphyses are rarely excavated. The presence of an ossifying but unfused iliac crest indicates whether or not an individual is in the acceleration phase, while the beginning of fusion of the iliac crest to the ilium is indicative that PHV has been passed and that for females, menarche has been achieved. Palma et al. (1967) focused on the iliac crest and its association to menstruation through the examination of 30, 14-year-old patients with Turner's syndrome. Their findings indicated that 86.6% (26 females) did not originally have an ossified iliac crest and of the 14 individuals who underwent hormone treatment to induce menstruation, 12 later displayed an ossification of the epiphysis by 14 years of age.

3.1.4 Puberty and chronic diseases

The decrease in the onset of puberty in modern developed countries is a topic that has received a great deal of research into the possible causes (Bonjour and Chevalley 2014; Sorensen et al., 2011; Euling et al. 2008; Tsatsoulis et al. 1999; Lomniczi and Ojeda 2016; Fisher and Eugster 2014; Parent et al. 2003). The impact of pathology upon the pubertal cycle must also be considered due to the increase in predisposition to chronic infections like tuberculosis and leprosy (Marais et al. 2005).

It is necessary to understand the overall biological changes that increase an adolescent's susceptibility to chronic infections and the known impacts that said chronic infections would have upon the progress and development of puberty. One such cause for this higher susceptibility is the result of a maturing immune system and in the case of tuberculosis a greater chance for adolescent to develop the chronic form of the disease versus children. While there have been few studies examining the impact of pathological conditions on puberty, the study by Lewis et al. (2016) highlighted the association and delay in pubertal maturation with chronic conditions and in particular, tuberculosis, in osteological samples. The study identified that 135 (22%) of the examined population of adolescents from medieval London exhibited some delay in their pubertal development. While the direct biological foundations behind the delay in pubertal maturation and tuberculosis are unknown the relationship must be acknowledged and further explored. It has been identified, especially in boys, that the presence of chronic inflammatory disease delays the attainment of peak height velocity (Proos and Gustafsson, 2012).

3.2 PUBERTY AND ADOLESCENCE IN THE ARCHAEOLOGICAL RECORD

The study of adolescents in bioarchaeology has only been fully explored in the last 15 years. The first study was by Legge (2005) who examined 22 non-adults from prehistoric North America. He employed fusion of the distal humerus, proximal radius, proximal ulna and the fusion of the ilium, ischium, and pubis to assign a pubertal stage to a skeletal element. In 2010, Djuric et al. examined 81, 9^{th}-13^{th} century Serbian skeletons. They studied the health of adolescents, who they identified by the eruption of the second permanent molar and fusion of the long bone epiphyses. They were only able to sex 44 (54.3%) skeletons and identified that acute infectious disease represented a significant burden in the adolescents from medieval Serbia.

The most extensive research into adolescents and puberty to date was carried out by Shapland and Lewis (2013, 2014) on 594 medieval skeletons from medieval England. They developed a method to identify six stages of puberty attainment using the clinical literature to identify specific skeletal and dental features. Their findings charted the start and end of medieval puberty and identified that adolescents were undergoing the earliest pubertal phases at a similar timing as modern populations but that the later stages of pubertal maturation were significantly delayed.

3.2.1 Puberty attainment methods

The development of the adolescent growth spurt and the onset of puberty in relation to bone age is charted through a sequence of bone developments. These developments while first examined in detail in clinical practice by Marshall and Tanner (1986) were adapted for use in archaeological skeletal remains by Shapland and Lewis (2013, 2014; Lewis 2017). They used changes to the dentition, the wrist, the hand, pelvis, and cervical vertebrae to identify six stages of pubertal development, in addition to PHV and menarche. The first two osteological features canine mineralization and hamate hook development correlate directly to the beginning of the pubertal cycle, namely, the acceleration phase and peak height velocity. Meanwhile the fusion of the hand bones, radius, iliac crest identify the deceleration phase onward, and the cervical vertebrae maturation occurs in varying stages throughout puberty.

3.2.1.1 Initiation or Pre-puberty

The initiation phase is often referred to as pre-puberty because it is the preliminary phase that marks that no physical or developmental changes that are part of puberty have yet occurred or as just beginning. The importance of this phase is to be used as a baseline indicator for the start and initiation of puberty in an adolescent. The commencement of this stage will be examined for the bulk of individuals in order to assess the average age of onset for puberty generally in the post-medieval period as well as to identify if there is any regional variation in the distribution of pubertal onset. The adolescent individual's growth starts in the initiation phase and increases through the acceleration phase until they have reached peak height velocity (Marshall and Tanner, 1986).

3.2.1.2 Acceleration

The acceleration phase of puberty represents the interim period after the pubertal growth spurt has commenced and the individual is increasing in stature. One important part of the identification of adolescents in this stage is that they have not yet reached an age that would be culturally defined as indicative of development such as secondary sexual characteristics. Despite that, there are some physical differences with the onset of puberty such as breasts budding in girls and an increase in body mass and pubic hair in both sexes. In girls this time period usually occurs before any boys have commenced puberty and therefore have an impact on the interpersonal interactions between the sexes. In addition, the duration of this stage is not long as it is generally only around 8 months from the onset of puberty (Shapland and Lewis 2013).

3.2.1.3 Peak Height Velocity

Peak height velocity is a crucial developmental stage in adolescent puberty that has significant and distinct impacts on the growth based on the sex of the individual but for both sexes it is the maximum growth in height. In females, peak height velocity indicates their transition to womanhood through an increase in their breast size (Marshall and Tanner, 1986) and occurs roughly from the ages 12 -14 in modern British females. In males, PHV is indicative of further musculature and weight increase that has positive increases on their physical capacities (Philippaerts et al. 2006). This stage is not only one of physical development but also a possible change in the social perceptions of the adolescent as they continue to develop the secondary sexual characteristics that are the very physical acknowledgments of adulthood. This once again brings into the question of skeletal age versus cultural age that was earlier examined.

Recent research regarding growth in the spine and PHV has been done by Nowak-Szczepanska and Koziel (2016). The authors attempt to examine the sexual dimorphism that is present in the development of body proportions of 121 boy and 111 girls during adolescence through the use of metrics. The specific areas of the body that are examined are the forearm length and knee height relative to the height trunk and limb length.

The examinations by Newman and Gowland (2015, 2017) have expanded on the use of vertebral measurements to not only include the transverse, anterior and posterior measurements but also the body height. They built upon the research by Wang et al. (2007) that there is an increase in the overall vertebral body height that occurs in three stages with rapid height growth from birth to five years. There is then dormancy from the ages of 5-10 with the additional growth resuming during puberty. This increase in the vertebral body height occurs during the process of columnar proliferation, differentiation, and mineralization of chondroblasts.

It has been reported that the fusion of the proximal ulna epiphysis preceded the achievement of PHV in males and females and as such we should expect to see fusion of the phalangeal epiphyses and capitulum of the lateral distal humerus shortly after PHV (Houston, 1980; Roche, 1976). Due to the importance of such physical developments in the social acceptance of a person as an adult, any delay in the attainment of PHV would play a significant impact on the adolescents standing in society.

In a modern study of the sexual dimorphism in growth of the forearm in 121 boys and 111 girls, Nowak-Szczepanska and Koziel (2016), found that there was no significant change in the length of the forearm during PHV but in girls there was a significant increase just 1 year before and during the adolescent growth spurt. In addition it has been established by other researchers that early maturation may not only have an influence on the height of an individual but also other body length proportions like relative leg length (Schooling et al. 2010; McIntyre and Kacerosky 2011).

3.2.1.4 Deceleration

It is approximately one year after achieving peak height velocity that girls will begin to experience menarche while boys develop a full adult voice. This is indicative of the deceleration phase of puberty in which growth continues but at a slower rate of development (Shapland and Lewis 2013). Additionally, it is during this stage that the epiphyses of the major long bones continue to fuse. It is at the start of this stage that girls will begin to ovulate and viewed as soon to be able to reproduce (Shapland and Lewis 2013, Lewis et al. 2015).

3.2.1.5 Maturation

The maturation phase indicates that the majority of long bones has fused or is partially fused and that the individual is at the end of puberty. Given the large age range necessary to identify any possible shifts in the onset and duration of puberty the final stage of completion is present for individuals who still fall within the age range but have completed their pubertal cycle and have complete fusion of all epiphyses. Physically the adolescent males and females would be outwardly sexual mature and females would experience regular ovulation (Lewis et al 2015).

3.2.1.6 Completion or post puberty

The completion phase and post puberty are indicative that the individual has fully completed their adolescence and are now biologically an adult. The timing and onset of this phase is important in order to fully conclude the study of puberty and chart adolescent development. Physically, individuals have reached their maximum height and have all of the observable features of an adult (Shapland and Lewis 2013, Lewis et al. 2015).

3.2.2 Puberty studies

In a large scale comprehensive analysis of the pubertal growth spurt in medieval England, Lewis et al. (2015) identified that adolescents commenced puberty at around 10-12 years which is similar to modern data. The difference between the two periods is represented in a delayed onset of menarche by up to three years from around 15 years of age and even higher at 17 years of age in females from the city of London (Lewis 2015). Medieval males took longer during the deceleration phase of the pubertal growth spurt with individuals as old as 21 being identified in contrast to modern European males having completed their deceleration phase by the ages of 16-18.

Arthur et al. (2016) used Shapland and Lewis; (2013, 2014) methods to explore pubertal age in 34 adolescents (8-20 years of age) from Roman Britain in conjunction with a sex and age-at-death. Their findings suggest that overall there is a pattern of a longer period of pubertal development, with adolescents achieving later completion and puberty relative to modern European adolescents. The majority of the sample was made up of females (n=24, 73%) limiting their conclusions on the attainment of PHV in a small sample of boys. More work on a larger sample from the Roman period is necessary to fully explore and validate the conclusions.

Henderson and Padez (2016) conducted an examination of 56 adolescents of known age-at-death, sex, cause of death and occupation from 19th-20th century Portugal to test the efficacy of the methods and examine the pubertal timing in a known sample. They found that the average age of menarche in females was 15 years and that this, while marginally higher, was consistent among the sample, although ill health may have played a part in the delay in pubertal development. Further research has been conducted into palaeo-puberty by Doe et al. (2017) on 54 individuals from a Hispano-Muslim cemetery from the 11th-13th centuries. They were able to assign a pubertal stage to 32 adolescents and discovered that while the onset of growth began at the same age as modern Spaniards, there was a delay in the achievement in PHV. Additionally, there was an extended period of growth due to delays in the later stages of puberty and females were found to progress more quickly in comparison to their male counterparts. The strikingly similar pubertal results to other studies do draw into question whether there are unforeseen artefacts in the method themselves (Doe et al. 2017).

3.3 HEALTH AND ADOLESCENCE IN THE POST-MEDIEVAL PERIOD

Adolescents in the post-medieval period would have had to deal with a range of different health effects in the environment. Some of these detrimental health effects like delayed growth, industrialization, socioeconomic status, metabolic and infectious diseases have been researched archeologically. Some of the metabolic and infectious diseases recently studied in post-medieval England are scurvy, rickets, syphilis, and tuberculosis. While the previous chapter has dealt primarily with the general structure of the social and political setting of post-medieval England, this section focuses on the historical accounts on what adolescent lives would have been like. Throughout contemporary writing of the time and biographies no direct mention is made of the period of life known as adolescence.

Work and in the case of women primarily in the form of household service was clustered around two age groups the younger and older. The younger age group would be comprised primarily of orphans or illegitimate children were placed to help provide for their survival and subsistence, while the older and larger group would be of women who entered as a life stage between puberty and marriage (Mendelson and Crawford 1998). The migration of adolescents and young adults would have a significant effect on the mind-set and health. The size of the young adult population of London was higher than the national average and correlated to the decline of young-adults in more rural areas of the country due to migration to industrializing cities (Davenport et al. 2010). Even though they are not a direct cause of mortality, poverty and socio-economic status are two of the most powerful predictors of mortality (Cavigelli and Chaudhry 2012) because they control the access to resources that are essential for growth, development, tissue maintenance and immune response.

In 1842, the health reformer Edwin Chadwick expressed concerns that factory labour was resulting in the physiological deterioration of the nation and describes in his sanitary report the rampant spread of disease. The endemic and epidemic levels of disease among the poor were a consequence of the squalid living conditions, poor nutrition, hygiene and sanitation. In addition to the biological foulness that was common in the slum areas, these impoverished locations were also deemed to be the breeding grounds for immorality which was also believed to be spread like a contagion. The detrimental effects of urbanization is evident in the example of Liverpool where the average life expectancy was as low as 15 years for some male labourers and 13 year old girls from working class families were up to 7 cm shorter than girls from better backgrounds (Whol 1983 13). These working poor were seen as a personally responsible for their own poor health state due to their own unwillingness to better themselves, their poor dietary habits and risky behaviour (Chadwick 1842).

The need for migrants was noted upon at the time by the surgeon Francis Sharp's (cited by Engels 1950) report on the necessity of the steady stream of migrants from the rural to urban environment and the necessity of the "race of mill hands". The use of the word race in this context brings focus to another complication to the social structure of the end of the post-medieval period, namely, that of the perception of the poor working class. This idea of the working poor being viewed as another race and lesser by Victorian elites is examined by Gowland (2018). She notes that the self-differentiation between the classes was distinct not only due to power relationships between the rich and poor but also due to the observable differences that were observable. Frederick Engels (1844) in his "*Condition of the working classes in England*" described a range of bodily deformations in the working children of Manchester. These deformities included scrofula, spinal curvatures, rickets, stunted growth, pale skin, thin hair and dull eyes (Engels 1950). Engels was not alone in his description of the working young with mentions of factory children being small and pale in comparison to rural children. As these contemporary authors indicate, social class was performed through the body in the form of the numerous difficulties of impoverishment and the punishing manual labour that subjected the lower classes great harm.

The majority of post-medieval adolescents spent their time in an apprenticeship or other forms of child labour. At the start of the post-medieval period there is conflicting evidence as to the brashness of adolescent males. Male apprentices in 16^{th} century Bristol were viewed as con troubling presence due to their rude, lewd, headless, and immature behaviour (Yarbrough 1979). It was such that during the 16^{th} century adolescence was seen as a time of waywardness, "riotous living", pride, lust and a defiance of authority. During this time children as early as 13 moved from their homes to work in an official capacity during the beginning of the period; though these apprenticeships do not discount the use of children under the age of 13 in domestic and rural work applications (Humphries and Leunig 2009). The effects of status and the impact of social inequality were examined in a study of 403 children aged 0-17 years from 17^{th} and 18^{th} century London by Newman and Gowland (2016). This study utilized the measurements of long bone diaphyseal length, cortical thickness, vertebral neural canal size and prevalence of other indicators of stress in order to differentiate between the health of individuals from one high status two middle status and one low status cemetery sites. They found that the low status site exhibited the expected deficient growth values, and unexpectedly, that the high status site demonstrated poor growth during infancy. While the bulk of this study was focused upon the children and infants the practices and culture of childcare that are represented in the form of artificial infant feeds and keeping children indoors would have had an effect on the overall health as the child grows into adolescence.

The impact of industrialization on growth was explored by Mays et al. (2008) in 857 post-medieval (18^{th} -19^{th} century) urban and rural skeletons. They found that in using diaphyseal bone lengths of children and adolescents to determine growth there was only larger bone dimensions in the rural Wharram Percy context that coincides with prolonged breast feeding practices. There were no significant differences in the health of individuals living in each environment that would be expected from a transition from a rural to urban environment. DeWitte et al. (2016) examined three skeletal assemblages in order to assess the impact that socioeconomic status had on mortality and survival in post-medieval London using frailty and hazard analysis. Their findings indicate that there was elevated mortality and reduced survival among the lower socio-economic children but that there was no effect in adults based upon status. The study further suggests that migrants were at least as healthy, if not healthier, than London's native born population (DeWitte et al. 2016) and could be potential evidence of migrant selectivity.

Scurvy, a prominent metabolic disease has had numerous contemporary investigations into the effects of the disease an in 1934, Still reported that Cheadle (1878) and Barlow (1883) in the latter half of the 19th century were performing clinical investigations of scurvy and that most cases of scurvy were in children aged over 1 year. The effects of vitamin C deficiency in children in archaeology have been examined by several authors in the medieval and post-medieval period. Brickley and Ives (2006) examined 164 juveniles from St Martin's cemetery England and identified that there were longstanding scorbutic changes in the poorer infants from the community possibly related to the shortages of potatoes due to blight. The presence and effect of scurvy in the great Irish famine (1845 – 1852) was explored by Gerber and Murphy (2012) and indicated that scurvy indirectly influenced famine related mortality in 970 skeletons from mass burials in Kilkenny City.

Historically the presence of rickets has been greatly noted and the first documentation of the disease by David Whistler in 1645 identified the condition as the "*Morbus Anglorum" or English disease* (Zhang et al. 2016). This was due to the common association between English cities and a general lack of sunlight due to industrialization. In an examination of 291 adults from the post-medieval (18^{th}-19^{th} century) St. Martins, Birmingham Brickley et al. (2007) identified seven individuals with osteomalacia using back-scattered scanning electron microscopy as well as macroscopic skeletal lesions indicative of childhood rickets. While the palaeopathological study of rickets has a long standing history, several recent examinations of children with rickets have been undertaken in post-medieval England (Mays et al. 2006, Mays et al. 2009), post-medieval (1866) Netherlands (Veselka et al. 2015), and post-medieval (16^{th}-18^{th} century) France (Schattmann et al. 2015).

It was during the post-medieval period that syphilis became a significant health problem in Britain as the period between 1493 and 1530 saw syphilis rise to epidemic magnitudes and was known as the 'great pox' (to differentiate between smallpox) (Roberts and Cox 2003). The term "great pox" was first used to describe the infection of syphilis by the Italian physician Fracastoro in 1530 (Kiple 1997). Syphilis was originally considered to be representative of sinfulness and its sexually transmitted nature was not understood until the 1520s (Roberts and Cox, 2003). The recent examination of St. Mary Spital of 5387 Medieval (1120-1539) individuals by Walker et al. (2015) indicated that in there was little change in the prevalence of treponemal disease in the pre and post-Columbian periods; though the latter half of their sample (1400-1539) shows a dramatic rise that may be reflective of a European epidemic that is highlighted in documentary sources. One case of possible congenital syphilis has been researched by Ioannou et al. (2015). The 8-10 year old male from the 19th century was found with severe tuberculosis as well as mulberry molars and screwdriver incisors indicative of congenital syphilis. There are additional dental abnormalities that resemble teeth that have been treated with mercury in response to congenital syphilis.

Pulmonary tuberculosis or consumption as it was known during the time was probably the most significant cause of death during the end of the post-medieval period. It was described by John Bunyan 1628 – 1688 as a condition that so often took him down to the grave (Cook 1992:7). Despite affecting individuals from all classes, it was the disadvantaged who were much more susceptible due to poor nutrition and overcrowding which exacerbated its spread and the virulence. There has also been research into occupational activity with a 12-14 year old post-medieval (1711-1857) adolescent who was identified with lesions indicative of "phossy jaw" due to phosphorus poisoning (Roberts et al. 2016); this skeleton was representative of both possible medical treatment using phosphorus and in the match making process.

3.3.1 Health in the Navy

Humphries and Leunig (2009) found that male merchant seamen who chose to migrate to London were on average taller than those who chose not to when they examined the 1844-1848 "register of Seamen's Tickets" from the Admiralty and Board of Trade's General Registry and Record Office. They additionally note that the most common age for boys to go out to see was the age of 14 and was parallel to the standard age of apprenticeship for a trade (Humphries and Leunig 2009).

The average height of a seaman was 5 feet $5^1/_4$ inches tall. Tillet who at the age of 13 (1873) was driven to join the navy to flee a life of "hunger, continuous scolding and punishment". This apparent attractiveness of navy life would not have held true for all individuals and would likely have been most appealing to the young poor and impoverished boys. Humphries and Leunig (2009) identified that the average heights of males who entered the service at younger ages were shorter than those that entered even a year later. The advantageous diet, while monotonous, that would have been afforded to navy boys has been estimated to have been 4888 calories per day in 1785 (Macdonald 2014).

3.4 SUMMARY

As can be seen the adolescent time period is one of distinct biological, social, and psychological change in all time periods. The post-medieval adolescent as such would be exposed to greater pathological, physical and social influences than when they were children and that has been observable through their actions and the descriptions of their contemporaries. While the exact methods will be outlined in chapter 4 it is important to understand the physical and psychological fundamentals of puberty and the environment in which post-medieval adolescents lived.

Chapter 4 Materials and Methods

The study sample comprised of a primary sample of skeletons that were examined by the author and a secondary database of skeletons compiled from past archaeological studies. The primary sample contains 460 adolescents and 424 in the secondary sample.

4.1 PRIMARY SITES

The 12 sites utilized in this study were chosen based upon the size of their adolescent sample availability, the duration of use, geographical location, and differing economic stratification (Figure 4.1, Table 4.1).

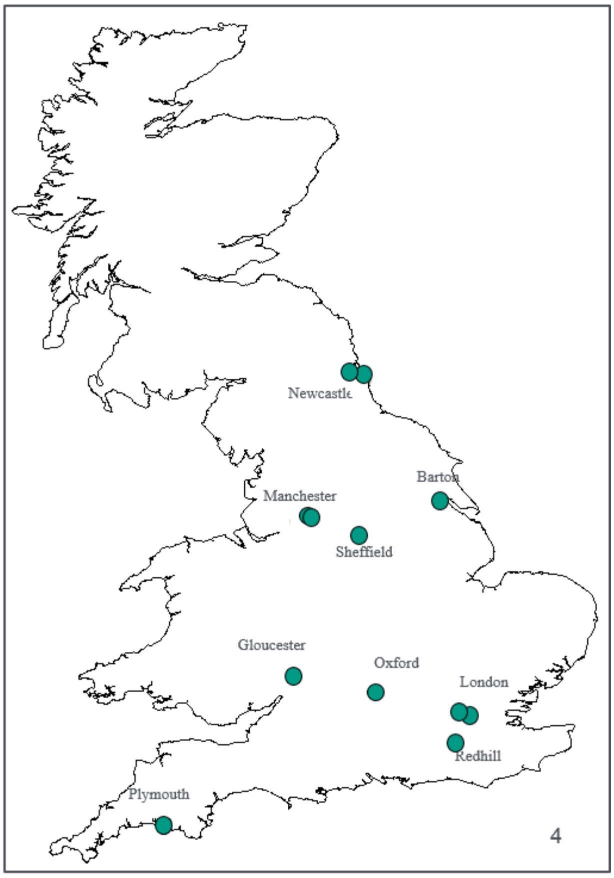

Figure 4.1: Primary site locations

4.1.1 Site types

The primary sample was divided into three distinct site types Infirmary (2), Urban (8), and Semi-Urban (2). The infirmary sites were represented by a regional hospital, Radcliffe Infirmary in Oxford and the Plymouth Naval Hospital. The Urban sites came from geographical locations across England, including London. The Semi-Urban contexts comprised two sites, Barton-upon-Humber, Lincolnshire and individuals buried in the small town of Redhill in Surrey.

Table 4.1 :Primary sites and reported number of adolescents, ordered by site type

Site and Location	Date (AD)	Site Type	Number of Adolescents
Naval Hospital, Plymouth	1762-1824	Infirmary (Naval)	65
Radcliffe Infirmary, Oxford	1770-1855	Infirmary (general)	107
St. Peters Church, Barton-upon-Humber.	1500-1850	Semi-urban	93
St Johns Church, Redhill, Surrey	1750-1850	Semi-Urban	24
St. Oswald's Priory, Gloucester	1540-1857	Urban	16
Cross Street, Manchester	1692-1788	Urban	20
Carver street, Methodist Chapel, Sheffield	1700-1850	Urban	14
Coach Lane, North Shields, Tyne and Wear	1711-1857	Urban	26
Spitalfields, London	1750-1850	Urban	50
St Brides Crypt, London	1770-1849	Urban	23
The Church of St Hilda, Coronation Street, Sheffield	1812-1846	Urban	9
Swinton Unitarian cemetery, Manchester	1858-1900	Urban	13
Total			**460**

The Primary and secondary samples are classified in two different ways as a result of the data that was collected. While the goal was to have the secondary samples follow same structure as the primary sample (by site-type) but due to the secondary sample data available only being from urban locations that was not possible. In addition, all but one of the secondary sample sites were from Urban London. As such, the secondary sample was compared to the primary sample as an urban context. For inter-sample comparisons the sample sites were divided by social status in order to further explore the dataset. The high, middle, low, mixed social classifications were used and based upon previous site reports.

4.1.2 St Peter's Church, Barton-upon-Humber

The small market town of Barton-upon-Humber is located at the northernmost portion of Lincolnshire, on the south bank of the River Humber. While there was some localized habitation of the area as early as the Roman period, there is little evidence to indicate that it was a major settlement. For most of its history, Barton-upon-Humber remained a small market town with a stable population of around 1000 individuals, the majority of who would have been involved in agriculture (Bryant, 2003; Waldron, 2007). Waldron (2007) suggests that the post-medieval portion of the population would have suffered from high levels of infectious and gastrointestinal disease, while contemporary accounts from the 1400s describe Barton-upon-Humber as "a poor rural town" (Clapson, 2005:17). Manorial accounts indicate that children were active members of the workforce that began receiving wages at ten years of age (Massingberd, 1906). While, specific tasks are not outlined it is believed that some of the activities children engaged in would have been tending to livestock and gathering wild foods, in addition to assisting adults with field work (Massingberd, 1906; Houlbrooke, 1986).

The town's economy was stimulated in the early 17th century with the increase in importing and exporting, boat building, fishing, and the manufacturing of bricks. Between 1793 and 1796 and the coming century, the character of Barton was wholly changed to non-farming related trades and professions (Rodwell, 2007). With new factories the population rose to almost 4000 individuals by the mid-19th century, which inevitable led to problems with over-crowding and waste disposal (Russel, 2002; Clapson, 2005). It is likely that these conditions contributed to the risk of contracting infectious and gastrointestinal diseases (Waldron, 2007). It should be noted however, that the individuals buried at St. Peter's Church represented the wealthy and middle-class members of the population who lived in the more desirable and less crowded areas of the town (Clapson, 2005; Rodwell and Atkins, 2011). The parish burial registers list the occupations of some adult individuals as gentlemen, tailors, clerks, and shopkeepers (Booth pers. comm., 2015). The middle-class nature of the town was evident in the opportunities available to the children as it was common for them to receive education at school (Massingberd,1906), and it is likely that there would be no need for the children to assist in agricultural work due to the financial independence of their family. It is also possible that individuals buried at St. Peter's Church would have had access to medical care with a number of apothecaries and surgeons being listed in the parish registers, and one woman was listed as a midwife (Booth pers. comm., 2015).

The 1978-1984 excavation of St. Peter's church uncovered 2,800 articulated burials from inside and outside the building (Waldron 2007). The cemetery was divided into five phases of habitation, from the Anglo-Saxon and Norman (Phase E) to the Georgian and Victorian (Phase A). The only phases addressed in this project were dated to the early post-medieval (Phase B and A). The diet of the individuals from St Peter's church was identified through the isotopic analysis of a sample of the skeletons and revealed that the population ate a varied diet comprised of vegetables, meat, freshwater fish and a small proportion of marine foods (Beavan et al., 2011:765). A number of springs and streams that drained into the River Humber supplied the town with fresh drinking water (Rodwell and Atkins, 2011). The individuals from the site have been recently examined by multiple authors examining the use of vertebral stress (Watts 2011, Watts 2013b, and Watts 2013c) and pubertal development (Shapland and Lewis 2013, 2014; Lewis 2015). There were originally 183 individuals reported as falling within the 10-25 year age range.

4.1.3 The Crescent Naval Hospital, Plymouth

The Royal Naval Hospital in Plymouth was one of two purpose built hospitals used to treat Royal Navy servicemen from the late 18th and 19th century. The cemetery, known as Stray Park was located approximately a mile away, and was used from 1762 to 1824 to bury common seamen and marines who perished in the hospital. Given the duration of the cemetery's use, many of the individuals would have been involved in the Seven Years War, the American War of Independence, the Napoleonic Wars, and the War of 1812.

Hospital musters for Plymouth show that between the years of 1764 and 1824, 7,690 seamen died within the hospital (Plymouth Hospital Musters 1792-1824).

Of these individuals the majority were interred in Stray Park with some individuals being buried at private expense in the churchyards of nearby villages.

There were two excavations of the Stray Park burial ground, the first was carried out by Exeter Archaeology in 2007 and excavated approximately 170 individuals. The more recent excavation conducted in 2014-15 by AOC Archaeology exhumed 310 skeletons. The Stray Park burial ground was discovered as a result of ground works in a former car showroom at the intersection of Crescent Street and Athenaeum Place. The first excavation comprised an area of approximately one tenth of the total burial ground. The reason that the site is called The Crescent despite the original name of the burial ground being located at Stray Park, was to maintain continuity with the name that was assigned during the excavation. While most of the excavation was completed by Exeter Archaeology, only limited post-excavation analysis was carried out. Half of the assemblage, 117 skeletons, are currently being held at the University of Reading while the other half of is housed at Bournemouth University. There were originally 97 individuals reported as being between the ages of 10-25 years.

4.1.4 St. Oswald's Priory, Gloucester

The cemetery of St. Oswald's priory extends throughout the transition from a rural burial complex to a parish cemetery that was responsible for serving the poorer urban population. The town of Gloucester resides in the valley of the River Severn which throughout history was the rivers lowest bridge point. The parish of St. Oswald's was relatively small and comprised 102 households in 1563 with a small increase to 119 household of approximately 406 parishioners by 1773. It was in the late 1700s when Gloucester experienced large number of young migrants from the surrounding countryside, due to new economic development in the form of industrial and manufacturing expansion (Herbert 1988). The new influx to nearly 2000 (Heighway and Hare 1999) parishioners would have had a significant impact on daily life. This higher population led to intensive development of existing streets and suburban expansion in attempts to deal with overcrowding. In the first half of the post-medieval period (1534-1700), 69% of apprentices came from outside the city and is indicative of the influx of rural-urban migrants to the area and the corresponding growth in population. The effects of the overcrowding and growing population led to problems in waste disposal and sanitation that were further impacted by frequent epidemics that had an impact in the decline of large sections of the community (Clarke 1988).

The priory was dissolved in 1537 and the church was said to be in left in a ruinous state. The parish of St. Oswald's continued to exist and the north aisle of the building was adapted by blocking the north aisle arcade with doors and windows newly inserted (Heighway and Bryant 1999). The church became known as St. Catherine's from 1541 despite the old name being occasionally used until the end of the 1500s.

St Oswald's excavations have yielded 602 burials and the cemetery was in use from the Roman period (Heighway and Bryant 1999). There were six primary phases in which the burials were chronologically assigned based upon their location in relation to the building, and their relative age of deposition. While the majority of the excavated individuals were from the Norman period, there were 124 individuals who were from the post-medieval period. Despite the fact that the Dissolution caused much of the land of St Oswald's to be sold and the overall area of the cemetery to be greatly reduced, the church and area to the north continued to be used for burials until 1653. After the church was demolished in 1653, the burials continued in the area to the north of the ruined north nave wall until 1855. There were originally 29 individuals reported as being between the ages of 10-25 years.

The post-medieval parish, like its counterpart served a large area that was one of the poorest in 18th century Gloucester (Rogers 1999). In addition to the skeletal evidence in the report by Rogers (1999), the occupations listed on some of the remaining stone monuments in the graveyard dating from 1682 to 1839 are indicative of a lower working class. The skeletal report corroborates that the post-medieval individuals exhibited evidence of poor hygiene and a low standard of health (Rogers, 1999).

The Parish registers provide documentary evidence for representativeness in regards to sex distribution. Some of the occupations listed included a cordwainer, labourer, pin-maker, soap-boiler, servant, gardener, yeoman, blacksmith, brewer, hawker, bootmaker, baker, basket-maker, stone mason, tanner, and “the bell-maker” (Rogers 1999). From the ten examples where the ages were recorded on the stone monuments, the average age of death of the population was calculated to be 58 years. There were originally 20 individuals falling between the ages of 10-25 years.

4.1.5 Swinton Unitarian cemetery, Manchester

A portion of the Swinton Unitarian Free Church site was being cleared for redevelopment and an archaeological excavation took place by a combined team from Oxford Archaeology North and South. The Swinton site consisted of a small brick-built chapel constructed in 1858 and burial ground established in 1863 with the first interment occurring that year. The church itself was a central part of the community and thrived until it was demolished in 1984 as a result of a severe storm. A total of 330 individual burials dated from 1863 to 1963 were excavated, but only the pre-1900s individuals were examined by Oxford Archaeology. Of the 330 burials, 116 individuals were recorded with 205 being taken for immediate reburial (Gibson 2014). There were originally 27 individuals listed as falling between the ages of 10-25 years.

4.1.6 Radcliffe Infirmary, Oxford

The archaeological and historical background to the site is detailed in numerous sources (MoLAS 2007; MoLA 2009ab; 2010ab; Munby 2013; Purcell Miller Tritton 2010).

In 1770 the Radcliffe Infirmary was established was as a teaching hospital that with its own burial ground within the Parish of St Giles. Following its closure in 1855, the land became a garden for the adjacent hospital fever ward. In the early 20th century, the burial ground was partly built over by an extension to the eye hospital (1921-1939), formerly the fever ward, and a laboratory to the south, constructed between 1939 and 1957. In 2003, the Radcliffe Infirmary site was sold to the University of Oxford, who demolished the hospital in preparation for the proposed re-development.

A 1992 transcript was made by the Oxfordshire Family History Society for the surviving burial register of the Radcliffe Infirmary burial ground indicating that 95 burials had taken place. Aside from a single burial in 1771, all burials were between 1815 and 1855, and the maximum in any one year was 11, in 1830. The burial records also suggest that many of those interred were not from Oxford, but were from elsewhere in the county and further afield (David Clark pers. com). The transcript of the burial register is part of an extensive collection of historic archive material relating to the Radcliffe Infirmary, held by Oxfordshire Health Archives and hosted by Oxford Health NHS Foundation Trust and Oxfordshire County Council. Some of the documents found in the Bodleian Library provide demographic information of the burials from 1830-1836 that includes the patient's name, parish of residence, date of burial and age at burial. Additionally, there is a register of operations from 1838-74 giving information on the patient's name, the surgeon's name, the procedure (e.g. hernia/ amputation) and the outcome.

In 2007 a preliminary archaeological evaluation was conducted by Museum of London Archaeology (MoLAS) and revealed two burials from the Infirmary burial ground and an east-west aligned boundary ditch with no datable artefacts (MoLAS 2007). Additionally, this first investigation also revealed evidence for a middle Neolithic-early Bronze Age monumental landscape, Saxon settlement, and early $18^{th}/19^{th}$ century infirmary (MoLA 2010a).

In 2009-2010 MoLA carried out an evaluation within the former burial ground in order to assess its spatial extent, depth, and the density and state of preservation of the burials within it. Comprising of two trial trenches, the works revealed 36 individual burials and a pit containing several skeletons, as well as local concentrations of disarticulated human bone (MoLA 2010a). Some burials included evidence for coffins, in the form of wood stains, nails and coffin furniture, such as grips and grip plates.

The human remains revealed during the 2009-2010 evaluation were found to be in a good state of preservation and a further archaeological investigation by MoLA

(2010b), recovered a small amount of disarticulated human remains. There were originally 109 individuals reported as being between the ages of 10-25 years.

4.1.7 Coach Lane, North Shields

North Shields is located out the outskirts of Newcastle-upon-Tyne and like other post-medieval coastal settlements experienced an expansion in sea trade due to the introduction of steam engines and the enlargement of existing ports. In 2010, Pre-Construct Archaeology (PCA) Ltd excavated a Quaker burial ground in use from 1711 -1857. North Shields during the 1700-1800s was undergoing rapid development and the heavily populated community focused primarily on shipping, fishing, and coal mining (Proctor et al. 2014). The heavy industrialization of the town was noted in a government report with the environmental conditions being considered deplorable with the narrow streets: “more justly compared to wells filled with noxious emanations…” (Second Report of the Commissioners 1895: 19). This heavy industrialization had an impact on the air and water pollution and there were numerous instances of epidemics like cholera (Proctor et al. 2014). Some of the documented professions from the burial register are those of junior painter, grocer, shopkeeper, master mariner, and linen weaver.

Two hundred and forty-four individual graves and 18 charnel features were excavated yielding 236 skeletons and several hundred disarticulated bones (PCA 2012, Proctor et al. 2014). Over half of the skeletons were adults of mid/older age with a large percentage of the non-adults being five years of age or younger. While the social status of this assemblage is mixed, the fact that many in the cemetery were of Quaker belief indicates that the people would have likely been devoted to peaceful principles, adopting plain dress, speech and living to separate themselves from what they believed to be a corrupt world (Dandelion 2008). There were originally 30 individuals listed as falling between the ages of 10-25 years.

4.1.8 The Church of St Hilda, Coronation Street, Newcastle-Upon-Tyne

St Hilda's Parish Church is located in South Shields, to the south of the River Tyne in the outskirts of modern day Newcastle. The area of South Shields was a manufacturing and shipbuilding city that underwent rapid expansion in both size and population density, much like the sister city of North Shields. The local industries that are noted for employing this population were jobs such as shipyards and gasworks (Gibson et al. 2009). It is likely, that like other cities of this time this population was exposed to poor sanitation and polluted work environments as a result of the burgeoning industrial centres. In 1855, the churchyard was closed due to concerns of burial overcrowding (Gibson et al. 2009).

In 2006, the excavations at the burial ground of St Hilda's church began and were completed in 2007. The burial ground had an earliest date of use in AD 1402 but the excavation area was split into three contexts that date to the 18th and 19th centuries. There were 204 (114 adult, 90 non-adults) excavated and are currently housed at Sheffield University. The sample is believed to be representative of a working-class Northern population (Gibson et al. 2009). There were originally 15 individuals listed as being aged between 10-25 years.

4.1.9 St Bride's Crypt, London

The first church built at the site of St Bride's was constructed in the early sixth century and was rebuilt multiple times over the centuries. Due to its location between London and Westminster, in 1205 the "Curia Regis" or royal council of administrators to King John was held in the church. In 1666 with the Great Fire of London, the church was entirely destroyed despite having its own fire engine (Milne, 1997).

In the 1950s Grimes carried out an excavation of the crypt as a result of damage that occurred to the church due to a bomb from the Second World War. This excavation exposed the church's long history of building phases as well as skeletal remains from a medieval charnel house and post-medieval individuals interred in the crypts. These crypt burials were performed for a specific time period throughout the late medieval and post-medieval period and ceased when the church crypts were sealed by an act of Parliament in the 1850s. The skeletons in the crypts were of middle to upper class. There were originally 23 individuals listed as begin aged between 10-25 years.

4.1.10 Christ Church Spitalfields, London

The earliest known use of the area that would come to be the present parish of Christ Church was a cemetery serving the Roman town of Londinium. These Roman burials were later disturbed throughout the 17th century due to residential development. In the 12th century the largest hospital in the city of London, St Mary's Spital was constructed in the area. In 1714 the first design for Christ Church was created designed with a raised main floor and crypt below. The construction began and the vaults were likely completed around 1724 (Molleson et al. 1993).

Christ Church Spitalfields was consecrated in 1729 by an act of parliament and the crypt had burials from 1729 to 1857 when burials were stopped. Despite specific instructions that the church was not to be used for intra-mural burial, the first interment in the new vaults at Christ church took place within just days of their consecration. During this time over 1000 interments were made in the vaults while 67,000 were buried in the churchyard (Molleson et al. 1993). An archaeological examination of the vaults became possible during the 1970s was a result of restoration. The original excavation was directed by Reeve for the incumbent and parochial church council and found 968 skeletons (Adams and Reeve 1987).These individuals were believed to have been of the "middling sort" socially with the majority of them being of French Huguenot descent. Many of these individuals were involved in the silk industry. While some of them were prosperous master weavers, others were hard working journeymen weavers, merchants, surgeons and tradesmen (Molleson et al., 1993). There were originally estimated to be 60 named individuals listed as being between 10-25 years of age range, although many more were identified osteologically.

4.1.11 Cross Street, Manchester

Cross Street Chapel, originally the "Dissenters' Meeting House", is the Mother Church of Non-Conformity in Manchester. The original Chapel was erected in 1694 and was probably the very first building erected for Non-Conformist worship in Lancashire (Baker 1884). Despite the loss of the burial registers it is believed that the graveyard was present from the consecration of the chapel until it closed due to the Burial Rights Act of the mid-1850s. The original chapel was destroyed in the blitz in 1940 and a new chapel was built on the old foundations that opened in 1959. This was demolished in the 1990s and the present office building erected, within which a new chapel was accommodated (CFA 2015).

In October 2013, CFA Archaeology Ltd. was engaged to confirm if there were still graves in situ before construction to construct the new Metrolink city crossing pass. Two trial excavations were made that found two rows of graves extending under the pavement and CFA oversaw the excavation and exhumation of remains in 2014-2015 (CFA 2015). Any remains beneath a depth of 2 meters were left *in situ* as they would not pose a problem there for the subsequent construction. Seventy family graves were discovered containing 241 complete individuals (71 male, 68 female). In addition, 17,679 fragments of disarticulated human bone were also excavated. Of the 241 individuals, 172 were named by CFA with some degree of confidence. Despite the congregation being believed to be relatively prosperous there was no evidence of lead or lead lined coffins that would indicate that the skeletons were of a higher social status (CFA 2015). There were originally estimated to be 24 individuals listed as falling within the tested 10-25 year age range.

4.1.12 Carver Street, Sheffield

The city of Sheffield developed greatly in the post-medieval period due to an ideal location for water powered industries and available raw materials in the surroundings that led to the city's specialization in cutlery production (Chartres and Hey, 2006). Throughout the period Sheffield continued to grow and industrialize. In, *A Tour thro' the whole island of Great Britain (1724-1727),* author Daniel Defoe later wrote that:

> "This town of Sheffield is very populous and large, the streets narrow, and the houses dark and black, occasioned by the continued smoke of the forges, which are always at work: Here they make all sorts of cutlery-ware, but especially that of edged-tools, knives, razors, axes, &. and nails; and here the only mill of the sort, which was in use in England for some time was set up, for turning their grindstones, though now 'tis grown more common."

The Carver Street Methodist chapel was built in 1805, and located in the heart of Sheffield city centre. It was the primary location for non-conformist burials in the city and served a large congregation in Sheffield in the 19th century. Its records indicate that burials likely took place from 1806-1855, with an estimated 1,600 individuals interred in its grounds. Like many non-conformist cemeteries from this time, it is likely that the burial population consisted of a mix of middle to low status individuals.

Excavations took place in 1999, and led to the recovery of 106 individuals (74 adult, 32 non-adults) with coffins, fittings, and other finds, and a large quantity of disarticulated skeletal material. Of the excavated skeletons, 22 were identified as falling within the adolescent age range (10-25 years of age) and 14 were included in the project due to preservation.

4.1.13 St John's Church, Surrey

At the beginning of the 19th century the area now known as Redhill consisted of a patchwork of small communities linked by the early coach roads that connected London to Brighton (Moore, 1999). The town did not become established until the 1840s and St. John's Church was constructed in 1843. The close one hour travel time between Redhill and London quickly became popular with people who wanted to live in the clean air of the countryside but continue to work and socialize in the city. New houses, inns and shops developed to cater for these new residents and by the end of the century the population had risen to around 12,000 people (Moore, 1999). In the 1920s, a local resident, T.R. Hooper, who wrote in his memoirs that the people of Redhill belonged to “two distinct classes, the old rural inhabitants, very rustic and rural, and the newcomers gentry, London businessmen and others brought by the new railway”(Moore, 1999: 69). Recorded occupations in St. John’s parish registers reflect the influx of the middle classes, with lawyers, stockbrokers, journalists, architects, plumbers, servants, butchers, carpenters, tobacconists, and hairdressers appearing in the lists. In addition, there was a local workhouse, which according to census returns housed 232 inmates in 1842 (Moore, 1999). The burial registers show that a small number of children interred within the cemetery of St. John’s had come from the workhouse, although the majority had lived in the surrounding parishes. St John’s Church contains an estimated 4000 burials from 1843 through to the 1960s despite the churchyard being officially closed in 1896 (Kefford, 2013). The land in the northern area of the churchyard was excavated in 2015 and any burials post-dating 1915 (identified through the parish records, grave markers or coffin plate information) were reburied immediately. A total of 250 individuals were excavated by AOC Archaeology, including 93 adults and 157 non-adults (0–17 years). Of the excavated skeletons, 26 were identified as falling within the adolescent age range (10-25 years of age) and 24 were included in the project.

4.2 SECONDARY SITES

In order to achieve a more complete understanding of the health of adolescents during the post-medieval period, data from numerous secondary sites were collected. This data was in the form of both published and unpublished reports. The name, location, date and number of individuals can be seen in Table 4.2. All of the secondary sites are from an urban context and other than the Bullring, Birmingham were all located within post-medieval London. As such, when examining the secondary sites comparisons will be made based on social status as described in section 4.2.1.

Table 4.2: Secondary sites and reported number of adolescents, ordered by date

Site and Location	Date (AD)	Social status	Number Adolescents
Bishopgate, London	1540-1714	Low	26
St. Thomas Hospital, London	1540-1714	Low	46
St. Botolphs, London	1595-1660	Mixed	10
Crossbones, London	1598-1853	Low	26
Bowling Green, London	1660-1853	Mixed	55
St. Benet Sherehog, London	1670-1853	Mixed	21
Chelsea Old Church, London	1700-1850	High	17
St Marylebone, London	1750-1850	High	23
The Bullring, Birmingham	1750-1850	Middle	91
St. Brides Lower, London	1770-1849	Low	20
Paddington, London	1770-1853	Middle	14
All-Hallows-by the Tower, London	1776-1835	High	14
City Bunhill, London	1833-1835	Low	13
St Mary and St Michael, London	1843-1845	Low	48
Total			**424**

Ages-at-death for individuals within the secondary sample were arranged and analysed based on the age categories established by the Museum of London in the WORD database (Table 4.3) and the age categories can be seen in Table 4.3 below. Age, sex, stature, and pathology were all recorded for the secondary sample.

Table 4.3: Estimated age-at-death and age categories provided in WORD

Age group (years)	Description
6-11	Later childhood
12-17	Adolescence
18-25	Young Adult

4.2.1 Social Status

While the overall information for post-medieval adolescent social status is limited there is some information as to the general opportunities and environmental exposures that they could be subjected to. A high status adolescent would be given the greatest opportunities of all social classes with preferential access to food resources, better housing and better general living conditions (Mays et al. 2009). These, wealthy adolescents would have been more likely to be breastfed during childhood either by their own mothers or by wet-nurses, while poor infants were more likely to be fed a nutritionally poor mixture of grains and broth, milk and/or water (Fildes, 1996). These adolescents of both sexes would often have private tutors from a young age and be taught to read and write. Throughout the period, it was the high status adolescents that were able to attend and pay for the best and most prominent apprenticeships in good locations. This would provide them not only with skills but often a real future profession from which to survive.

A low status adolescent would have been the worst off as they were likely exposed to the harshest of environmental factors and the greatest amount of pollution and disease, while having the least access to diverse food resources. These harsher environments have also been found to have a negative impact on stature and growth (Mays et al., 2009; Hughes-Morey, 2016). These individuals would also be likely working from a young age in some capacity in order to help supplement the familial income (Humphries, 2010). In the beginning of the period, these adolescents would have rarely had the opportunity to travel as a result of an apprenticeship but were likely mobile migrants. As the period progressed it was likely that these adolescents who would have been the most likely to work in the new manufacturing and factory workhouses (Humphries, 2010).

A middle status adolescent would have had additional opportunities afforded to them unique to those of lower status, not due to social stratification but due to the nature of greater socio-economic flexibility. They would have had access to some of the high class foodstuffs high in the form of animal protein and fats as well as a range of fruits and vegetables (Molleson et al. 1993). These adolescents would have some opportunity to travel and be accepted in apprenticeships. They would be from a wide range of lifestyles throughout the country but their parents would have had steady jobs as Artisans, Master Craftsmen, Merchants, and Professionals (Burnet et al. 1984). Some of these adolescents would have had the opportunity to learn to read and right though it would depend on family tradition and sex as males had preferential treatment in this regards (Molleson et al. 1993).

4.3 METHODS

For the purpose of this study, the term ‘adolescents’ was used to describe individuals aged between 10 and 25 years to ensure that all stages of pubertal development were fully incorporated. Where possible, sex, age-at-death, stature, pubertal stage estimation, was recorded for each individual. Pathological changes included: metabolic and infectious diseases, non-specific stress markers (i.e. dental enamel hypoplasia, endocranial lesions, vertebral neural canal size, and vertebral body height) and other environmental stress indicators such as maxillary sinusitis. Emphasis was placed on identifying where infection was present, whether it was healed or was still active, and the possible effects that infection would have had on the development of the individual.

4.3.1 Sex Estimation

Males and females experience variations in the rate of maturation and growth that are crucial for cranial and pelvic morphological development, which increases the difficulty in identifying the sex in immature skeletal remains (Wilson et al., 2015). The youngest individuals (10 – 13) were sexed using the elements of the ilium which had the best results for the age range, the mandible, and the distal humerus (Phenice, 1969; Schutkowski 1993; Sutter 2003; Falys et al., 2005; Rogers, 2009; Wilson et al. 2008; 2011; 2015). Sex was only assigned when at least two elements from two different skeletal areas agreed.

For individuals over the age of 15 years, sex was assessed using standard adult procedures based upon the pelvis namely, the angle of the greater sciatic notch, ventral arc, subpubic concavity, medial aspect of the ischio-pubic ramus (Buikstra and Ubelaker, 1994). With individuals over the age of 16 years cranial features of the supra-orbital ridges, mastoid processes, nuchal crest, and mandibular morphology (Bass, 2005) were used as verification indicators to supplement any possibly lacking identifiable elements. Due to the issues of feminized male skulls at such a young age (Walker, 20015), caution was taken in the confirmation of a male sex estimate.

There were increased complexities in the ageing of non-adults when the dentition was not present. In any instances where there was ambiguity as to whether a younger non-adult fell within the 10 -25 year age range, care was taken to exclude the individual from the primary sample. In regards to sexing the non-adults, there were difficulties in the youngest age range (10-13.9) due to a lack of sexual dimorphic characteristics. As such, the skeletons included in the sample are all that fell within the age range and includes both those sexed and unsexed. Within the 10 -13 year age range the skeletons were able to assigned a sex in 80% of the cases which fell within the accuracy of previous studies on sexing using the sciatic notch angle 72%, sciatic depth 81%, and between 72-85% for the auricular surface of the ilium (Wilson et al. 2015).

4.3.1.1 Distal humerus

The use of the humeral morphometrics to determine the sex of the individuals was based on the technique originally developed by Rogers (1999) that was refined and expanded by Falys et al. (2005). In their examination of 351 humeri from the skeletal assemblage of St. Bride's London, Falys et al. (2005) suggested that females demonstrate a sharp V-shaped trochlear constriction while males express a broader and more rounded U-shape (Figure 4.2). They found the highest accuracy rates were achieved the olecranon fossa shape at 84.6%, the trochlear symmetry was accurate in 81.5% of individuals and the medial epicondyle angle had the lowest accuracy at 78% (Falys et al. 2005).

The specific humeral elements used in this study were: the olecranon fossa shape (a), the angle of the medial epicondyle (b), trochlear constriction (c), and trochlear symmetry (c) (Rogers, 1999, 2009; Falys et al., 2005) (figure 5.2.2). Each trait was assigned a value from 1-5, where 1 is a score of very male, 2 male, 3 indeterminate, 4 female, and 5 very female.

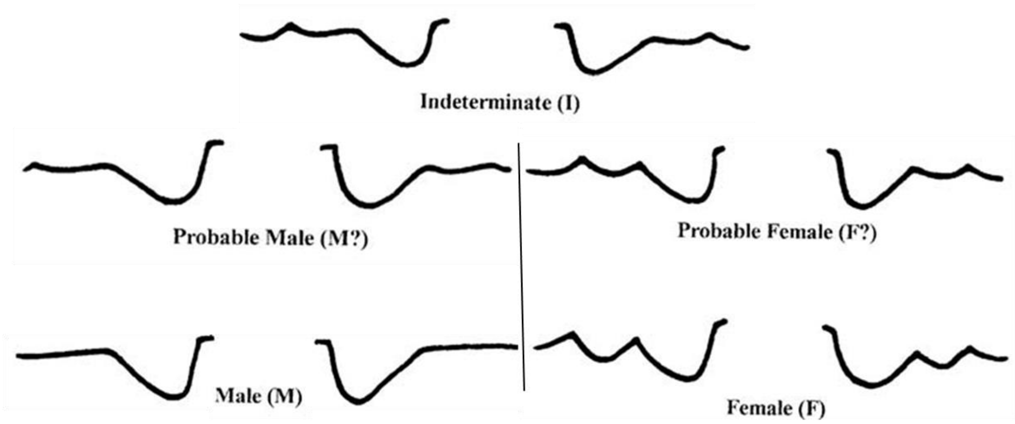

Figure 4.2: *Sexual dimorphism in trochlear constriction after Falys et al. (2005:5)*

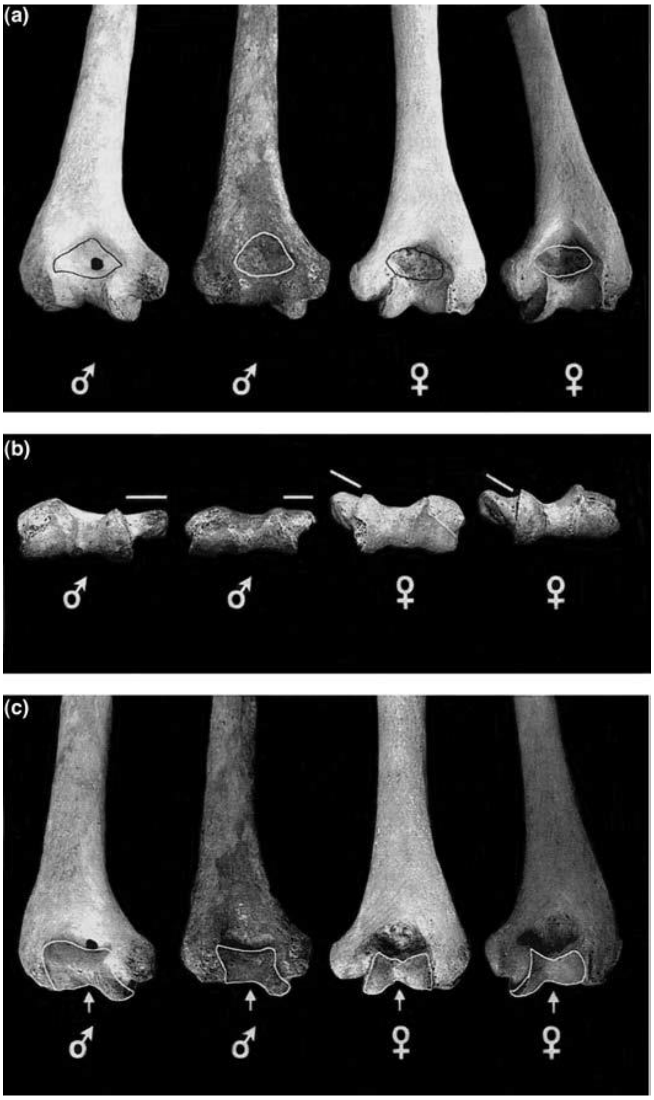

Figure 4.3: *Humeral elements observed by Falys et al. (2005:2) marked with the (a) olecranon fossa shape, (b) the angle of the medial epicondyle, and (c) trochlear constriction and trochlear symmetry.*

4.3.1.2 The Ilium

The elements used to assign a sex for the ilium were: elevation of the auricular surface, depth and angle of the greater sciatic notch, and the depth of the greater sciatic notch (Sutter, 2003; Wilson et al., 2015). The same grading system from 1-5 was employed for each feature. While the auricular surface related directly to the height with a score of 1 representing no elevation to the auricular surface, and a score of 5 representing Weaver's (1980) complete elevation over the entire length of the auricular surface. Accuracy of each element in the identification of sex has been estimated to be: the sciatic notch angle 72%, sciatic depth 81%, and between 72-85% for the auricular surface, based upon observations of 191 dry ilia from Lisbon and London (Wilson et al. 2015).

4.3.2 Adolescent Ageing

Age-at-death of an individual is the foundation from which the examination on puberty and the general health of the individual is built. In the primary sample this project utilized the age categories established by Lewis et al. (2016) on medieval populations. The primary and secondary samples were compared separately in regards to ages. Any markers that were used to evaluate the pubertal stage (i.e. canine mineralization, hamate hook development, fusion of the distal humerus, iliac crest, distal phalanges, and cervical vertebrae maturation) were omitted from use in the assessment of skeletal age. Individuals were aged primarily using dental mineralization (Moorrees et al. 1963a,b), however, for individuals without dentition, an indistinct foveal indentation on the proximal radial head was considered to be an indication less than 10 years of age (Scheuer and Black, 2000) and excluded from the study sample. Similarly, individuals with a fused 1st-2nd sacral vertebrae and fused medial clavicle epiphysis were considered to be over 25 years and were excluded from the final study sample. In instances where individuals over 25 years had not yet fully matured, the age range for the examination was extended.

Mean dental age was considered the most accurate indicator for age. However, for the purpose of creating the largest possible sample on which to assess puberty, all individuals were assigned a final 'minimum age-at-death' based upon the lowest estimates of their dental age (Liversidge and Marsden 2010), or the extent of their skeletal development when dental age was not available, following Lewis et al. (2016). Individuals were placed into five age categories: 10-13.9 years, 14.0-16.9 years, 17.0-19.9 years; 20-21.9 years and 22-25 years. These age categories mirrored those used by Lewis et al. (2016) and Arthur et al. (2016) in order to allow comparisons in the development of puberty in post-medieval England, to the Roman and medieval period.

4.3.2.1 Dental Age

Dental age is the most accurate method to determine chronological age as it has a strong genetic blueprint (Cardoso et al. 2010). The primary method for determining the dental age-at-death of the individuals was through the calcification of the permanent mandibular dentition. Where possible, radiographic assessments of dental development were taken using digital radiographs but when these facilities were not available, a macroscopic assessment of each tooth was employed.

A mean age for each tooth was estimated using Moorrees et al.'s (1963) standard for all teeth (MFH) other than the third molar and the mandibular canine, which was excluded from the age assessment as it was used to assess pubertal stage.

As the third molar is the last tooth to develop and erupt, many age estimates relied on this tooth for a dental age assessment. The third molar is known to be highly variable in its development, providing variable age ranges. To date Liversidge and Marsden's (2010) scheme is the most researched and as it was based on MFH, was used to provide ages for the development of the third molar. When the sex of the individual was unknown, the mean age combined both the male and female values and this mean age was then taken as the minimum age for the individual.

Figure 4.4: *Radiograph of the development of the mandibular third molar in an adolescent estimated to have a mean dental age of 14.0 years.*

4.3.2.2 Skeletal Age

When the dentition was absent or individuals had completed their dental development, skeletal maturation was used to assess the age-at-death, omitting the markers used to assign a pubertal stage (see Section 5.4).

Given the variability in timing of an individual's physical development, the age ranges identified in Scheuer and Black (2000) based on a variety of radiographic and skeletal sources were used for assessing the timing of an individual's age at fusion. The age ranges assigned for epiphyseal fusion by sex are presented in Table 4.4.

Table 4.4: Epiphyseal fusion age ranges (years)

Age range of Epiphyseal fusion	Females	Males
Humerus	13-17	16-20
Femoral head	14-17	16-19
Distal femur	14-19	16-20
Proximal tibia	14-17	16-18
Distal tibia	12-13	14-15

4.3.2.3 Vertebral annular rings

Vertebral annular rings were utilized in order to identify and categorize the adolescent individuals, and to provide an additional metric from which to narrow the age range for each sample. The method first developed by Albert and Maples (1995) examined the state of fusion of the annular ring of the thoracic and L1-L2 vertebra in a study of 55 black and while individuals of both sexes from the age of 11 to 32 years. This work was further expanded upon by Albert et al. (2010) in the analysis of 57 known individuals from the Robert J. Terry skeletal collection from the Smithsonian Institution in Washington DC. The individuals examined were of European and African-American descent, 23 of which were female with 34 males who were aged from 14 to 27 years. It is to be expected that, between the individuals examined in this study and theirs, there were minor variations in the fusion timing due to environmental and genetic differences. Average ages of fusion for the cervical, thoracic and lumbar vertebrae are summarized by Schaefer et al. (2009).

Each vertebral annular ring and vertebrae was examined for extent of fusion and scored between 0-4 (Table 4.5).

Table 4.5: Vertebral annular rings stages (from Albert and Maples 1995: 624-625 and Albert et al. 2010)

Stage	Description
Stage 0	Indicated that there is no union present between the vertebral bodies and the epiphysis. The centrum is bare and there is no part of the epiphysis attached at all.
Stage 1	Fusion between the epiphysis and the vertebral body has begun or progressed to 50 % in which there is a gap seen exhibited in up to half of the centrum.
Stage 2	Union between the epiphysis and the vertebral body is almost complete with less than 50% of the ring remaining open while the rest is fully united with no gaps to recent union. In this stage recent union signifies that the epiphysis is fully fused with the continued persistence of thin grooves.
Stage 3	Is represented by full fusion that has been complete for some time. In addition a scar which is a demarcation in colour between the centrum and the epiphysis may still be seen. There is no lack in depth between the two as the fusion has union remodelled.

4.3.2.4 Ischial epiphysis

The ischial epiphysis and the extension of the ischio-pubic ramus occur between 13-16 years of age in both sexes (Schaefer 2009). The ischial epiphysis is the small flake that appears on the superior aspect of the ischial tuberosity. The timing of its fusion to the pelvis occurs in both sexes between the ages of 13-16 years. While the extension of the epiphysis of the ischio-pubic ramus which starts fusing at 12-13 in girls and 14-15 in boys.

4.3.2.5 Basilar synchondrosis

Basilar synchondrosis is the fusion of the basilar suture at the base of the skull between the occipital and sphenoid (Table 4.6). The closure of the suture is considered to occur between 15 years and 17 years in both sexes and complete by 25 years (Kahenna et al. 2003; Bassed et al. 2010; Shirley and Jantz 2011). There was a large variation in the age of fusion with outliers as early as 10 years having fused sutures (Kahenna et al. 2003). The most reliable is the end date of 25 years. As such, a fused basilar synchondrosis was used to eliminate older individuals from the study sample.

Table 4.6: Basilar synchondrosis fusion stages (from Shirley and Jantz 2012: 582)

Score	Description
Unfused ⁄ open	Visible gap between the basilar portion of occipital and the sphenoid with no bone present in gap
Fusing ⁄ closing	Synchondrosis beginning to ossify, the gap is narrowing and becoming filled with bone
Fused ⁄ closed	Occipital and sphenoid are continuous at the basilar portion with no gap remaining between them. A fusion scar may be still be present.

4.3.2.6 Final age determination

Table 4.7 summarises the skeletal maturation features used to assign an individuals to their age category.

Table 4.7: Characteristics of individuals within each age categories

Age category (years)	Developmental characteristics
10.0-13.9	Individuals were identified by dental calcification and development, the onset of epiphyseal fusion commencing in the cervical vertebrae. Individuals with foveal indentation of the proximal radial epiphysis, recently erupted mandibular canines were considered to be aged 10 years and over.
14.0-16.9	Eruption and development of the third molar, the commencement of fusion of the femoral head, distal humerus, the medial epicondyle of the humerus in females. Onset of distal radial epiphyseal fusion.
17.0-19.9	Fused proximal epiphysis of the radius, fusing proximal epiphysis of the humerus.
20.0-21.9	Complete long bone diaphyseal fusion, an open S1-S2 of the sacrum (closes 20-25), an unfused or flaked medial clavicle (18-21), a fused or fusing ischial epiphysis and vertebral annular rings (18-23), and an extended epiphysis of the ischio-pubic ramus (18-21)
22-25	Possessed a fused S1-S2, fused medial clavicle epiphysis, complete vertebral annular ring fusion, and fused basilar synchondrosis.

4.3.3 Assigning Pubertal Stages

Following Lewis et al. (2016), puberty was divided into six stages: initiation or pre-puberty, the acceleration phase, peak height velocity (PHV) or transition, deceleration, maturation, and completion or post-puberty. Each individual was assigned a pubertal stage when three or more features could be observed and agreed (Table 4.8).

Table 4.8: Combined pubertal stage development (Lewis et al. 2015: 4)

Stage	Canine Mineralization	Hamate hook	Distal Radius and Phalanges	Iliac Crest	CVM
Initiation or Pre-puberty	F Root ½ to ¾ developed	Stage G No hook Present	Stage 1 Proximal epiphysis of MC2 (PP2) is narrower than shaft with an unfused distal radius	Epiphysis not present	1
Acceleration	G/H Root complete to ½ the Apex	Stage H or H.5 Hook appearing or increasing in size	Stage 2 Proximal phalanx of PP2 and epiphyses of equal width an unfused distal radius	Epiphysis 50% complete, unfused	2
Peak height velocity	H Apex Complete	Stage I Hook Complete	Stage 3 PP2 width increases Proximal ulna fusing/fused Capitate of distal humerus fusing Distal radius unfused	Epiphysis 50–75% complete, Unfused	3
Deceleration	H Apex Complete	Stage I Hook Complete	Stage 4 Capping of phalangeal epiphyses Distal radius unfused	Risser 3-4 Epiphysis 75–100% complete, Non to partial union	4-5
Maturation	H Apex Complete	Stage I Hook Complete	Stage 5 Fusing of MC3 proximal epiphysis (PP3) Distal radius partially fused	Risser 4 Epiphysis 100% complete, partial union	5-6
Completion or Post-puberty	H Apex Complete	Stage I Hook Complete	Stage 6 Phalanges fused Distal radius fused	Risser 5 Fusion complete	6

Epiphyseal fusion was scored on a scale of 1 to 3 where (Buikstra and Ubelaker 1994):

1 No union
2 Fusion has begun and there is partial union between the metaphysis and epiphysis.
3 Union is complete with a faint or completely obliterated fusion line.

4.3.3.1 Canine mineralization

The stage of mandibular canine mineralization was estimated using Demirjian et al. (1985) with the sequence of pubertal development following the two most recent clinical (Coutinho et al. 1993; Khan and Ijaz, 2011) and archaeological studies (Shapland and Lewis 2013). A canine root mineralization stage of F was taken to indicate that the individual had commenced their growth spurt (Table 4.9).

Table 4.9: Canine mineralization stages

Pubertal stage	Dental phase	Development
Initiation	F	Root is ½ to ¾ developed
Acceleration	G	Root is complete to half of the apex
Peak height velocity	H	Apex complete

An example of the stages of canine mineralization that was used to identify pubertal stages can be seen in Figure 4.5.

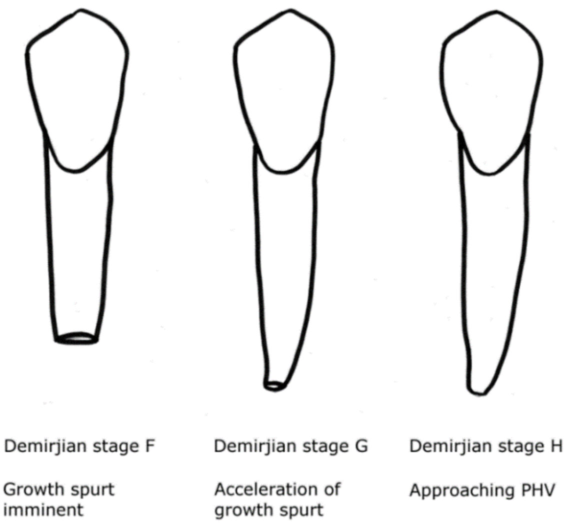

Figure 4.5: Canine mineralization (from Shapland and Lewis 2013:305)

4.3.3.2 Hamate hook development

The hamate was assigned a stage of development based upon Shapland and Lewis's (2013) revised design for use in dry bone (based upon Tanner et al. 2001 radiographs). The development of the hook from G to I and the pubertal stage can be seen in the Table 4.10 and Figure 4.6.

Table 4.10: Hamate pubertal stages

Pubertal Stage	Assigned Stage	Hamate development
Initiation	G	Hook undeveloped
Acceleration – early stage	H	Hook appearing
Acceleration – later stage	H.5	Hook developing
Peak Height Velocity	I	Hook complete

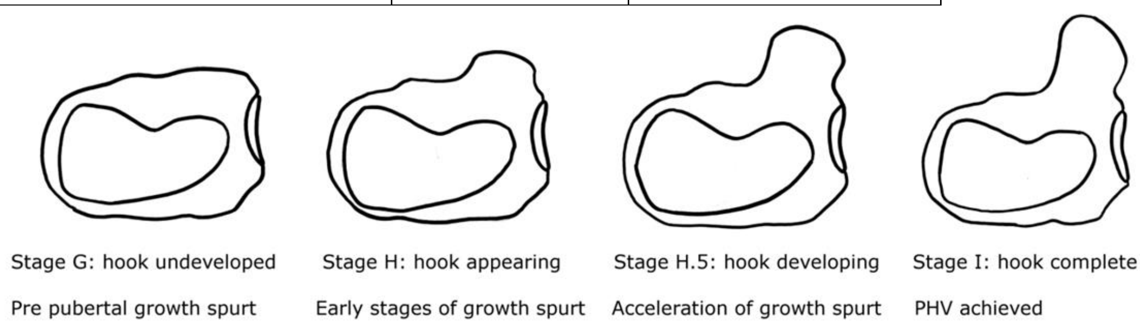

Figure 4.6: Hamate development (from Shapland and Lewis 2013:305)

While both stages H and H.5 fall within the acceleration phase, the extent of the hamate growth has been divided to aid in determining where in the acceleration phase the individual lies.

4.3.3.3 Fusion of the phalanges and distal radius

The phalanges were examined for morphometric changes and fusion in order to assess what pubertal stage the individual was in (Shapland and Lewis, 2013; Lewis, 2015a). The first three stages (i.e. initiation, acceleration, and PHV) were graded based upon the morphometric traits alone because fusion had not yet commenced. The radius, metacarpals and phalanges were assigned a later pubertal stage (i.e. deceleration and maturation) based upon the onset and completion of epiphyseal fusion (Table 4.11).

Table 4.11: Phalanges and distal radius pubertal stages

Pubertal Stage	Stage	Metacarpals and phalanges	Radius
Initiation	1	Proximal epiphysis of MC2 (PP2) is narrower than shaft with an	Distal radius unfused
Acceleration	2	Proximal phalanx of PP2 and the Epiphyses are of equal an width	Distal radius unfused
Peak Height velocity	3	PP2 width increases	Distal radius unfused Proximal ulna fusing or fused
Deceleration	4	Phalangeal epiphyses capped	Distal radius unfused
Maturation	5	MC3 proximal epiphysis (PP3) is fusing	Partially distal radius fused
Completion	6	Phalanges have fused	Fully fused distal radius

In cases where a fusion line was still visible, it was assessed that fusion had just commenced and the individual was graded as still being in the deceleration phase of the pubertal growth spurt.

4.3.3.4 Iliac crest ossification

The pubertal stage assignment of the iliac was based upon the complete formation of the epiphysis, and the onset and extent of the fusion to the iliac. It is often the case in archaeological contexts that unfused but ossified iliac crests are rarely recovered (Shapland and Lewis 2013). As such their absence was noted but not used to indicate that this developmental stage was not accomplished. The "Risser sign" of development was utilized for the assessment of growth and fusion of the iliac crest with full fusion only being achieved after the pubertal growth spurt has been completed (Table 4.12).

Table 4.12: Iliac development and fusion

Pubertal stage	Epiphyseal development	Epiphyseal fusion
Initiation	Risser 1: Epiphysis not present	No fusion
Acceleration	Risser 2: 50 % of epiphysis complete	No fusion
Peak height velocity	Risser 2-3: 50 -75% of epiphysis complete	No fusion
Deceleration	Risser 3-4: 75-100% of epiphysis complete	Non to partial fusing
Maturation	Risser 4: 100% complete epiphysis	Partial fusion
Completion	Risser 5: 100% complete epiphysis	Fusion complete

4.3.3.5 Cervical vertebrae maturation (CVM)

The six cervical stages that were originally used by Hassel and Farman (1995) and adopted for bioarchaeological purposes (Shapland and Lewis 2014) were used in this project. While other methods used throughout this project for assessing pubertal stage only correlated to a few stages, the development of the cervical vertebrae maturation extends throughout all pubertal stages with the final stage of 6 representing fully mature vertebrae during the completion stage. The 2nd to 5th cervical vertebrae were visually examined and the angle and tapering of the vertebral body were assessed with callipers being used to differentiate any difficulties in identification. The stage and depth of the vertebrae can be seen in Figure 4.7.

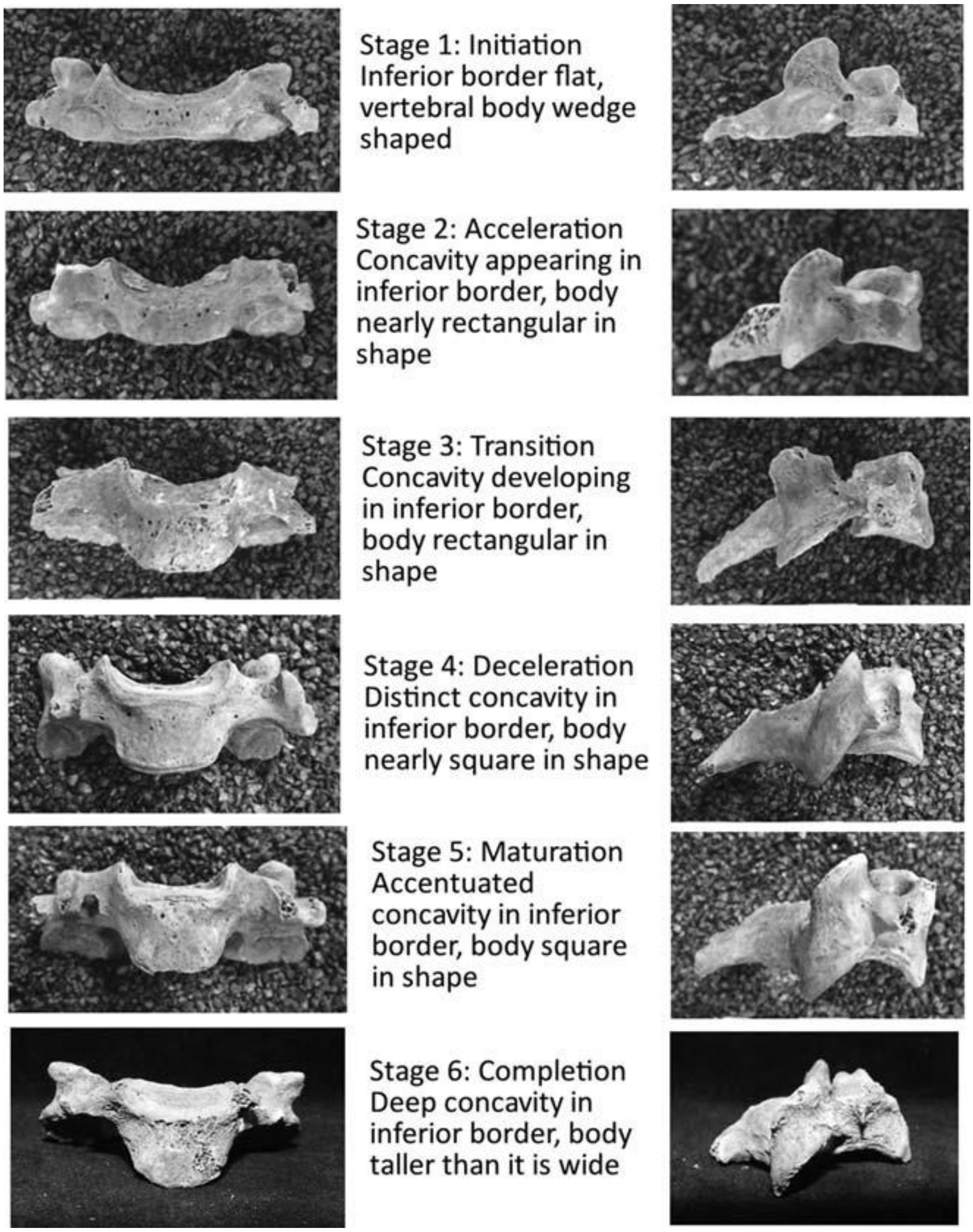

Figure 4.7: Six stages of cervical vertebrae maturation for the C3 and C4 (from Shapland and Lewis 2014: 146)

4.3.3.6 Peak height velocity

Peak height velocity was identified as occurring or already been attained based on four stages of pubertal development as they relate to the hamate hook, canine root, cervical vertebral maturation, and fusion of the bones in the wrist and ulna. Two of the metrics for PHV are a CVM stage of 3 and 4 (Shapland and Lewis, 2013, 2014; Lewis 2015) and a canine root stage of G which signifies that the root is complete or has an apex that is at ½. In both girls and boys this stage occurs between 0.4 and 1.3 years before PHV begins (Coutinho et al. 1993). Another indicator for PHV is the complete development of the hamate hook, known as stage I, which occurs around six month before PHV has been achieved (Grave and Brown 1976). Finally, the fusion of the proximal ulna, the capitulum of the humerus, and the fusion of the phalangeal epiphyses were utilized as indicators of PHV. The fusion of the proximal epiphysis of the ulna precedes PHV (Roche 1976), fusion of the phalangeal epiphyses and capitulum at the lateral distal humerus occurs shortly after PHV (Houston, 1980; Roche 1976).

4.3.3.7 Menarche

The ability to identify the onset of menarche was a specific goal in relation to the pubertal development. The association between a delay in the onset of menarche and a poor nutritional situation has been discussed by a multitude of sources irrespective of the climate, time period or ancestry of the individual (Gluckman and Hanson, 2006; Goyal et al., 2012; Zacharias and Wurtman, 1969). Menarche in females tends to occur during the deceleration phase, after PHV has been achieved. Despite its rare preservation, menarche was identified through the presence of an ossified but unfused iliac crest epiphysis when it was recovered.

The fusion of the distal hand phalanges, specifically the second finger (PP2), was used as an additional element of evidence indicating had occurred menarche.

4.3.4 Bone Growth, Stature, and Trauma

For the adolescents who had not yet completed physical fusion, the diaphyseal length was recorded by measuring the maximum length of the left femur using an osteometric board to the nearest millimetre. Diaphyseal length was only taken when the bone shaft was intact with no post-mortem damage to either metaphysis. When the bone was fusing at either or both epiphyses, and it was not possible to separate the diaphyses from the metaphyses due to curatorial measures, the length of the individual epiphysis was accounted for (Humphrey 1998). Epiphyseal lengths were then subtracted from the long bone length to provide diaphyseal length. Ubelaker (1989) provides standards for age estimation using diaphyseal length based on the Arikara Amerindian population from Dakota. Ubelaker (1989) aged the population dentally using Moorrees et al. (1963a, b) before correlating diaphyseal length and chronological age. The age groups provided by Ubelaker (1989) span one year intervals assigned to the diaphyseal mean length and range of variation and were used a comparative database.

Stature was recorded for all adolescents with completely fused epiphyses. The maximum length of the left femur was recorded using an osteometric board to the nearest millimeter. When the left femur was not present the right was used as substitute. Stature was then calculated using the standard regression equations for European males (2.38 (Femur + 61.41) ± 3.27) and females (2.47 (Femur) + 54.74 ± 3.72) (Ubelaker, 1989).

The presence of trauma was recorded based upon the manifestation of ante or post-mortem traumatic breaks in the bone or evidence of healing fractures. In addition, the presence of plastic deformations and possible dislocations were recorded (Lewis 2019). The location (such as the epiphysis) and size of the fracture were recorded with a focus on those that may have had social implications (Lovell 1997).

4.3.4 Indicators of Non-specific and environmental stress

In order to assess a general framework of adolescent health during the post-medieval period all skeletal lesions found were recorded to establish a specific or non-specific origin following criteria outlined by Ortner (2005) in the first instance. One of the primary aims of the study was to explore the impact of pathology on pubertal development. These stress indicators could be either environmental in the form of disease and infection, or nutritional, taking the form of metabolic and stunted growth development. When lesions were present an emphasis was placed upon identifying, when possible, whether the lesions were still active or had healed and remodelled in order to trace the possible impact of their occurrence on pubertal stage (Lewis et al. 2015).

4.3.4.1 Dental enamel hypoplasia (DEH)

Enamel hypoplasia occurs as either grooved linear furrows or pits on the surface of the dental enamel in both permanent and deciduous teeth. Enamel hypoplasia was scored when at least two non-adjacent teeth were present (Goodman and Rose, 1990). To determine whether the lesion was absent, at least four anterior teeth needed to be observable. Measurements were taken of the crown height from the apex to the cemento-enamel junction to identify the entirety of the tooth, and from the bottom of the fissure in the enamel to the cement-enamel junction to identify the age in which the hypoplasia occurred. The age in which DEH occurred was then used in the general health outline and to identify the extent to which an individual’s health may have been impacted by their living environment.

4.3.4.2 Haemopoietic disorders

Cribra orbitalia was identified by lesions occurring in the orbital roof that are usually bilateral, ranging in severity from small isolated pits to more severe ‘hair on end” appearance. All lesions were graded according to the guidelines established by Stuart-Macadam (1991) on a scale of 0-5 in severity (Table 4.13). Grades 1 and 2 of cribra orbitalia were considered pathological for the results chapter but for further refinement in the discussion only grades 3-5 were considered.

Table 4.13: Grading for cribra orbitalia

Score	Description
0	Normal bone surface
1	Capillary-like impression upon the bone
2	Scattered fine foramen
3	Large isolated foramen
4	Foramina have linked together to a trabecular structure
5	Outgrowth in trabecular form from the outer table.

Porotic hyperostosis is usually indicated by symmetrically distributed cranial lesions upon the outer table of only the frontal and parietal bones. It does occur, although much less frequently on the occipital. When fully developed, the lesions involved a direct visualization of the coarsened trabeculae. Due to lesions on the outer table being present in individuals with rickets and scurvy, a classification of porotic hyperostosis was only assigned when there lesions were isolated solely to the outer table of the cranium with no lesions on any other long bone surfaces or the crania and mandible that would indicate scurvy. Cribra orbitalia and porotic hyperostosis are also present indicators that an individual has vitamin C (scurvy) and D (rickets) deficiency. The presence of porotic hyperostosis was scored using the scheme above (Table 4.13)

4.3.4.3 Vertebral neural canal size (VNC) and vertebral body height

Vertebral neural canal size or VNC was identified by measuring the anterior posterior (AP) length and the transverse (TR) length in the neural canal of the vertebrae (Figure 4.8). All measurements of VNC followed the methods outlined by Watts (2011, 2013, 2015). Individuals were omitted from the recording of VNC if they exhibited congenital spinal abnormalities such as transitional vertebrae, supernumerary vertebrae, or scoliosis. All five lumbar vertebrae were assessed for VNC when possible.

Vertebral neural canal size as a non-specific stress indicator was first used by Clark et al. in 1986. Stunted growth which is an indicator of early life stress has been proven to be identified through the measurements of the anterior-posterior (AP) and transverse (TR) diameters of the neural canal (Watts 2011, 2013a, 2013b, 2015). The incorporation of vertebral body height by Newman and Gowland (2015) expanded upon the available data points to assess instances of stress through the examination of the vertebrae (Figure 4.8). While Newman and Gowland (2015) utilized vertebrae from the cervical (C5-C6), thoracic (T6-T8), and lumbar (L2-L4) portions of the spine, this project will only be using the thoracic (T6-T8) and lumbar (L2-L4) due to the use of the cervical vertebrae in the assessment of puberty.

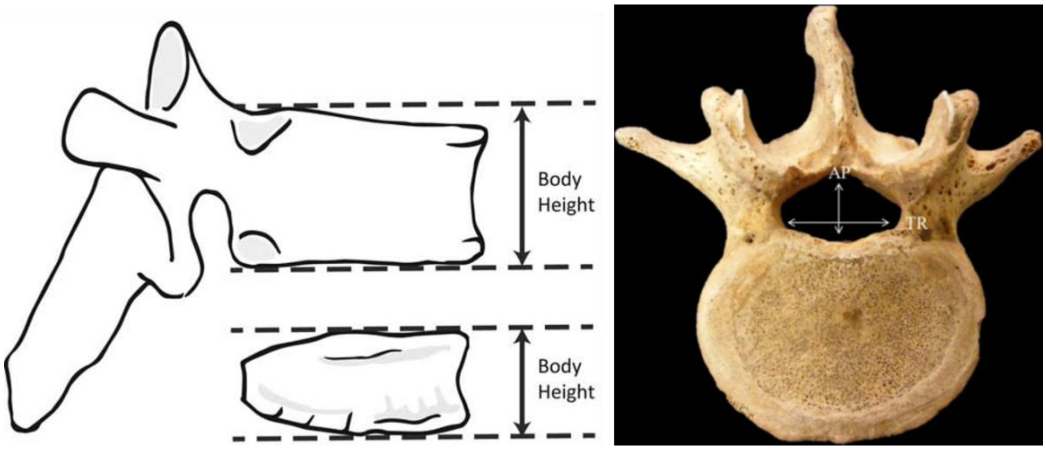

Figure 4.8: Dimensions for vertebral body height (left, from Newman and Gowland 2015:157) and measurement points for VNC (right, from Watts 2015:572)

4.3.4.4 Endocranial lesions

Endocranial lesions are reactive bone formation on the endocranial or inside of the skull. The lesions can appear as either isolated or diffuse layers of new bone growth in several different manifestations (Lewis 2004). They can manifest on the cortical surface, as ‘hair on end’ extensions from the diploe, as capillary impressions that extend into the inner lamina, or expand around the meningeal vessels (Lewis 2004). While the lesions are usually found on the occipital bone, they have also been recorded on the parietal and frontal bones following the areas of venous drainage.

4.3.5 Vitamin C and vitamin D deficiency

Vitamin C and D deficiency were examined due to their use in identifying environmental and dietary insufficiencies as well as the state of the individual’s overall health. In addition, a deficiency in vitamin C and D has been shown to possibly have an impact on the rate and timing of the pubertal onset (Lewis 2015).

4.3.5.1 Vitamin C deficiency - scurvy

The scorbutic lesions that result due to vitamin C deficiency are often quite subtle in their development with very few that can be definitively linked to scurvy, in addition to the fact that many individuals will not develop bony lesions when they possess the deficiency (Mays et al. 2012). The extent of scurvy in the samples was determined following the Ortner criteria for cranial changes related to Vitamin C deficiency (Ortner and Eriksen 1997) as well as the postcranial methods and locations for lesions from Brickley and Ives (2008). While the Ortner criteria were originally devised through the use of juvenile skeletons with a focus on lesions in the skull, the overall effects and distributions of scorbutic lesions are such that the same methods can be adapted with ease to suit an adolescent population. Abnormal porosity and porotic lesions on the sphenoid, mandible, maxilla, and parietal section of the cranium, as well as the presence of periostitis of the femur and scapula were all factors that indicated of the presence of scurvy. Ante-mortem tooth loss and abnormal porosity of the alveolar bone was also indicative of possible vitamin C deficiency. The porosity itself was inferred to be indicative of scurvy when it was uniform, regular, patterned, and occurred bilaterally (Stark, 2009). Great care was taken to differentiate periostitis of the femur and scapula from ossified haematomas that are a type of woven bone formation that sit upon the cortical bone and tend to be oval in shape and be indicative of co-occurrence with vitamin d deficiency.

4.3.5.2 Vitamin D deficiency - rickets and osteomalacia

Rickets was identified in adolescent individuals through not only the tell-tale bowing deformities of the long bones that occur during childhood but also through the macroscopic observation of fraying and flaring of the growth plate margins and metaphyseal junctions. The identification of whether any lesions found were indicative of an active or healing vitamin D deficiency was determined using the macroscopic features discussed by Mays et al. (2006) based upon 21 archaeological skeletons that were from a 19th century urban population from Birmingham, England and Brickley and Ives (2008).

Cases of vitamin D deficiency were identified as active when there was the presence of porosity on the cranial or postcranial skeleton and or a roughening or porosity of the bone beneath the epiphyseal growth plates (Mays 2006). Instances of a healing vitamin D deficiency were identified by the previously mentioned features being filled in with unmineralized osteoid while the individual was recovering from the disease, with the defects eventually being obliterated. An individual was classified as having healed vitamin D deficiency when there was a lack of both the porous cortices and the growth-plate abnormalities and by evidence of porosity limited to the concave surface of severe bending deformities due to mechanical remodelling.

Due to the subtle nature of the appearance of vitamin C and D deficiency concurring in the same individual, great care was taken to identify all atypical lesions and growth before a diagnosis was made. The diagnosis was conducted following the methods utilized by Schattmann et al. (2016) in the differentiation between incidences of rickets and scurvy. As has been touched upon in Chapter 3, when an individual possess both vitamin C and D deficiency there is often only the expression of a primary deficiency, though there can be shared features present in a single individual (Schattmann et al. 2016).

4.3.6 Infections

Great attention was taken in regards to the identification of chronic conditions and any lesions or bone changes were noted throughout the axial skeleton, long bones, and crania. A skeletal distribution of the lesions tuberculosis (4.3.6.2.3), syphilis

(4.3.6.3.1) and leprosy (4.3.6.3.3) can be seen in Figure 4.9 with in-depth descriptions of the pathologies present in their subsequent subsections. All lesions indicated in the skeletons below are based upon adult individuals as such the progression of certain lesions as a result of infectious diseases will be rare to find.

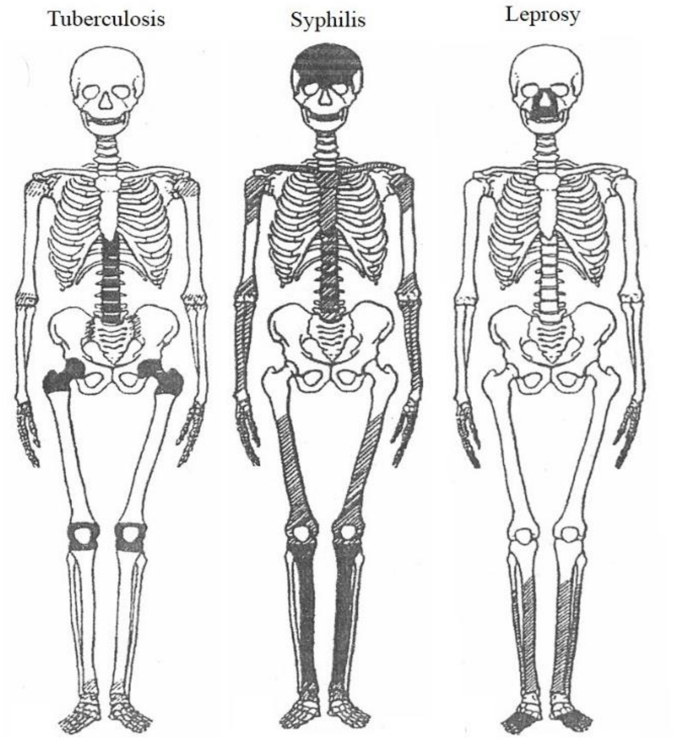

Figure 4.9: Skeletal distributions for specific infections (after Steinbock 1976: various)

4.3.6.1 Periosteal new bone formation, osteitis and osteomyelitis

All periosteal reactions were first recorded as expressions of non-specific bone growth, possibly of the periosteum, and determined to be periostitis after the full recording and examination of the skeleton was completed. The type of lesion (whether it was lamellar, woven bone or a mixture of both), location, whether it was diffuse or focal, and the type of vascularization were recorded for all possible periosteal bone formations (Weston, 2012). Osteomyelitis was diagnosed in the presence of a cloaca, involucrum, and sequestrum (Ortner 2003).

A grading system was assigned in relation lesions of the long bones that were as a result of non-specific infection (4.14). The distribution and positions of lesions were recorded.

Table 4.14: Grading system for new bone formation based on (Weston 2012; and Ortner 2003)

Score	Description
1	Inflammatory pitting
2	Localized deposit of woven bone
3	Diffuse woven bone
4	Plaque of lamellar bone
5	Diffuse lamellar bone
6	A mixture of both woven and lamellar bone

4.3.6.2 Respiratory infections

4.3.6.2.1 Maxillary Sinusitis

Maxillary sinusitis was recorded in all individuals in whom the sinuses were not intact but open as a result of post-mortem damage that allowed the visualization and examination of the sinus directly. Lesions in the sinus cavity were recorded according to Boocock et al. (1995) and Lewis et al. (1995) with special care being taken to not confuse broken root caps with smooth walled oro-antral fistulae.

Table 4.15: Grading system for Maxillary Sinusitis based on (Weston 2012; and Ortner 2003)

Score	Description
A	White or grey deposits of bone
B	Isolated spicules
C	Clusters of connected spicule
D	Remodelled plaque of lamellar bone

4.3.6.2.2 Visceral rib lesions

Any lesions on the visceral surface of the ribs were noted with great focus taken to observing the size, position on the rib, the extent of lytic destruction, and if any healing had occurred were documented. The lesions were scored as:

1. Localized lesions limited to the visceral surface of one or two ribs
2. Diffuse and being both unilateral and bilateral encompassing the visceral surfaces of multiple ribs.

4.3.6.2.3 Tuberculosis (TB)

Due to the chronic nature and high possibility for the reoccurrence of tuberculosis during the post-medieval period, the presence and spread of TB in an individual was noted. Tuberculosis was diagnosed when an adult or non-adult displayed classic lytic spinal changes with or without Pott's disease. Pott's disease is characterized by the collapse of thoracic vertebrae due to the anterior portion of the vertebral body no longer being able to provide support for the weight of the spine and creates a wedge-shape that tilts the upper trunk forward and generates the characteristic hunched back (Aufderheide and Rodriguez-Martin 1998). Some of the lesions indicative of tuberculosis are lytic lesions of the face, cranial vault, base, and vascular lesions of the inner table. While the skull is not commonly a site of involvement in adults, the broad age range in this project incorporates ages in which childhood tuberculosis would still be present or with possible healing occurring on the cranium. In addition to the cranium, lesions common in tuberculosis occur in the spine (generally from the L1 outward) and periosteal reactions on the pleural surface of the ribs. Pott's disease and TB may be accompanied by widespread new bone formation on the ribs and long bones

(Lewis, 2011) in the form of endocranial lesions (Lewis, 2004) which are areas of bone formation and reabsorption.

4.3.6.3 Other Infectious diseases

All evidence for other infectious diseases, including leprosy, smallpox and venereal syphilis were recorded to determine the extent of their prevalence throughout the environment and the degree of impact that they had upon the health and pubertal development of post-medieval adolescents.

4.3.6.3.1 Treponemal Disease

Endemic and venereal syphilis were identified by the presence of lesions on the cranial vault ("caries sicca"), facial bones and long bones (Aufderheide and Rodriguez-Martin 1998). Caries sicca is the most diagnostic feature of syphilis in dry bone. The location and severity of each lesion on the cranial vault was recorded with any possible reactive bone deposition and healing. Lytic lesions to the nasal cavity, nasal septum or perforation of the hard palate were considered indicative of syphilis, rather than leprosy, when it extended beyond the canines. Gummatous periostitis on the long bones was also considered diagnostic. Some individuals may have survived into older age with congenital syphilis, but the lack of dental stigmata make their specific diagnosis difficult (Lewis 2018).

Late onset congenital syphilis was diagnosed based upon the presence of dental dystropathies (Hutchinson incisors or mulberry molars) in addition to further macroscopic lesions on the long bones (Genç and Ledger 2000). The macroscopic lesions found to be indicative in association with the dental dystropathies were higoumenakis's sign in the clavicle, saddle nose, profuse periostitis and Gummatous lesions, Clutton's joints, saber shins, and neuropathy (Steinbock,

1976) with focus on the presence in the tibia. While mulberry molars are not specifically diagnostic of congenital syphilis, Moon molars and Hutchinson's incisors are considered pathognomonic (Lewis 2019).

The dental changes associated with congenital syphilis provide the best opportunity for analysis in the archaeological record with between 25% and 45% showing changes in the maxillary incisors and 22%–37% changes in the first molars, compared to 12% that showed skeletal evidence of the disease (Sarnet and Shaw, 1942; Hillson et al., 1998). While late onset congenital syphilis first manifests after 2 years of age, the lesions generally appear between 5 and 15 years of age (Steinbock 1976).

4.3.6.3.2 Smallpox

An individual was categorized as possibly having smallpox when the skeleton exhibited osteomyelitis of the elbow and reactive bone formation in other joints. The distal humerus, proximal radius and ulna were examined to identify any bilateral, multifocal enlarged cloacae, the enlargement of the metaphyses as a result of woven bone, or an enlargement of the distal humerus (Aufderheide and Rodriguez-Martin 1998). Any individuals displaying such lesions were not sexed using the methods adopted from Rogers (1999) or Falys et al. (2005). Instances of joint deformity or fusion were examined for the possibility of being related to non-suppurative arthritis (Ortner 2003). Attention was paid to the radius as due to the bilateral nature of the infection it is often affected in conjunction with the humerus and ulna. The most common secondary sites of infectious reactions are the ankles, knees, and wrists but reactions can affect any joint (Ortner 2003).

4.3.6.3.3 Leprosy

Individuals were categorized as having leprosy when there were indicative cranial and postcranial lesions. Cranial lesions that were determined to be of leprous origin comprised of destructive rhinomaxillary changes or RMS (Aufderheide and Rodriguez-Martin 1998). The rhinomaxillary changes and the extent of any active remodeling and resorption documented. The most pronounced postcranial lesions are those of the hands and feet, namely the absorption of the phalanges and concentric atrophy. Any phalanges affected by leprosy were not used in the assignment of pubertal stage. Bilateral new bone formation on the tibia and fibulae were also considered indicative of leprosy if paired with RMS.

4.3.10 Statistical analysis

All results that were found to fall within the 95% confidence level were considered significant. Non-parametric statistical tests included Pearson's Chi-square test to inform on all significant differences in the frequencies of skeletal pathology between site types, age groups, pubertal stage etc. unless otherwise stated (Shennan 1997):

$$X^2 = \Sigma \frac{(observed\ frequencies - expected\ frequencies)^2}{expected\ frequencies}$$

Kolmogorov-Smirnov Z was selected to test for differences in the distribution of two sets of observations in long bone measurements and growth (Shennan 1997: 60).

$$KS = 1.95\sqrt{\frac{n_1+n_2}{n_1 n_2}} \text{ for a minimum confidence level of 0.05}$$

An example of the recording form used for the primary sample data collection is provided in Appendix 1. Microsoft Excel 2014 was used as the software package to store the demographic and paleopathological data of the primary and secondary study sample. Microsoft Excel 2014 was also used for analysing frequency distributions and to perform the Chi-square tests.

SPSS version 23 &24 was utilized in the Kolmogorov-Smirnov Z statistical analysis and in the one-way ANOVA of all samples. It was also used in the binary logistic regression model to determine the association for vertebral metrics, pubertal stages, and the delay in pathology.

Chapter 5 : Results

5.1 THE STUDY SAMPLES

The study sample was made up of a combination of primary and secondary skeletal data. The final combined sample comprised 903 individuals aged from 10 to 25 years. The primary sample (n=460) is made up of 12 sites across England. The largest sample came from Radcliffe Infirmary (23%). The secondary sample (n=424) is derived from previous published and unpublished skeletal reports of 14 additional sites. The nature of post-medieval material means that skeletal remains are often reburied and are no longer available for examination, making skeletal reports an indispensable source of data. The regional distribution of the secondary dataset is heavily focused on London (n=264; 62%). This is due to the size of the city and modern construction that means post-medieval material are more likely to be disturbed, excavated and analysed.

5.1.1 The Primary Sample

A total of 460 individuals were examined in detail for information of their sex, age-at-death, growth, stature and pubertal stage. In addition, evidence for non-specific indicators of stress (e.g. enamel hypoplasia, VNC), specific and non-specific infections, metabolic disease and trauma, were recorded to allow a picture of what it was like to be an adolescent in post-medieval England. The total primary sample was divided three categories based upon site type: Infirmary, Urban, and Semi-Urban.

There were expectations for differences between the three site types, with the greatest pathological load being expected from the infirmary context followed by the urban context. Although inter-site variation in pathological loads between sites of the same category might be expected based on, for example, regional variability between the urban and semi-urban contexts, no significant differences were found, except for between the Infirmary sites (see discussion below). The data from individual sites were therefore pooled for further analysis; however, it is acknowledged that the lack of demonstrable differences is largely due to the small sample sizes. Pearson's chi-square tests were used to examine the significant differences in the frequencies of skeletal pathology between site types, age groups unless otherwise stated.

5.1.2 The Secondary Sample

While the use of secondary data cannot give first hand details about new avenues of research such as puberty, it is useful in providing a broader overview of what health looked like for the 10-25 year age group in post-medieval England. Due to the variable nature of the secondary data, individuals were placed into three age groups, 10-11 years, 12-17 years, and 18-25 years. These three age categories were used to examine trends throughout the secondary population as well as in contrast to the primary sample. The sex of all individuals after the age of 17 was recorded while few cases of under 17-year-olds have been assigned a sex by the original reporter. The secondary sites were all from urban locations and were divided by social status with all but one (Birmingham) located in London.

5.2 PRIMARY SAMPLE: DEMOGRAPHY

5.2.1 Sex distribution

A total of 385 (83.7%) individuals were assigned a sex. The sexed sample comprised 219 males and possible males (56. 9%) and 166 (43.1%) females and possible females (Figure 5.1). For the rest of the analysis, possible males and possible females were presented as part of an integrated male or female sample (Figure 5.2). Despite the sample comprising more males, males and females were evenly distributed throughout the age categories, with the lowest numbers, in the 20.0-21.9 year category (Table 5.1).

It should be noted that in the earliest age groups (10-13.9 years) there were a small number of individuals that could not be adequately aged or sexed and as such were omitted from the study. As such, the samples are not a direct representation of all adolescents in the age group. As such the selection of individuals has been further considered in regards to the demographic analysis.

Table 5.1 Number and percentage of individuals within each age category by sex

Age (years)	**Total sample**		**Male**		**Female**	
	number	%	number	%	number	%
10.0-13.9	107	23.83	50	47	33	31
14.0-16.9	95	21.16	42	44	32	34
17.0-19.9	118	26.28	55	47	49	42
20.0-21.9	47	10.47	28	60	17	36
22-25	82	18.26	44	54	35	43
Total	**449**		**219**	**49**	**166**	**37**

% represents a percentage of the number of individuals by the total population in the age category.

A difference in the distribution of males and females is more evident when the primary sample was divided by site type (Figure 5.1); males outnumbered females in the infirmary site by 63 (59.4%). This significant (X^2=20.24, P=.001 at 1 d.f.) difference in the sex distribution of infirmary males is primarily due to the inclusion of the primarily male Plymouth Naval site (Table 5.2).

Table 5.2: Sex of individuals in the infirmary sample

	Plymouth	Radcliffe
Male	60	56
Female	1	41
Indeterminate	3	6

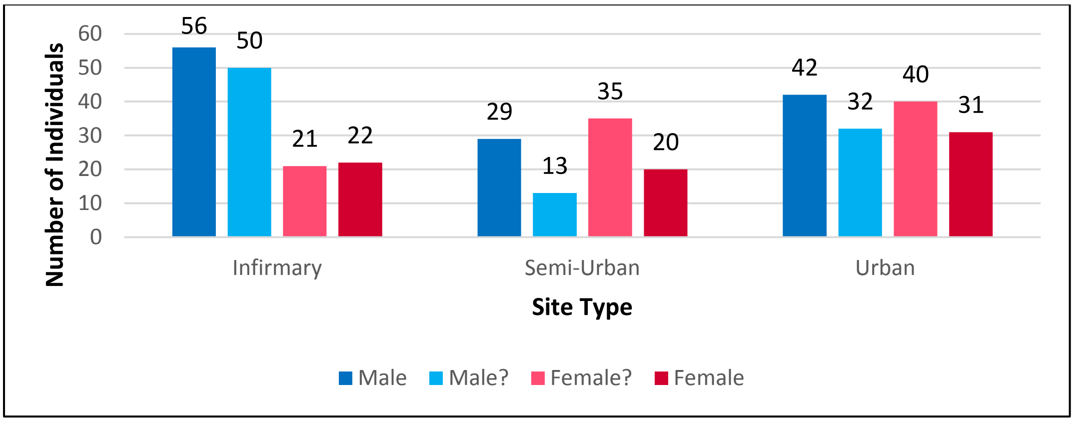

Figure 5.1: Sex distribution, by site type

Upon further examination, the 10-13-year age range in the Radcliffe infirmary comprised 15 males and only a single female.

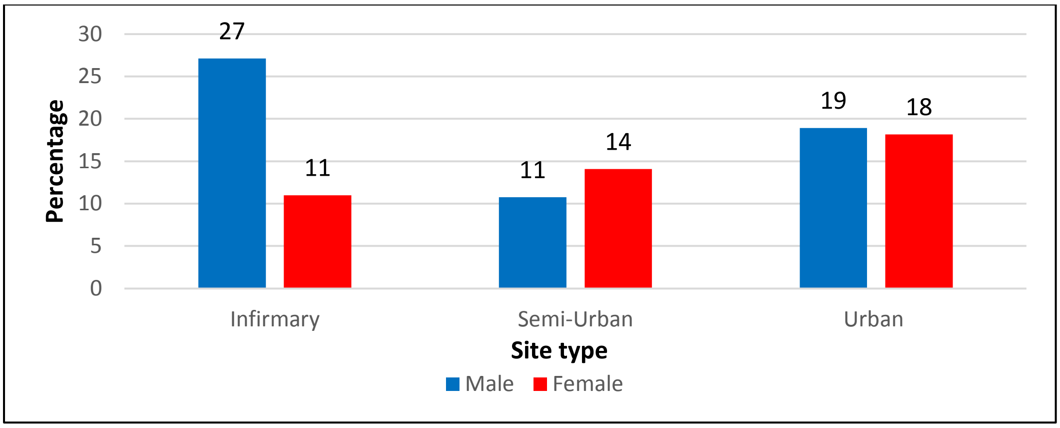

Figure 5.2: Percent of the total sexed population by site type.

5.2.2 Age-at-death

The total sample was divided into five age categories: 10-13.9 years; 14-17.9 years; 17-19.9 years; 20-21.9 years and 22-25 years (Table 5.3; Figure 5.3). For those individuals aged using dental development, one-year age categories based on dental mean age allowed puberty and growth assessment to be carried out. Of the total 460 individuals examined, 438 (95.2%) were assigned an age category and 369 (84.2%) of those were assigned using their mean dental age (Table 5.3, Figure 5.3). The age categories were further divided by site type (Table 5.3) to examine the distribution of age categories. The largest portion of the aged sample (n=123; 28.1%) were in the 17.0-19.9 year age range. In contrast only 48 (10.9%) of individuals fell into the 20.0-21.9-year age category, and the 20.0-21.9 year category had the lowest proportion of individuals throughout all site types (Table 5.4). The semi-urban population was the only one to have the highest number of individuals in the 10-13.9 year age category at 31 (33.7%).

Table 5.3: Number and percentage of individuals in each age category

Age Category	Infirmary		Urban		Semi-Urban		Total	
	n	%	n	%	n	%	n	%
10-13.9	22	13.6	32	19.9	41	35.7	95	21.7
14-16.9	35	21.6	32	19.9	21	18.3	88	20.1
17-19.9	55	34.0	47	29.2	21	18.3	123	28.1
20-21.9	23	14.2	15	9.3	10	8.7	48	11.0
22-25	27	16.7	35	21.7	22	19.1	84	19.2
Total	**162**	37.0	**161**	36.8	**115**	26.3	**438**	

% of the cohort by site type

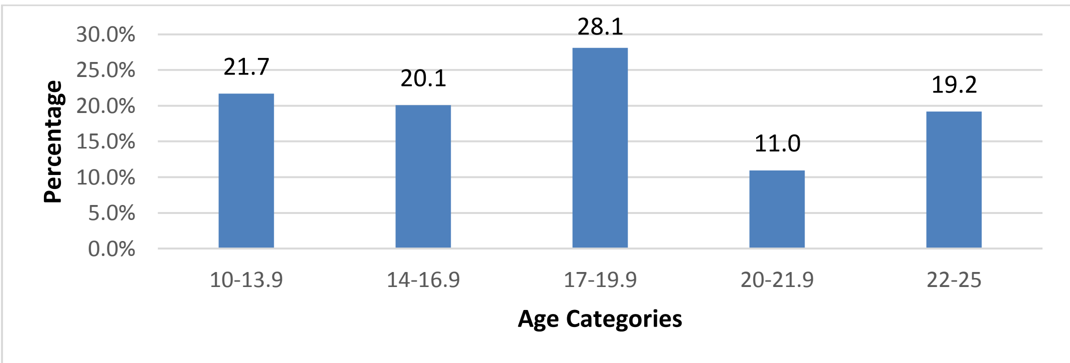

Figure 5.3: Percentage distribution of individuals in each age category.

Table 5.4: Number and percentage of individuals aged using the dentition, by site type

Age	Infirmary			Urban			Semi-urban		
	n	%	N	n	%	N	n	%	N
10-10.9	1	0.4	14	8	2.8	14	5	1.8	14
11-11.9	4	1.4	21	6	2.1	21	11	3.9	21
12-12.9	6	2.1	20	5	1.8	20	9	3.2	20
13-13.9	6	2.1	28	9	3.2	28	13	4.6	28
14-14.9	4	1.4	20	8	2.8	20	8	2.8	20
15-15.9	11	3.9	27	7	2.5	27	9	3.2	27
16-16.9	13	4.6	28	12	4.2	28	3	1.1	28
17-17.9	5	1.8	16	3	1.1	16	8	2.8	16
18-18.9	23	8.1	41	15	5.3	41	3	1.1	41
19-19.9	13	4.6	26	9	3.2	26	4	1.4	26
20-21.9	21	7.4	44	13	4.6	44	10	3.5	44
Total	**107**	**37.5**		**95**	**33.3**		**83**	**29.1**	

% of the cohort by site type

The chi-square tests for the 17-19-year age range were found to have a significant difference (X^2=10.78, P=.005 at 1 d.f.) between the semi-urban and urban contexts with an even greater significance (X^2=16.66, P=.001 at 1 d.f.) between the semi-urban to infirmary sites (Figure 5.4).

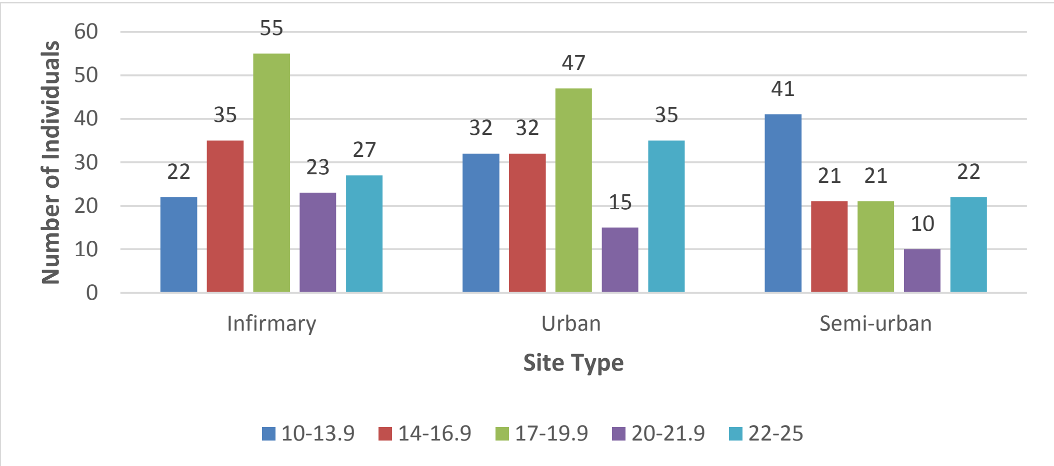

Figure 5.4: Age category distribution, by site type

When examined by age and sex, the proportion of possible males and possible females was higher in the younger age categories due to the difficulty in assigning a definitive sex prior to the complete fusion of the pelvis (Figure 5.5).

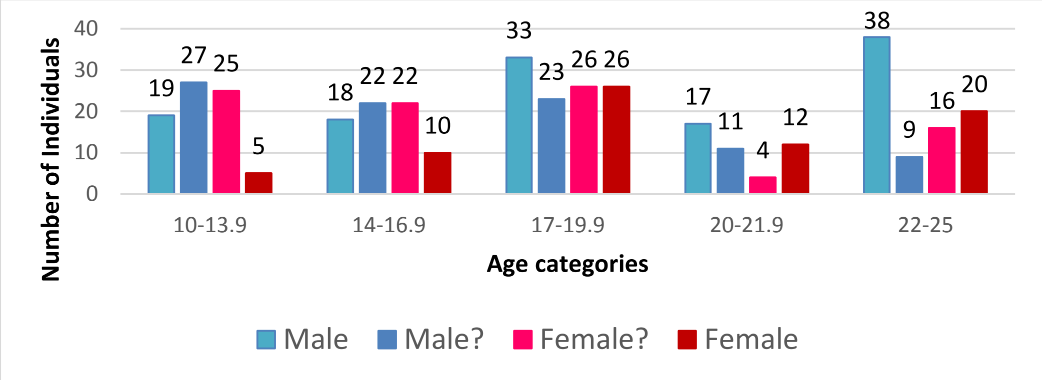

Figure 5.5: Sex distribution within each age group

5.3 SECONDARY SAMPLE: DEMOGRAPHY

Of the 424 skeletons in the database, 404 were of suitable preservation with an assigned age, sex, or pathology and the five site types by status are presented in Table 5.5. The only non-London site is The Bullring, Birmingham (n= 90, 21.9%). The majority (160, 37.7%) of the secondary sample comprised individuals from lower status London. The relationship between urban London has been further examined in the discussion.

Table 5.5: Ages of the secondary sample, by site type

	High		Low		Middle		Mixed		Birmingham		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
10-11	0	0.0	0	0.0	1	0.2	4	1.0	5	1.2	10	2.5
12-17	10	2.5	56	13.9	4	1.0	20	5.0	26	6.4	116	28.7
18-25	44	10.9	104	25.7	9	2.2	62	15.3	59	14.6	278	68.8

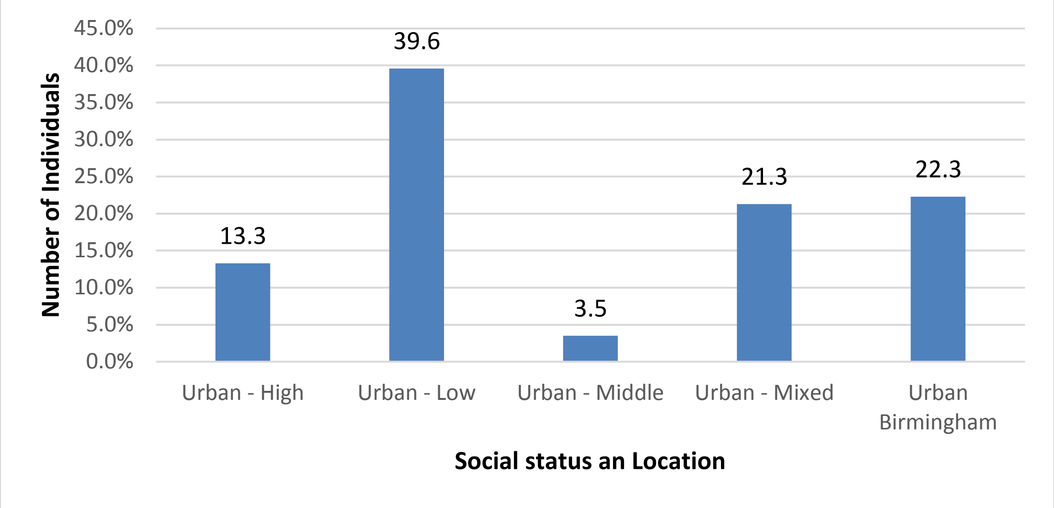

Figure 5.6: Percentage of the secondary sample by social status and location

5.3.1 Age-at-death and sex distribution

The age and sex distribution of the secondary sample is presented in Table 5.6. A total of 278 (67.6%) of the population fall within the later 18-25 year age category. While 23% of the population was identified within the 12-17 years range. There were 9, 10-11 year olds recorded, and 85, 12-17 year olds recorded though they were not sexed due to standards in previous reports but are still presented in Table 5.6 Figure 5.7.

The overall age distribution among the different social statuses indicated that 10-11 year olds were only identified in the Middle and Mixed London status sites and in Birmingham (Figure 5.7). The Low status London context had the highest (104, 25.7%) number of individuals recorded. Meanwhile it is evident that despite the urban social contexts the 18 – 25 year age range was over 60% of each site population (Figure 5.7).

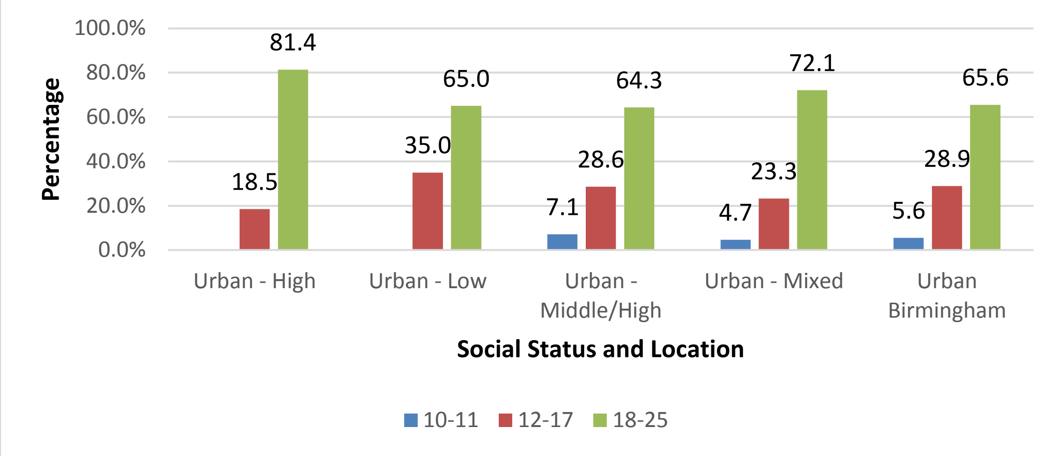

Figure 5.7: Age category distribution by urban social status in the secondary sample

The 112 indeterminate sexed skeletons have been included due to the large number of them being aged in the adolescent pubertal age range (Figure 5.8, 5.9). This large discrepancy between the 18-25 year age range and the lower ranges is due to a combination of factors including the difficulty in ageing and sexing children and young adolescents and new standards and techniques that have only recently come out in the past decade to further refine the ages at death.

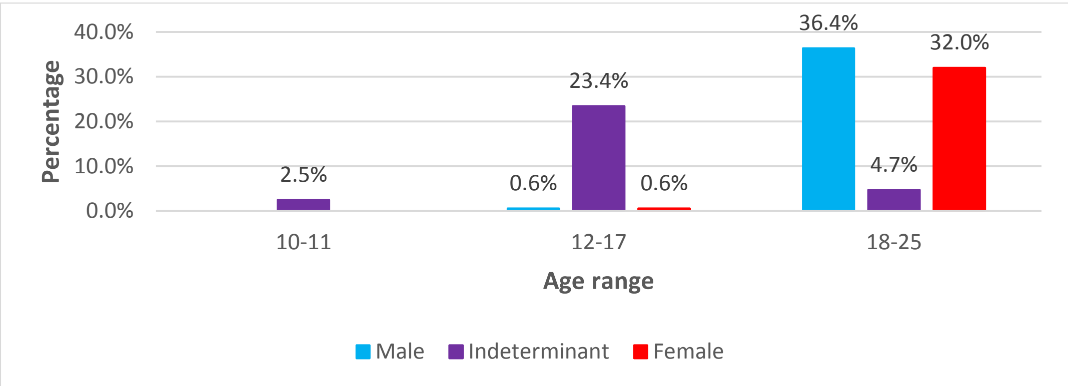

Figure 5.8: Total secondary sample age and sex distribution

Table 5.6: Age (years), sex, and social status of the secondary sample

	Urban - High			Urban - Low			Urban - Middle			Urban - Mixed			Urban Birmingham			Total		
	M	F	I	M	F	I	M	F	I	M	F	I	M	F	I	M	F	I
10-11	0	0	0	0	0	0	0	0	1	0	0	5	0	0	4	0	0	10
12-17	1	1	8	0	0	56	0	0	4	1	1	24	0	0	20	2	2	112
18-25	17	22	5	46	40	18	15	11	0	24	20	6	30	23	1	132	116	30
Total	**18**	**23**	**13**	**46**	**40**	**74**	**15**	**11**	**5**	**25**	**21**	**35**	**30**	**23**	**25**	**134**	**118**	**152**

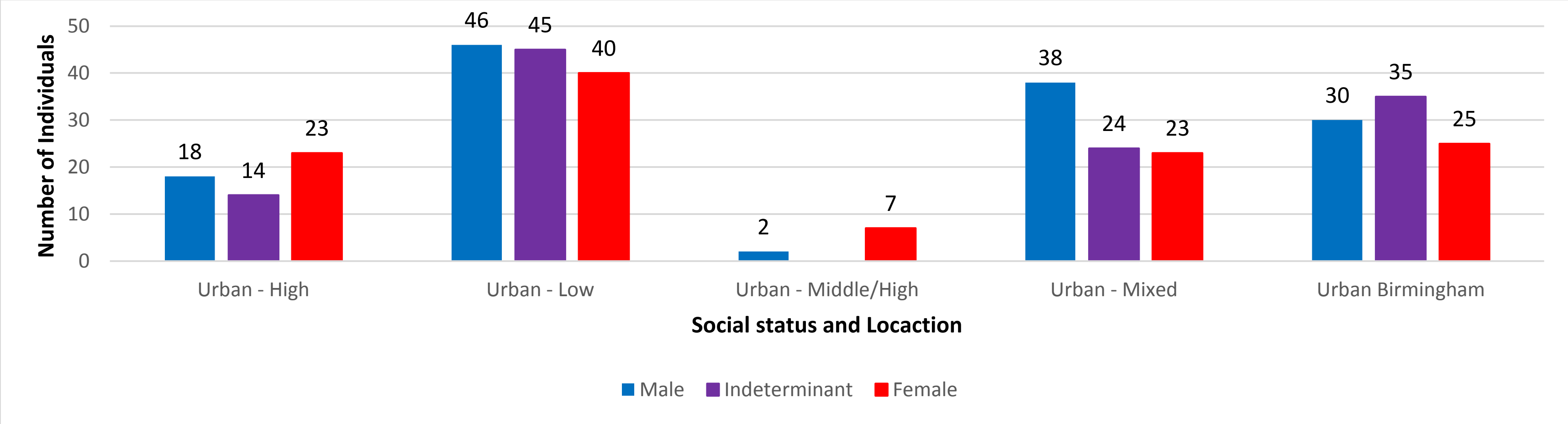

Figure 5.9: Sex distribution of adolescents among urban social status

5.4 GROWTH AND DEVELOPMENT

5.4.1 Primary sample: diaphyseal lengths

The diaphyseal length of the left femur was recorded in millimeters in unfused bones. Growth was measured in 70 (15.2%) individuals, including 22 (31.4%) females, 48 (68.6%) males and 3 (4.3%) individuals of indeterminate sex. Mean male and female lengths indicated that there were distinct differences in male lengths but that the females were much closer in the overall distribution (Figure 5.10 and Figure 5.11) overall. Despite the differences in overall distribution and grouping, there was no significant difference found among the site types.

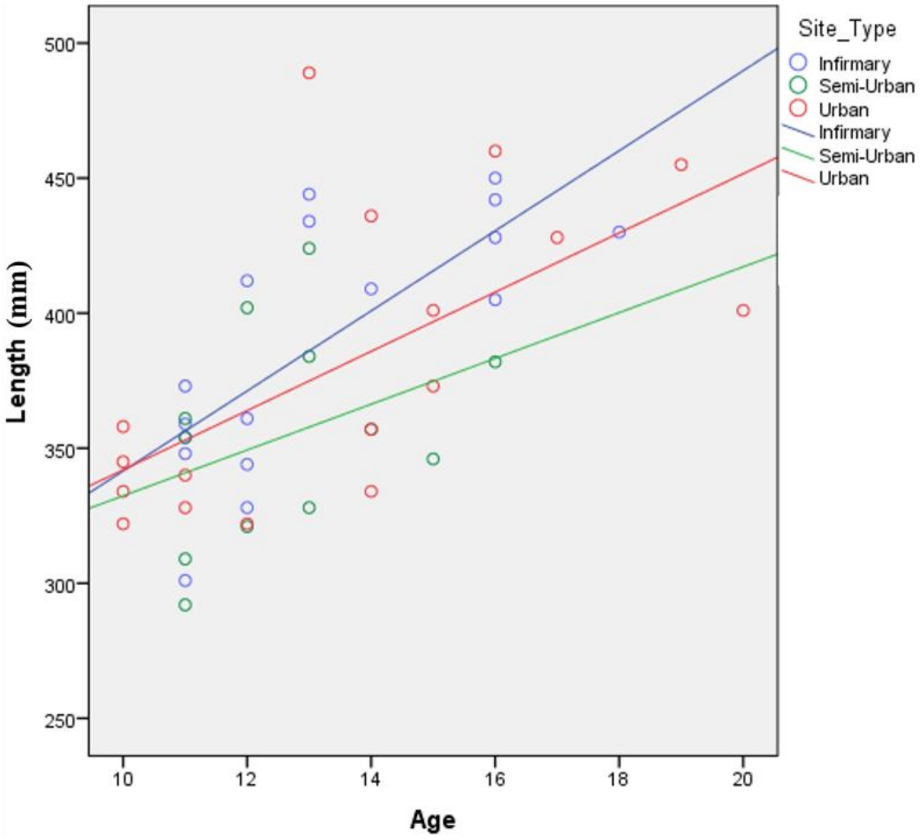

Figure 5.10 : Mean length in mm in males of unfused femora based upon age and site type

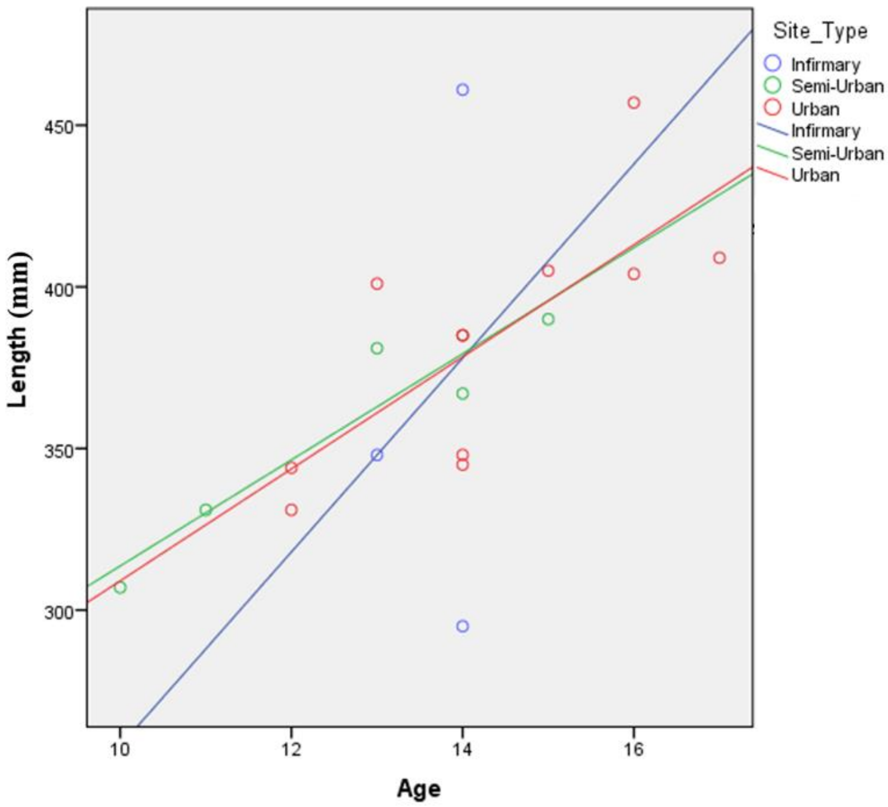

Figure 5.11: Average length in mm in females of unfused femora based upon age and site type

Overall, the distribution of femoral diaphyseal lengths in the primary sample indicated that shorter femoral lengths occurred in the semi-urban males, with the infirmary males being the tallest (Figure 5.12). However, the urban sample contained the tallest male (13-years-old, 489mm), as well as the oldest males with unfused femora (19 and 20 years). In the female sample, all the femora had fused by 18 years (Figure 5.12). Only three females from Radcliffe infirmary had femoral diaphyses available to measure and they were all aged between 13-14 years. The Radcliffe sample contained both the shortest female (295mm) and one of the tallest (461mm), indicating a high degree of variability within this group (Figure 5.12). Neither the male nor female's femoral growth were found to be significant when compared for normality.

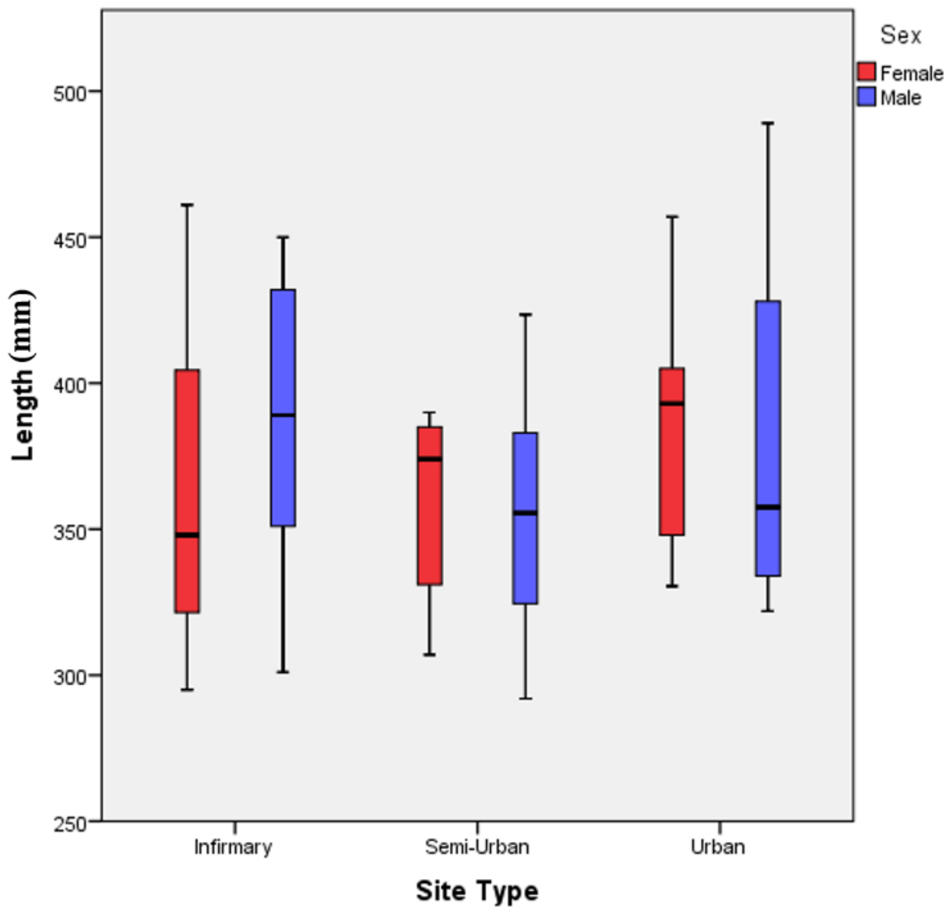

Figure 5.12*: Mean diaphyseal lengths for males and females, by site type and sex. The black line within the box is the mean length while the upper and lower tails represent the range of lengths recorded.*

5.4.2 Primary Sample: stature

Stature was recorded for all individuals with fused or fusing epiphyses. Of the 146 individuals assigned a stature of which 75 were male and 71 female. For site type, 74 individuals were from an Infirmary, with 35 and 37 from the Urban and Semi-Urban sites, respectively (Figure 5.13).

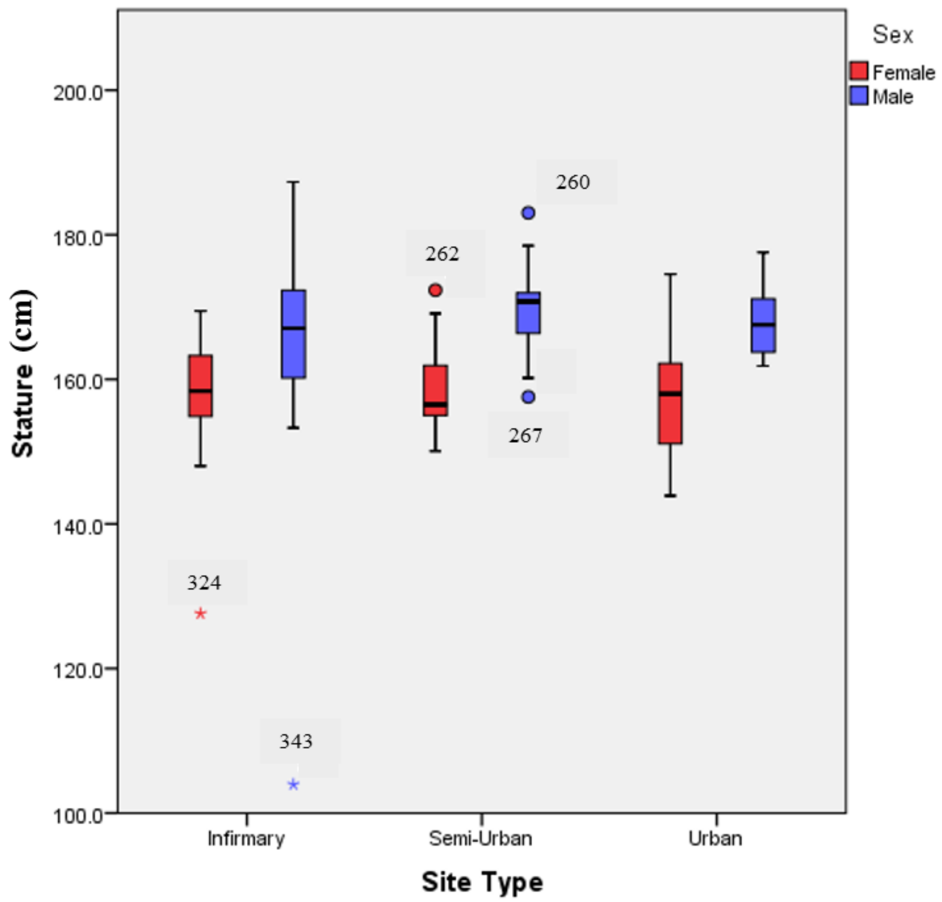

Figure 5.13: Stature of males and females by site type. The black line inside the box is the mean height (cm) for that sex and site type while the upper and lower tails are the range of recorded lengths. Individual plots are skeleton numbers

The difference in mean stature between urban men (168.6cm) and women (157.6cm) was the greatest by a small margin, with an average difference of 10.9cm, compared to 10.6cm in the semi-urban males (169.7cm) and females (159.1cm). There is an 8.0cm difference in the mean height between males (166.3cm) and females (158.3cm) in the infirmary context. When comparing the males and females across the site types, while the mean stature for females in all site types was similar, the urban context had the lowest average female height at 157.6cm. There was a 1.5cm height difference between the Urban and Semi-urban females (Figure 5.14). Males do not follow the same pattern. Unlike for their diaphyseal lengths, the Infirmary males had the shortest average height, at

166.3cm, which was 3.4cm shorter than the Semi-urban sample, and 2.2cm shorter than the Urban sample (Figure 5.14). This suggests that urban males had delayed maturation and that their epiphyses stayed open longer to allow them to "catch up" while the infirmary males fused while comparatively shorter. While the infirmary sample had the lowest mean stature, this group also contained the greatest range of heights, with the tallest individuals at 87cm and the shortest standing at just 103.9cm.

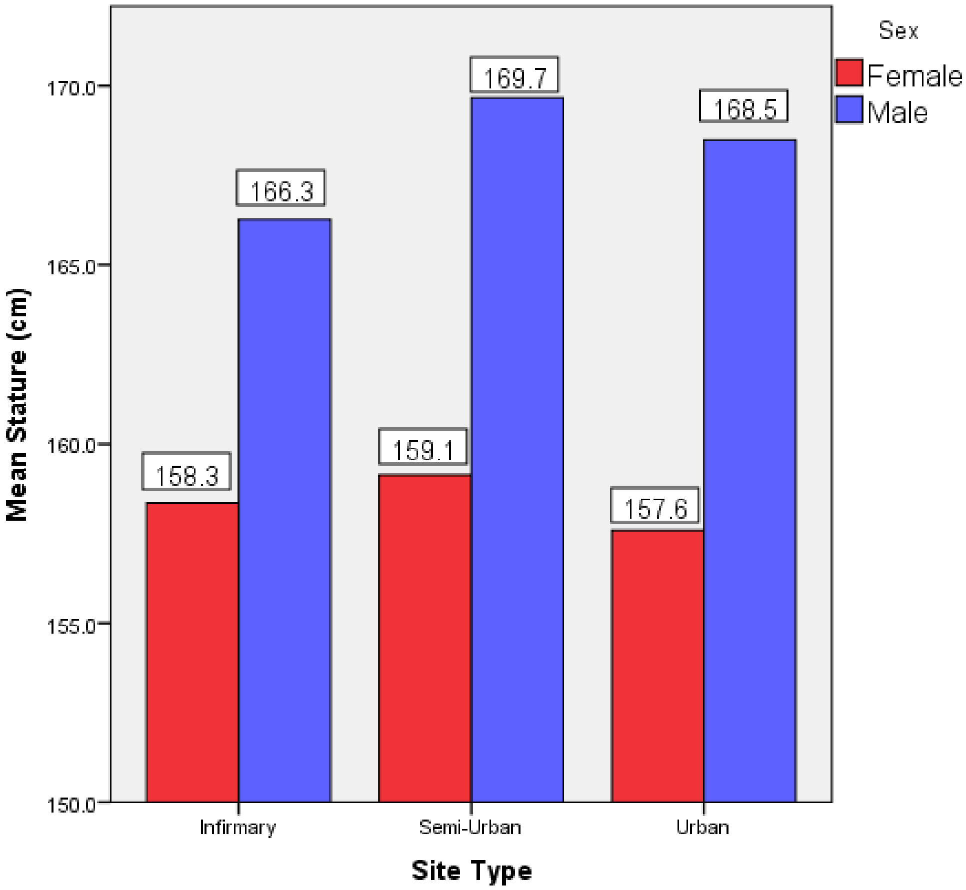

Figure 5.14: Mean femoral lengths (cm), by sex and site type

5.4.3 Secondary sample: stature

Stature was analysed for the secondary sample using measurements of various bones (mainly tibia and femur) provided in the reports, divided by sex and social status. Although some stature results were provided for indeterminate individuals, they were not included in order to be consistent with the primary sample.

The mean stature results indicate that females from low status sites were the shortest (mean = 153.9cm) while the high status females were the tallest (mean = 161.8cm) with a difference of 7.9cm between these two groups (Figure 5.15). The adolescents from the Urban - Birmingham context had the greatest mean stature. Within both the high and low social status groups there were single male outliers, each shorter than the mean stature at 154.7 (high status) and 144.5 (low status). The short high status male (Project Number 498) (18-25 years) had lesions consistent with resolved rickets as well as active new bone formation in the sinus. The low status male (Project Number 556) , also aged between 18-25 years, had visceral rib lesions indicative of an active infection in the left lung (White, 2015), as well as an active infection in the femora, tibiae and calcanei that may have been the result of TB (Figure 5.15).

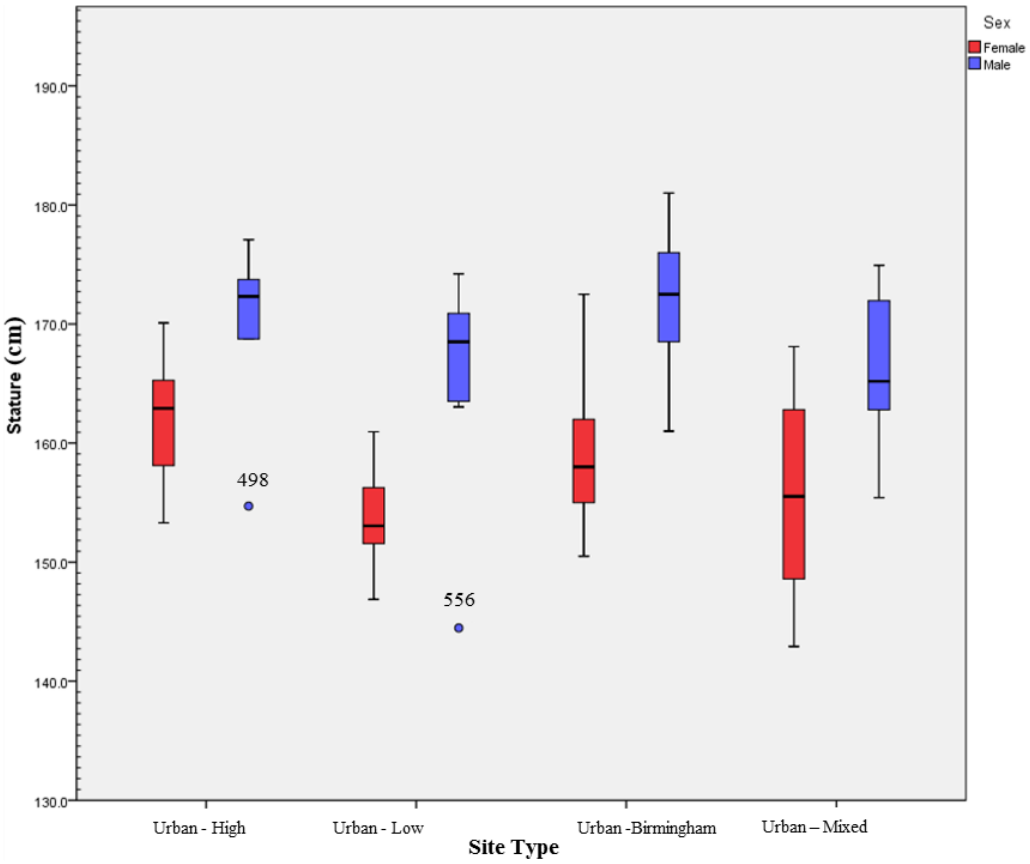

Figure 5.15: Male and female stature based on secondary data and site type. The black line inside the box is the mean height (cm) for that sex and site type while the upper and lower tails are the range of recorded lengths. Individuals 498 and 556 are outliers

The average male stature indicated that Birmingham had the tallest stature (172.4) and the second tallest female stature (158.7). The shortest males and females were from the low status context. While the high status females were the tallest present.

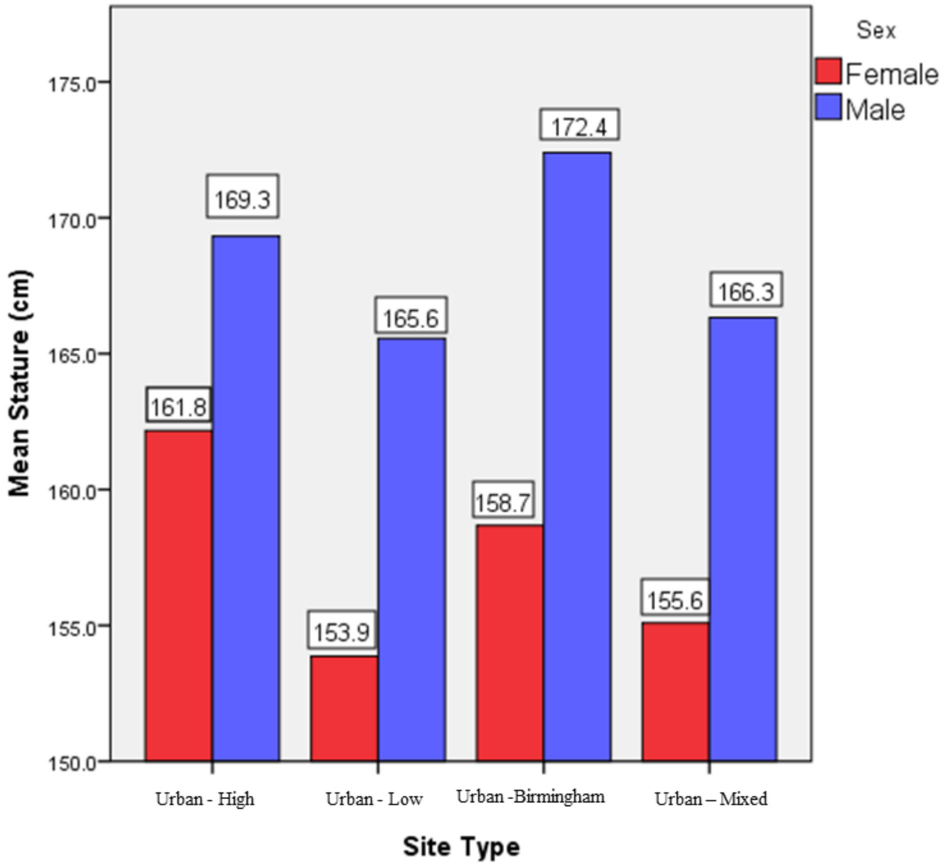

Figure 5.16: Bar Graph of the mean stature of males and females in the secondary sites by site type in mm

5.4.4. Primary sample: vertebral development

Vertebral neural canal size (VNC) and vertebral body height (VBH) were measured in 194 individuals with three or more preserved lumbar vertebrae, and without spinal abnormalities. There were 71 individuals recorded with vertebral stress from the infirmary population, 39 from the semi-urban sample population and 84 from the urban context (Table 5.7). The sex distribution included 103 (53.1%) males, 83 (42.8%) females, and 8 of indeterminate sex (Table 5.8). The total vertebral measurements and pairwise comparison tests for the anterior posterior, transverse and vertebral body height measurements can be seen in the attached digital appendix. They were not included in the results due to the overall number and size of tests run. There were no significant differences between the vertebral dimensions among each sex when comparing site types.

Table 5.7: Individuals with recorded vertebral development by age category in the primary sample

Age	N	%
10.0-13.9	40	20.6
14.0-16.9	34	17.5
17.0-19.9	52	26.8
20.0-21.9	20	10.3
22-25	44	22.7
Total	194	

Table 5.8: Mean lumbar vertebrae measurements (mm) by sex and type in millimeters

	AP		TR		BH	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**
L1	17.09	16.92	20.97	21.91	25.67	21.91
L2	16.15	15.87	20.84	22.05	26.01	22.05
L3	14.98	15.04	20.99	21.24	25.18	21.24
L4	15.16	15.38	21.21	21.96	26.04	21.96
L5	15.77	16.65	23.51	24.04	26.52	24.04

Among the average AP and TR measurements, the L3 had the closest mean size in millimeters between sexes among all vertebral canal measurements. The results of the AP measurement follow the general trend with the decrease the size of the vertebrae from the L1-L3 and then increase again from the L3 – L5 (Figures 5.17, 5.18, 5.19).

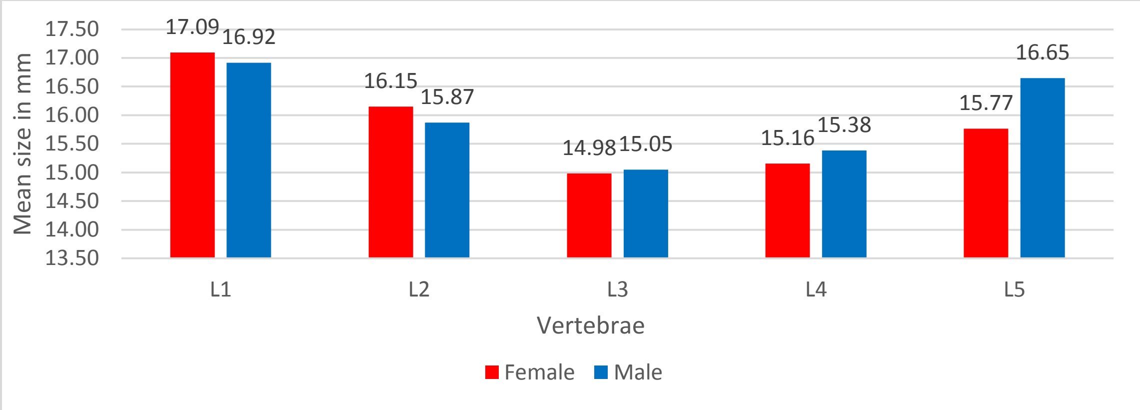

Figure 5.17: Mean AP lumbar vertebrae measurements (mm) between sexes

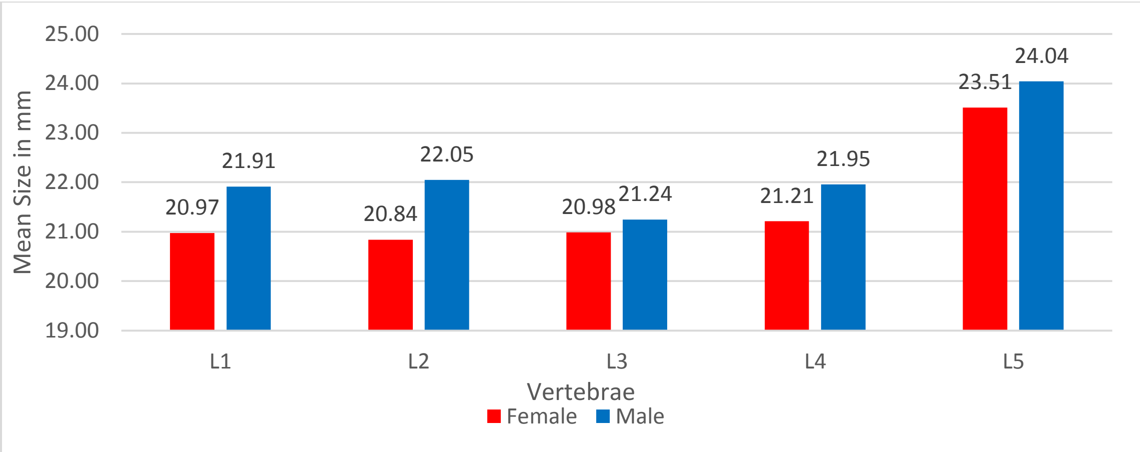

Figure 5.18: Mean TR lumbar vertebrae measurements (mm) between sexes

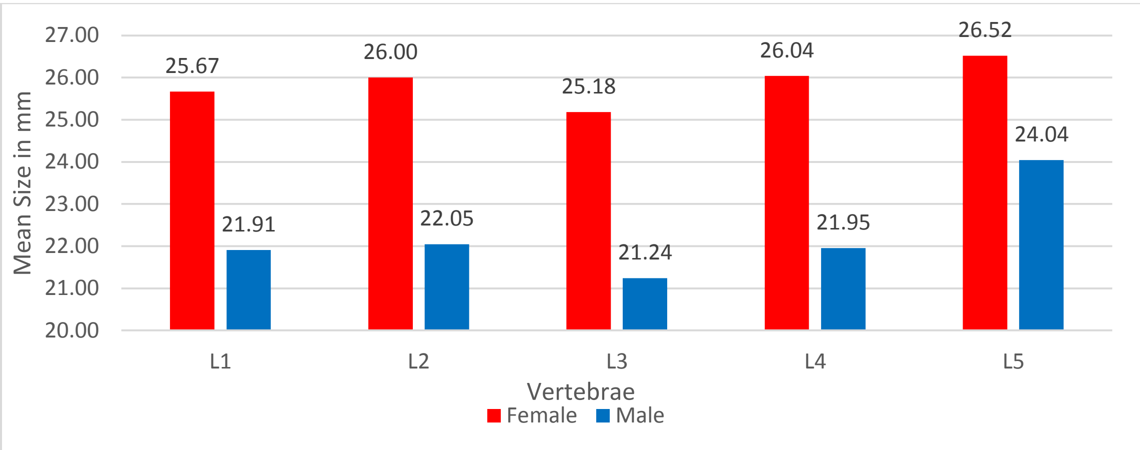

Figure 5.19: Mean BH lumbar vertebrae measurements (mm) between sexes

5.4.4.1 Anterior-posterior dimensions

A pairwise comparison of the mean anterior posterior measurements indicated that the L4 AP measurement in 17-19.9 year old males was significantly larger than for the 22-25 year olds (Table 5.09). There was no significant difference in the means for females.

5.4.4.2 Transverse dimensions

A comparison of transverse measurements in both males and females between the ages of 10-13-years age ranges and the 17-19.9 year age range (Table 5.10) indicated that the L5 was significantly larger than all other vertebral dimensions.

5.4.4.3 Vertebral body height

In all 388 vertebrae measured, the 10-13-year old males the mean vertebral body height was statistically smaller between the L1and L3 (0.019), and the L1 and L4 (0.007). In addition, the mean body height between the L2 and L3 (0.008) and L2 and L4 (0.003) were significantly smaller.

Table 5.9: Significant vertebral measurements

Vertebral Measurement	Mean Difference (I-J) (mm)	Std. Error	df	Sig.	95% Confidence Interval for Difference	
Male AP					Lower Bound	Upper Bound
17-19.9 to 22-25 (L4)	2.025	0.583	250.182	0.006	0.374	3.677
Male TR						
10-13.9 L1 - L2	3.114	0.700	343.019	0.000	1.136	5.093
10-13.9 L1 - L3	3.263	0.700	343.060	0.000	1.284	5.241
10-13.9 L1 - L4	3.262	0.700	343.053	0.000	1.283	5.240
10-13.9 L1 - L5	2.704	0.705	341.141	0.002	0.711	4.696
17-19.9 L1 - L2	3.114	0.700	343.019	0.000	1.136	5.093
17-19.9 L1 - L3	3.263	0.700	343.060	0.000	1.284	5.241
17-19.9 L1 - L4	3.262	0.700	343.053	0.000	1.283	5.240
17-19.9 L1 - L5	2.704	0.705	341.141	0.002	0.711	4.696
Female TR						
10-13.9 L1 - L2	2.939	0.764	277.708	0.001	0.778	5.100
10-13.9 L1 - L3	2.757	0.697	273.616	0.001	0.786	4.729
10-13.9 L1 - L4	2.318	0.684	268.743	0.008	0.381	4.255
10-13.9 L1 - L5	2.027	0.696	272.239	0.039	0.058	3.995
17-19.9 L1 - L2	3.225	0.402	269.710	0.000	2.087	4.363
17-19.9 L1 - L3	2.777	0.406	270.044	0.000	1.627	3.927
17-19.9 L1 - L4	3.289	0.396	268.871	0.000	2.168	4.410
17-19.9 L1 - L5	2.818	0.396	268.794	0.000	1.698	3.938
Male BH						
10-13.9 L1 - L3	2.038	0.650	282.120	0.019	0.198	3.877
10-13.9 L1 - L4	2.224	0.650	282.114	0.007	0.385	4.064
10-13.9 L2 - L3	2.211	0.650	282.158	0.008	0.372	4.051
10-13.9 L2 - L4	2.398	0.650	282.140	0.003	0.558	4.237

5.5 PALAEOPATHOLOGY

5.5.1 The Primary Sample

Within the primary sample, 438 skeletons were complete enough to be assessed for the presence of pathology. A total of 348 (75.7%) individuals showed some evidence of pathology (Table 5.10) with 181 males and 130 females.

The age distribution of the pathology in the primary sample indicated that the highest number of individuals in the infirmary (n=46) and urban (n=38) context were the 17-19.9 year age range (Figure 5.20). There were significantly more (X^2=21.3, P=.001, at 1 d.f.) infirmary 17-19.9 year olds compared to Semi-urban and significantly (X^2=14.87, P=.001, at1 d.f.) more Urban to semi-urban 17-19.9 year olds. These differences become more distinct when further examining the sex distribution of the 17-19.9 year age range as the majority (n=32) of the infirmary context with pathology was male and was to be expected given the higher number of males in the context. The female population in contrast in the 17-19.9 year age category comprised of the majority of the pathological load in the urban (n=23) and semi-urban (n=9) contexts. The 20-21.9 year age category had the smallest numbers of pathological adolescents (n=35) (Figure 5.20).

Table 5.10: Number and percentage of adolescents with pathology based on age category, sex, and site type

	Infirmary				Urban				Semi-urban			
Age Categories	Male		Female		Male		Female		Male		Female	
	n	%	n	%	n	%	n	%	n	%	n	%
10-13.9	16	94.1	2	100.0	13	86.7	9	75.0	10	71.4	11	68.8
14-16.9	15	75.0	8	100.0	9	75.0	12	85.7	3	37.5	5	50.0
17-19.9	32	84.2	10	83.3	11	84.6	23	85.2	4	80.0	9	69.2
20-21.9	13	92.9	8	100.0	7	70.0	2	66.7	3	75.0	2	40.0
22-25	11	78.6	12	100.0	19	86.4	7	53.8	9	81.8	7	63.6
Total	**87**	**84.5**	**40**	**95.2**	**59**	**81.9**	**53**	**76.8**	**29**	**69.0**	**34**	**61.8**

N= number of adolescents with pathology in each age category by sex and site type while % is the percentage of total population within each sex, age category, and site type

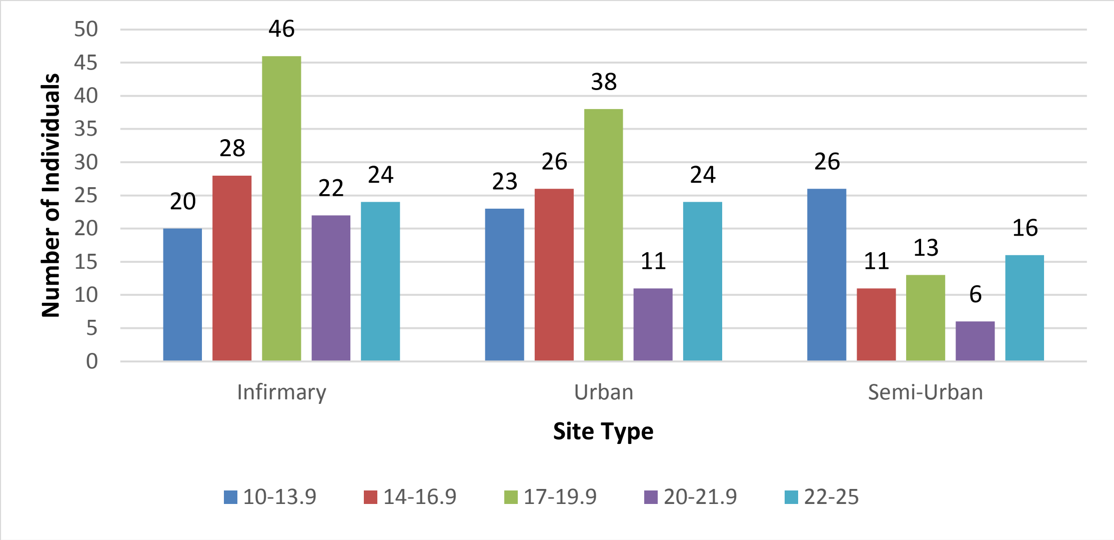

Figure 5.20: Age category distribution of individuals with pathology based upon site type

The adolescents with pathology in the infirmary context continue to be predominantly male throughout all age ranges (Figure 5.21) Overall males had a greater percentage of pathology in the infirmary context and the chi-square indicated a significant (X^2=35.07, P=.001, at1 d.f.) difference between the males and females.

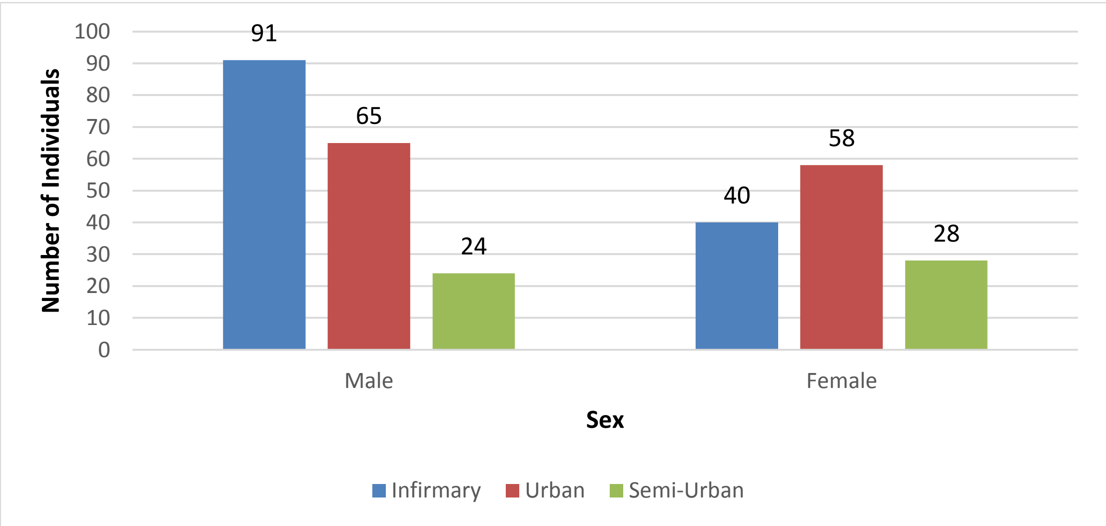

Figure 5.21: Sex distribution of individuals with pathology by site type

5.5.1.1 Dental enamel hypoplasia

A total of 66 (15.3%) individuals were identified as having two or more teeth present with an enamel hypoplasia and 61 (92.4%) were sexed (Table 5.11). Of the 7278 permanent teeth available for examination, 430 (59.5%) displayed dental defects.

The sex differences for individuals with enamel hypoplasia indicated that there is a significant difference (X^2=4.08, P=.05, at1 d.f.), between the male and female individuals in Urban sites but not in the Infirmary (15% to 14%) and Semi-Urban (6% to 5%) contexts (Figure 5.22). There is also a significantly (8.6%) lower number of males with EH from the infirmary to urban contexts (X^2=4.30, p=.05, at1 d.f.). There is not a significantly higher number of females to males with DEH in the urban sample population, but the relationship between the urban and semi-urban female population indicates that there is a significant (X^2=6.20 p=.025 at1 d.f.) difference of females with enamel hypoplasias.

Table 5.11: Crude prevalence rates of enamel hypoplasia by sex

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Male	20	18.9	106	9	10.3	87	3	9.4	32	32	14.2	225
Female	8	14.3	56	17	21.5	79	4	10	40	29	16.6	175
Total	**28**	**17.3**	**162**	**26**	**15.7**	**166**	**7**	**9.7**	**72**	**61**	**15.3**	**400**

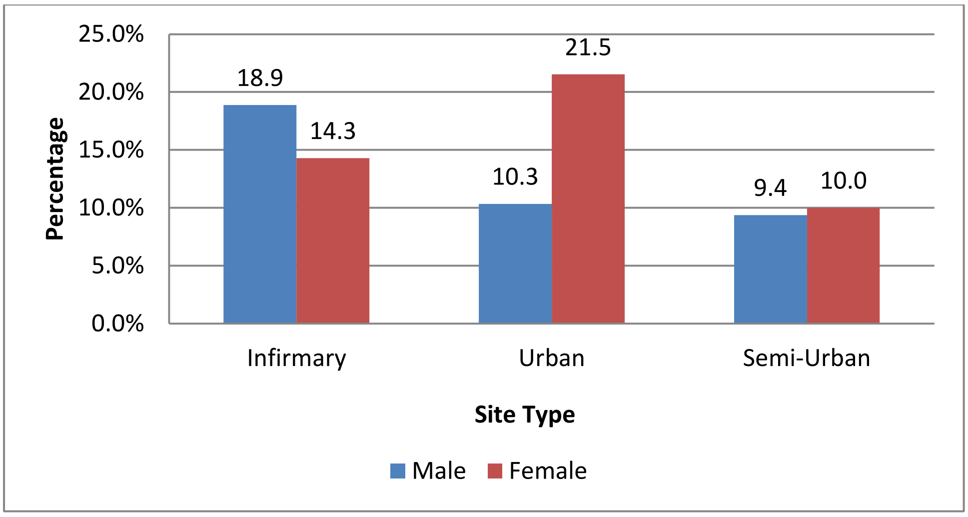

Figure 5.22: Crude prevalence rates of Enamel hypoplasia by sex

The age distribution of enamel hypoplasias in the crude prevalence rate indicates that there were more adolescents with the pathology from the 17-19.9 year age ranges and up (Table 5.12, Figure 5.23). The first 3 age categories comprised 81.8% (n= 54) of the adolescents with DEH (Table 5.12).

Table 5.12: Table of Crude prevalence rates of enamel hypoplasia by age category

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	6	25.0	24	9	25.7	35	4	9.5	42	19	18.8	101
14-16.9	4	11.4	35	6	24.0	25	1	5.0	20	11	13.8	80
17-19.9	12	20.7	58	10	18.9	53	2	11.1	18	24	18.6	129
20-21.9	4	19.0	21	1	11.1	9	1	7.1	14	6	13.6	44
22-25	3	12.0	25	2	6.3	32	1	5.3	19	6	7.9	76
Total	**29**	17.8	**163**	**28**	18.2	**154**	**9**	8.0	**113**	**66**	15.3	**430**

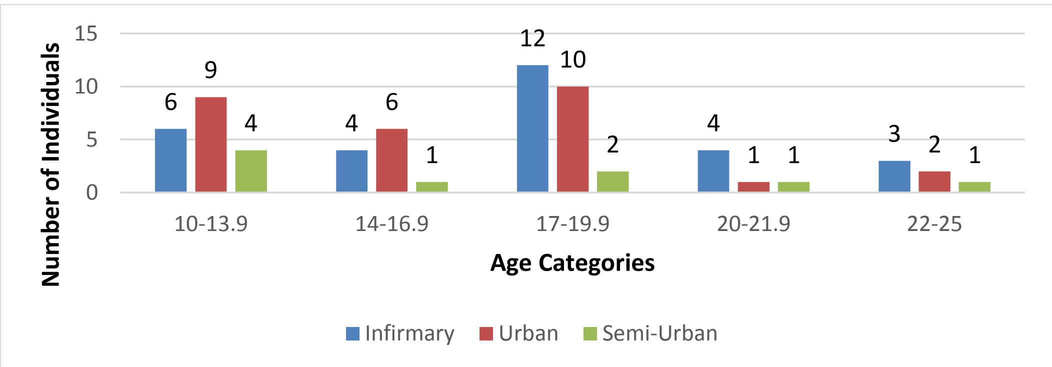

Figure 5.23: Crude prevalence rates of enamel hypoplasia by age category

True prevalence rates of enamel hypoplasia were calculated by the erupted teeth present. In the total population 430 of 7129 teeth (6.0% TPR) were identified with enamel defects and an associated age category (Table 5.13, Figure 5.24) The infirmary context had 200 of 2863 teeth (7.0% TPR) affected while Urban was found to have 189 of 2629 teeth (7.2% TPR) present with enamel defects. The semi-urban context had a significantly lower presence of hypoplasia with only 41 of 1637 (2.5% TPR) (X^2=35.53, p<.001 at1 d.f.).

Table 5.13: True prevalence rates of enamel hypoplasia in erupted permanent teeth by sex

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Male	125	6.6	1907	117	9.3	1260	15	2.2	668	257	6.7	3835
Female	68	8.0	854	64	5.1	1266	19	2.5	757	151	5.2	2877
Total	**193**	**7.0**	**2761**	**181**	**7.2**	**2526**	**34**	**2.4**	**1425**	**408**	**6.1**	**6712**

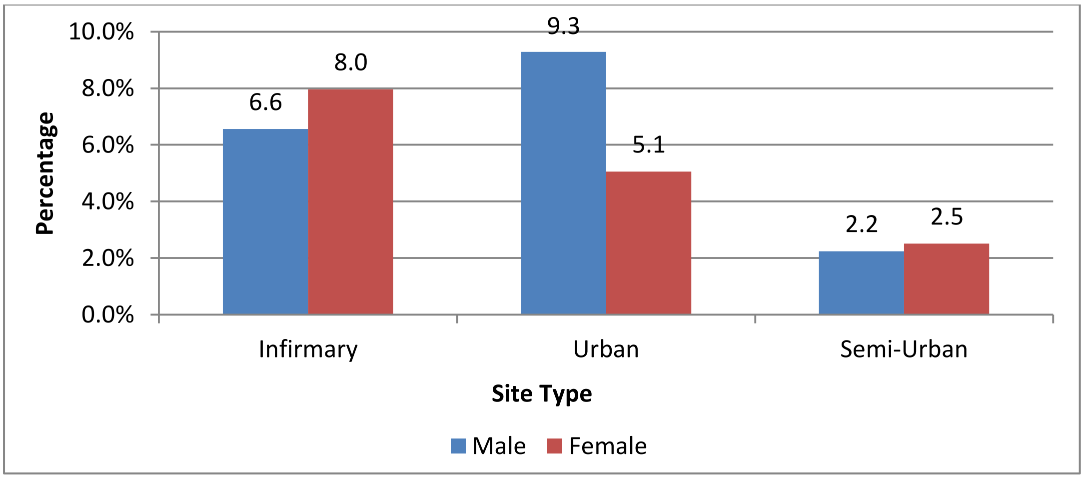

Figure 5.24: True prevalence rate of dental enamel hypoplasia by sex

The 10-13.9 year old age range had the highest proportion of DEH among the urban context. In the semi-urban context, the TPR indicated that only 2 teeth (0.6%) had DEH from the 14-16.9 year age range and 3 (0.7%) from the 22-25 year age range (Table 5.14, Figure 5.25).

Table 5.14: True prevalence rates of dental enamel hypoplasia in erupted permanent teeth by age

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	32	7.3	436	57	13.1	434	26	5.8	450	115	8.7	1320
14-16.9	41	8.1	509	48	7.0	686	2	0.6	356	91	5.9	1551
17-19.9	70	6.5	1078	70	8.6	815	5	1.7	290	145	6.6	2183
20-21.9	34	9.6	354	1	0.5	194	5	3.8	133	40	5.9	681
22-25	23	4.7	491	13	2.0	644	3	0.7	408	39	2.5	1543
Total	**200**	**7.0**	**2868**	**189**	**6.8**	**2773**	**41**	**2.5**	**1637**	**430**	**5.9**	**7278**

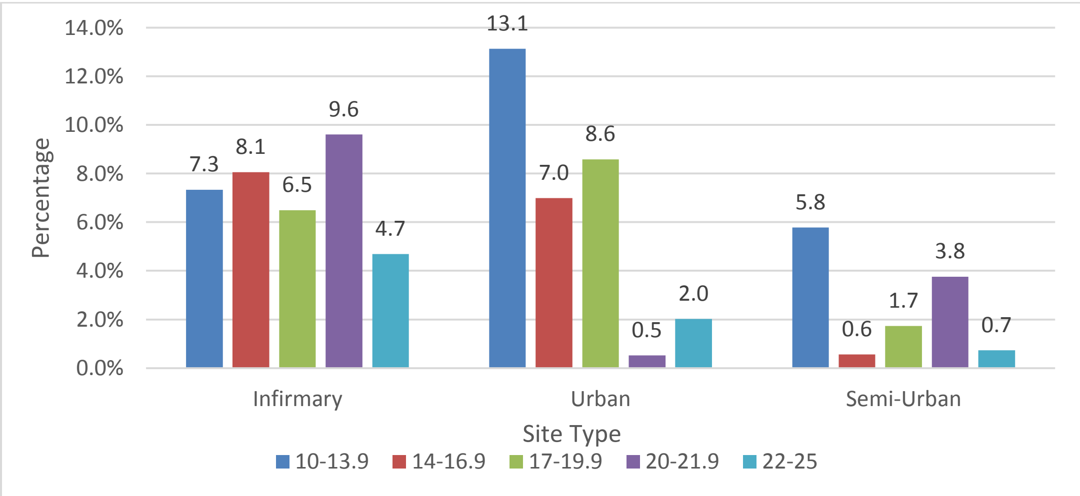

Figure 5.25: True prevalence rate of dental enamel hypoplasia

5.5.1.2 Endocranial lesions

The distribution of lesions between the site types is striking, only one individual in the Semi-urban location, yet a high number in the infirmary sample. There were 138 intact or partial present crania with 33 (23.9%) found to have the presence of endocranial lesions.

The age distribution of the TPR indicated that the semi-urban context only had endocranial lesions among the 14-16.9 and 20-21.9 year age ranges (Table 5.15). The infirmary context had adolescents in each age range with endocranial lesions while the urban was in all except the 17-17.9 year age range (Figure 5.26)

Table 5.15: True prevalence rates of individuals with endocranial lesions by age and site type

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	1	5	22	4	13	32	0	0	41	1	1	95
14-16.9	6	17	35	3	9	32	1	5	21	5	6	88
17-19.9	4	7	55	4	9	47	0	0	21	8	7	123
20-21.9	2	9	23	0	0	15	1	10	10	1	2	48
22-25	4	15	27	2	6	35	0	0	22	4	5	84
Total	**17**	**10**	**162**	**13**	**8**	**161**	**2**	**2**	**115**	**32**	**7**	**438**

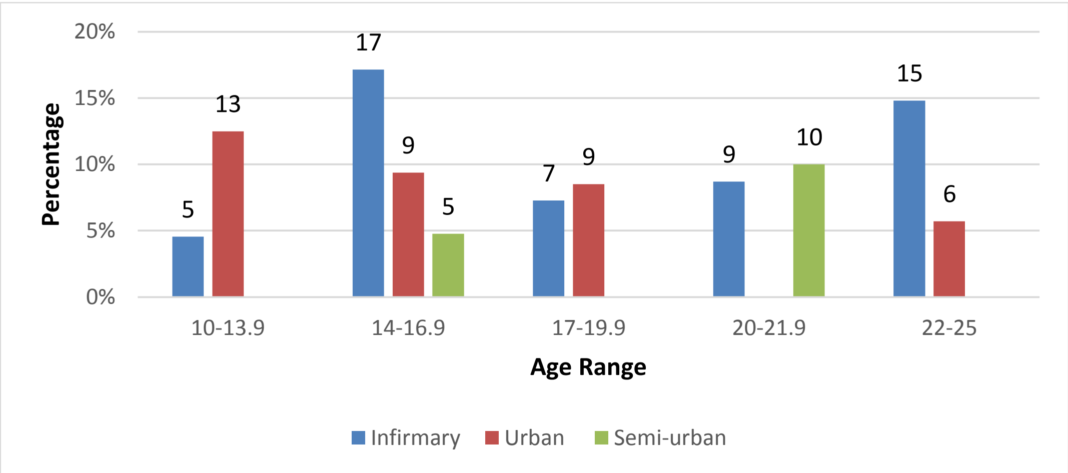

Figure 5.26: Percentage of individuals with endocranial lesions by site type and age

While there were no semi-urban adolescents with endocranial lesions the entire urban context (n=22) were female. In contrast to this the Infirmary context was predominantly male (n=12) with only 3 (20%) females identified with endocranial lesions (Table 5.16, Figure 5.27).

Table 5.16: True prevalence rate of endocranial lesions by sex

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Male	12	22.2	54	0	0.0	31	0	0.0	17	12	11.8	102
Female	3	13.0	23	22	61.1	36	0	0.0	18	25	32.5	77
Total	**15**	**19.5**	**77**	**22**	**32.8**	**67**	**0**	**0.0**	**35**	**37**	**20.7**	**179**

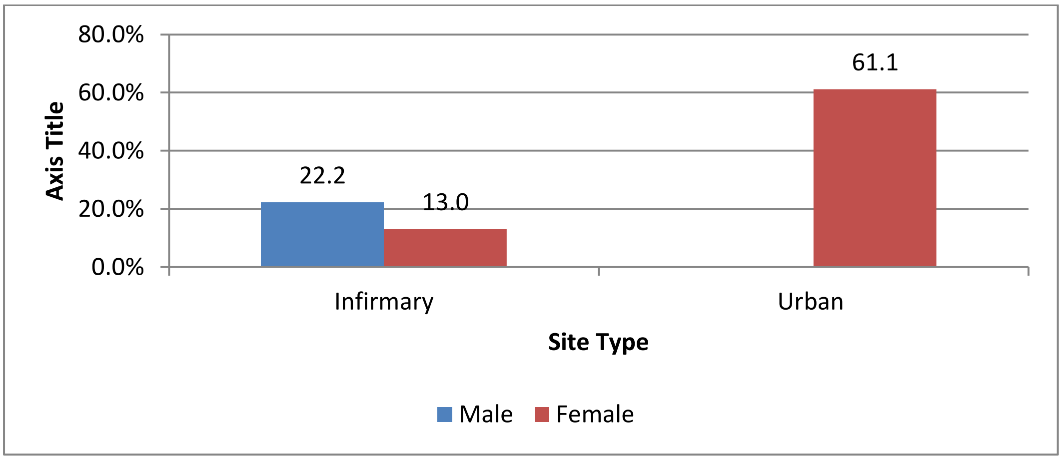

Figure 5.27: True prevalence rate of endocranial lesions by sex

5.5.1.3 Sub-periosteal new bone formation

All instances of new bone formation were recorded and assessed for both their healed and active states. The specific cases were recorded as sub-periosteal new bone formation (SNBF) when there were no additional indicators of a specific cause or infectious disease, and at least 50% of the skeleton was present. A total of 108 (25% of the pathological population) individuals were identified as presenting with new bone growth somewhere on the body. The primary locations for these healed and active pathologies appeared predominantly on the long bones.

The sex distribution indicates that infirmary females had a significantly (X^2=3.12, P=.005, at1 d.f.) higher incidence of SNBF than males and females from both other site types (Urban X^2=12.29, P=.001, at1 d.f.) (Semi-urban, X^2=19.98, P=.001, at1 d.f.) (Table 5.17, Figure 5.28).

Table 5.17: Crude prevalence rates of SNBF by sex

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Male	30	33.0	91	16	26.7	60	8	26.7	30	54	29.8	181
Female	25	61.0	41	14	25.5	55	4	11.8	34	43	33.1	130
Total	**55**	**41.7**	**132**	**30**	**26.1**	**115**	**12**	**18.8**	**64**	**97**	**31.2**	**311**

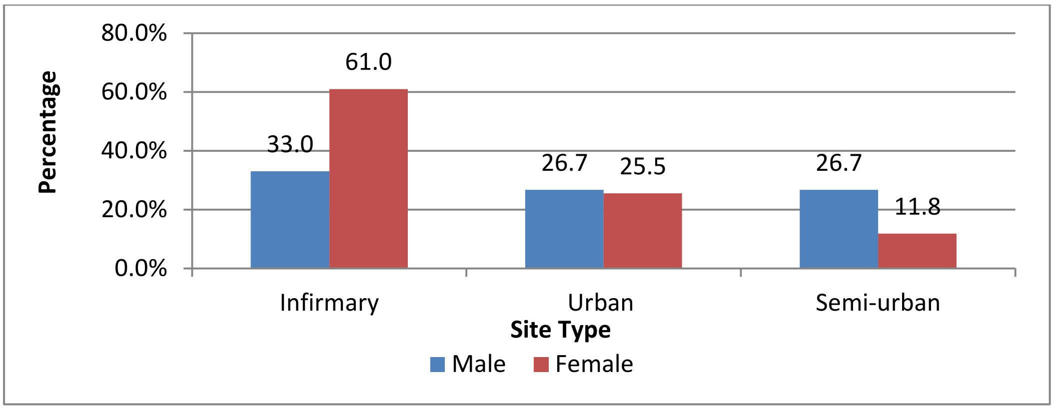

Figure 5.28: Crude prevalence of new bone formation by sex

The age distribution indicated a general pattern of the infirmary context having the highest incidence of SNBF outside of the 17-19.9 year age category in which the urban context was the highest (Table 5.18, Figure 5.29), although none of these differences were significant.

Table 5.18: Crude prevalence rates of SNBF by age

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	11	50.0	22	4	12.5	32	7	17.1	41	22	23.2	95
14-16.9	14	40.0	35	8	25.0	32	2	9.5	21	24	27.3	88
17-19.9	13	23.6	55	14	29.8	47	3	14.3	21	30	24.4	123
20-21.9	11	47.8	23	3	20.0	15	1	10.0	10	15	31.3	48
22-25	11	40.7	27	5	14.3	35	1	4.5	22	17	20.2	84
Total	**60**	37.0	**162**	**34**	21.1	**161**	**14**	12.2	**115**	**108**	24.7	**438**

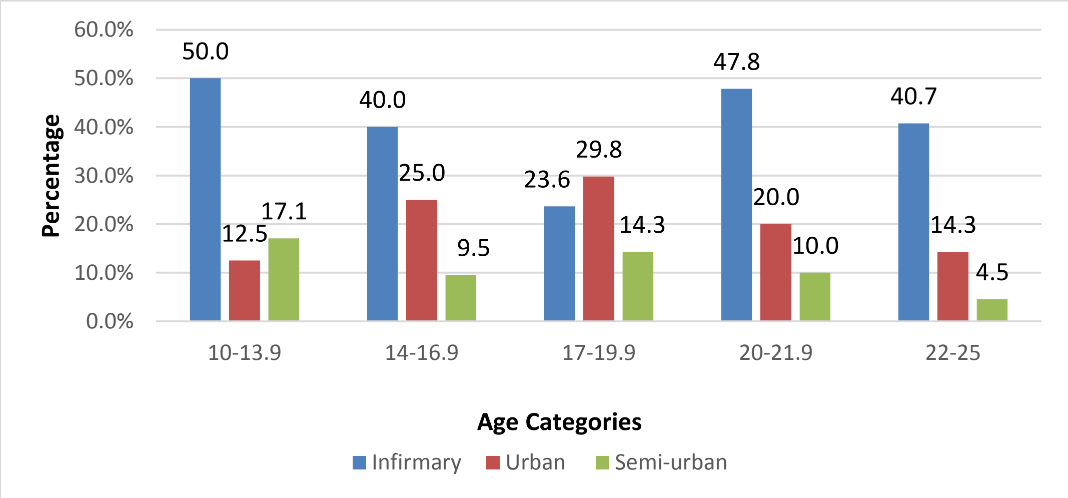

Figure 5.29: Crude prevalence of new bone formation by age

A total of 63 (58.3%) adolescents had healed periosteal new bone (Table 5.19), while 44 (40.7%) had an active infection (Table 5.21). Any individuals identified with both healed and active lesions were categorized as having an active lesion. The highest prevalence of new bone formation cases came from the infirmary site (healed= 55.6%; active =52.3%) (Table 5.20, Table 5.20). Among 10-13.9 year olds with healed new bone formation, the infirmary context comprised 36.4% but only 18.2% of the active new bone formation (Figures 5.29 and 5.30)

Table 5.19: Crude Prevalence rates of healed new bone formation

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	8	36.4	22	1	3.1	32	2	4.9	41	11	11.6	95
14-16.9	6	17.1	35	2	6.3	32	3	14.3	21	11	12.5	88
17-19.9	6	10.9	55	10	21.3	47	2	9.5	21	18	14.6	123
20-21.9	6	26.1	23	2	13.3	15	1	10.0	10	9	18.8	48
22-25	9	33.3	27	4	11.4	35	1	4.5	22	14	16.7	84
Total	**35**	**21.6**	**162**	**19**	**11.8**	**161**	**9**	**7.8**	**115**	**63**	**14.4**	**438**

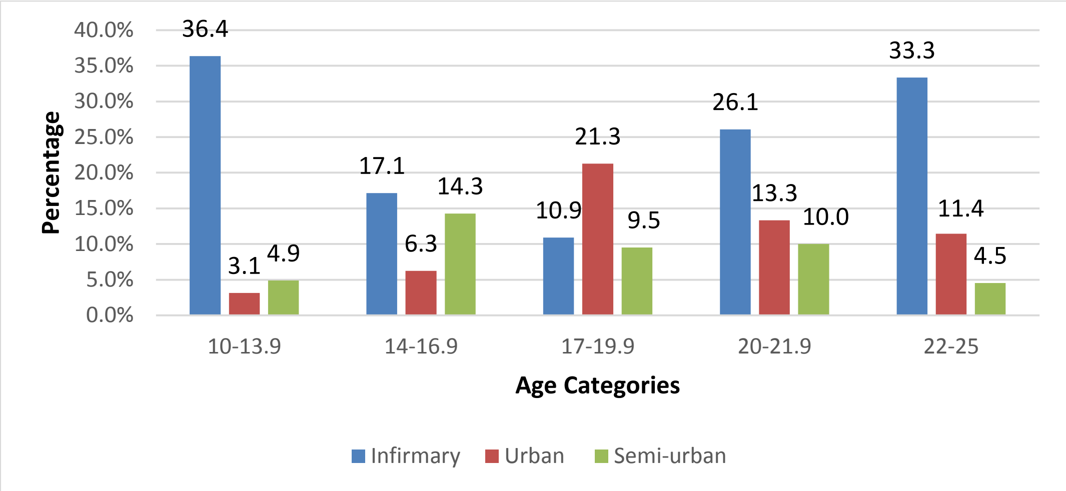

Figure 5.30: Frequency of total healed new bone formation by age

Table 5.20: Crude prevalence rates for active new bone formation

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	4	18.2	22	3	9.4	32	4	9.8	41	11	11.6	95
14-16.9	8	22.9	35	7	21.9	32	0	0.0	21	15	17.0	88
17-19.9	5	9.1	55	4	8.5	47	1	4.8	21	10	8.1	123
20-21.9	4	17.4	23	1	6.7	15	0	0.0	10	5	10.4	48
22-25	2	7.4	27	1	2.9	35	0	0.0	22	3	3.6	84
Total	**23**	**14.2**	**162**	**16**	**9.9**	**161**	**5**	**4.3**	**115**	**44**	**10.0**	**438**

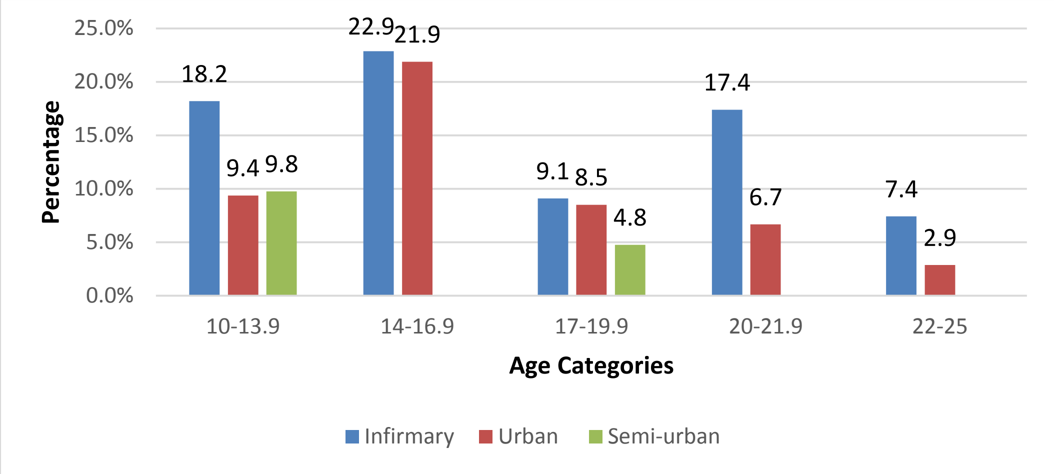

Figure 5.31: Prevalence of active new bone formation

5.5.1.4 Osteitis and osteomyelitis

In addition to periosteal new bone formation, five individuals had osteitis and seven had osteomyelitis. These individuals had no further evidence of a specific infection.

The age distribution of osteitis and osteomyelitis in the primary sample indicated that there were no 14.0-16.9 year olds identified with the pathology. The 10.0-13.9 year age range for the infirmary context had the made up 4.0% of the infirmary population with the disease (Table 5.21, Figure 5.31). There were 2 females with the pathology, 1 urban and 1 semi-urban.

Table 5.21: Total number of individuals with osteitis or osteomyelitis

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	2	9.1	22	1	3.1	32	1	2.4	41	4	4.2	95
14-16.9	0	0.0	35	0	0.0	32	0	0.0	21	0	0.0	88
17-19.9	1	1.8	55	1	2.1	47	1	4.8	21	3	2.4	123
20-21.9	1	4.3	23	0	0.0	15	0	0.0	10	1	2.1	48
22-25	1	3.7	27	2	5.7	35	0	0.0	22	3	3.6	84
Total	5	**3.1**	**162**	4	**2.5**	**161**	2	**1.7**	**115**	**11**	**2.6**	**430**

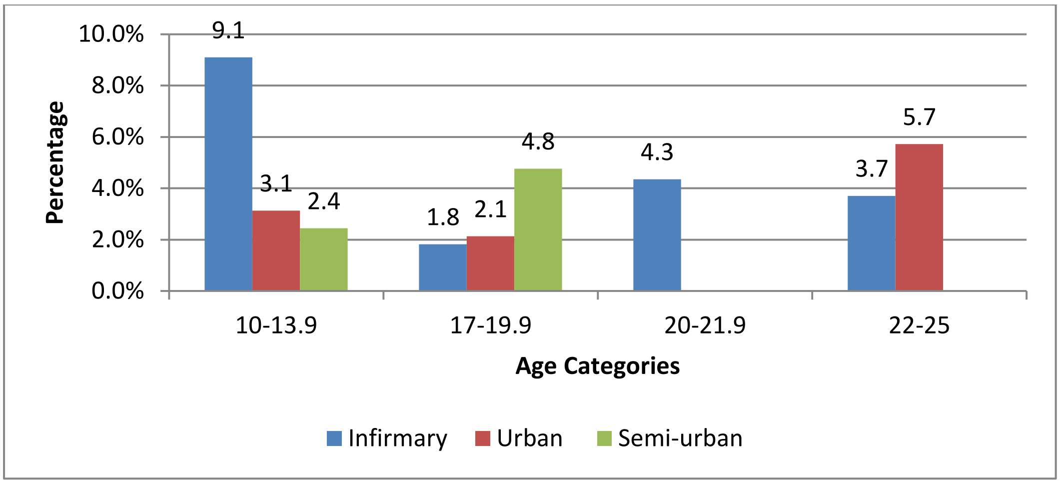

Figure 5.32: percentage of adolescents with osteitis or osteomyelitis by age and site type

5.5.1.5 Respiratory disease

Respiratory diseases included maxillary sinusitis or visceral rib lesions that did not have evidence of endocranial lesions or tuberculosis. 15.3% of the infirmary context was found with visceral rib lesions and none were found in the semi-urban context Figure 5.32. The urban context was found with the highest amount of maxillary sinusitis (7.75%) and the lowest rates of tuberculosis and visceral rib lesions Figure 5.32.

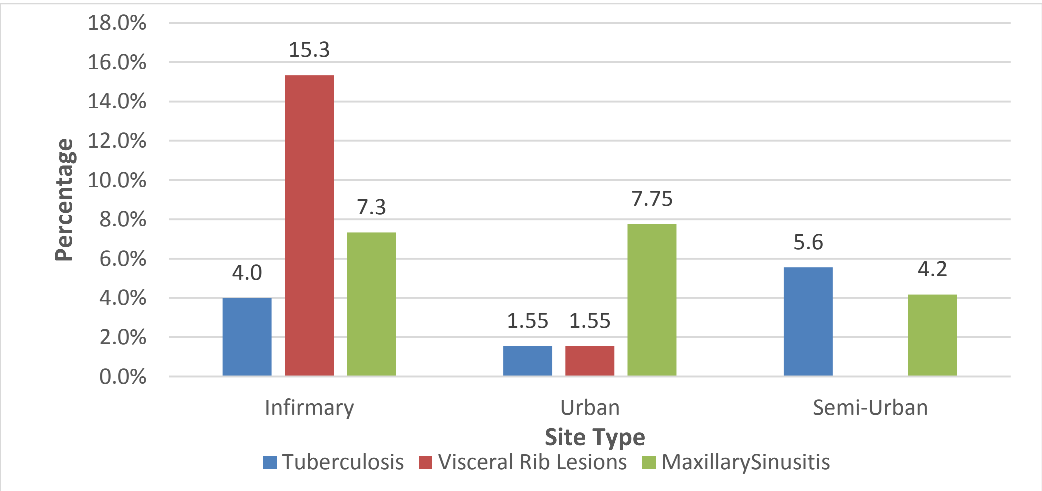

Figure 5.33: Percent of individuals with respiratory infections

A total of 24 (5.2% of the total primary sample) individuals were observed with maxillary sinusitis of which, 13 (56.5%) of the individuals were male, 9 (39.1%) female and one was of indeterminate sex.

The site distribution of maxillary sinusitis (Table 5.23) shows that 14 (8.7%) adolescents from the Urban context had maxillary lesions which were second to the Infirmary sample of 17 (10.5%). Despite being a higher number of individuals and percentage of the population the difference between the sites was not significant in terms of CPR.

Table 5.22: CPR of maxillary sinusitis, by age

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	1	4.5	22	0	0.0	32	0	0.0	41	0	0.0	95
14-16.9	1	2.9	35	4	12.5	32	0	0.0	21	0	0.0	88
17-19.9	4	7.3	55	4	8.5	47	0	0.0	21	1	0.8	123
20-21.9	0	0.0	23	0	0.0	15	1	10.0	10	0	0.0	48
22-25	2	7.4	27	2	5.7	35	0	0.0	22	2	2.4	84
Total	**17**	**10.5**	**162**	**14**	**8.7**	**161**	**1**	**0.9**	**115**	**24**	**5.5**	**438**

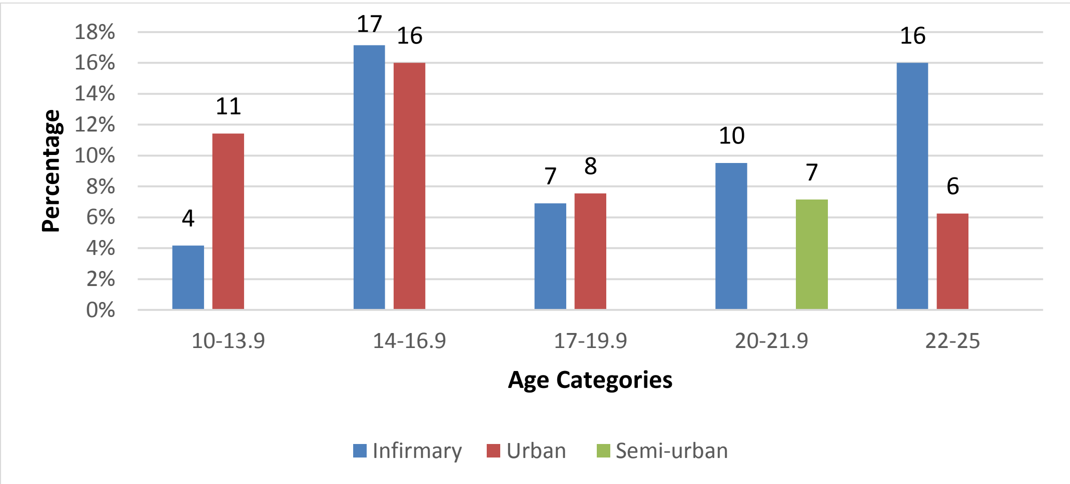

Figure 5.34*: Crude percentage of maxillary sinusitis*

There were 125 sinuses examined with 30 (24%) sinuses affected (Table 5.23). Of the 30 sinuses affected 29 (97%) were from sexed individuals while one was from an individual of indeterminate sex. There were 15 (23.8%) male sinuses affected and 14 (22.6%) female sinuses affected (Table 5.24). While no overall significant difference was found between the sexes based upon true prevalence, there was a significant difference (X^2=5.16, p<.05 at 1 d.f.) between the urban and infirmary females (Table 5.25).

Table 5.23: True prevalence rate of maxillary sinusitis in males and females

Sex	True Prevalence Rate		
	n	%	N
Male	15	23.8	63
Female	14	22.6	62
Total	**29**	**27.1**	**107**

n is the number of sinuses with pathology while N is the total number of observed sinuses.

Table 5.24: True prevalence rate of maxillary sinusitis in males and females by site

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Male	10	20.8	48	4	44.4	9	1	16.7	6	15	23.8	63
Female	5	13.5	37	7	41.2	17	2	25.0	8	14	22.6	62
Total	**15**	**17.6**	**85**	**11**	**42.3**	**26**	**3**	**21.4**	**14**	**29**	**23.2**	**125**

n = the number of sinuses with pathology while N is the total number of observed sinuses.

A total of 25 (5.4% of the total primary sample) individuals had visceral rib lesions. 23 of these were from the infirmary site type with only two cases identified from urban sites. The crude prevalence rates for the sex show that there were 16 (64%) males, 7 (28%) females, and 2 (8%) of indeterminate sex (Table 5.25). A total of 2676 ribs were found in the primary sample with 143 (5.3%) having some form of lesion and the overall lack of non-specific visceral rib lesions in semi-urban site types is striking.

Table 5.25: Crude prevalence rate of Visceral Rib lesions based upon site type

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	3	13.6	22	0	0.0	32	0	0.0	41	3	3.2	95
14-16.9	2	5.7	35	1	3.1	32	0	0.0	21	3	3.4	88
17-19.9	7	12.7	55	1	2.1	47	0	0.0	21	8	6.5	123
20-21.9	6	26.1	23	0	0.0	15	0	0.0	10	6	12.5	48
22-25	4	14.8	27	0	0.0	35	0	0.0	22	4	4.8	84
Total	22	13.6	**162**	2	1.2	**161**	0	0.0	**115**	24	5.5	438

One infirmary male was of poor preservation and as such a distinct age category could not be assigned

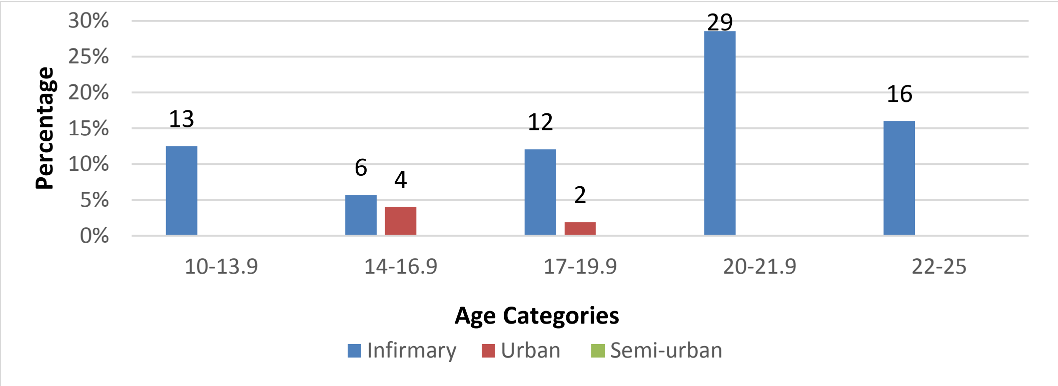

Figure 5.35: Crude prevalence rate of visceral rib lesions by site type

Of the total ribs collected 2571 ribs were in individuals assigned a sex. Of those, 85 (3.3%) ribs with visceral rib lesions were male and 56 (2.1%) were female (Table 5.27). The females in the infirmary context had a significantly (X^2=10.09, p<.005 at 1 d.f.) higher number of affected ribs than the urban females. Additionally, the infirmary males were also significantly higher (X^2=14.72, p<.001 at 1 d.f.) than those in the urban context (Table 5.26, Figure5.36).

Table 5.26: True prevalence rate of visceral rib lesions by sex

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Male	73	7.5	977	12	2.5	484	0	0.0%	121	85	5.4	1582
Female	9	8.2	563	10	3.0	332	0	0.0%	94	56	5.7	989
Total	**119**	**7.7**	**1540**	**22**	**2.7**	**816**	**0**	**0.0%**	**215**	**86**	**3.3**	**2571**

n is the number of ribs with pathology while N is the number of observed ribs.

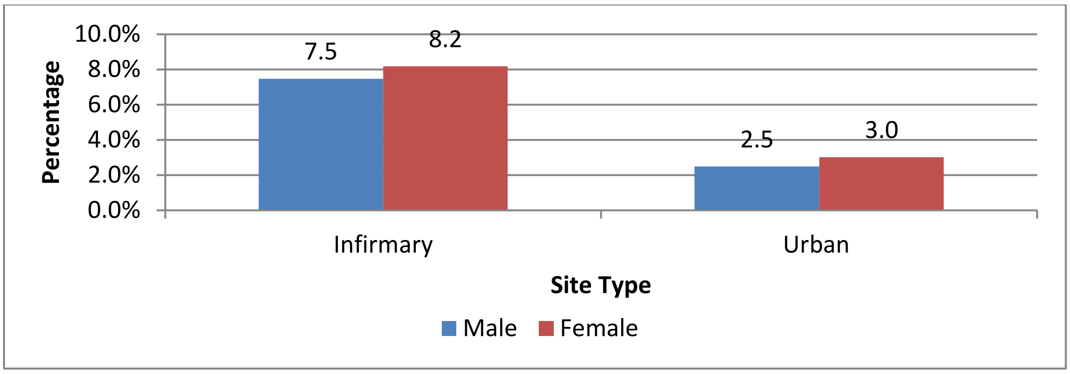

Figure 5.36: True prevalence rate of visceral rib lesions by sex

The TPR by age indicated that the 20-21.9 year age range in the male infirmary context had the highest prevalence of visceral rib lesions (Table 5.27, Figure 5.36).

Table 5.27: True prevalence rate of visceral rib lesions by site type and age

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	23	8.0	288	0	0.0	147	0	0.0	116	23	4.2	551
14-16.9	11	4.3	258	10	7.8	129	0	0.0	21	21	5.1	408
17-19.9	19	4.2	451	12	7.4	162	0	0.0	50	31	4.7	663
20-21.9	43	22.8	189	0	0.0	90	0	0.0	32	43	13.8	311
22-25	25	7.4	336	0	0.0	313	0	0.0	22	25	3.7	671
Total	**121**	**8.0**	**1522**	**22**	**2.6**	**841**	**0**	**0.0**	**241**	**143**	**5.5**	**2604**

n is the number of ribs with pathology while N is the number of observed ribs.

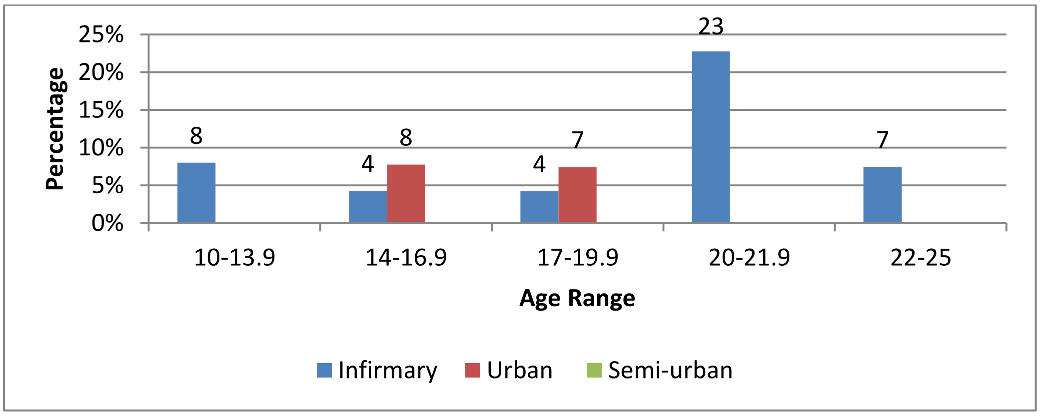

Figure 5.37: True prevalence rate of visceral rib lesions by site type

In the primary sample 148 individuals were complete enough to be assessed for tuberculosis. The majority of the vertebrae in the spine were well preserved in addition to half of the ribs, and the major long bones and pelvis. Of those, 15 (10.1%) had lesions consistent with tuberculosis (Table 5.28). The 6 skeletons in which a definitive differential diagnosis was made are highlighted.

Table 5.28: All adolescents with tuberculosis as well as age sex, pubertal stage, and site type

Project Number	Site type	Sex	Age Category	Puberty	Tb assessment
5	Urban	1	16-16.9	2	vertebral lesions
18	Urban	5	18-18.9	5	Endocranial lesions, healed and active periosteal new bone growth on the tibia, femora, humerus, and radius
100	Infirmary	1	18-18.9	3	Vertebral lesions, rib lesions and woven bone on the humerus and femur
111	Infirmary	3	15-15.9	?	Vertebral lesions
128	Infirmary	3	20-22	?	Lesion at the right shoulder, maxillary sinusitis, and visceral rib lesions
159	Infirmary	2	19-19.9	?	woven bone on the manubrium, humerus, scapula, clavicle, ribs and endocranial lesions
211	Urban	4	14-14.9	3	Maxillary sinusitis, vertebral porosity, Healed and active woven bone at the joint surfaces of the hip.
230	Semi-Urban	4	13-13.9	2	Periosteal bone growth on the femurs, tibia, ulna and radius
236	Semi-Urban	4	13-13.9	2	Porosity on the vertebrae, lesion at the knee, woven bone on the scapula and shoulder
255	Semi-Urban	5	20-21.9	6	Vertebral lesions, lesions at the knee
285	Semi-Urban	4	22-25	6	vertebral lesions and new bone growth on the tibia
288	Semi-Urban	3	16-18	1	Vertebral lesion, lesion on the manubrium and visceral rib lesions
314	Infirmary	4	18-18.9	5	Vertebral lesions, active woven bone on the femur, lesion in the knee, and maxillary sinusitis
319	Infirmary	1	20-21.9	5	Healed and active woven bone at the joint surfaces of the knee and shoulder.
423	Urban	5	17-19	5	Maxillary sinusitis, vertebral porosity, Healed and active woven bone at the joint surfaces of the knee and shoulder.

There were 4 (26.7%) males, 8 (53.3%) females, and 3 (20%) of indeterminate sex. Adolescents from the 10-13.9 year age range with tuberculosis were only present in the semi-urban context (Table 5.29). Two (13.3%) of the cases of tuberculosis in the infirmary context were a male and female from Radcliffe Infirmary while the other 4 (26.7%) were from the Plymouth Naval hospital (Table 5.29).

Table 5.29: Sex of individuals with tuberculosis in the primary sample

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Male	3	12.5	24	1	2.8	36	0	0.0	24	4	4.8	84
Female	1	8.3	12	3	10.3	29	4	17.4	23	8	12.5	64
Total	**4**	**11.1**	**36**	**4**	**6.2**	**65**	**4**	**8.5**	**47**	**12**	**8.1**	**148**

n is the number of individuals with tuberculosis while N is the number of observed individuals with pathology.

The urban context had 4 adolescents that were evenly distributed from the 14-16.9 (n=2, 11.8%) year age and 17-19.9 (n=2, 12.5%) year age range (Table 5.30). The age ranges for the infirmary context lacked individuals from the 10-13.9 and 22-25 year age categories (Figure 5.37).

Table 5.30: Age of tuberculosis in the primary sample

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	0	0.0	0	0	0.0	12	2	11.8	17	2	5.9	34
14-16.9	1	16.7	6	2	11.8	17	0	0.0	8	3	9.7	31
17-19.9	3	27.3	11	2	12.5	16	1	16.7	6	6	18.2	33
20-21.9	2	50.0	4	0	0.0	6	1	20.0	5	3	20.0	15
22-25	0	0.0	5	0	0.0	17	1	8.3	12	1	2.9	35
Total	**6**	**18.8**	**26**	**4**	**5.9**	**68**	**5**	**10.4**	**48**	**15**	**10.1**	**148**

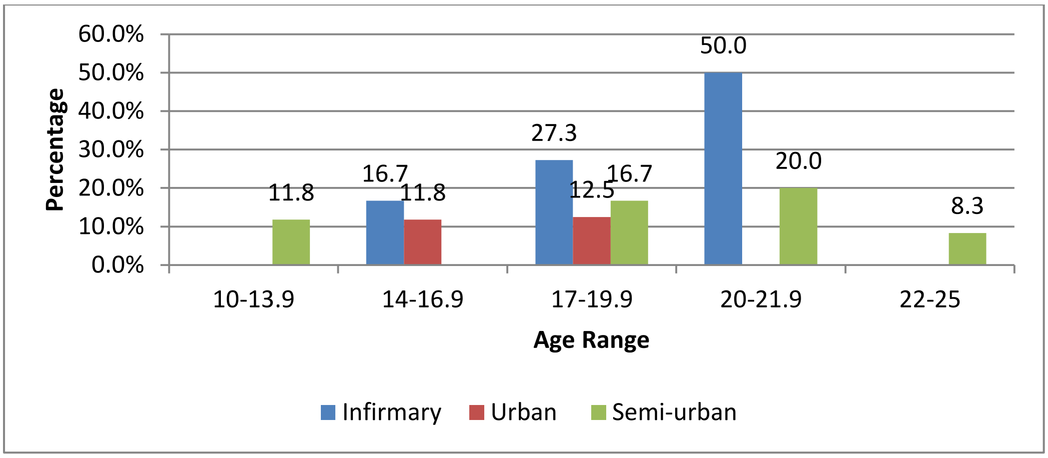

Figure 5.38: True prevalence rate of tuberculosis in the primary sample

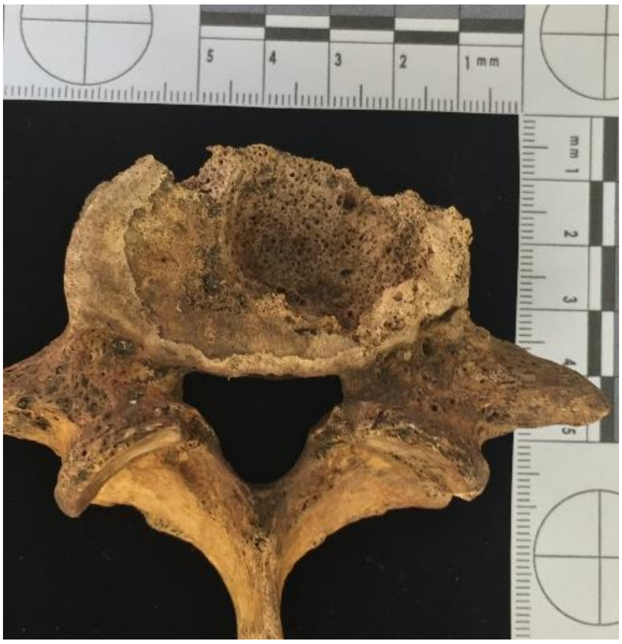

Figure 5.39: Large lytic lesion in the L4 Sk 3234 from the Radcliffe infirmary.

5.5.1.6 Metabolic and Haematological disease

In both of the samples the metabolic diseases examined were vitamin C (Scurvy) and D (Rickets), while the Haemotological diseases that were examined are cribra orbitalia and porotic hyperostosis. The percentage of the sample with cribra orbitalia was over 15% in all site types Figure 5.39.

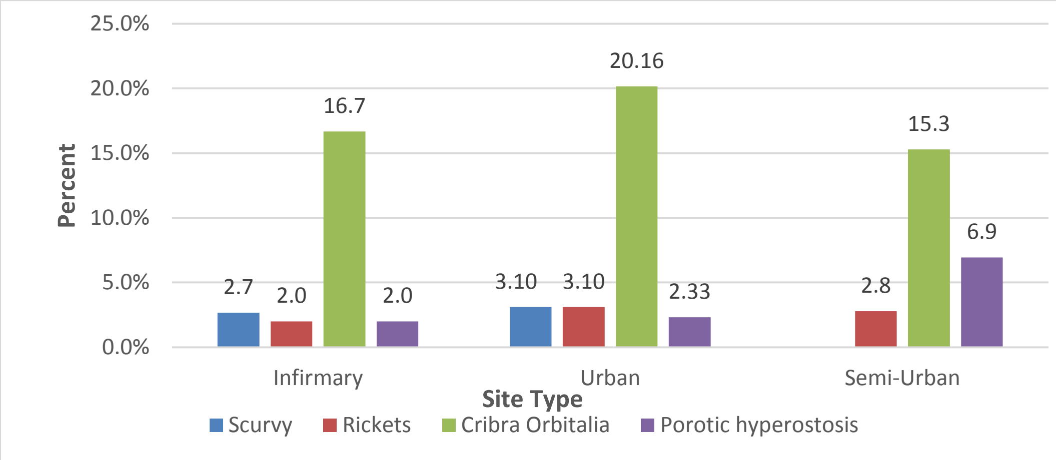

Figure 5.40: Percent of individuals with metabolic or hemopoietic diseases

<u>5.5.1.6.1 Vitamin C Deficiency (Scurvy)</u>

In the primary sample 8 (2.3%) individuals were diagnosed with scurvy, 4 were adolescents from the Infirmary and the other 4 were from the urban context. Three of the 4 infirmary individuals with scurvy were males from the Plymouth Naval hospital while the other was from the Radcliffe context. These males had abnormal porosity on the long bones and mandible with some reactive periosteal new bone formation as well. In contrast 2 males and 1 female and one undetermined sex were identified in the Urban sites (Table 5.31).

Table 5.31: Sex distribution of scorbutic lesions by site type in the primary sample

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Male	4	4.4	91	2	3.3	60	0	0.0	30	6	3.3	181
Female	0	0.0	41	1	1.8	55	0	0.0	34	1	0.8	130
Total	**4**	**3.0**	**132**	**3**	**2.6**	**115**	**0**	**0.0**	**64**	**7**	**2.3**	**311**

The age distribution of scurvy indicated that the age group with the greatest number (n= 3, 37.5%) of adolescents was in the 10 -13 year range. Meanwhile the 14.0-16.9 and 17.0-19.9 age ranges both had 2 (25%) individuals each. It should be noted that the oldest individuals (from the 17.0-19.9 and 20.0-21.9 age ranges) were from the naval hospital context of Plymouth (Table 5.32, Figure 5.40).

Table 5.32: Age distribution of adolescents with scurvy in the primary sample

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	1	4.5	22	2	6.3	32	0	0.0	41	3	3.2	95
14-16.9	0	0.0	35	2	6.3	32	0	0.0	21	2	2.3	88
17-19.9	2	3.6	55	0	0.0	47	0	0.0	21	2	1.6	123
20-21.9	1	4.3	23	0	0.0	15	0	0.0	10	1	2.1	48
22-25	0	0.0	27	0	0.0	35	0	0.0	22	0	0.0	84
Total	**4**	**2.5**	**162**	**4**	**2.5**	**161**	**0**	**0.0**	**115**	**8**	**1.8**	**438**

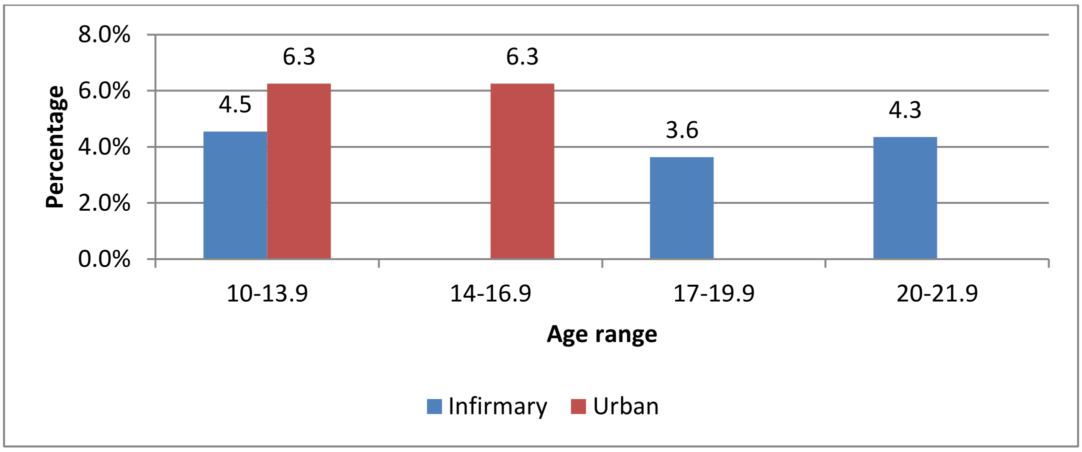

Figure 5.41: Age range of scurvy as a percent of the total primary sample with pathology

5.5.1.6.2 Vitamin D deficiency (Rickets)

In the primary sample nine (2.9%) adolescents were found to have evidence of rickets. All adolescents with vitamin D deficiency were able to be sexed with there being 5 male and 4 females (Table 5.33, Figure 5.41). It should be noted that the two cases of vitamin D deficiency in the semi-urban context were both male. In the infirmary context both males with rickets were from the Plymouth Naval site while the one female was from Radcliffe infirmary. The significant difference between the urban females and males is possibly representative of less exposure to vitamin D in females.

Table 5.33: Sex distribution of rickets and osteomalacia in the primary sample

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Male	2	2.2	91	1	1.7	60	2	6.7	30	5	2.8	181
Female	1	2.4	41	3	5.5	55	0	0.0	34	4	3.1	130
Total	**3**	**2.3**	**132**	**4**	**3.5**	**115**	**2**	**3.1**	**64**	**9**	**2.9**	**311**

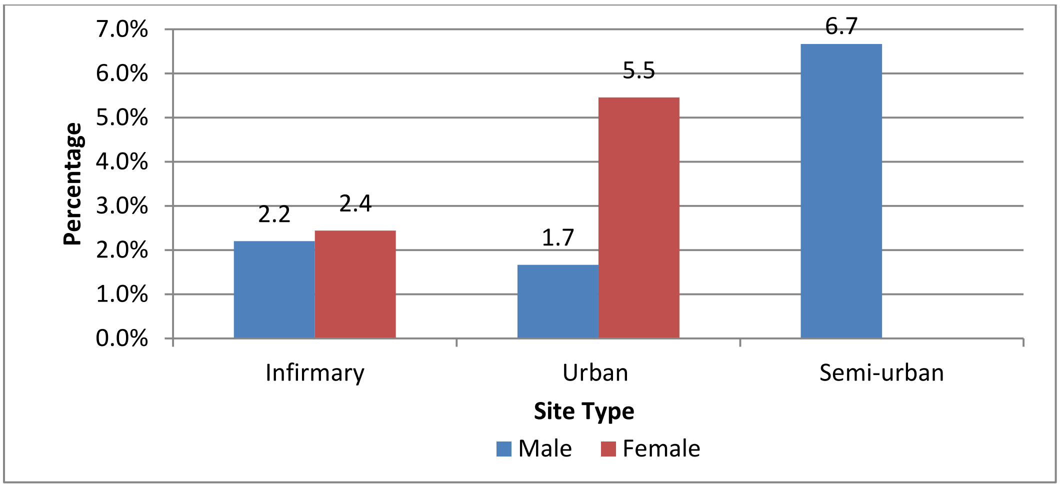

Figure 5.42: Percentage of individuals with rickets in the primary sample by sex

The age distribution of rachitic individuals indicated that the majority of cases were from an urban context but that there was a single individual from all age ranges except the 14.0-16.9 range. It also indicates that the age in which the most cases of rickets were found was the 17.0-19.9 age range with 4 (44.4%) (Table 5.34, Figure 5.42) but was not statistically significant.

Table 5.34: Age distribution of rickets osteomalacia in the primary sample

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	0	0.0	22	1	3.1	32	1	2.4	41	2	2.1	95
14-16.9	0	0.0	35	0	0.0	32	0	0.0	21	0	0.0	88
17-19.9	3	5.5	55	1	2.1	47	0	0.0	21	4	3.3	123
20-21.9	0	0.0	23	1	6.7	15	0	0.0	10	1	2.1	48
22-25	0	0.0	27	1	2.9	35	1	4.5	22	2	2.4	84
Total	**3**	**1.9**	**162**	**4**	**2.5**	**161**	**2**	**1.7**	**115**	**9**	**2.1**	**438**

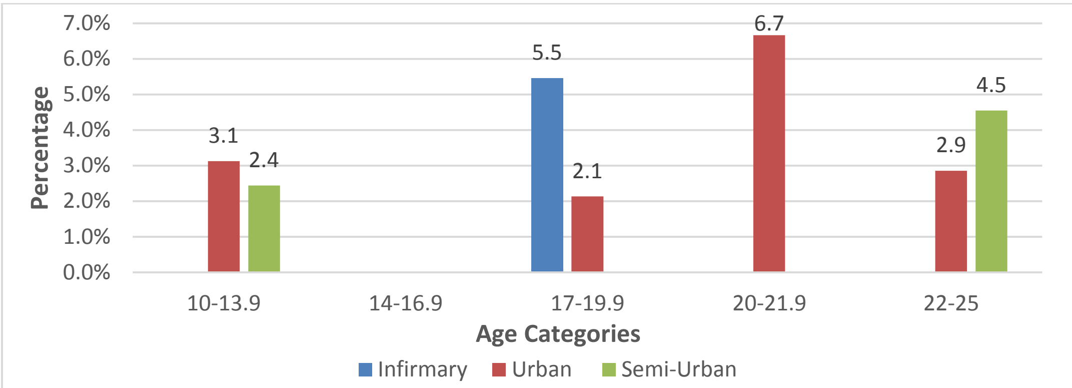

Figure 5.43: Percentage of individuals with rickets bye site type and age category

CAS84 skeleton 2662 – Case of juvenile rickets

The 10 – 11 year old possible male was from an urban context and was found to have been in the initiation phase of puberty. Pathologically there was evidence of lateral bowing in the upper femoral mid-shafts that indicate juvenile rickets. There was also active and porous woven bone present bilaterally on the medial tibial mid-shafts with healing pockets of woven bone on the tibial mid-shafts. Additionally there was evidence of active grade 3 cribra orbitalia in both orbits.

5.5.1.6.3 Cribra Orbitalia

A total of 63 (14.4%) individuals were found to have either healed or active cribra orbitalia. 57 individuals found with cribra orbitalia were assigned a sex with 32 (52%) males and 25 (40%) female with 5 (8%) of indeterminate sex. Pubertal stages were able to be assigned to 42 (14.3%) with cribra orbitalia (Table 5.35, Figure 5.43). Throughout the primary sample 370 orbits were identified with 92 (24.9%) orbits found with cribrous lesions of some degree.

There were no individuals from the 17-19.9 age range with cribrous lesions and 20-21 years in the semi-urban site (Table 5.36, Figure 5.43). The large percentage (21%) in the 22-25 year range was predominantly healing grade 1 or 2 individuals which have been recorded for the sake of the results but will not be further explored in the discussion.

Table 5.35: Crude prevalence rate of cribra orbitalia by age category

Age Categories	**Infirmary**			**Urban**			**Semi-urban**			**Total**		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	5	4.2	24	9	11.4	35	4	9.5	42	18	2.0	101
14-16.9	4	17.1	35	3	16.0	25	2	10.0	20	9	7.5	80
17-19.9	10	6.9	58	6	7.5	53	0	0.0	18	16	7.8	129
20-21.9	3	9.5	21	2	0.0	9	0	0.0	14	5	0.0	44
22-25	3	16.0	25	6	6.3	32	5	26.3	19	14	7.9	76
Total	**25**	**10.4**	**173**	**26**	**9.1**	**154**	**11**	**0.9**	**113**	**62**	**5.6**	**430**

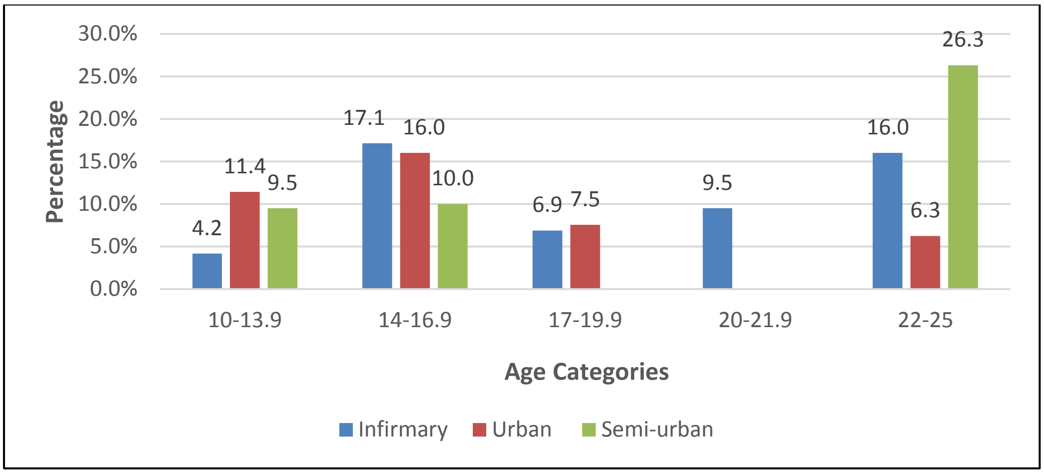

Figure 5.44: Crude percentage of Cribra by age category

It is evident from Figure 5.43 that the Semi-Urban context had a lower prevalence of orbital lesions that Urban and Infirmary categories. In addition, only grade 1 and 2 stages of severity were found. Despite the expectation that there would be a higher incidence of Cribra Orbitalia in infirmary sites, urban locations had a greater proportion of the grades 1 and 2 and the only individual found in grade 5. The Infirmary contexts did have a higher number of individuals with grade 3 and 4 cribrotic lesions (Table 5.36, Figure 5.44).

Table 5.36: Crude prevalence rates of severity of cribrotic lesions

Grade	Infirmary		Urban		Semi-Urban	
Grade 1	6	9.7	10	16.1	8	12.9
Grade 2	10	16.1	10	16.1	4	6.5
Grade 3	5	8.1	2	3.2	0	0.0
Grade 4	4	6.5	2	3.2	0	0.0
Grade 5	0	0.0	1	1.6	0	0.0
Total	**25**	**40.3**	**26**	**41.9**	**11**	**17.7**

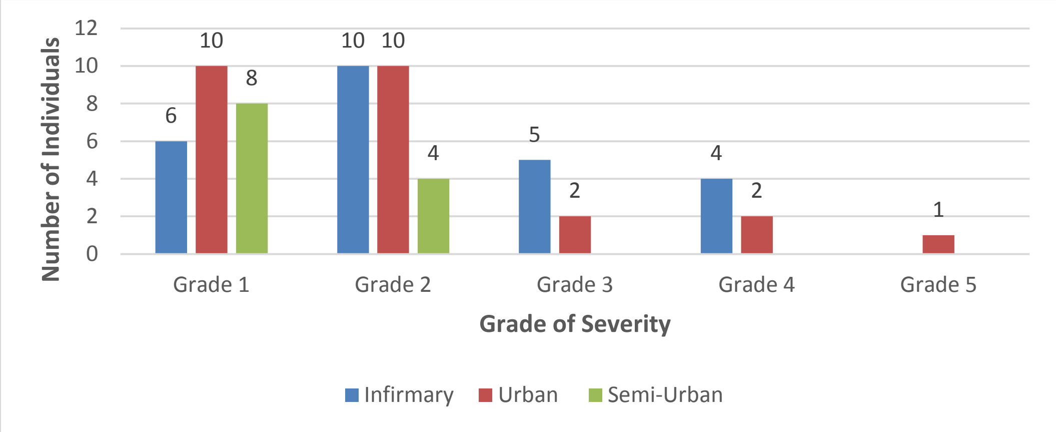

Figure 5.45: Severity of Cribra Orbitalia by site type

The TPR for cribra orbitalia was conducted from 365 orbits that were collected and 88 (24.9%) were assigned a sex (Table 5.37, Figure 5.45) while 92 (25.2%) were able to be assigned an age category (Table 5.37). The TPR indicated a non-significant difference between the semi-urban sexes. Meanwhile, the TPR in the urban males was significantly (X^2=4.70, p<.05 at 1 d.f.) greater than the Semi-urban males.

Table 5.37 True Prevalence rate of Cribra orbitalia by sex

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Male	23	21.1	109	20	33.3	60	4	12.5	32	47	23.4	201
Female	15	25.9	58	16	27.1	59	10	27.8	36	41	26.8	153
Total	**38**	**22.8**	**167**	**36**	**30.3**	**119**	**14**	**20.6**	**68**	**88**	**24.9**	**354**

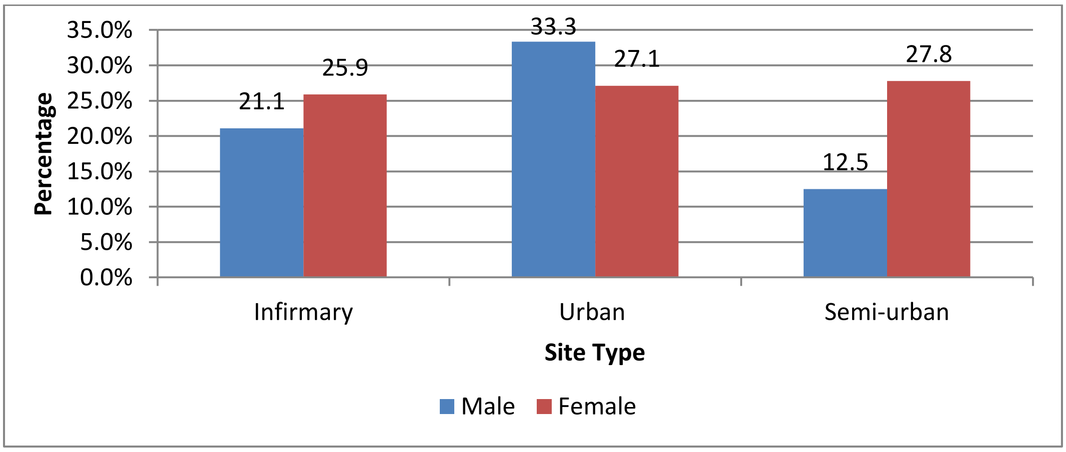

Figure 5.46: True prevalence rate of cribra orbitalia by sex

When the TPR is examined by age the results indicate that despite the large difference between the infirmary and urban 20-21.9 year olds there was no significant difference (Table, 5.38, Figure 5.46).

Table 5.38: True prevalence rate of Cribra Orbitalia by site type

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	9	34.6	26	15	48.4	31	5	16.1	31	29	33.0	88
14-16.9	5	19.2	26	3	8.6%	35	3	23.1	13	11	14.9	74
17-19.9	14	29.2	48	8	27.6	29	0	0.0	9	22	25.6	86
20-21.9	6	20.0	30	2	50.0	4	0	0.0	2	8	22.2	36
22-25	5	14.3	35	9	33.3	27	8	42.1	19	22	27.2	81
Total	**39**	**23.6**	**165**	**37**	**29.4**	**126**	**16**	**21.6**	**74**	**92**	**25.2**	**365**

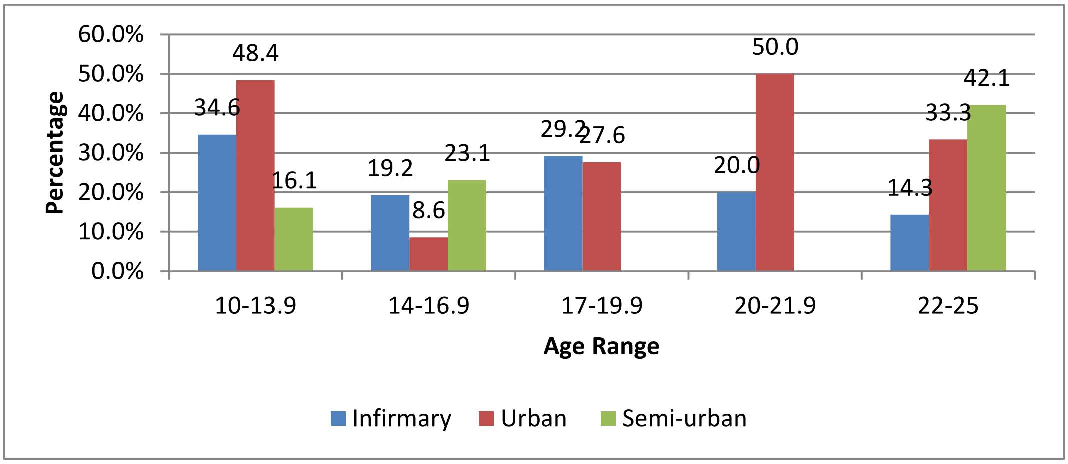

Figure 5.47: True prevalence rate of Cribra Orbitalia by site type

5.5.1.6.4 Porotic hyperostosis

All skeletons that contained porosity on the crania but did not have any further indicators of metabolic diseases or treponemal infections have been classified as having porotic hyperostosis. The number of individuals who had porotic hyperostosis throughout the total population was only 10 individuals (2.9% of pathological population). Additionally, 4 (40%) of the individuals found with porotic hyperostosis also had cribrous lesions. The distribution of porotic hyperostosis among the sample population had 3 individuals from infirmaries, 2 for urban sites, and 5 from semi-urban sites (Table 5.39). The three infirmary individuals and one of the semi-urban individuals were identified with cribra orbitalia.

Table 5.39: Crude prevalence of Porotic hyperostosis

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	0	0.0	22	0	0.0	32	1	2.4	41	1	1.1	95
14-16.9	0	0.0	35	0	0.0	32	0	0.0	21	0	0.0	88
17-19.9	1	1.8	55	0	0.0	47	2	9.5	21	3	2.4	123
20-21.9	1	4.3	23	1	6.7	15	0	0.0	10	2	4.2	48
22-25	1	3.7	27	1	2.9	35	2	9.1	22	4	4.8	84
Total	**3**	**1.9**	**162**	**2**	**1.2**	**161**	**5**	**4.3**	**115**	**10**	**2.3**	**438**

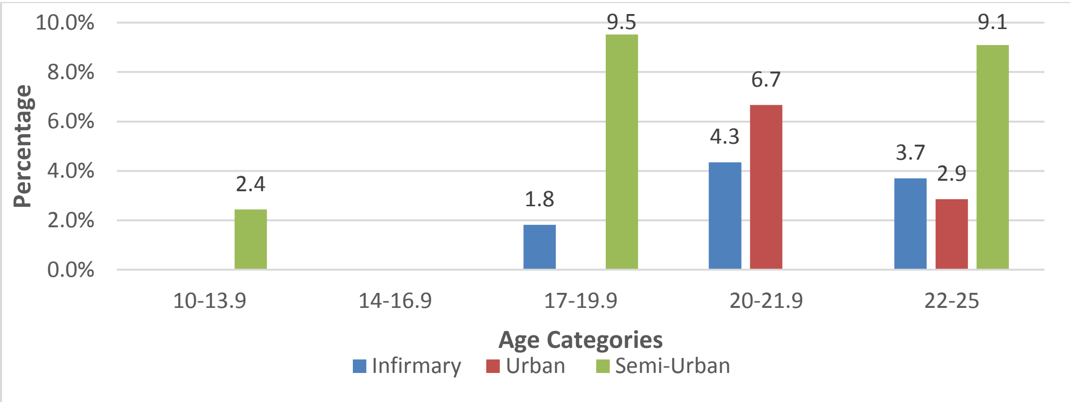

Figure 5.48: crude prevalence rate of porotic hyperostosis by age and site

5.5.1.7 Other Pathology

In the primary sample there were other diseases found such as, treponematosis, poliomyelitis, and neoplastic conditions. While treponematosis was present as well in the secondary sample, leprosy, spina bifida, and Scheuermann's disease were unique to the primary sample.

5.5.1.7.1 Treponematosis (Syphilis)

A total of 12 (3.4 %) individuals in the primary sample were identified as having treponematosis (Table 5.40, Figure 5.48). The 3 skeletons with a definitive differential diagnosis of venereal syphilis are highlighted. Given the long time that is required to develop pathognomonic lesions for venereal syphilis especially carries sicca it is unexpected to be present in adolescents. In the three cases in which carries sicca were present, each adolescent was over the age of 15 with the oldest in the 22-25 year age range. The 15 and 16 year old could potentially have contracted the disease as they were still growing.

Table 5.40: Treponematosis in the primary sample by age, sex, pubertal stage and site type

PR#	Site type	Sex	Age	Puberty	Assessment
9	Urban	2	16-16.9	3	Healed and active periosteal woven bone on the tibia, ulna, humerus, radius, clavicle, and scapula
36	Urban	1	22-25	6	Healed and active periosteal woven bone on the tibia, femora
56	Urban	1	22-25	5	Carries Sicca, osteomyelitis bone grown on both femurs, radius, ulna, tibia, and clavicle
96	Semi-Urban	4	10-10.9	1	Congenital syphilis, Mulberry molars and shovel incisors
102	Infirmary	2	20-21.9	6	Dense spiculated bone growth on the tibia, femora, ulna, radius, and scapula.
109	Infirmary	1	15-15.9	2	Caries Sicca
160	Infirmary	2	17-20	5	Congenital syphilis, Mulberry molars and shovel incisors, active visceral rib lesions
161	Infirmary	3	18-21	?	Congenital syphilis, Mulberry molars and shovel incisors, active visceral rib lesions
238	Semi-Urban	1	13-13.9	?	Healed and active periosteal woven bone on the tibia, ulna, humerus
258	Semi-Urban	4	17-19	4	Healed and active periosteal woven bone on the tibia, femora
311	Infirmary	1	16-16.9	3	Caries Sicca, periostitis on the scapula, manubrium ulna, radius, ilia
330	Infirmary	2	22-25	5	Dense spiculated bone growth on the tibia, femora, ulna, radius, and scapula

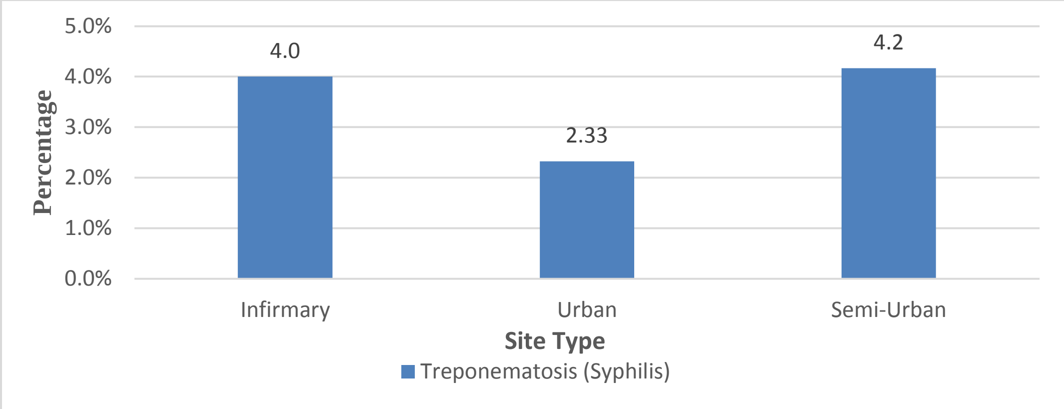

Figure 5.49: Percent of individuals with treponematosis in the primary sample

Of the 12 individuals affected, 2 (16.7%) were female. These two females were identified in the semi-urban context (Table 5.41). One of these females was diagnosed with congenital syphilis identified from Hutchinson's incisors and mulberry molars (Figure 5.50) while the other individual was identified with lesions symptomatic of contracted venereal syphilis that were present in the form of skeletal lesions throughout the long bones.

Figure 5.50: Hutchinson's incisors and Mulberry molars

Table 5.41: Sex and site type of adolescents with treponematosis

	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Male	6	5.7	106	3	3.4	87	1	3.1	32	10	4.4	225
Female	0	0.0	56	0	0.0	79	2	5.0	40	2	1.1	175
Total	**6**	**3.7**	**162**	**3**	**1.8**	**166**	**3**	**4.2**	**72**	**12**	**3.0**	**400**

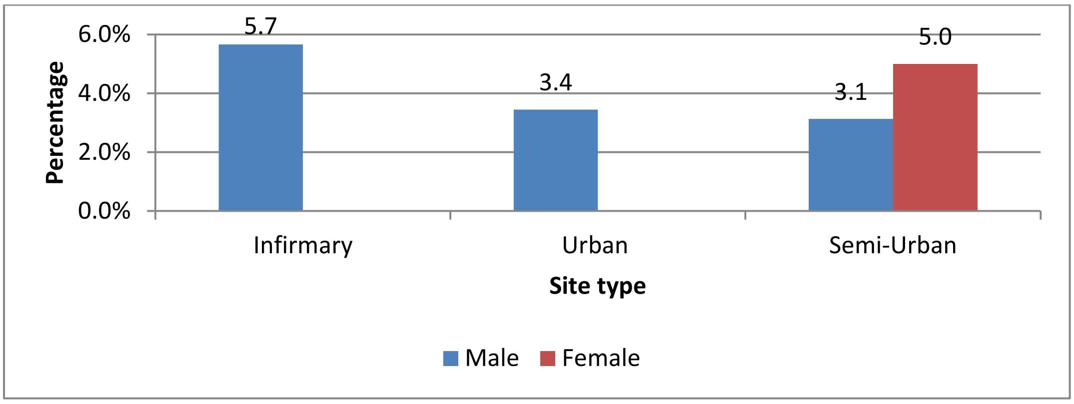

Figure 5.51 Sex and site type of adolescents with treponematosis

The age and site distribution of treponematosis among the primary sample indicated that the infirmary context had adolescents from all age groups except the 10-13.9 year age range and that despite the relatively large difference between the infirmary and urban 14-16.9 year olds this was not significant (Table 5.42, Figure 5.52). While there were only 3 adolescents with a definitive differential diagnosis of venereal syphilis it is of note that they were all males over the age of 15, which is unexpected at such a young age.

Table 5.42: Age and site type of adolescents with treponematosis

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	0	0.0	0	0	0.0	12	2	11.8	17	2	6.9	29
14-16.9	2	33.3	6	1	5.9	17	0	0.0	8	3	9.7	31
17-19.9	2	18.2	11	0	0.0	16	1	16.7	6	3	9.1	33
20-21.9	1	25.0	4	0	0.0	6	0	0.0	5	1	6.7	15
22-25	1	20.0	5	2	11.8	17	0	0.0	12	3	8.8	34
Total	**6**	**23.1**	**26**	**3**	**4.4**	**68**	**3**	**6.3**	**48**	**12**	**8.5**	**142**

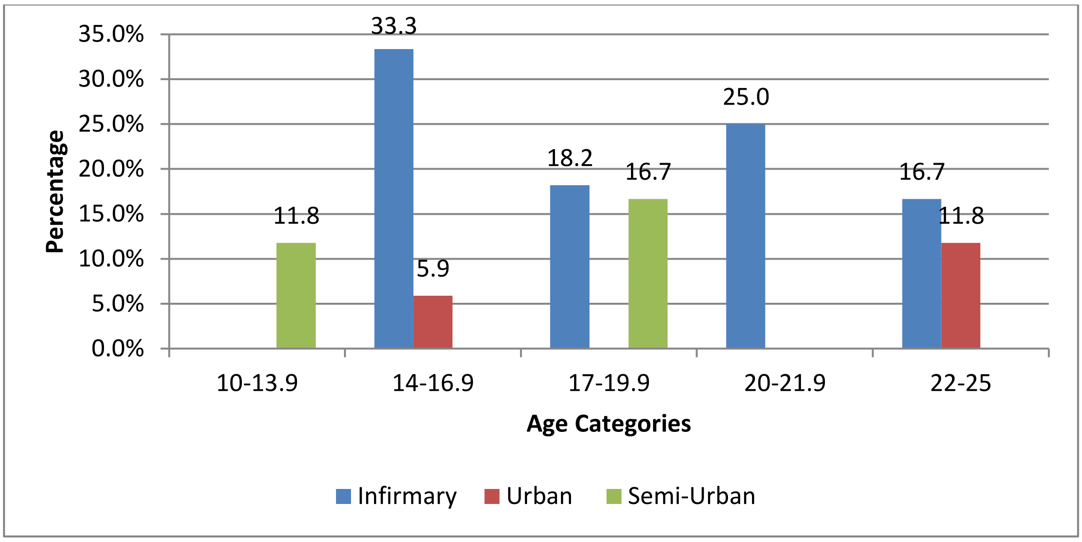

Figure 5.52: Age and site type of adolescents with treponematosis

5.5.1.7.2 Poliomyelitis

BH84 skeleton 1425 was identified as a 20 – 22 year old male in the completion phase of puberty. The skeleton was found with a possible case of poliomyelitis in which the right femur and tibia were highly gracile and atrophied. The extent of the atrophy can be seen both macroscopically (Figure 5.53) as well as in the radiograph in (Figure 5.54).

Figure 5.53: Atrophied right femur possibly indicative of polio

Figure 5.54: *Radiograph of the left and right femur*

5.5.1.7.3 Neoplastic conditions

In the Radcliffe infirmary there were several cases of neoplastic conditions, three of the most significant instances of the condition have been presented.

Figure 5.55: Male right rib with a large neoplastic bone growth

Figure 5.56: OXIB 4103- 18 year old female in the maturation phase with Metastatic blastic possibly non-Hodgkins lymphoma of the T10. (Ian Watts Pers com 2017)

Figure 5.57: Ewing sarcoma in the left ilia of a young adolescent male (11-14) who reached the acceleration phase of puberty

5.5.1.8 Trauma and Treatment

In the primary sample the number of adolescents with medical treatment was the highest in the infirmary context but the presence of trauma was the lowest. In contrast the urban contest was the exact opposite (Figure 5.58). The semi-urban sample was found with an even number of both trauma and treatment.

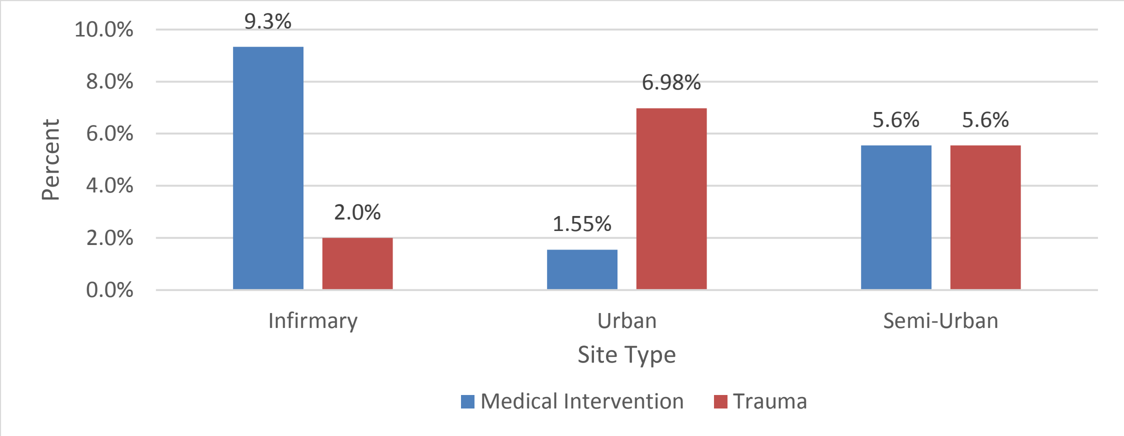

Figure 5.58: Percent of individuals with Trauma and Treatment

<u>5.5.1.8.1 Trauma</u>

In the primary sample 35 individuals were identified with some form of trauma. The sex distribution indicated that the majority of adolescents with trauma among all site types were male (60% in the Urban, 63.2% in the Infirmary, and 60.0% in the Semi-Urban). There was only 1 (2.9%) individual with trauma in the primary sample that was not assigned a sex. The sex distribution indicated that the infirmary had even levels of male and females with trauma. While the semi-urban context had the largest difference between the sexes, it was still not statistically significant. Of these individuals, the Urban context made up 10 (28.6%) of the population with 19 (52.3%) from the infirmary and 5 (14.3%) from the semi-urban contexts (Table 5.43). The semi-urban context only had individuals from the 17-19.9 year age range and the 22-25 year age range. The site distribution indicated that a majority of the adolescents with trauma were from the infirmary context (Figure 5.59).

Table 5.43: Crude prevalence rates of individuals with trauma by site type and age category

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	3	12.5	24	1	2.9	35	0	0.0	42	4	4.0	101
14-16.9	5	14.3	35	0	0.0	25	0	0.0	20	5	6.3	80
17-19.9	3	5.2	58	5	9.4	53	3	16.7	18	11	8.5	129
20-21.9	4	19.0	21	2	22.2	9	0	0.0	14	6	13.6	44
22-25	5	20.0	25	2	6.3	32	2	10.5	19	9	11.8	76
Total	**20**	11.6	**173**	**10**	6.5	**154**	**5**	4.4	**113**	**35**	**8.1**	**430**

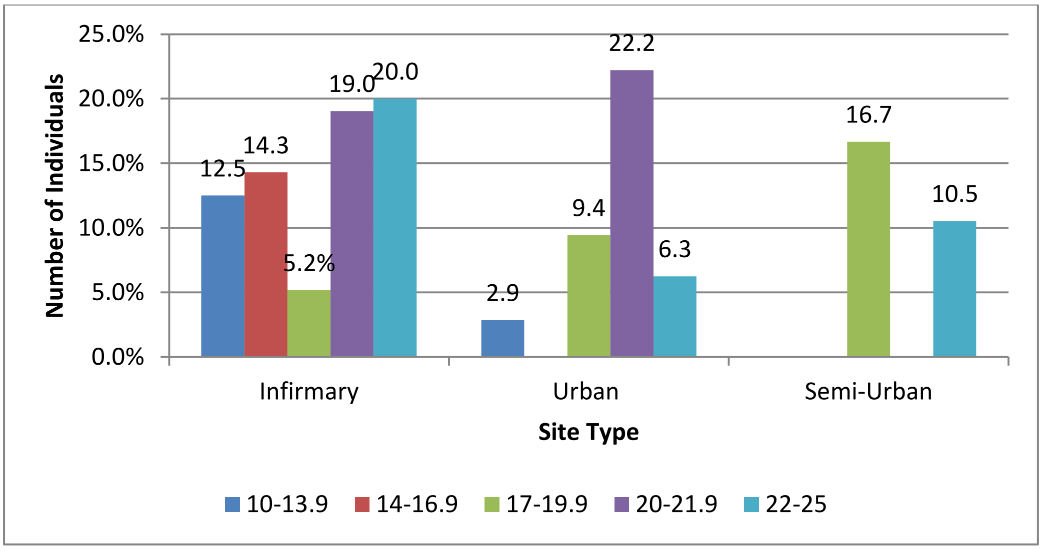

Figure 5.59: Crude percentage of individuals with trauma by site type and age category

The only trauma found in the Semi-Urban context was in the form of axial trauma such as vertebral and rib fractures. Axial trauma had the highest prevalence (n=27, 77.1%) among all traumas (Table 5.44, Figure 5.60).

Table 5.44: Trauma distribution in the primary sample by location and site type

Trauma Location	Infirmary		Urban		Semi-Urban		Total	
	n	%	n	%	n	%	n	%
Upper limbs	1	50.0	1	50.0	0	0.0	2	5.7
Lower limbs	5	83.3	1	16.7	0	0.0	6	17.1
Axial	14	51.9	8	29.6	5	18.5	27	77.1
Total N	**20**	57.1	**10**	28.6	**5**	14.3	35	100.0

% represents the percentage of individuals with the trauma out of the total found

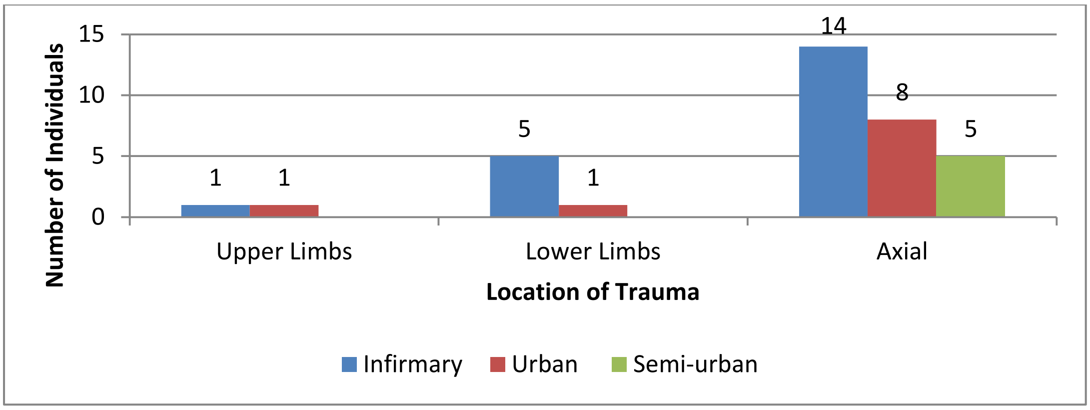

Figure 5.60: Distribution of trauma in the primary sample by location and site type.

<u>5.5.1.8.2 Treatment</u>

In the total primary sample 21 adolescents were identified with some form of medical intervention. Of 21 individuals identified, the majority 15 (71.4%) were from the infirmary context with only 3 (14.3%) from the semi-urban and 2 (9.5%) from the urban. There are some specific differences in the age distribution and sex of individuals found with medical intervention. In the entire primary sample only 3 (14.3%) females were identified with the rest of the sample being comprised of males (13, 61.9%) and indeterminate sex (3, 14.3%). This is partially due to the presence of the naval sailors but the 3 individuals from the naval hospital are only a small portion of the total infirmary sample (11 individuals).

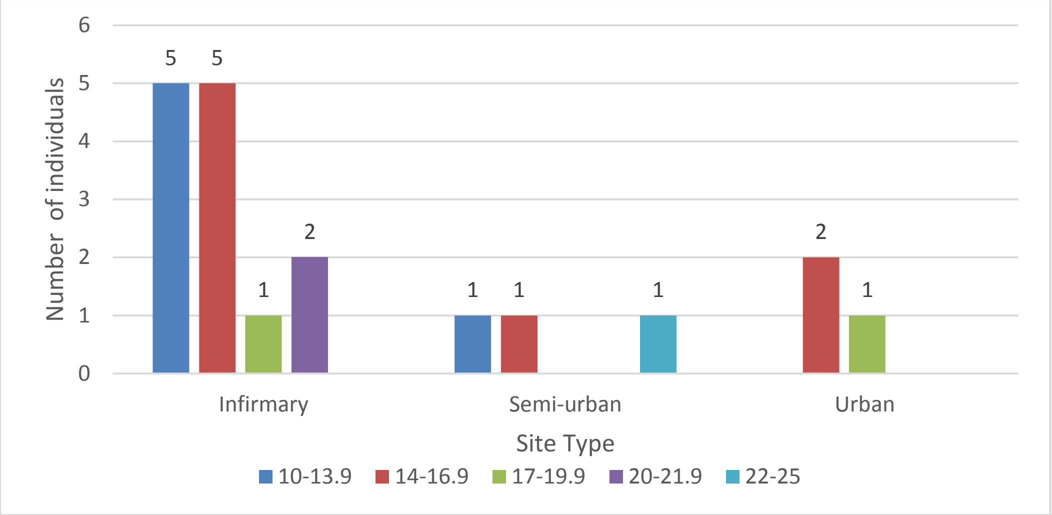

Figure 5.61: Ages of individuals with medical interventions by site type

The types of medical treatment found were a mixture of amputations (8, 38.1%), craniotomies (6, 28.6%), and cut marks.

5.5.2 Secondary Sample

Within the secondary sample, 323 (78.6%) out of the 411 individuals were recorded as having a pathology (Figure 5.60). Of these, 233 (72.1%) were from the London contexts and 90 (27.9%) were from Birmingham. In addition, Birmingham was the only location in which 100% of adolescents were reported as having some form of pathology (Figure 5.62). Non-specific stress was recorded in the presence of enamel hypoplasia and periosteal new bone formation. Unlike the primary sample, no vertebral measurements were recorded due to the relatively recent development of the techniques.

The prevalence of pathology was higher in the low status urban groups and this was statistically significant (X^2=7.41, p<.01 at 1 d.f.).

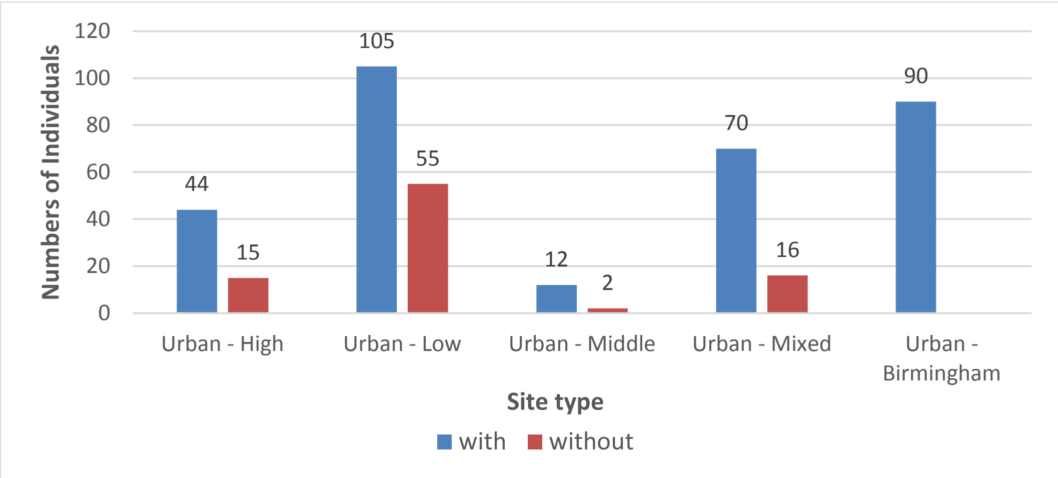

Figure 5.62: Number of individuals with and without pathology by site type

When the sexed individuals were analyzed, 36.5%% males and 31.7% females had pathology, but low status urban males had the highest percentage, and the middle-status males and females had the lowest rates (Figure 5.63) which is also likely due to the overall small number (n=14) of adolescents from that social group.

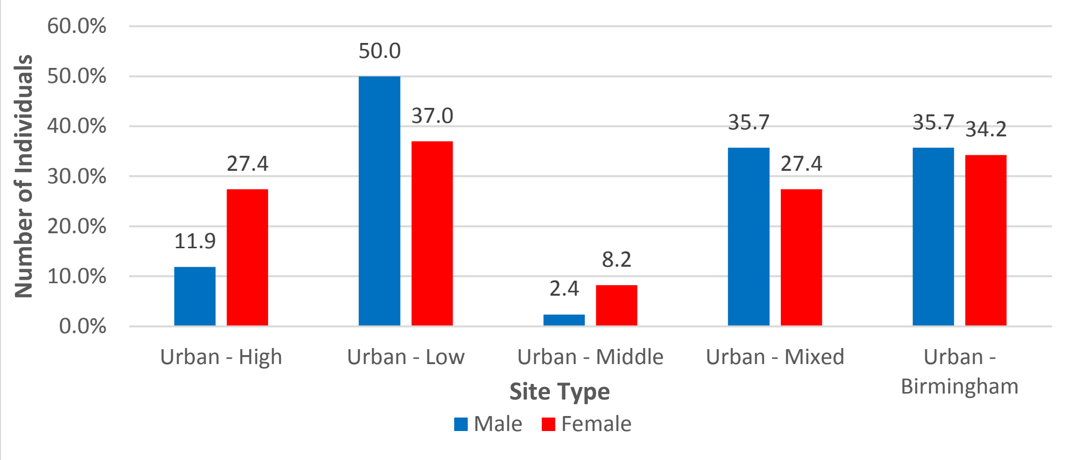

Figure 5.63: Percent of sexed individuals with pathologies by urban site type

5.5.2.1 Dental enamel hypoplasia

In the secondary sample, 54 (16.7%) of the 323 individuals with dentitions were reported to have enamel hypoplasia (Table 5.45). Of these, only 25 (46.3%) could be assigned a sex (14 males; 11 females). None of the adolescents from the high-status London sites were recorded as having enamel hypoplasia, while 44 individuals or 81.5% of the Birmingham group displayed them (Figure 5.62). The low and middle status London sites had nearly comparable prevalence rates. This may reflect widespread nutritional deficiencies in the Birmingham children that was not being experienced in London or may be an artefact of how these lesions were recorded.

Table 5.45: Prevalence of enamel hypoplasia, by sex and site type

	Low	%	Middle	%	Urban - Birmingham	%	Mixed	%
Male	2	3.7	0	0.0	12	22.2	0	0.0
Female	1	1.9	2	3.7	8	14.8	0	0.0
Indeterminate	2	3.7	2	3.7	24	44.4	1	1.9
Total	**5**	**9.3**	**4**	**7.4**	**44**	**81.5**	**1**	**1.9**

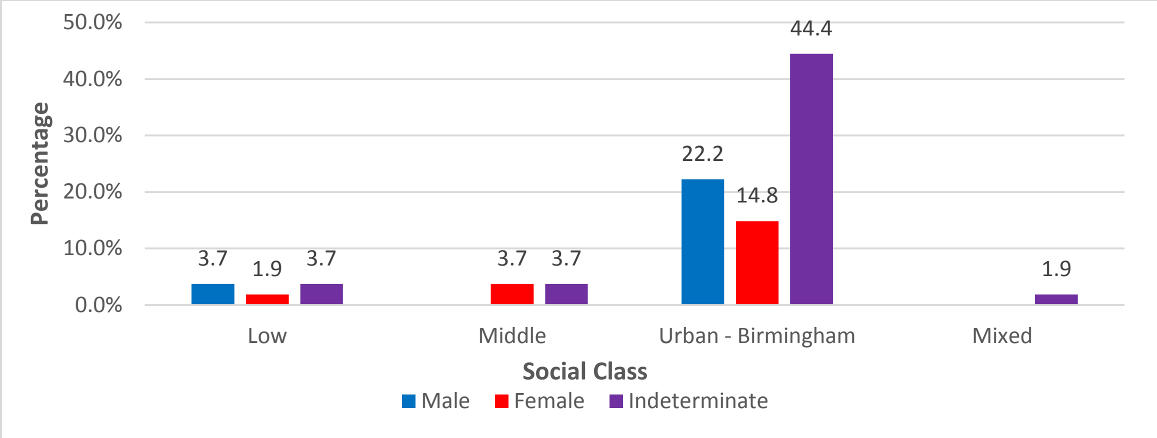

Figure 5.64: Prevalence of DEH by sex and site type

Despite the high number of individuals and prevalence rate of DEH from Birmingham in the secondary sample, the majority (n=24, 44.4%) were found to be in the 18-25 year age range (Table 5.46, Figure 5.65).

Table 5.46: Age and number of individuals with enamel hypoplasia

	Low	%	Middle	%	Birmingham	%	Mixed	%
10-11	0	0.0	0	0.0	6	11.1	0	0.0
12-17	2	3.7	2	3.7	14	25.9	1	1.9
18-25	3	5.6	2	3.7	24	44.4	0	0.0
Total	**5**	**9.3**	**4**	**7.4**	**44**	**81.5**	**1**	**1.9**

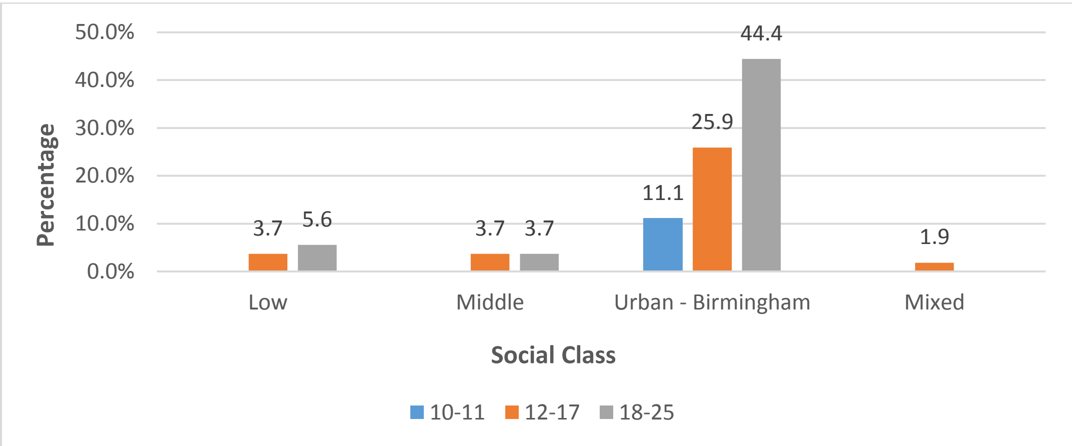

Figure 5.65: Age distribution enamel hypoplasia among site types

5.5.2.2. Endocranial lesions

Only 5 (1.5%) of the 323 individuals in the secondary sample were reported to have endocranial lesions. Lesions were recorded in all secondary site types except for the London middle-status group and in Birmingham.

5.5.2.3 Periosteal new bone formation

A total of 104 (32.2%) individuals were reported to have healed or active periosteal new bone formation. A sex was assigned to 73 (70.9%) of these. There were 41 (39.4%) males and 32 (30.8%) females with new bone formation (Figure 5.66) with an even distribution among the social classes.

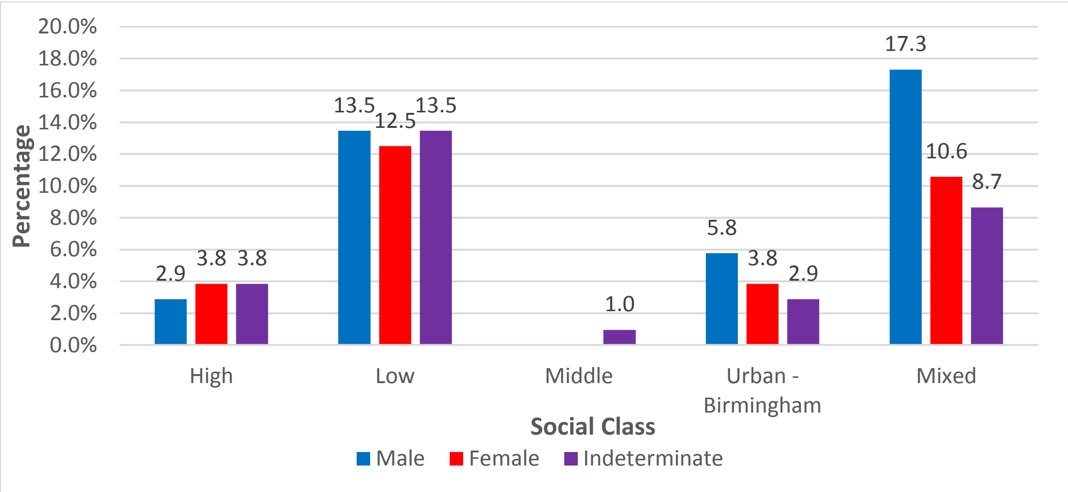

Figure 5.66: Sex and site distribution of individuals with new bone formation

When ageing, the majority (n=75; 72.1%) were in the 18-25 year age category, with 23 (22.1%) in the 12-17 year age range and the lowest number (6, 5.8%) of individuals with lesions were in the 10-11 year age range. All site types were recorded as having periosteal new bone formation but there was only one individual from the London middle context (Table 5.47).

Table 5.47: Age of individuals with new bone formation by site

Age	High	%	Low	%	Birm*	%	Middle	%	Mixed	%
10-11	3	2.9	0	0.0	1	1.0	0	0.0	2	1.9
12-17	1	1.0	12	11.5	0	0.0	3	2.9	7	6.7
18-25	7	6.7	29	27.9	0	0.0	10	9.6	29	27.9
Total	**11**	**10.6**	**41**	**39.4**	**1**	**1.0**	**13**	**12.5**	**38**	**36.5**

**Birmingham*

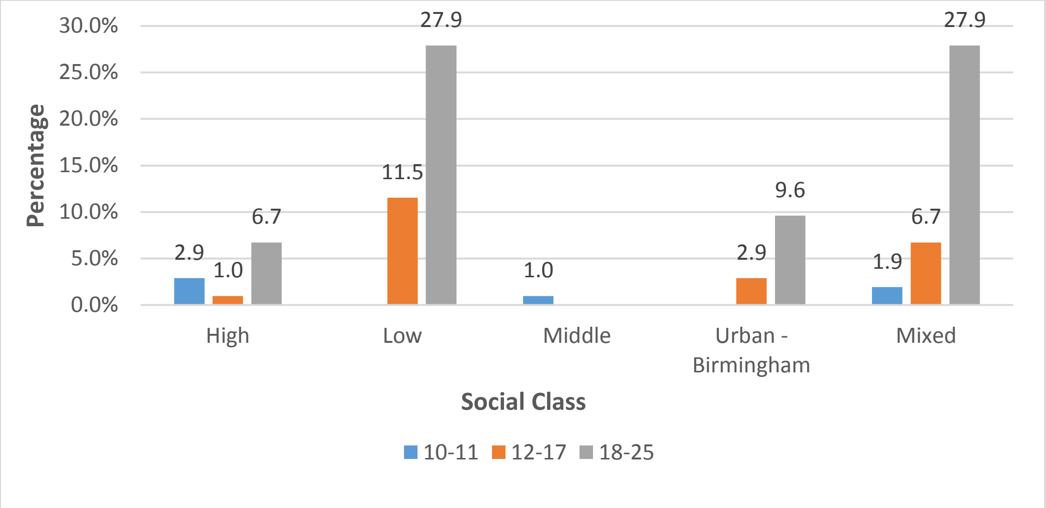

Figure 5.67: Age distribution of individuals with periosteal new bone formation

There was a higher prevalence (32.2%, n=104) of periosteal new bone growth in the secondary sample when compared to the primary study group (25%, n = 108). This may be the result of the secondary sample comprising only urban individuals.

5.5.2.4 Osteitis and osteomyelitis

There were 6 (1.9%) adolescents with osteitis, but only one case of osteomyelitis recorded. All of the adolescents with osteitis were in the 18-25 year age category while the one osteomyelitis case was aged 12-17 years. Four cases of osteitis and the osteomyelitis case came from low-status London, while 2 cases of osteitis were from Birmingham.

5.5.2.5 Respiratory infections

In the secondary sample 6 (1.9%) of the 323 individuals with pathology were identified with lesions in the maxillary sinus. Of the identified individuals 4 were able to be sexed with 3 females, 1 male, while 2 were of an indeterminate sex. Two of the cases were from the high context while 2 were from the Birmingham context with the last 2 from the mixed context (Table 5.48). Only one of the individuals with maxillary sinusitis, who was from the high context, was found to have visceral rib lesions and no other indicators of tuberculosis.

Table 5.48: Age distribution of Maxillary sinusitis

	High	%	Middle	%	Birmingham	%	Mixed	%
10-11	0	0.0	0	0.0	0	0.0	0	0.0
12-17	1	16.7	0	0.0	0	0.0	1	16.7
18-25	1	16.7	1	16.7	1	16.7	1	16.7
Total	**2**	**33.3**	**1**	**16.7**	**1**	**16.7**	**2**	**33.3**

In contrast to the primary sample there was a significantly (X^2=5.25, p<.05 at 1 d.f.) lower presence of maxillary sinusitis in the secondary sample. Birmingham had the highest crude prevalence rates of infection overall (27.8%), particularly for visceral rib lesions (21%), with maxillary sinusitis being most prevalent in the middle status urban sites (8.3%). Caution is needed when interpreting these results, as not all sites would have been examined for pathology to the same degree.

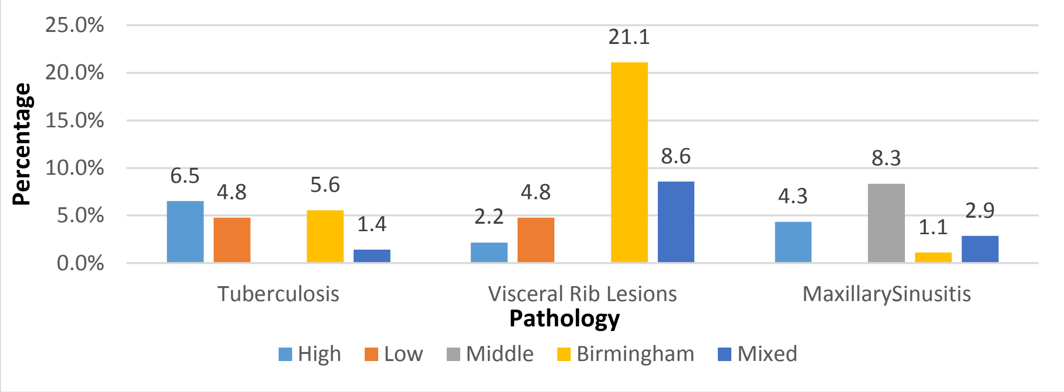

Figure 5.68 Percent of individuals with respiratory infections

There were 31 (9.6%) of the 323 individuals with pathology with visceral rib lesions. Sex was able to be assigned to 23 (69.9%) of the identified individuals with 13 (39.4%) males and 10 (30.3%) females recorded with 9 (27.3%) unsexed individuals.

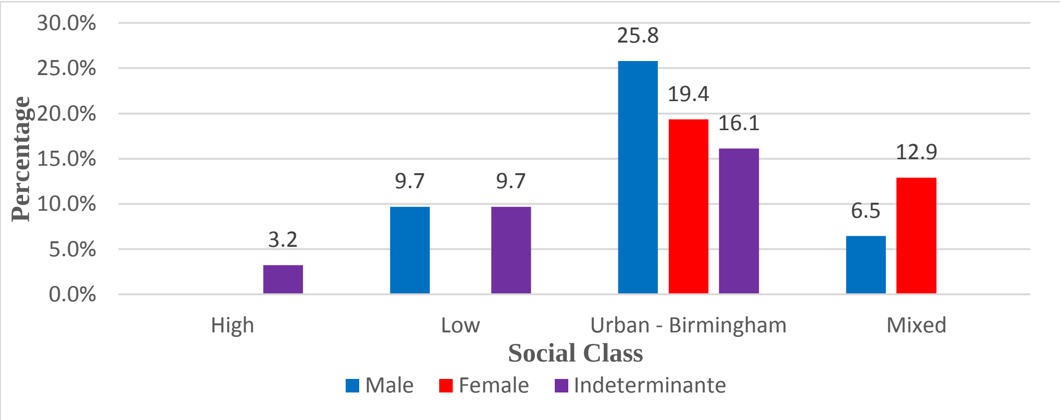

Figure 5.69: Sex distribution of adolescents with visceral rib lesions

While there were no instances of visceral rib lesions in the middle context the majority (19, 61.3%) of adolescents were found to be from the Birmingham context. The 19 adolescents represented 21.1% of the Birmingham sample that had visceral rib lesions and is possibly an indicator of chronic respiratory infections. Of the Birmingham adolescents with visceral rib lesions, 28.2% more were in the 18-25 year age range (Figure 5.70).

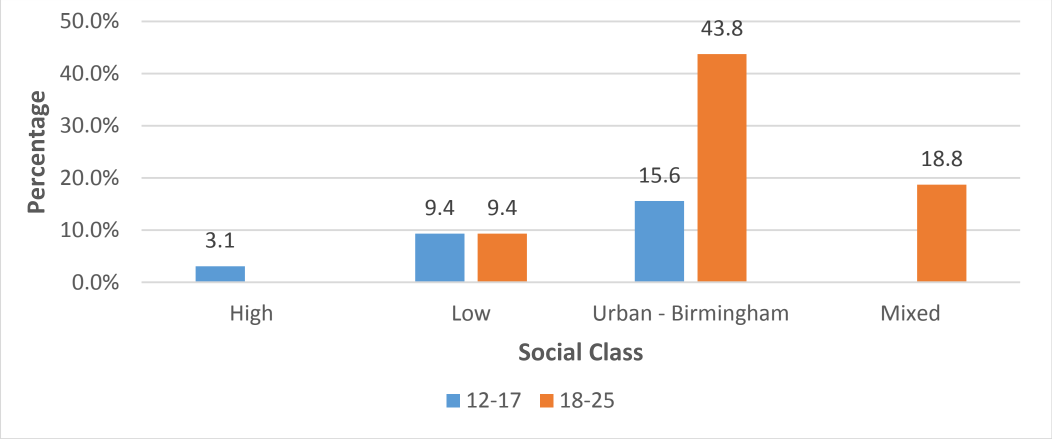

Figure 5.70: Age distribution by social class of visceral rib lesions

5.4.2.7 Tuberculosis

In the secondary sample 15 (4.6%) of the 323 individuals with pathology were found with skeletal changes indicative of tuberculosis. The sex distribution was 9 males and 4 females with one indeterminate individual being found.

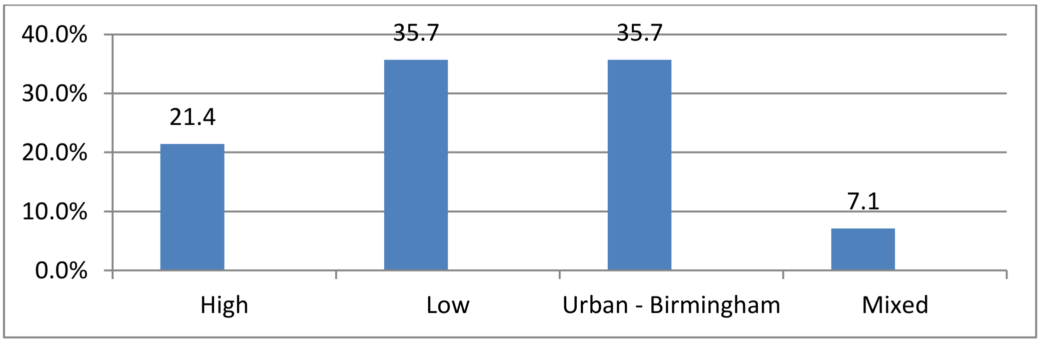

Figure 5.71: Percentage distribution of tuberculosis among site types

All but one (14) individuals were found to be in the 18 – 25 age range while the other individual was in the 12-17 age range, specifically 16-17 years of age. Individuals with evidence of tuberculosis were recorded in all secondary site contexts except the middle status sites. The two largest were each 5 (35.7%) adolescents in the Low and Birmingham contexts indicating that there were similarities in the percentage and number of individuals contracting tuberculosis both in impoverished London settings as well as in Birmingham. Additionally the high status London context had 3 (21.4%) individuals identified possibly indicating that despite social status the presence of tuberculosis in dense urban settings was prevalent.

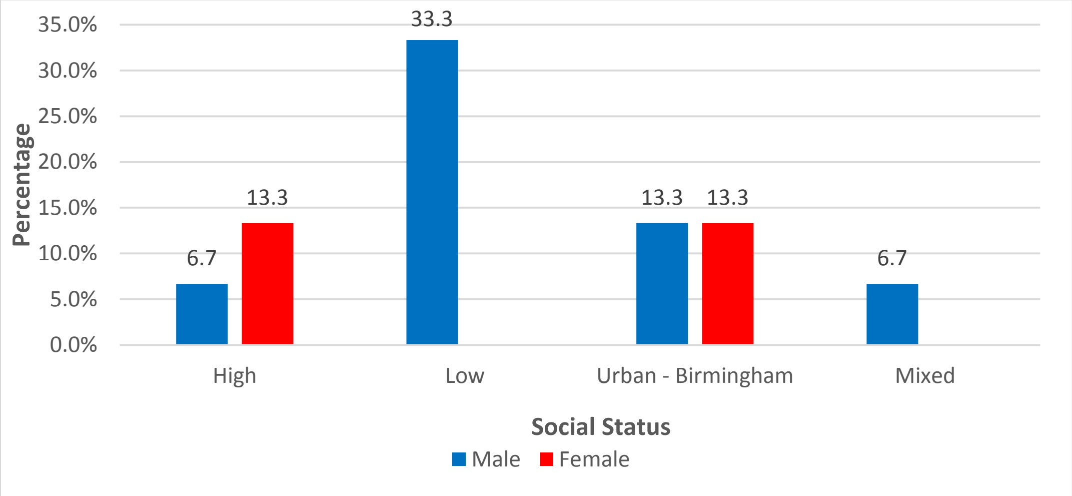

Figure 5.72: Sex of individuals with Tuberculosis

5.4.2.6 Metabolic and blood disorders

Overall in the secondary sample there was relatively little scurvy recorded with the high status context having the most (4.3%) (Figure 5.73)The presence of metabolic and blood disorders indicated that cribra orbitalia was present in a large percentage of all site types other than Birmingham. The presence of rickets in the Secondary population was highest in the middle status context.

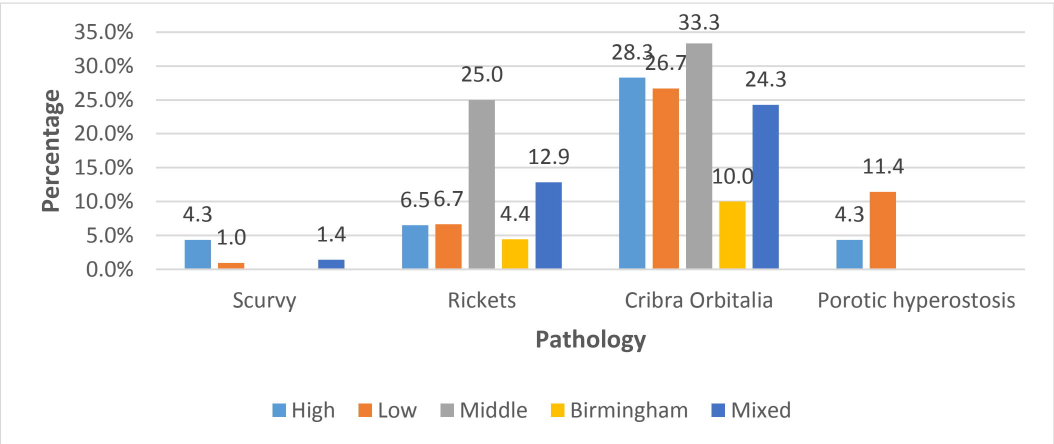

Figure 5.73: Percent of individuals with metabolic and haematological disease

Vitamin C Deficiency (Scurvy)

Only 4 individuals from the secondary sample were found with lesions indicative of vitamin C deficiency. The majority (3) of the scorbutic individuals were unable to be sexed with only a single male identified. The three unsexed individuals were all in the 12-17 year age range with one being aged at 15. The site distribution of scurvy indicated that half of the individuals identified were from the High status sites with one from the Low and one from the Mixed.

Vitamin D deficiency (Rickets)

26 (8%) of the 323 individuals with pathology from the secondary sample had active or residual rickets. Of the 26 rachitic individuals 11 were sexed as male, 4 sexed as females, with 11 being indeterminate. 9 of the indeterminately sexed individuals were in the age range of 12 – 17 while only 2 were in the 18 – 25 age range (Table 5.49).

Table 5.49: Sex of individuals with rickets

	High	**%**	**Low**	**%**	**Middle**	**%**	**Birm**	**%**	**Mixed**	**%**
Male	1	3.8	2	7.7	1	3.8	1	3.8	6	23.1
Female	0	0.0	1	3.8	1	3.8	0	0.0	2	7.7
Indeterminate	2	7.7	4	15.4	1	3.8	3	11.5	1	3.8
Total	**3**	**11.5**	**7**	**26.9**	**3**	**11.5**	**4**	**15.4**	**9**	**34.6**

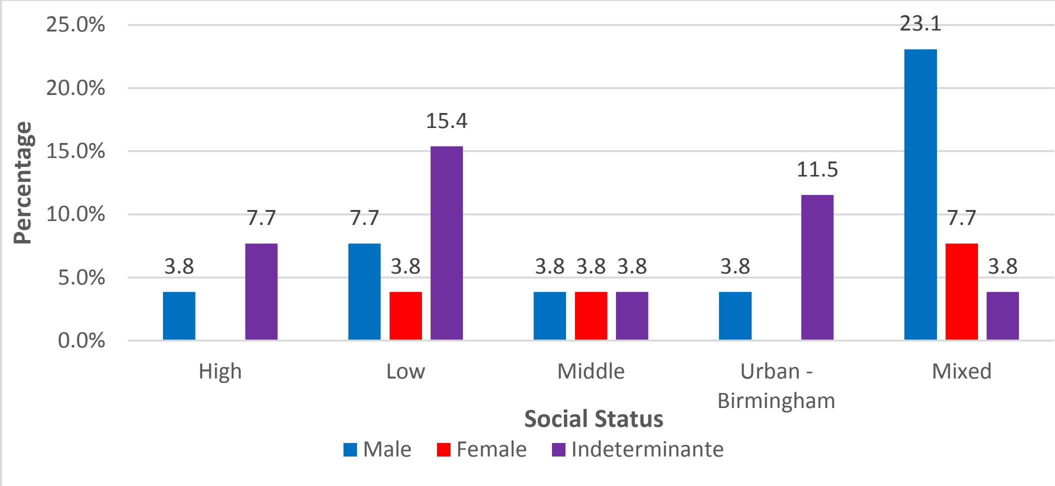

Figure 5.74 Sex distribution by site type of rickets

All secondary site types had the presence of rickets with the majority (9, 34.6%) of the individuals coming from mixed contexts though it should be noted that the incidence at Low social status sites was also very high at (7, 26.9%). This is in contrast to the 3 (11.5%) from the high and middle London context and 4 (15.4%) from the Birmingham context (Table 5.50, Figure 5.75).

Table 5.50: Age distribution of rickets

	High	%	Low	%	Middle	%	Birm*	%	Mixed	%
10-11	1	3.8	0	0.0	0	0.0	0	0.0	0	0.0
12-17	1	3.8	4	15.4	1	3.8	0	0.0	1	3.8
18-25	1	3.8	3	11.5	2	7.7	4	15.4	8	30.8
Total	**3**	**11.5**	**7**	**26.9**	**3**	**11.5**	**4**	**15.4**	**9**	**34.6**

**Birmingham*

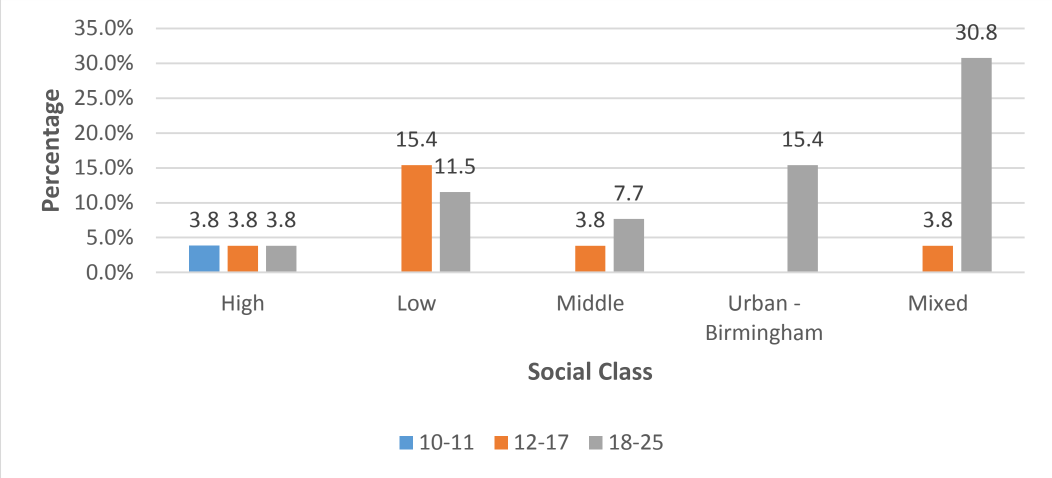

Figure 5.75: Age distribution by social class of rickets

There were 71 (22%) individuals with cribrous lesions found in the secondary sample and all site types were included. Of these there were 16 (22.5%) males and 21 (29.6%) females sexed (Figure 5.74). The majority, 34 adolescents (47.9%) were unable to be assigned a sex.

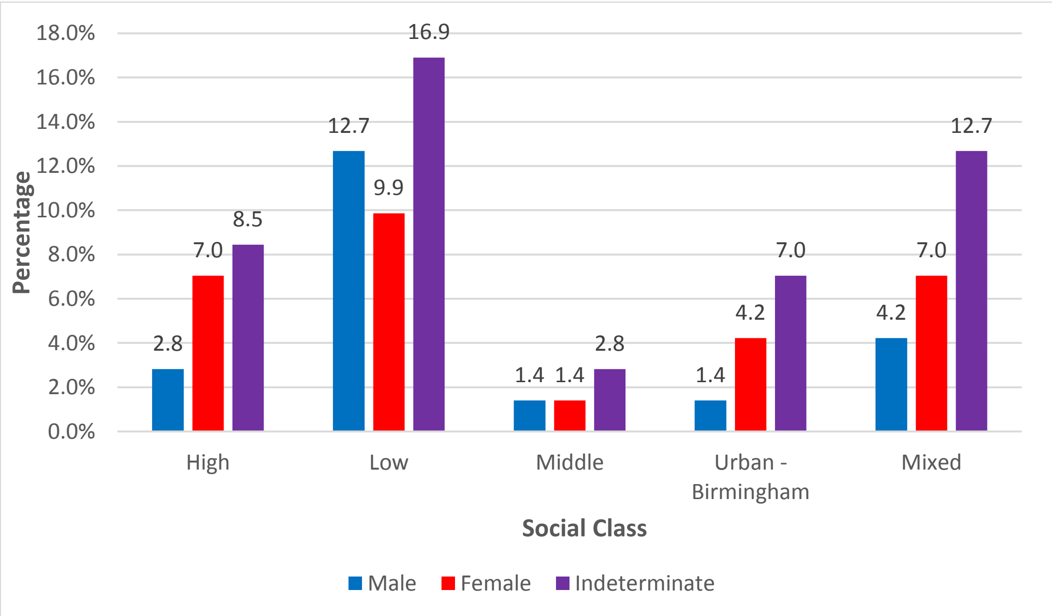

Figure 5.76: Percentage of individuals based upon sex

The age distribution of cribra orbitalia indicates a large percentage (39.4%) were from the Low status contexts (Figure 5.77).

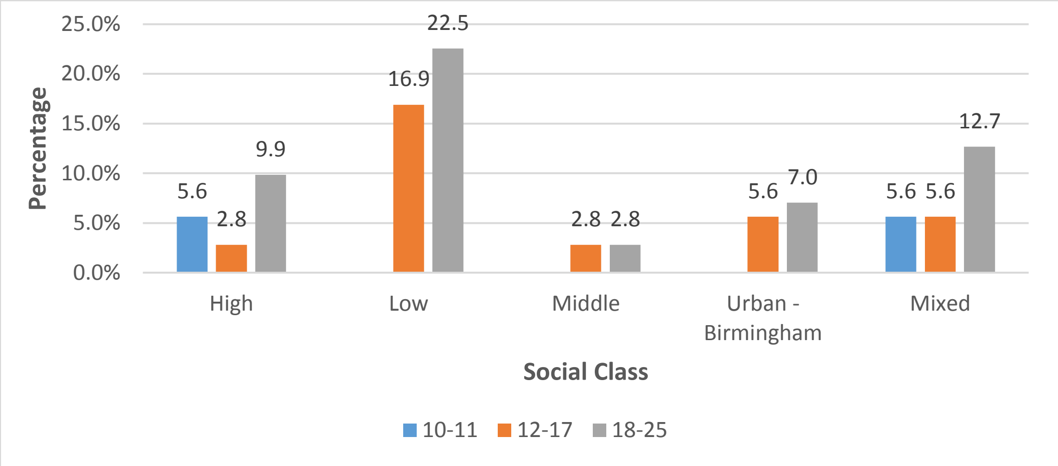

Figure 5.77: Age distribution of adolescents with cribra orbitalia

The majority (51, 71.8%) of the grades for cribrous lesions were grade 1 and 2 (table 5.49, Figure 5.76) with 17 (23.9%) being from the third grade. The lower severity would not often been described as pathological for the majority of the cribrous population. In the first and second grades all secondary site types were present unlike in the upper grades which consisted of only the low, middle and mixed contexts for the third grade (Table 5.51). This third grade comprised of 13 (18.3%) of the total cribrous sample and in addition to being the largest context with the lesions was also statistically significant in the third grade. The fourth and fifth grades were much smaller with only 2 individuals present in grade four and 1 in grade 5 (Figure 5.78).

Table 5.51: Grade of individuals with cribrous lesions

Grade	High	Low	Middle	Birmingham	Mixed	Total
Grade 1	7	7	2	4	6	26
Grade 2	5	7	4	4	5	25
Grade 3	0	13	1	0	3	17
Grade 4	0	1	0	0	1	2
Grade 5	1	0	0	0	0	1
Total	**13**	**28**	**7**	**8**	**15**	71

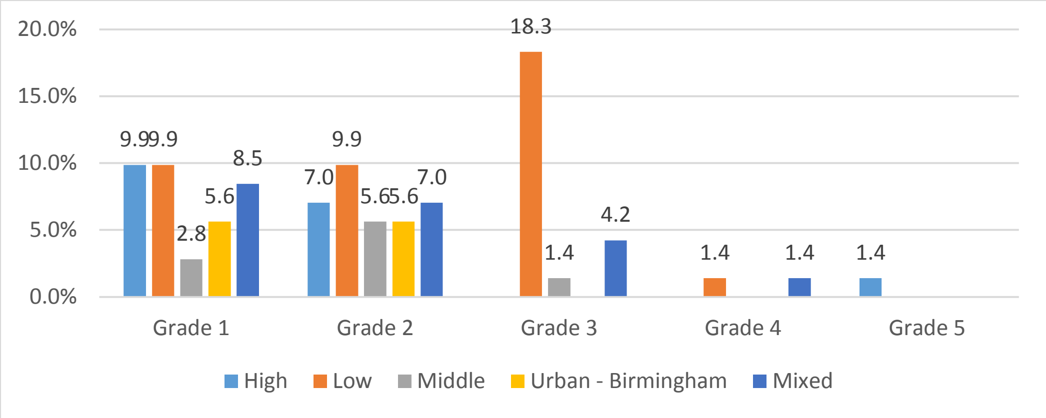

Figure 5.78: site distribution by grade of cribra orbitalia

Porotic hyperostosis

14 (4.3%) of the 323 individuals were recorded as having porotic hyperostosis. There were 8 males and 4 females sexed with 2 unsexed individuals. The 2 unsexed individuals were recorded as being in the 12-17 age range. Of the 14 cases of Porotic hyperostosis 9 (64.3%) of them were recorded in conjunction with cribrous lesions and only 5 were identified without them.

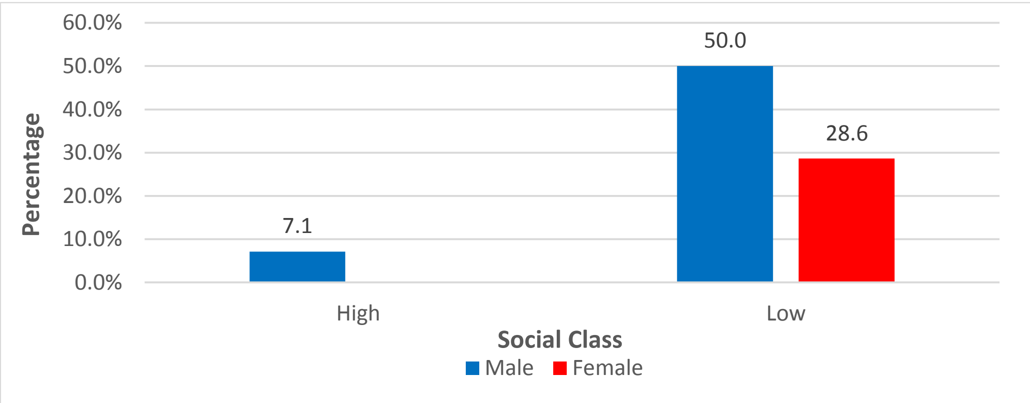

Figure 5.79: Percentage of porotic hyperostosis by sex

The vast majority (12, 85.7%) of adolescents with porotic hyperostosis were from the low status London context. Meanwhile the 2 other individuals were from the high status London context.

5.4.2.7 Other infections

In the secondary sample in addition to treponematosis, osteitis, and osteomyelitis there was recorded evidence of leprosy, spina biffida occulta, and Scheuermann's disease.

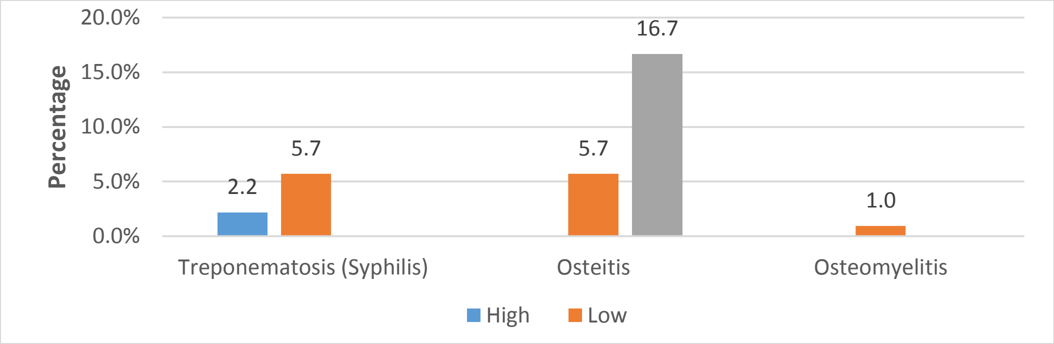

Figure 5.80: Percent of individuals with other infectious disease indicators

Treponematosis (Syphilis)

Treponemal lesions were identified in 8 (2.5%) of the 323 individuals with pathology. The sex distribution of the population indicates 3 males, 3 females and 2 indeterminate individuals had treponemal disease. The site distribution indicated that the majority (5, 87.5%) of cases of syphilis were found in the low status sites with the single additional case being from a high status site (Figure 5.81). In addition there was no evidence of treponematosis outside of London in the secondary sample.

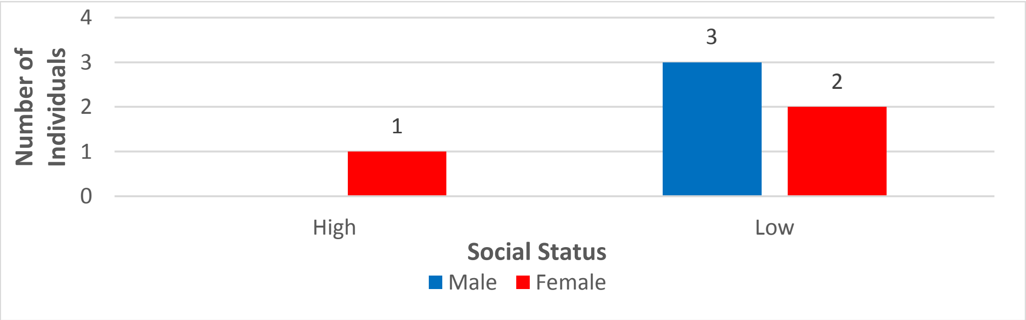

Figure 5.81: Sex of individuals with treponematosis

5.3.5.4 Leprosy

There was one recorded individual with leprosy in the secondary context. This male was aged to be in the 18 – 25 year category and identified from a high status London context. The leprosy was diagnosed from the resorption of the right 5th metacarpal & 4th right proximal hand phalanx. Additionally there was, resorption of anterior maxillary alveolar bone and anterior projection of anterior teeth, leading to severe under-bite

5.3.5.5 Spina Bifida

There were three individuals that were identified with complete non-union of the neural arch diagnosed as Spina Bifida Occulta. All three individuals were from low status London sites with one being aged as female and the other two indeterminate. The female was in the 18-25 age categories with spondylolysis and non-specific periostitis, while the other two were in the 12 -17 age range. One of the unsexed adolescents was also found to rickets while the other had no additional pathology identified.

5.3.5.6 Scheuermann's Disease

There were two recorded cases of Scheuermann's disease from the London low status urban context and the urban Birmingham context. The male 18-25 year old was recorded as having Scheuermann's disease in the mid- lower thoracic vertebrae with anterior extension and wedging to the bodies of T7-8. Additionally, the anterior and inferior portions of the disks appear herniated with the presence of large Schmorl's nodes.

The unsexed 13-14 year old adolescent from the Birmingham urban context was reported with Scheuermann's disease that affected the thoracic vertebrae. There was also periostitis affecting the ribs, serpens endocrania symmetrica or raised inter-cranial pressure and cox valga affecting the right femur.

5.4.2.8 Trauma and treatment

The presence of trauma in the secondary sample consisted of 58 individuals with trauma and 11 individuals with some form of medical treatment. No adolescents from the middle status London context were found with either trauma or treatment. The mixed status context had the highest rate of trauma recorded (Figure 5.82). The low status context while having a higher percentage than the high status context was not significantly.

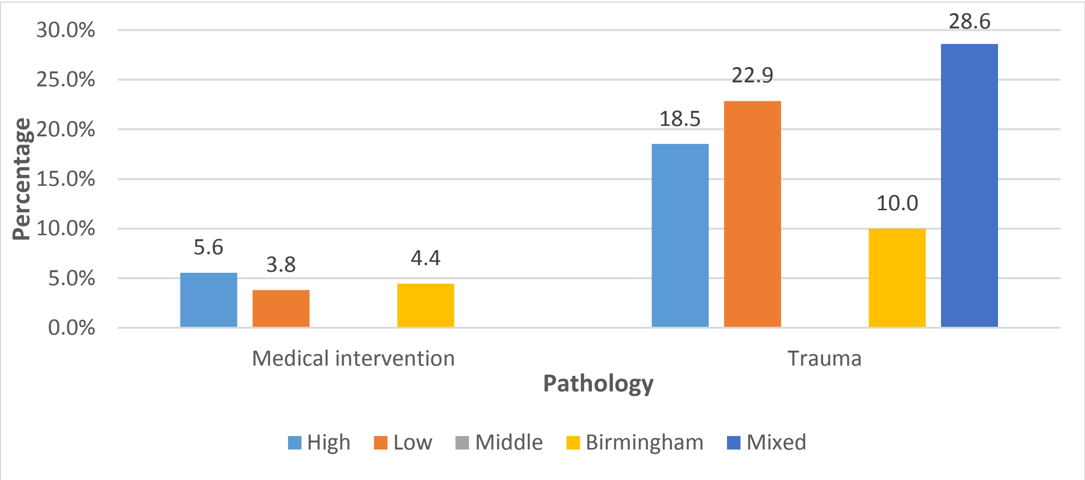

Figure 5.82: Percent of individuals with trauma and treatment

Trauma

In the secondary sample 58 (18.0%) adolescents were identified with some form of trauma. A sex was able to be assigned to 47 (75.9%) adolescents with 32 (55.1%) males and 12 (20.1%) females. The majority (14, 24.1%) of these males were from the low status London context (Figure 5.83).

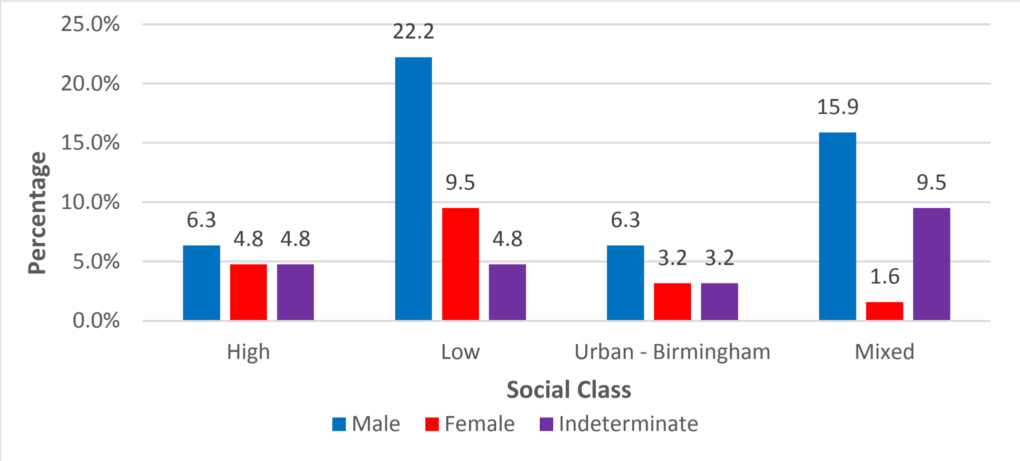

Figure 5.83: Sex distribution of trauma in the secondary sample

The age distribution indicated that the majority of the secondary sample population with trauma were from 18-25 year olds from the Low (20, 31.7%) and mixed (17, 27.0%) contexts. The Birmingham context had the lowest amount of trauma throughout the secondary sites (Figure 5.884) while there was no presence of trauma in the middle status London context. It should be noted that there were only 2 (3.3%) difference between the Birmingham and high status London contexts.

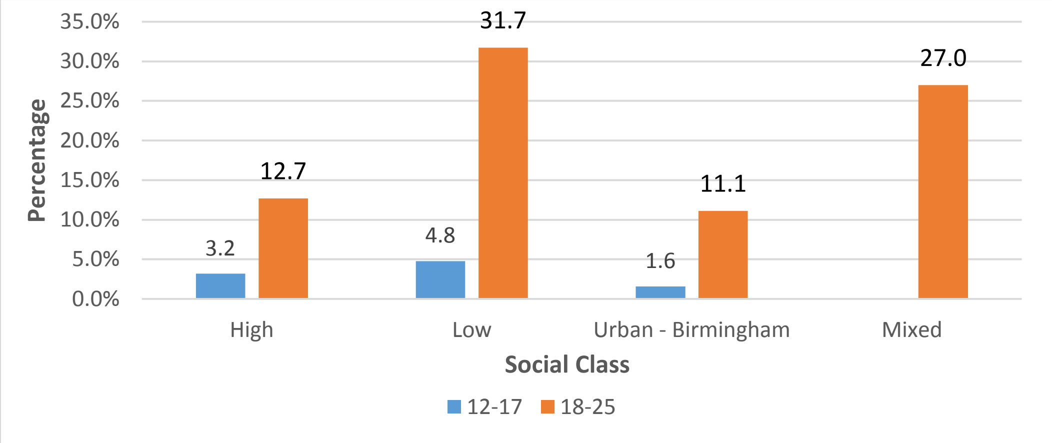

Figure 5.84: Age distribution of trauma in the Secondary Sample

In the secondary population the vertebral category of trauma had the highest crude prevalence rate (n=21, 34.4%) (Table 5.52, Figure 5.85). In contrast to the primary sample, the presence of trauma in the upper limbs was higher. Additionally, the presence of facial trauma in the form of healed septum fractures was not present in the primary sample.

Table 5.52: Distribution of trauma in the secondary sample by location and social status

Trauma Location	High		Low		Mixed		Birmingham		Total	
	n	%	n	%	n	%	n	%	n	%
Upper limbs	2	20.0	1	10.0	5	50.0	2	20.0	10	16.4
Lower limbs	2	16.7	6	50.0	4	33.3	0	0.0	12	19.7
Axial	6	15.4	17	43.6	10	25.6	6	15.4	39	63.9
Total N	10		24		19		8		61	

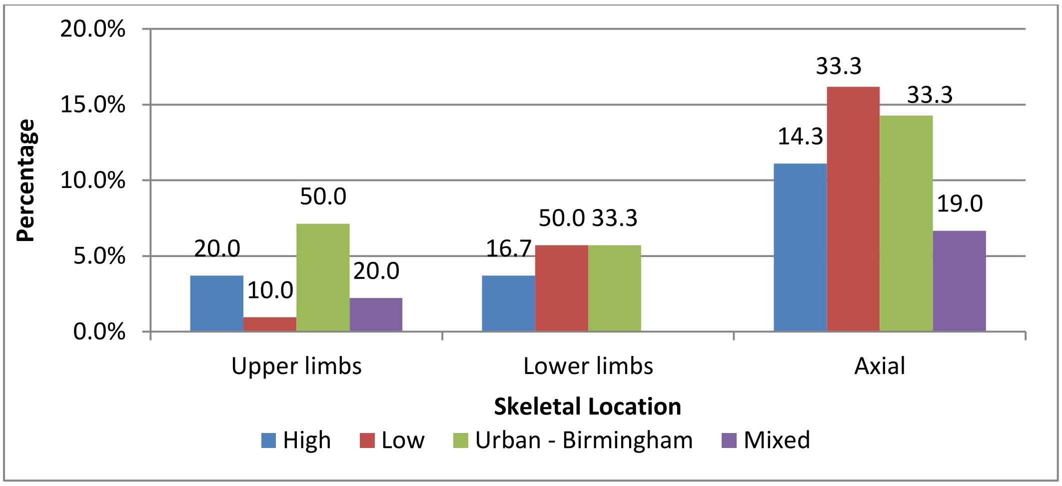

Figure 5.85: Distribution of trauma in the secondary sample by location and social status

Treatment

In the secondary sample 11 (3.4%) individuals were recorded as having some form of medical intervention in the secondary sample. Of these 11 individuals 5 (45.5%) were sexed as male, 2 (18.2%) as female and 4 (36.4%) were unsexed. The majority (4, 36.4%) of the medical interventions were from the Low status context.

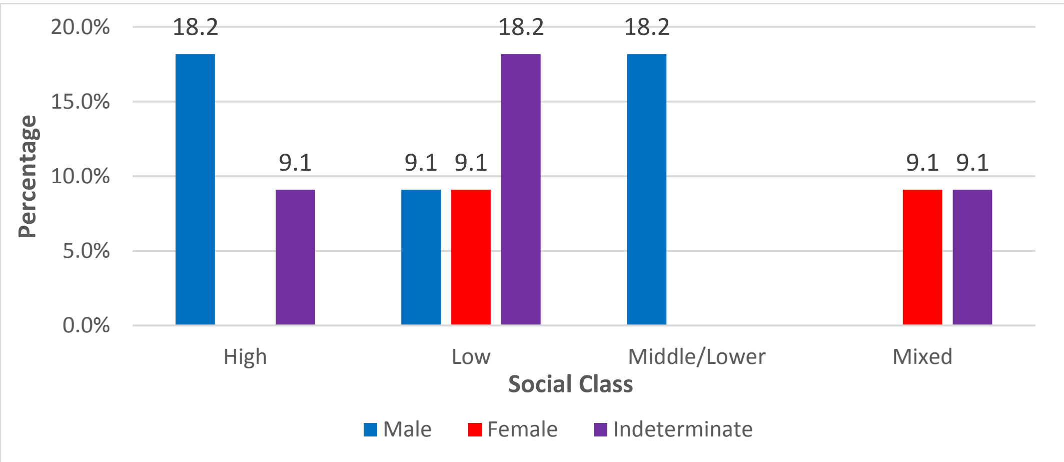

Figure 5.86: Sex distribution of Medical interventions in the secondary sample

9 of the medical interventions recorded were craniotomies with one being a possible craniotomy and the other being an amputation. The amputation was from

an 18-25 year old male from the high status context that was identified with the only case of leprosy in the secondary sample.

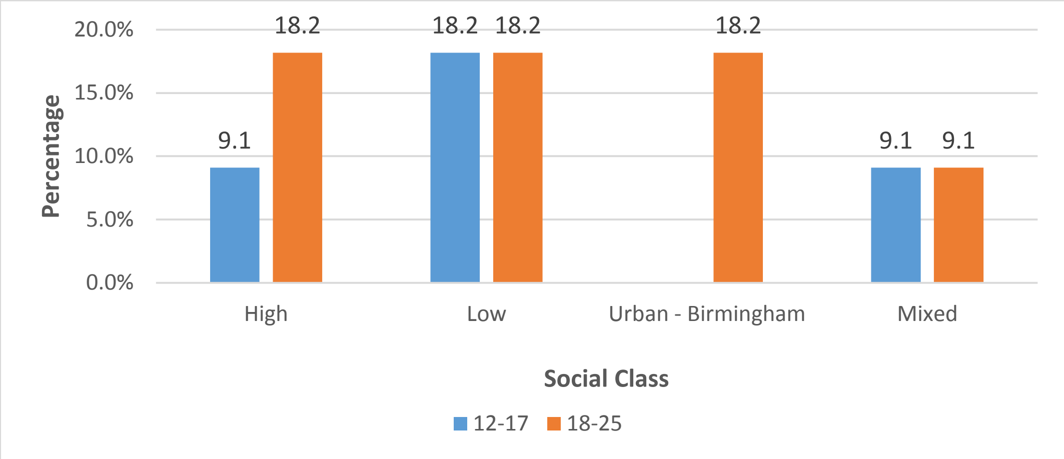

Figure 5.87: Age distribution of medical intervention in the secondary sample

Chapter 6 : Result Part 2: Puberty Assessment

6.1 THE STUDY SAMPLE

Only sexed individuals who could be aged by dental development and/or independent skeletal features were included in the puberty sample. Of the 460 individuals in the primary sample, 364 (79.1%) were assigned a puberty stage (Table 6.1, Figure 6.1). Of these, 298 (81.9%) were assigned a mean dental age (166 males; 129 females) and could be examined in more detail (Table 6.2, Figure 6.1). Seven sexed individuals (1.9%) were excluded as they could not be assigned an independent age category due to a lack of skeletal elements. The 22-25 age range had the largest total number (n= 73, 22.1%) of individuals in the sample with the 20-21.9 age range consisting of 40 (12.1%) individuals. Small numbers meant that it was not possible to explore pubertal stage attainment by site type, but individuals from particular site contexts are highlighted where possible.

Table 6.1: Total puberty sample by sex and age category

Age, Sex and Site type	Infirmary			Urban			Semi-Urban			Total		
	M	**F**	**I**	**M**	**F**	**I**	**M**	**F**	**I**	**M**	**F**	**I**
10-13.9	16	2	1	14	11	1	11	14	2	41	27	4
14-16.9	18	7	0	11	13	3	7	9	2	36	29	5
17-19.9	29	12	2	12	24	5	5	11	0	46	47	7
20-21.9	14	8	0	8	3	0	4	4	0	26	15	0
22-25	11	12	1	18	12	0	10	10	0	39	34	1
Total	**88**	**41**	**4**	**63**	**63**	**9**	**37**	**48**	**4**	**188**	**152**	**17**

Table 6.2: Individuals assigned a mean dental age, by sex

Age (years)	Total sample		Male		Female	
	n	%	n	%	n	%
10.0-10.9	11	3.3	7	2.1	4	1.2
11.0-11.9	19	5.7	12	3.6	7	2.1
12.0-12.9	17	5.1	11	3.3	6	1.8
13.0-13.9	22	6.6	13	3.9	9	2.7
14.0-14.9	16	4.8	4	1.2	12	3.6
15.0-15.9	24	7.3	15	4.5	9	2.7
16.0-16.9	22	6.6	14	4.2	8	2.4
17.0-17.9	15	4.5	5	1.5	10	3.0
18.0-18.9	38	11.5	24	7.3	14	4.2
19.0-19.9	24	7.3	15	4.5	9	2.7
20.0-21.9	42	12.7	25	7.6	17	5.1
22.0-25.0	81	24.5	45	13.6	36	10.9
Total	**331**		**190**		**141**	

In the mean dental age of the primary sample, males outnumbered females in all age categories except at 14 and 17 years (Figure 6.2).

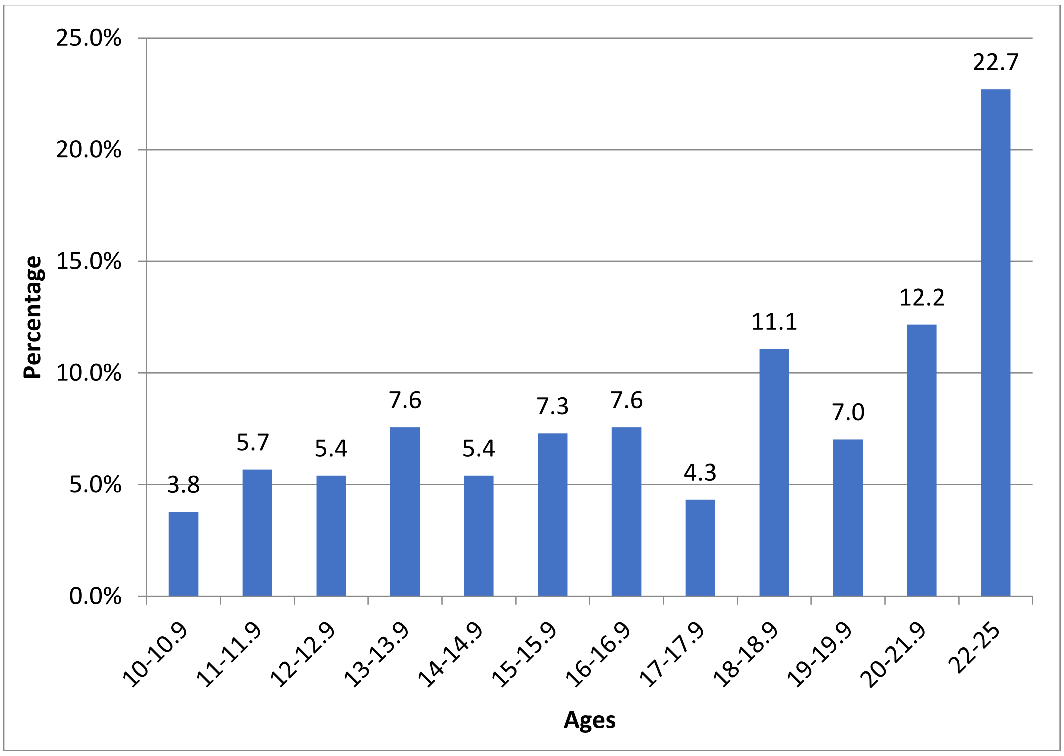

Figure 6.1: Distribution of mean dental ages in the puberty sample

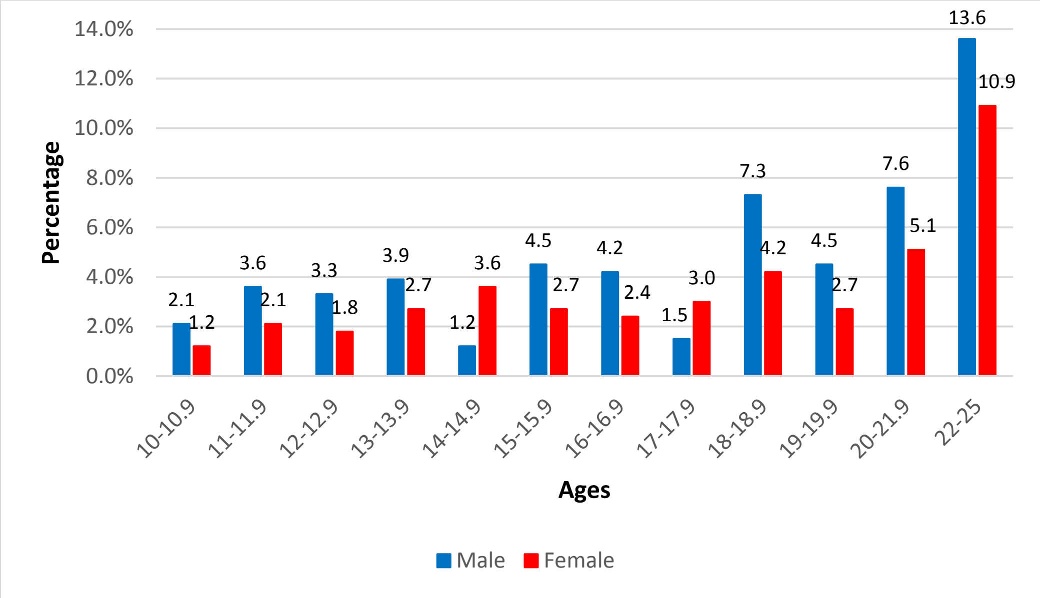

Figure 6.2: Proportion of males and females in each dental age category

In the total puberty sample, the highest percentage of individuals (n=101; 28%) fell within the Completion stage (Figure 6.3), with the lowest number of individuals found in the Initiation phase at the time of their death (n=26; 8%).

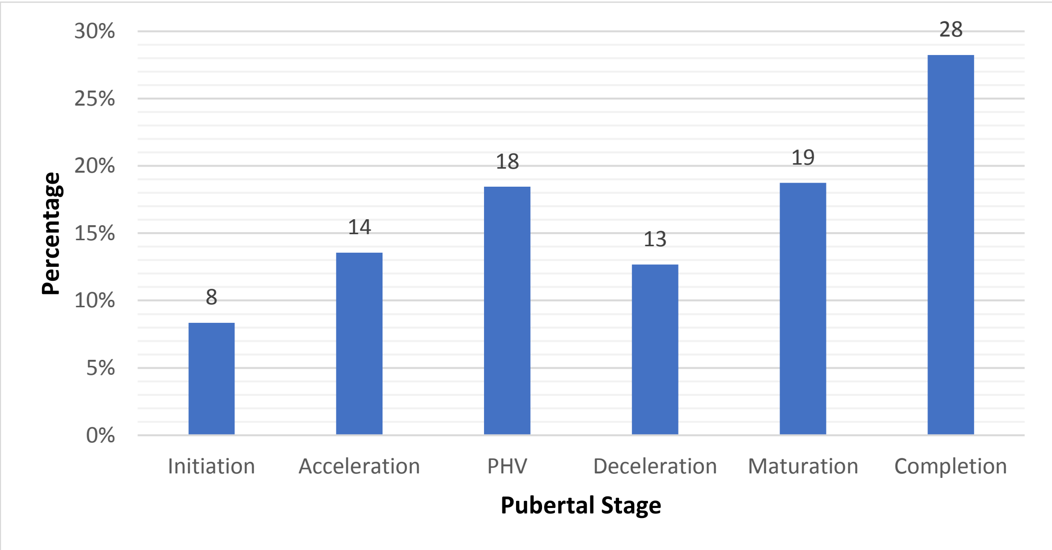

Figure 6.3: Percentage in each puberty stage in the total sample

6.2 PUBERTAL STAGE ATAINMENT

6.2.1 Initiation phase

A total of 14 individuals fell within this stage. The overall age range for the initiation phase was 11-13 years (n = 40). All 10.0-10.9 year olds (n=11, 3.3%) were pre-pubertal. In the males, 50% of those aged 11.0-11.9 years (n=6/12) were in the initiation phase, while two (40%) females had not yet begun puberty. By 12 years, 44% (n= 4) of males were in the initiation phase and 2 of 6 (33%) of the females were still pre-pubertal. By 13 years, only 1 female (11%) and 2 males (20%) remained in the initiation phase. The average age of initiation was 11.0 years in females and 11.2 years in males.

6.2.2 Acceleration phase

The acceleration phase had begun in both sex cohorts by 11.0-11.9 years, but there was a difference in the start of this phase between sexes. In females, the acceleration phase spanned 11.0 to 15.9, or 4.9 years, with the highest proportion of females aged 13.0-13.9 years. In males this phase started 9 months later at 11.9 but also finished after 5 years at 16.9 years. The average age of males in the acceleration phase was 13.3 years (n=7 or 70%) however, one 16-year-old male with possible TB was the oldest to die while still in this phase. While the average age of males in this phase is 13.3 years, the majority of males in the 15-15.9 year age group (n=6, 46.2%) died in the acceleration phase.

6.2.3 Peak height velocity

The age range for females at PHV was between 13.0 and 18.9 years with the average age at PHV of 14.8 years. The youngest female at PHV was an 11.5 year old from a low status urban site with possible scurvy. Despite this outlier, the majority of females were at PHV by 13.0-13.9 years (n= 3, 13.6%), with a peak at 14-14.9 (n= 6, 27.3%). The number of individuals at PHV in the later age categories declines steadily, with the exception of a single female in the 18-18.9 year age range with possible rickets.

The age range for PHV in males was 15.0 to18.9 years with an average age of 16.2 years. At 15 years 5 (38.5%) males were at PHV with one male reaching PHV earlier at 13-13.9 years. This individual was from an urban context with active Grade 3 cribra orbitalia and minor porosity on the anterior vertebral bodies. None of the males aged 14-14.9 years had achieved PHV. Females entered PHV around 2 years ahead of males, but had a greater range of ages. While the majority of 17 and 18 year olds had entered the deceleration phase, 40% (n=2) of 17 year olds and 17.6% (n=3) of 18 years olds died while at PHV.

6.2.4 Menarche

The onset of menarche occurs at the end of PHV in females, and just before the deceleration phase. None of the 25 females in the PHV stage were found to have an ossified but unfused iliac crest. However, 16 females (64%) in the deceleration phase were identified as having achieved menarche due to a partially fused iliac crest or partially fused phalanges. They had an average age of 16.2 years.

6.2.5 Deceleration phase

Like PHV, the deceleration phase shows a marked difference between the sexes with a longer duration of the pubertal phase in females and a shorter duration in the males. In the female sample, deceleration began at 14.0 years and ended at 19.9 years. The greatest number of females in this phase were aged 14-14.9 years (n= 4, 25%). The number of females in each age category were comparable (n= 2 or 3) until the 19-19.9 year age category. The mean age of deceleration for girls was 16.1 years. A single female outlier aged 19-19.9 years from an urban context, had a gracile and shorter left arm (humerus, ulna, and radius) suggestive of disuse atrophy, and possible trauma to the frontal bone. In the male sample, 13 of the 14 individuals (92.8%) were aged between 15.0-18.9 years. The oldest individual in this stage was aged 20.0-21.9 years from an urban high-status context and they displayed spina bifida occulta (open S3-5).

6.2.6 Maturation phase

Females reached maturation between the ages of 17.0 to 25 years, while males reached this stage between 18.0 to 25 years. The majority (n=8, 53.3%) of 20-21.9 year old females were in the maturation phase and had not completely finished their pubertal development, compared to only 24% (n=6) of males.

6.2.7 Completion

In both sexes, most of the 22-25 year age group had completed their puberty development, although some individuals died before reaching this final stage. The youngest female entering this stage was 17-17.9 years, with the majority (n=7) who died at 20-21.9 years falling within this stage. In females, the ages of 17-18 are a mixture of phases including PHV, deceleration, maturation, and completion. In males, the earliest age of completion was 18-18.9 years (n=3). From 18-25 years, the pubertal stages present included the maturation and completion stage. Only 4 (33%) males in the 19.0-19.9 year age range were found to be in the completion stage but this increased to 18 (72%) in the 20.0-21.9 year age category and 33 (84.6%) at 22-25 years.

6.3 POST-MEDIEVAL PUBERTY

A summary of the ages of attainment for each stage is presented in Table 6.3. The numbers of individuals in each stage and age category are provided in Tables 6.4 and Figure 6.4 for females and Table 6.5 and Figure 6.5 for males. Males began to lag behind females at PHV where the usual 2 year gap between male and female skeletal maturation becomes evident. However, by deceleration the females appear to have lost this advantage and have similar average ages for the duration of their development.

Table 6.3 Average age and age range for each stage of attainment, by sex for dentally aged individuals

Puberty stage	Male		Female	
	Age range	Average age	Age range	Average age
Initiation	10-13	11.2	10-13	11.0
Acceleration	11-16	13.3	11-15	12.8
Peak height velocity	15-18	16.2	13-19	14.8
Deceleration	15-18	16.8	14-19	16.1
Maturation	18-25	20.3	17-25	20.4
Completion	18-25	22.4	17-25	23.0

Table 6.4: Female pubertal stage by age category

Age Categories	Initiation			Acceleration			PHV			Deceleration			Maturation			Completion		
	n	%	N	n	%	N	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	9	12.5	72	11	15.3	72	4	5.6	72	0	0.0	72	0	0.0	72	0	0.0	72
14-16.9	0	0.0	70	3	4.3	70	15	21.4	70	9	12.9	70	0	0.0	70	0	0.0	70
17-19.9	0	0.0	100	0	0.0	100	3	3.0	100	7	7.0	100	13	13.0	100	6	6.0	100
20-21.9	0	0.0	41	0	0.0	41	0	0.0	41	0	0.0	41	8	19.5	41	7	17.1	41
22-25	0	0.0	74	0	0.0	74	0	0.0	74	0	0.0	74	7	9.5	74	27	36.5	74
Total	**9**	**2.5**	**364**	**14**	**3.8**	**364**	**22**	**6.0**	**364**	**16**	**4.4**	**364**	**28**	**7.7**	**364**	**40**	**11.0**	**364**

%percentage of the total sample in each age group, n is the number of individuals in each category while N is the total number of individuals in each category

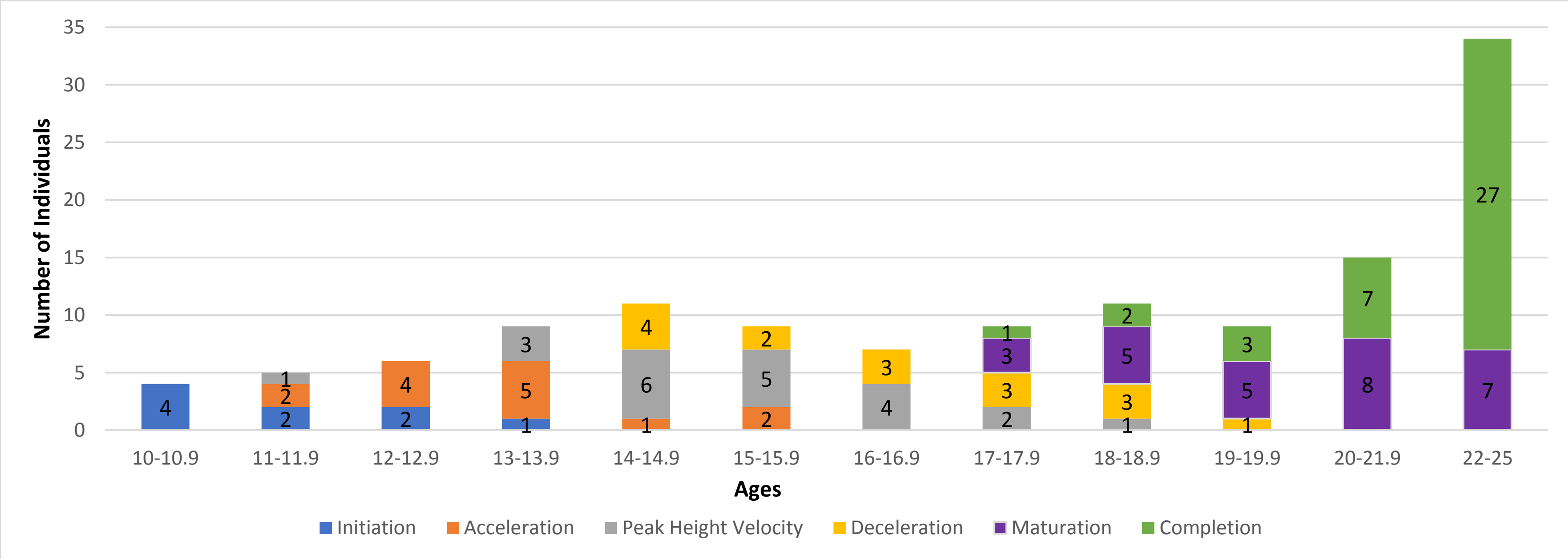

Figure 6.4: Total number of females in each stage by mean dental age

Table 6.5: Male pubertal stages by age category

Age Categories	Initiation			Acceleration			PHV			Deceleration			Maturation			Completion		
	n	%	N	n	%	N	n	%	N	n	%	N	n	%	N	n	%	N
10-13.9	19	26.4	72	18	25.0	72	1	1.4	72	0	0.0	72	0	0.0	72	0	0.0	72
14-16.9	0	0.0	70	11	15.7	70	14	20.0	70	5	7.1	70	0	0.0	70	0	0.0	70
17-19.9	0	0.0	100	0	0.0	100	5	5.0	100	8	8.0	100	14	14.0	100	7	7.0	100
20-21.9	0	0.0	41	0	0.0	41	0	0.0	41	1	2.4	41	6	14.6	41	18	43.9	41
22-25	0	0.0	74	0	0.0	74	0	0.0	74	0	0.0	74	6	8.1	74	33	44.6	74
Total	**19**	**5.2**	**364**	**29**	**8.0**	**364**	**20**	5.5	**364**	**14**	**3.8**	**364**	**26**	7.1	**364**	**58**	**15.9**	**364**

%percentage of the total sample in each age group, n is the number of individuals in each category while N is the total number of individuals in each category

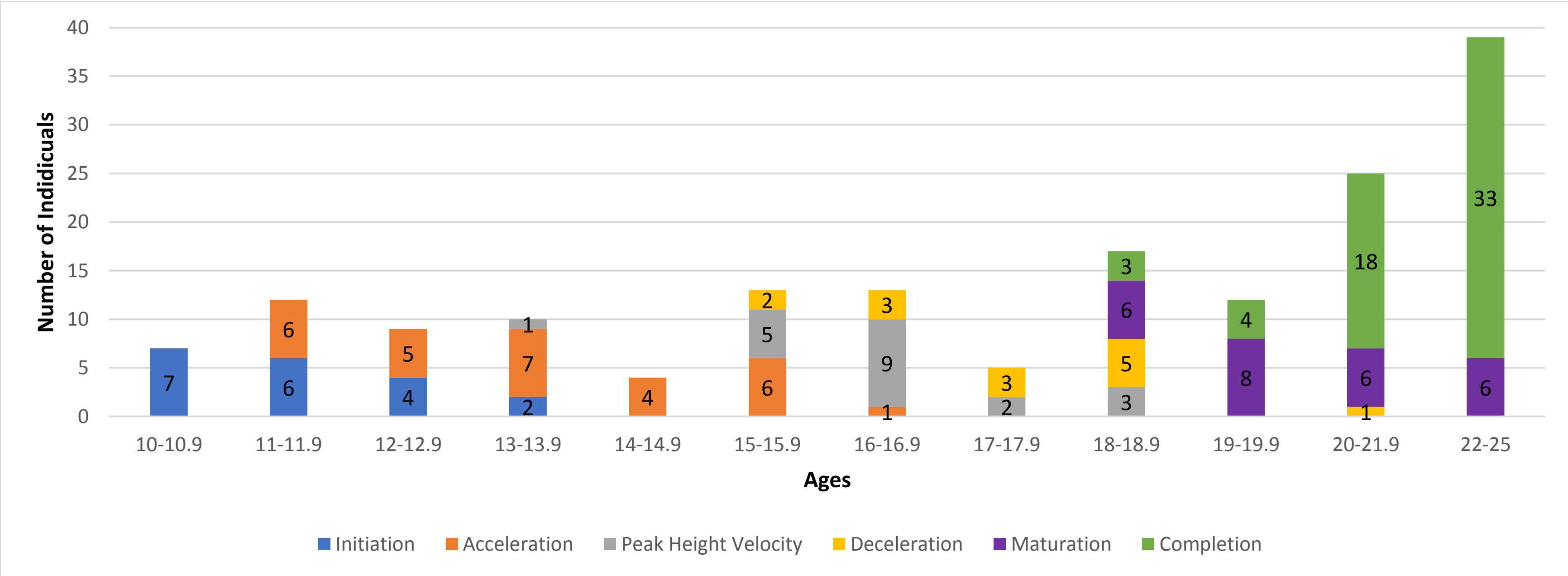

Figure 6.5 Total number of males in each stage by mean dental age

6.3.1 Contextual Differences in Pubertal development

The regional examination of pubertal development is an amalgamation of both sexes due to the number of individuals, with all ages being based upon dental development to 19 and then fusion. While the difference between the pubertal stages and regional location was not statistically significant, there appear to be trends among the sample that was recorded that will be explored.

When examining puberty based upon regional location, there were several trends that stood out as distinctive. In all contexts, individuals were found to still be in the maturation phase into the 22-25 years age range.

The infirmary context had an acceleration phase that ranged from 11-15 years that while shorter than the overall male range by 1 year was the same as the female range. The PHV started at 13 like in the post-medieval female but the latest was a year earlier at 18 years (Figure 6.6). Overall the infirmary context saw age ranges for pubertal development that followed the female age ranges minus 1 year at the latest age for the acceleration, PHV, Deceleration phases. The Maturation phase in contrast resembled the total male age range. Despite the similar ranges for the deceleration phase, the average age of deceleration in the Infirmary context was 16.8, the same as the male mean age. This is not surprising given the much higher percentage of the infirmary sample population that were male. The 11 year old individual that was found to have started the acceleration phase was one of the females from Radcliffe. There was an overall uniformity in the pattern of ages to stages in the infirmary context, with no single adolescents exhibiting a distinct pubertal delay.

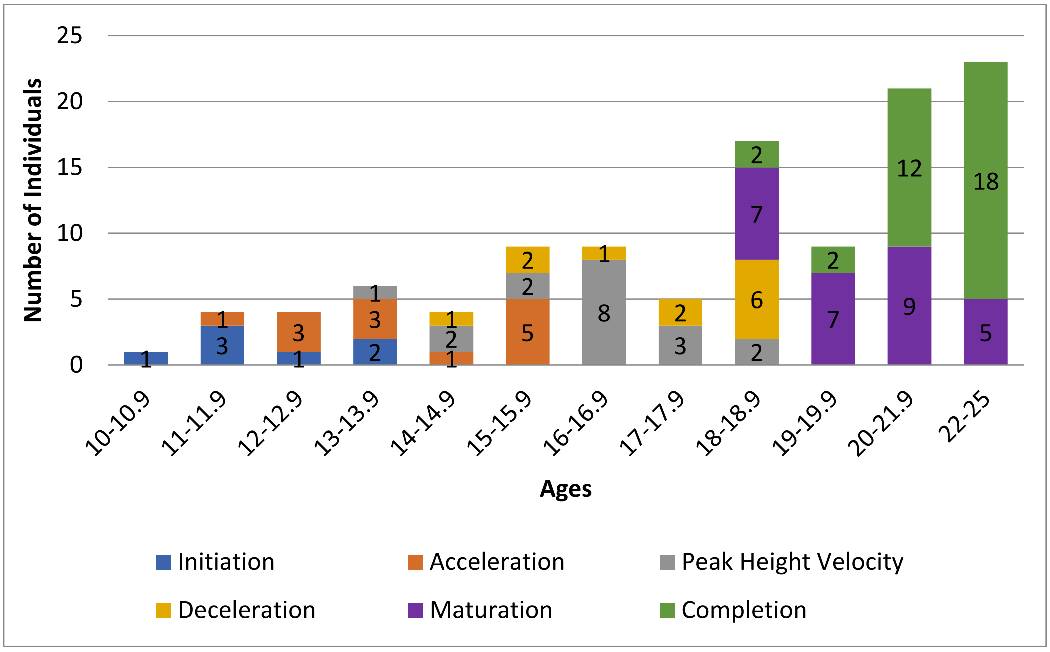

Figure 6.6: Pubertal stage as a measure of the pubertal sample in the infirmary context

All 11 year olds recorded in the urban context were found to have already commenced puberty. Additionally, the acceleration, PHV, and deceleration phases all had broader age ranges than either other site type indicating a greater variety in the possible timing of puberty. This is likely due to the greater possibility for infection and metabolic disease in more urban settings. The urban context had the only individual that was found with PHV in the 11-11.9 year age range (Figure 6.7). This outlier in the post-medieval period was closest adolescent to the modern ages of PHV in the sample. The deceleration phase was the broadest phase spanning 14 to 20-21.9 years of age. There were two delayed individuals that were still in the deceleration phase in the 19-19.9 and 20-21.9 year age range.

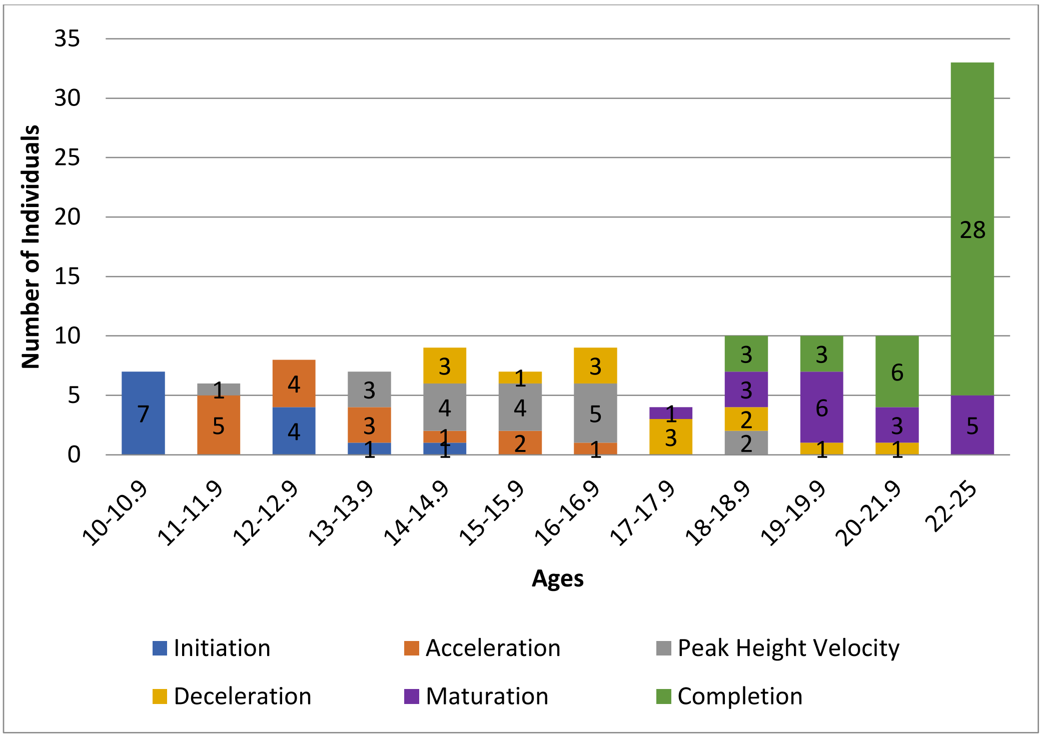

Figure 6.7: Pubertal stage as a measure of the pubertal sample in the urban context

The effects of the sample's age distribution are most acutely seen in the semi-urban context with the two oldest age ranges, as well as in the PHV phase. In the semi-urban context, 63% of the individuals identified for pubertal development were found to be in the 20-21.9 and 22-15 year old age categories. As such there were several age ranges with only 1 or 2 individual's worth of data. This is a confounding factor that requires further data to make more definitive hypotheses upon. What can be identified is that the data indicates a very short range of ages 15-17.9 years in which the adolescents would be undergoing the deceleration phase. PHV in the semi-urban context was fragmented with the majority (4, 66%) of the pubertal phase being found in the 15-15.9 age category (Figure 6.8). The two other individuals were found in the 18-18.9 = and 20-21.9 year age ranges. Additionally, the Semi-urban context was the only one in which there were any individuals whose PHV was delayed until the age of 20-21.9 years.

Ultimately the low numbers of adolescents in each age category, pubertal stage, and site type make it impossible to identify sex differences and create difficulties in determining significant contextual differences.

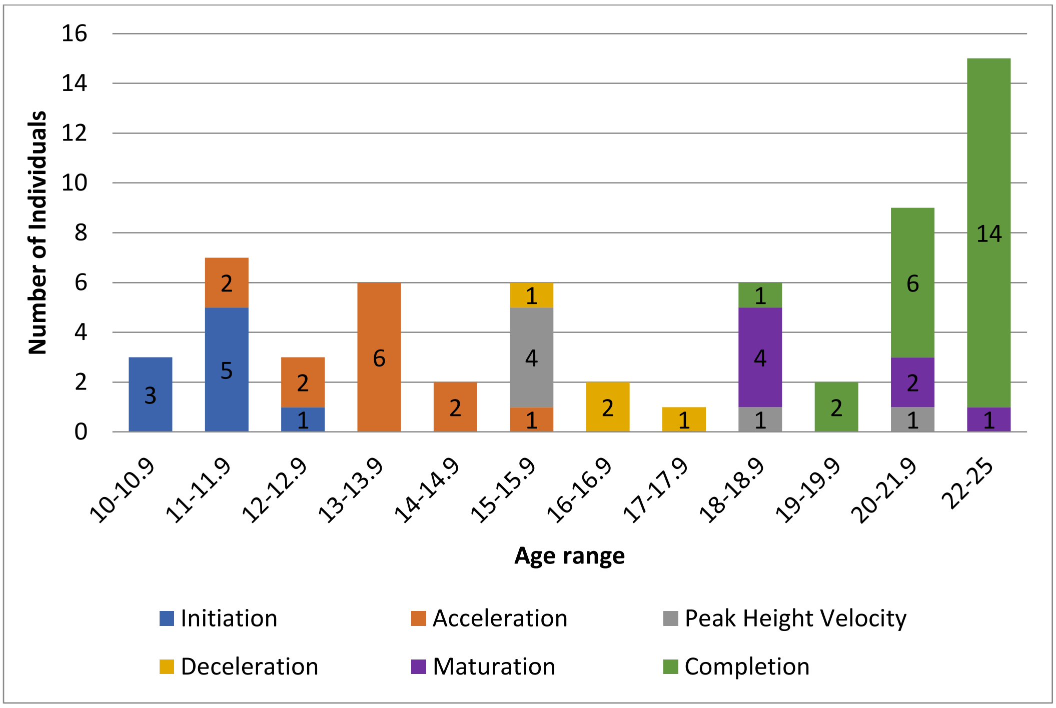

Figure 6.8: Pubertal stage as a measure of the pubertal sample in the Semi-Urban context

6.4 THE IMPACT OF PATHOLOGY ON PUBERTAL ATAINMENT

In order to ensure a good sample size from which to assess the impact of pathology on skeletal maturation, all skeletally aged individuals were assigned a single 'minimum age' and added to the individuals with mean dental ages. Individuals were considered delayed in their pubertal development when they remained within a stage but exceeded the mean age for the stage for both males and females (1.5+ years). The 18 non-sexed adolescents who had pathology were recorded but were not judged as to whether they were delayed in their pubertal development (Figure 6.9).

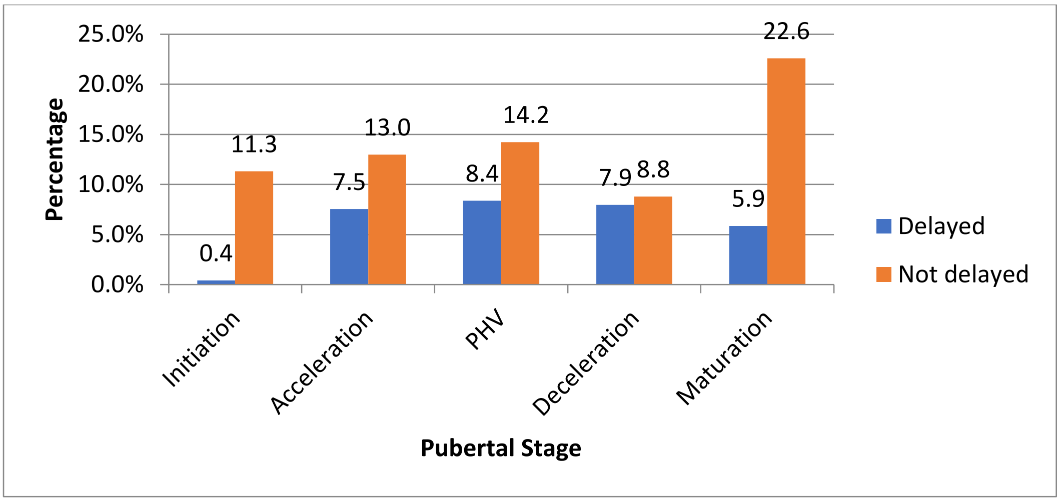

Figure 6.9 Percentage of adolescents delayed and not delayed at each pubertal stage

Of the 364 skeletons assigned a pubertal stage, 277 (76.1%) had a pathology and 72 (26%) of the puberty sample were delayed. In the delayed group 56 (77.8%) had a visible pathology while 16 (22.2%) showed no pathology (Table 6.6 and 6.7). There was no significant difference between the numbers of delayed adolescents with and without pathology.

Table 6.6: Minimum age (years), sex, and pathology of the delayed group

Minimum Age	Number			Pathology	
	Male	Female	Total	Yes	No
10	-	-	0	-	-
11	-	-	0	-	-
12	-	-	0	-	-
13	1	5	6	3	3
14	3	1	4	1	3
15	6	7	13	10	3
16	2	5	7	6	1
17	7	7	14	11	3
18	8	4	12	11	1
19	-	1	1	0	1
20	1	1	2	2	0
21	-	-	0	-	-
22	6	7	13	12	1
Total	**34**	**38**	**72**	**56 (77.8%)**	**16 (22.2%)**

Table 6.7: Minimum age (years), sex and pathology status of the non-delayed group

Minimum Age	Number			Pathology	
	Male	Female	Total	Yes	No
10	7	6	13	13	-
11	13	6	19	16	3
12	11	6	17	13	4
13	12	6	18	15	3
14	3	10	13	11	2
15	7	2	9	6	3
16	19	5	24	21	3
17	2	14	16	14	2
18	10	10	20	17	3
19	12	8	20	18	2
20	24	13	37	32	5
21	1	1	2	1	1
22	30	26	56	44	12
Total	**151**	**113**	**264**	**221 (83.7%)**	**43 (16.3%)**

To assess the impact of particular pathologies on pubertal development, conditions were separated into three main classifications: chronic infection, metabolic and haemopoietic diseases, and non-specific stress

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6.4.1. Chronic infections

6.4.1.1 Tuberculosis

A total of 8 (2.5%) adolescents with tuberculosis were assigned a pubertal stage, sex and site type. Although numbers are too small to carry out a statistical test, the prevalence of TB was highest in the female sample (n= 5; 4.2%). (Table 6.8, Figure 6.10).

Table 6.8 Sex and pubertal stage of adolescents with tuberculosis

Age Categories	Male			Female			Total		
	n	%	N	n	%	N	n	%	N
Initiation	0	0.0	18	0	0.0	9	0	0.0	27
Acceleration	1	4.8	21	2	16.7	12	3	9.1	33
PHV	1	4.5	22	1	5.3	19	2	1.9	41
Deceleration	0	0.0	18	0	0.0	16	0	0.0	34
Maturation	1	3.7	27	2	6.1	33	3	5.0	60
Completion	0	0.0	50	2	6.5	31	2	2.5	81
Total	**3**	1.9	**156**	**5**	4.2	**120**	**10**	3.6	**276**

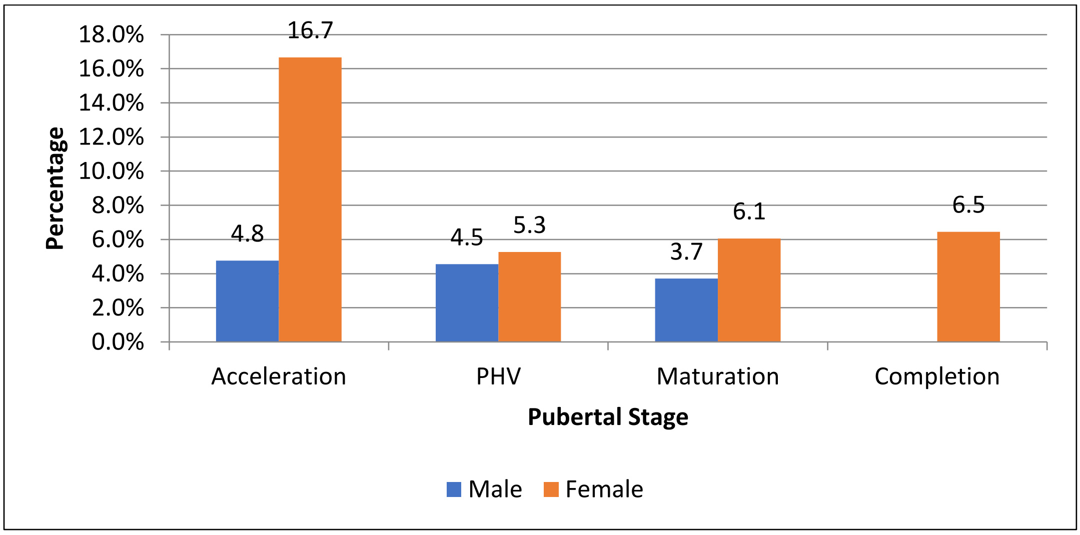

Figure 6.10: Sex and pubertal stage of adolescents with tuberculosis in the primary sample

The majority of TB individuals (50%) came from the semi-urban context (Table 6.9, Figure 6.11). While there was no statistically significant difference between the semi-urban and infirmary contexts, the semi-urban were significantly (X^2=4.46, P=.05 at 1 d.f) greater than in the urban context.

Table 6.9: Site type and pubertal stage for individuals with tuberculosis

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Initiation	0	0.0	7	0	0.0	10	1	10.0	10	1	3.7	27
Acceleration	0	0.0	14	1	9.1	11	2	25.0	8	3	9.1	33
PHV	1	5.6	18	1	5.6	18	0	0.0	5	2	4.9	41
Deceleration	0	0.0	16	0	0.0	14	0	0.0	4	0	0.0	34
Maturation	2	7.1	28	2	9.1	22	0	0.0	10	4	6.7	60
Completion	0	0.0	31	0	0.0	32	2	10.5	19	2	2.4	82
Total	**3**	2.6	**114**	**2**	3.7	**107**	**5**	8.9	**56**	**12**	4.3	**277**

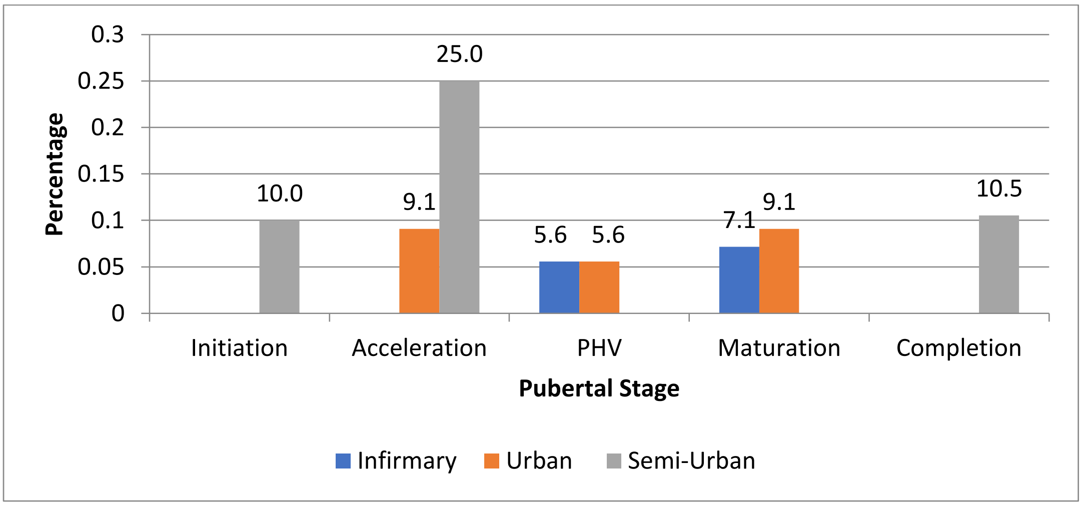

Figure 6.11: Percentage of individuals in the primary sample with tuberculosis and pubertal stages

6.4.1.2 Treponemal disease

Ten (83.3%) of the 12 adolescents with treponemal disease were assigned a pubertal stage. While the numbers were too small for statistical analysis, the majority of the adolescents were male (n=8, 66.7%). The males died throughout pubertal development, while the two females with treponemal disease died during initiation and deceleration (Table 6.10, Figure 6.12).

Table 6.10: Sex of adolescents with treponemal disease by pubertal stage

	Male			Female			Total		
	n	%	N	n	%	N	n	%	N
Initiation	0	0.0	18	1	11.1	9	1	3.7	27
Acceleration	1	4.8	21	0	0.0	12	1	3.0	33
PHV	2	9.1	22	0	0.0	19	2	4.9	41
Deceleration	0	0.0	18	1	6.3	16	1	2.9	34
Maturation	3	11.1	27	0	0.0	33	3	5.0	60
Completion	2	4.0	50	0	0.0	31	2	2.5	81
Total	**8**	5.1	**156**	**2**	1.7	**120**	**10**	3.6	**276**

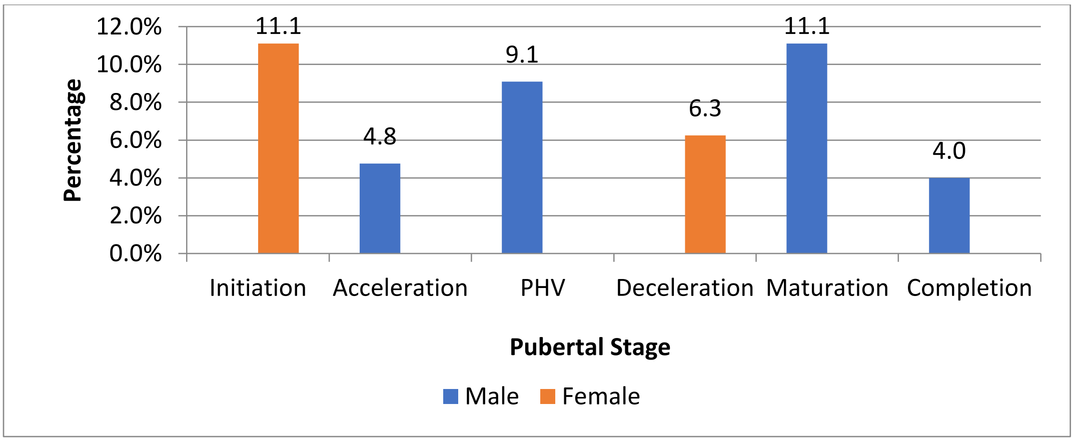

Figure 6.12: Sex of adolescents with treponemal disease by pubertal stage

When examining the distribution of adolescents with treponematosis by site type, the pubertal results indicate that the initiation and deceleration phase were comprised entirely of the semi-urban context. While the numbers of individuals in each site type and stage is low (1-2 individuals) it does indicate that the infirmary had adolescents with treponematosis in 4 pubertal stages while the urban had 3 and the semi-urban had 2 (Table 6.11, Figure 6.13).

Table 6.11: Puberty and site type of adolescents with treponematosis in the primary sample

	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Initiation	0	0.0	7	0	0.0	10	1	10.0	10	1	3.7	27
Acceleration	1	7.1	14	0	0.0	11	0	0.0	8	1	3.0	33
PHV	1	5.6	18	1	5.6	18	0	0.0	5	2	4.9	41
Deceleration	0	0.0	16	0	0.0	14	1	25.0	4	1	2.9	34
Maturation	2	7.1	28	1	4.5	22	0	0.0	10	3	5.0	60
Completion	1	3.2	31	1	3.1	32	0	0.0	19	2	2.4	82
Total	**5**	4.4	**114**	**3**	2.8	**107**	**2**	3.6	**56**	**10**	3.6	**277**

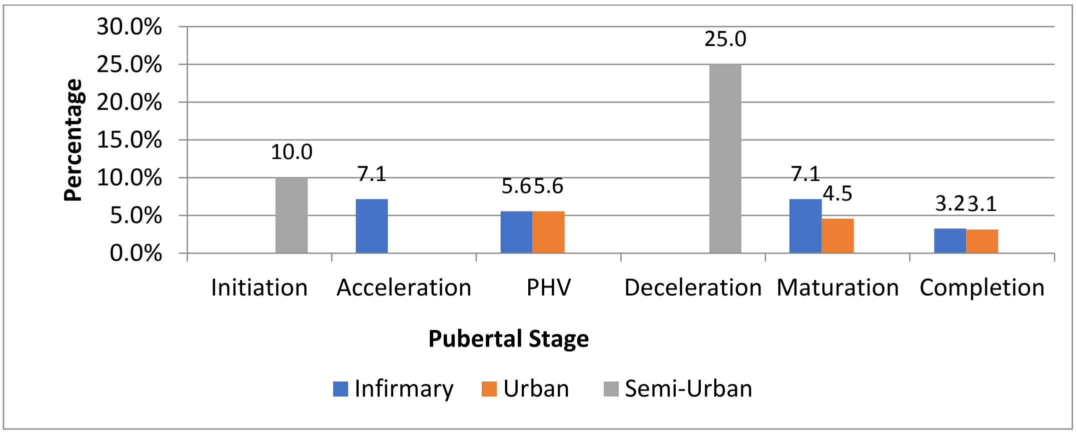

Figure 6.13: Puberty and site type of adolescents with treponematosis in the primary sample

Of the 56 delayed adolescents identified with a pathology, 39 (69.6%) had a chronic disease. Three (4.2%) had lesions suggestive of treponemal disease while 5 (6.9%) had tuberculosis (Table 6.8). The percentage of the adolescents delayed and not delayed with treponematosis was not found to be significant but the delayed adolescents with tuberculosis and were found to be significantly (X^2=9.41, P=.005 at 1 d.f) greater than those without. Two of the delayed adolescents with tuberculosis were in the acceleration phase while the other 2 were in PHV (Table

6.12). In contrast, all of the delayed adolescents with treponematosis were male while the majority (n=2, 66%) was in the deceleration phase.

Table 6.12: Puberty stage, site type, and sex of individuals with TB and treponemal diseases, by age. Delayed individuals are highlighted in bold.

Skeleton Number	Site Type	Sex	Age	Puberty stage:	Condition	Delayed
96	Semi-Urban	F?	10	Initiation	Treponemal	No
230	**Semi-Urban**	**F?**	**13**	**Acceleration**	**TB**	**Yes**
236	**Semi-Urban**	**F?**	**13**	**Acceleration**	**TB**	**Yes**
211	Urban	F?	14	PHV	TB	No
109	**Infirmary**	**M**	**15**	**Acceleration**	**Treponemal**	**Yes**
288	**Semi-Urban**	**F?**	**16**	**PHV**	**TB**	**Yes**
5	Urban	M	16	Acceleration	TB	No
311	Infirmary	M	16	PHV	Treponemal	No
9	Urban	M?	16	PHV	Treponemal	No
423	Urban	F	17	Maturation	TB	No
160	Infirmary	M?	17	Maturation	Treponemal	No
258	Semi-Urban	F?	17	Deceleration	Treponemal	No
100	**Infirmary**	**M**	**18**	**PHV**	**TB**	**Yes**
314	Infirmary	F?	18	Maturation	TB	No
18	Urban	F	18	Maturation	TB	No
319	Infirmary	M	20	Maturation	TB	No
255	Semi-Urban	F	20	Completion	TB	No
102	Infirmary	M?	20	Completion	Treponemal	No
56	**Urban**	**M**	**22**	**Deceleration**	**Treponemal**	**Yes**
330	**Infirmary**	**M?**	**22**	**Deceleration**	**Treponemal**	**Yes**
285	Semi-Urban	F?	22	Completion	TB	No
36	Urban	M	22	Completion	Treponemal	No

6.4.2 Metabolic and haemopoietic diseases

Individuals assigned a pubertal stage with evidence of scurvy, rickets, and cribra orbitalia are considered here. Due to the large number of individuals with cribra orbitalia, a table showing delayed and non-delayed individuals is provided in Appendix #. There were 22 delayed adolescents with a metabolic disease: one (4.5%) displayed vitamin D deficiency and 17 (77.3%) had cribra orbitalia. No individuals with scurvy were delayed.

6.4.2.1 Scurvy

Seven adolescents with scurvy from the primary sample were able to be assigned a pubertal stage. Of the 7 adolescents with a puberty stage five (71.4%) were male and one (14.3%) was female (Table 6.13; Figure 6.14).

Table 6.13: Puberty of adolescents with scurvy by sex

	Male			Female			Total		
	n	%	N	n	%	N	n	%	N
Initiation	1	5.6	18	0	0.0	9	1	3.7	27
Acceleration	1	4.8	21	0	0.0	12	1	3.0	33
PHV	0	0.0	22	1	5.3	19	1	2.4	41
Deceleration	1	5.6	18	0	0.0	16	1	2.9	34
Maturation	0	0.0	27	0	0.0	33	0	0.0	60
Completion	2	4.0	50	0	0.0	31	2	2.5	81
Total	**5**	3.2	**156**	**1**	0.8	**120**	**6**	2.2	**276**

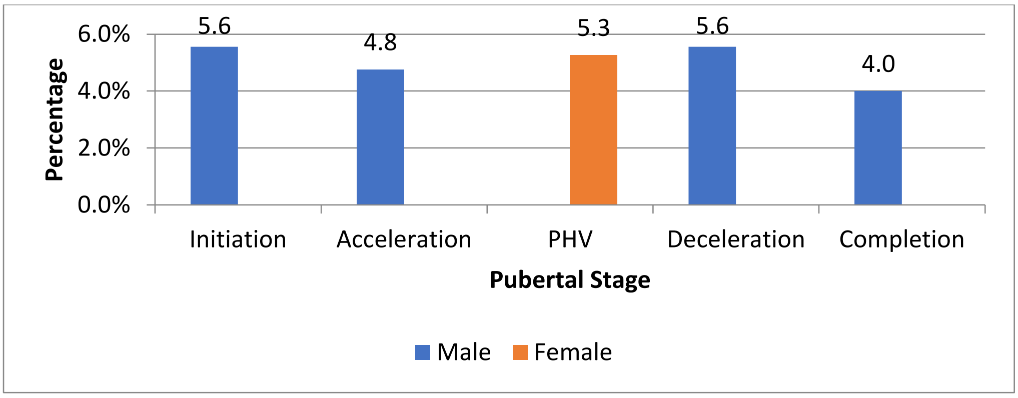

Figure 6.14: Puberty of adolescents with scurvy by sex

None of these adolescents were from the semi-urban context. The infirmary adolescents with scurvy were only found in the initiation and completion stages of puberty while the urban individuals were in the acceleration, PHV, and deceleration phases (Table 6.14, Figure 6.15).

Table 6.14: Puberty of adolescents with scurvy by site type

Age Categories	Infirmary			Urban			Semi-Urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Initiation	1	14.3	7	0	0.0	10	0	0.0	10	1	3.7%	27
Acceleration	0	0.0	14	2	18.2	11	0	0.0	8	2	6.1%	33
PHV	0	0.0	18	1	5.6	18	0	0.0	5	1	2.4%	41
Deceleration	0	0.0	16	1	7.1	14	0	0.0	4	1	2.9%	34
Maturation	0	0.0	28	0	0.0	22	0	0.0	10	0	0.0%	60
Completion	2	6.5	31	0	0.0	32	0	0.0	19	2	2.4%	82
Total	**3**	2.6	**114**	**4**	3.7	**107**	**0**	0.0	**56**	**7**	2.5%	**277**

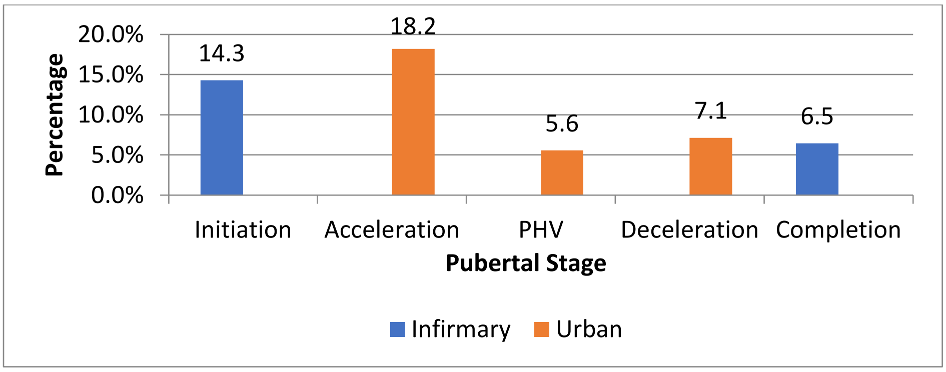

Figure 6.15: Puberty of adolescents with scurvy by site type

6.4.2.2 Vitamin D deficiency

Eight (1.9%) individuals were able to be assigned pubertal stage in addition to sex and age. There was an even (50%) distribution between the sexes of adolescents with rickets (Table 6.15; Figure 6.16). The pubertal assessment indicated that the initiation phase of puberty had the highest percentage (11.1%) (Figure 6.16). There were no adolescents with vitamin D deficiency that were found to be in the acceleration phase. Males and females were present in all phases other than the acceleration and completion phases.

Table 6.15: Sex and pubertal development of individuals with vitamin D deficiency

	Male			Female			Total		
	n	%	N	n	%	N	n	%	N
Initiation	2	11.1	18	0	0.0	9	2	7.4	27
Acceleration	0	0.0	21	0	0.0	12	0	0.0	33
PHV	0	0.0	22	1	5.3	19	1	2.4	41
Deceleration	1	5.6	18	0	0.0	16	1	2.9	34
Maturation	0	0.0	27	2	6.1	33	2	3.3	60
Completion	1	2.0	50	1	3.2	31	2	2.5	81
Total	**4**	2.6	**156**	**4**	3.3	**120**	**8**	2.9	**276**

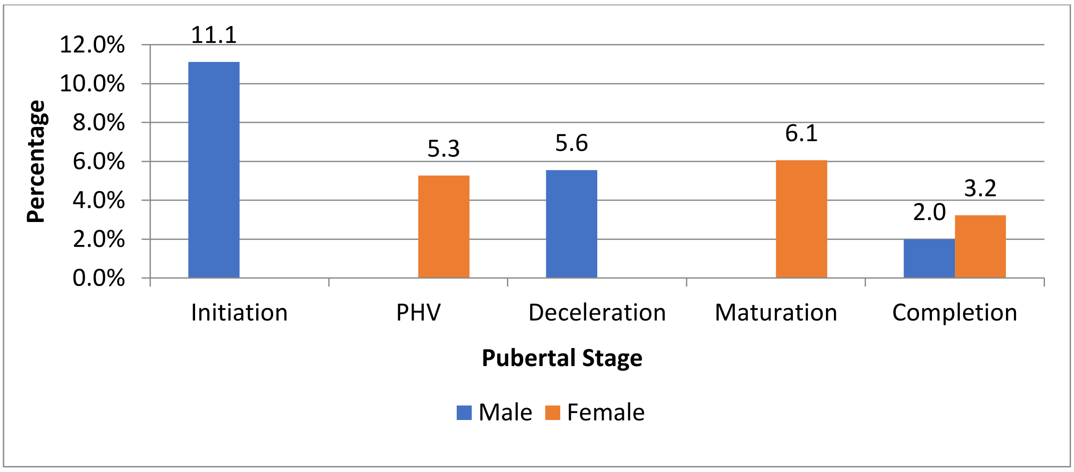

Figure 6.16: Sex and pubertal development of the vitamin D deficient sample

The site distribution indicated that the urban adolescents were delayed in all pubertal stages except the acceleration phase and deceleration phase. The initiation phase had the highest percentage of the population and was evenly split between the urban and semi-urban contexts (Table 6.16, Figure 6.17). The infirmary context only had adolescents in the deceleration and maturation phases.

Table 6.16: Pubertal status and site type with vitamin D deficiency

	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Initiation	0	0.0	7	1	10.0	10	1	10.0	10	2	7.4	27
Acceleration	0	0.0	14	0	0.0	11	0	0.0	8	0	0.0	33
PHV	0	0.0	18	1	5.6	18	0	0.0	5	1	2.4	41
Deceleration	1	6.3	16	0	0.0	14	0	0.0	4	1	2.9	34
Maturation	1	3.6	28	1	4.5	22	0	0.0	10	2	3.3	60
Completion	0	0.0	31	1	3.1	32	1	5.3	19	2	2.4	82
Total	**2**	1.8	**114**	**4**	3.7	**107**	**2**	3.6	**56**	**8**	2.9	**277**

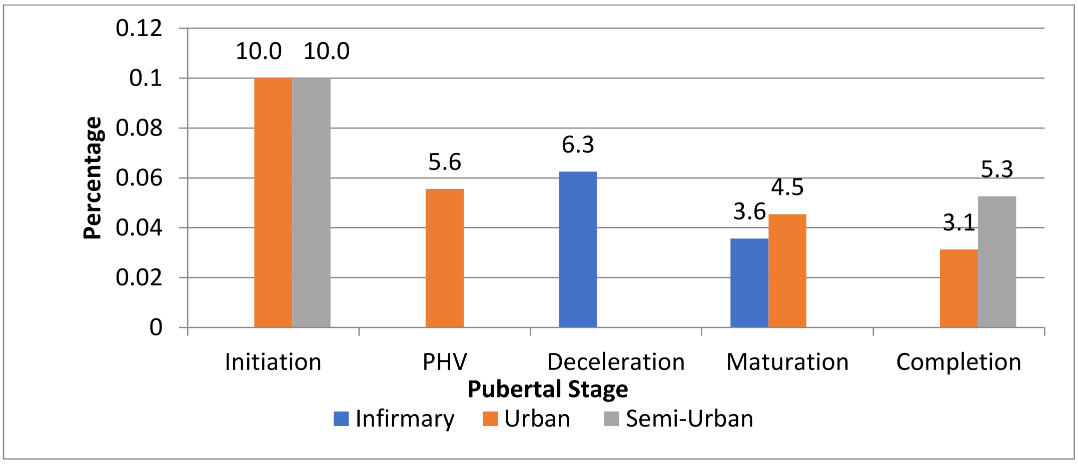

Figure 6.17: Pubertal status and site type of rickets in the primary sample

6.4.2.3. Cribra orbitalia

Fifty-one (82.3%) of the 62 adolescents observed with cribra orbitalia were assigned a pubertal stage, while 49 (79%) were also assigned a sex. There were even numbers of males (53.1%) to females (46.7%) (Table 6.17, Figure 6.18). 15 of the delayed adolescents with metabolic conditions were found with cribrous lesions.

Table 6.17 Cribra orbitalia by sex and pubertal stage

	Male			**Female**			**Total**		
	n	%	N	n	%	N	n	%	N
Initiation	5	27.8	18	3	33.3	9	8	29.6	27
Acceleration	5	23.8	21	1	8.3	12	6	18.2	33
PHV	3	13.6	22	4	21.1	19	7	17.1	41
Deceleration	4	22.2	18	1	6.3	16	5	14.7	34
Maturation	3	11.1	27	6	18.2	33	9	15.0	60
Completion	6	12.0	50	8	25.8	31	14	17.3	81
Total	**26**	16.7	**156**	**23**	19.2	**120**	**49**	17.8	**276**

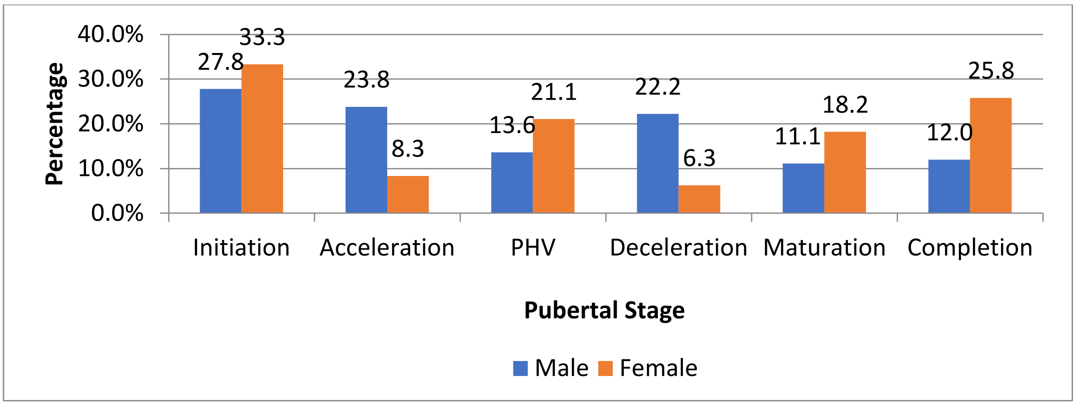

Figure 6.18: Sex and pubertal stages of cribra orbitalia

The adolescents with cribra orbitalia from the 14-16.9 year age range were only found to be in the PHV stage of puberty in contrast to all other ages that had multiple pubertal stages present (Table 6.18, Figure 6.19)

Table 6.18: Pubertal stage and age category of cribra orbitalia

Age Categories	10-13.9			14-16.9			17-19.9			20-21.9			22-25			Total		
	n	%	N	n	%	N	n	%	N	n	%	N	n	%	N	n	%	N
Initiation	7	28.0	25	0	0.0	11	0	0.0	0	0	0.0	0	0	0.0	0	7	19.4	36
Acceleration	5	20.8	24	0	0.0	25	0	0.0	0	0	0.0	0	0	0.0	0	5	10.2	49
PHV	2	33.3	6	4	36.4	11	0	0.0	10	0	0.0	0	0	0.0	0	6	22.2	27
Deceleration	0	0.0	0	0	0.0	1	4	18.2	22	0	0.0	1	0	0.0	0	4	16.7	24
Maturation	0	0.0	0	0	0.0	0	4	11.8	34	2	16.7	12	3	25.0	12	4	6.9	58
Completion	0	0.0	0	0	0.0	0	1	7.7	13	3	14.3	21	9	19.1	47	1	1.2	81
Total	**14**	25.5	**55**	**4**	8.3	**48**	**9**	11.4	**79**	**5**	31.0	34	**12**	44.1	59	**27**	9.8	**275**

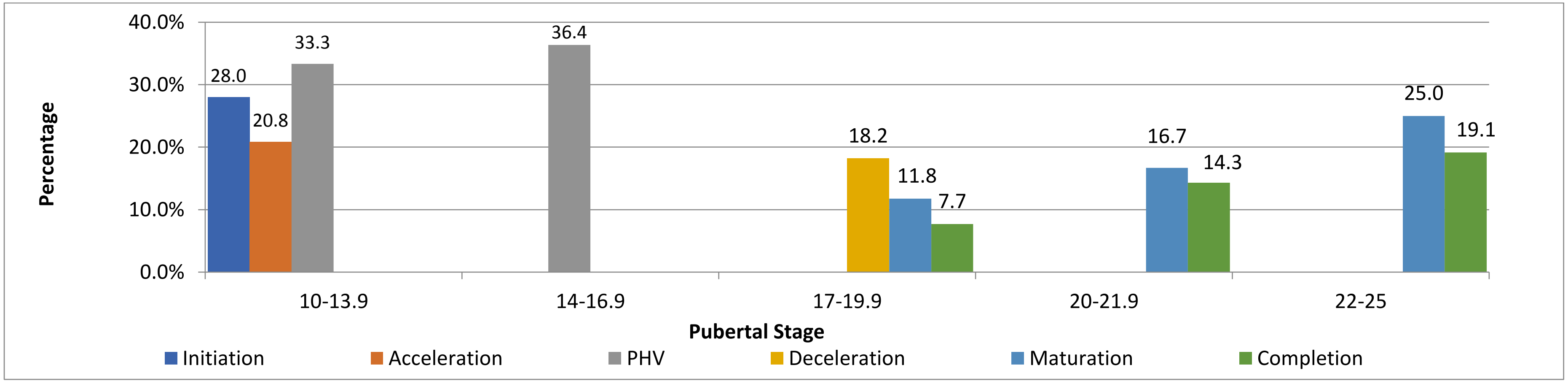

Figure 6.19: Percentage of adolescents with pubertal stages and age categories

The initiation, acceleration, and completion phases had individuals from all site types while the PHV, deceleration, and maturation phases were comprised of only the Urban and Infirmary contexts (Figure 6.19). The highest percentage of cribra orbitalia by site type was found in the Initiation phase (40%) (Table 6.19, Figure 6.20).

Table 6.19: Cribra orbitalia by pubertal stage and site type

Age Categories	Infirmary			Urban			Semi-Urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Initiation	1	14.3	7	4	40.0	10	3	30.0	10	8	29.6	27
Acceleration	3	21.4	14	3	27.3	11	2	25.0	8	8	24.2	33
PHV	2	11.1	18	5	27.8	18	0	0.0	5	7	17.1	41
Deceleration	4	25.0	16	1	7.1	14	0	0.0	4	5	14.7	34
Maturation	6	21.4	28	3	13.6	22	0	0.0	10	9	15.0	60
Completion	4	12.9	31	6	18.8	32	4	21.1	19	14	17.1	82
Total	**20**	17.5	**114**	**22**	20.6	**107**	**9**	16.1	**56**	**37**	13.4	**277**

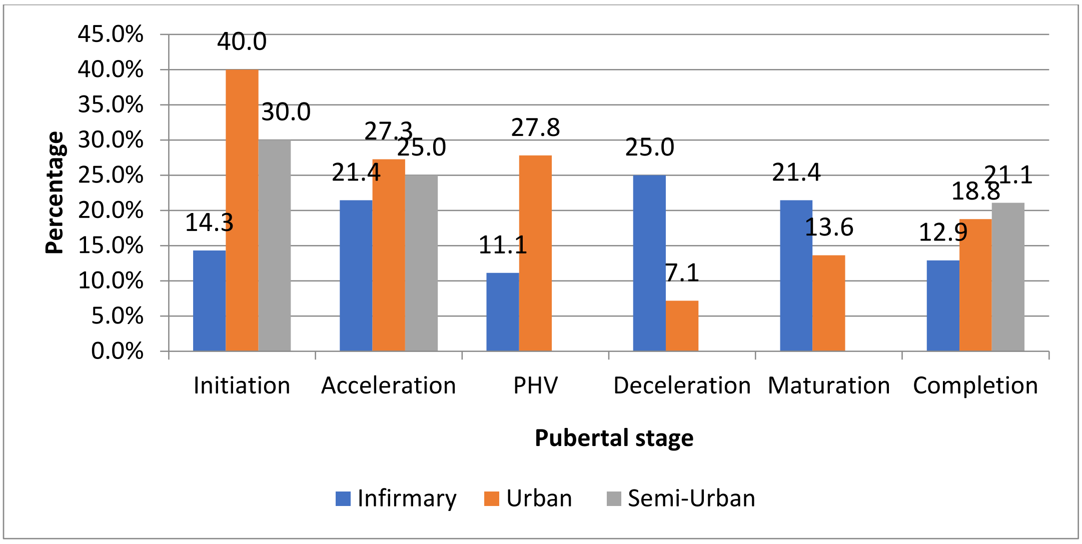

Figure 6.20: Rate of cribra orbitalia by pubertal stage and site type

6.4.3. Indicators of stress

6.4.3.1 Dental enamel hypoplasia (DEH)

Of the 66 individuals identified with DEH on the permanent teeth, 56 (84.8%) were assigned a pubertal stage. There was an even sex distribution among those identified with the defects (Table 6.20, Figure 6.21). Both sexes were found in all pubertal stages with adolescents that had DEH being greatest (n=10, 30.3%) in the acceleration phase. PHV was found with the smallest number of both males and females. The maturation phase had the largest difference between both sexes but they were not significant.

Table 6.20: Percentage of adolescents with DEH by sex and pubertal stage

	Male			Female			Total		
	n	%	N	n	%	N	n	%	N
Initiation	5	27.8	18	2	22.2	9	7	25.9	27
Acceleration	7	33.3	21	3	25.0	12	10	30.3	33
PHV	3	13.6	22	2	10.5	19	5	12.2	41
Deceleration	6	33.3	18	3	18.8	16	9	26.5	34
Maturation	4	14.8	27	11	33.3	33	15	25.0	60
Completion	4	8.0	50	6	19.4	31	10	12.3	81
Total	**29**	18.6	**156**	**27**	22.5	**120**	**56**	20.3	**276**

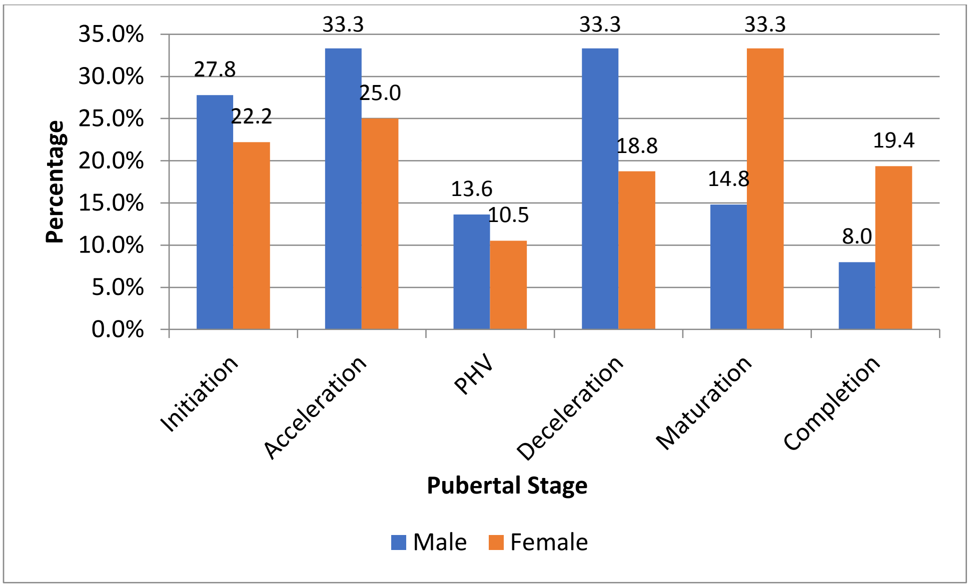

Figure 6.21: Percentage of adolescents with DEH by sex and pubertal stage

The majority of the only 6 (10.3%) of the Semi-urban sample was found with DEH and pubertal stage (Table 6.21, Figure 6.22). The majority of individuals died in the deceleration phase for the infirmary context and the acceleration phase of the urban context. The pattern of age at deaths is different for the infirmary context as after PHV there are 7 (43%) of the deceleration phase that was found with DEH.

Table 6.21: Pubertal stages of adolescents with DEH by site type

Age Categories	Infirmary			Urban			Semi-urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Initiation	2	28.6	7	4	40.0	10	1	10.0	10	7	25.9	27
Acceleration	5	35.7	14	5	45.5	11	1	12.5	8	11	33.3	33
PHV	2	11.1	18	2	11.1	18	1	20.0	5	5	12.2	41
Deceleration	7	43.8	16	2	14.3	14	0	0.0	4	9	26.5	34
Maturation	6	21.4	28	8	36.4	22	2	20.0	10	16	26.7	60
Completion	5	16.1	31	4	12.5	32	1	5.3	19	10	12.2	82
Total	**27**	23.7	**114**	**25**	23.4	**107**	**6**	10.7	**56**	**58**	20.9	**277**

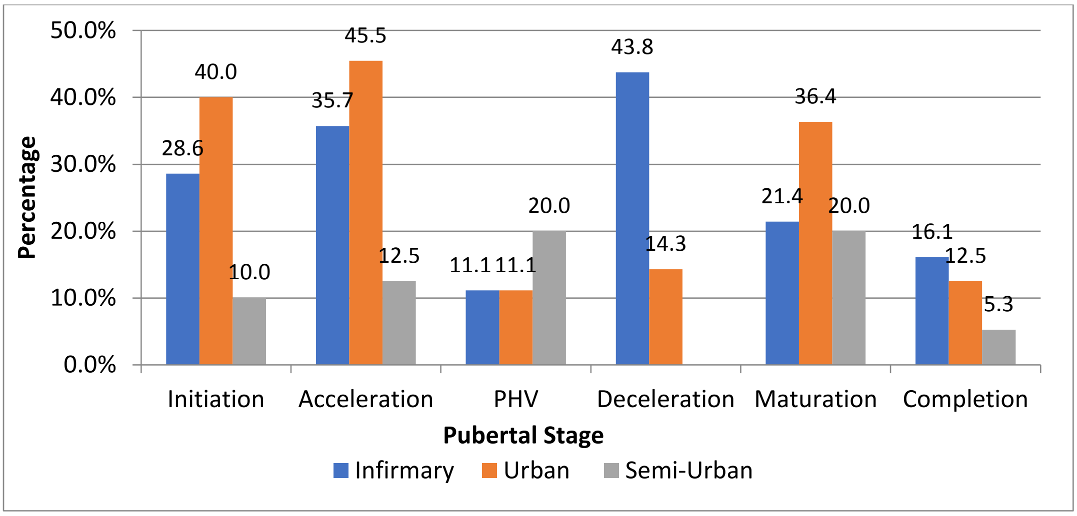

Figure 6.22: Percentage of adolescents with DEH by site type and pubertal stages

The age distribution of DEH indicated that the 17-19.9 year age range comprised of 4 pubertal stages and had the highest percentage of the deceleration (22.2%) and maturation phases (22.4%) (Figure 6.23).

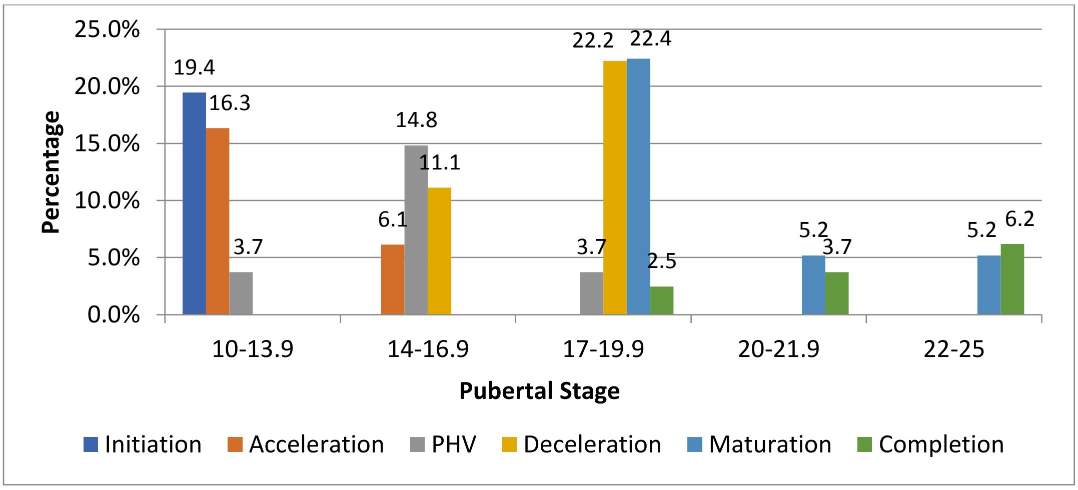

Figure 6.23: Adolescents with DEH by age and pubertal stage

6.4.3.2 Endocranial lesions

Of the 33 adolescents with endocranial lesions, 20 (60.6%) were assigned a pubertal stage in addition to age, sex and site type. The sex distribution of adolescents with endocranial lesions and pubertal development indicated that females were identified in all pubertal stages while males were not in the initiation and acceleration phase (Table 6.22, Figure 6.24). The deceleration phase had the largest difference between both sexes and was the only pubertal stage in which there were more males than females (Table 6.22, Figure 6.24).

Table 6.22: Sex and pubertal stage of adolescents with endocranial lesions

	Male			Female			Total		
	n	%	N	n	%	N	n	%	N
Initiation	0	0.0	18	1	11.1	9	1	3.7	27
Acceleration	0	0.0	21	1	8.3	12	1	3.0	33
PHV	2	9.1	22	2	10.5	19	4	9.8	41
Deceleration	4	22.2	18	1	6.3	16	5	14.7	34
Maturation	1	3.7	27	4	12.1	33	5	8.3	60
Completion	2	4.0	50	2	6.5	31	4	4.9	81
Total	**9**	5.8	**156**	**11**	9.2	**120**	**20**	7.2	**276**

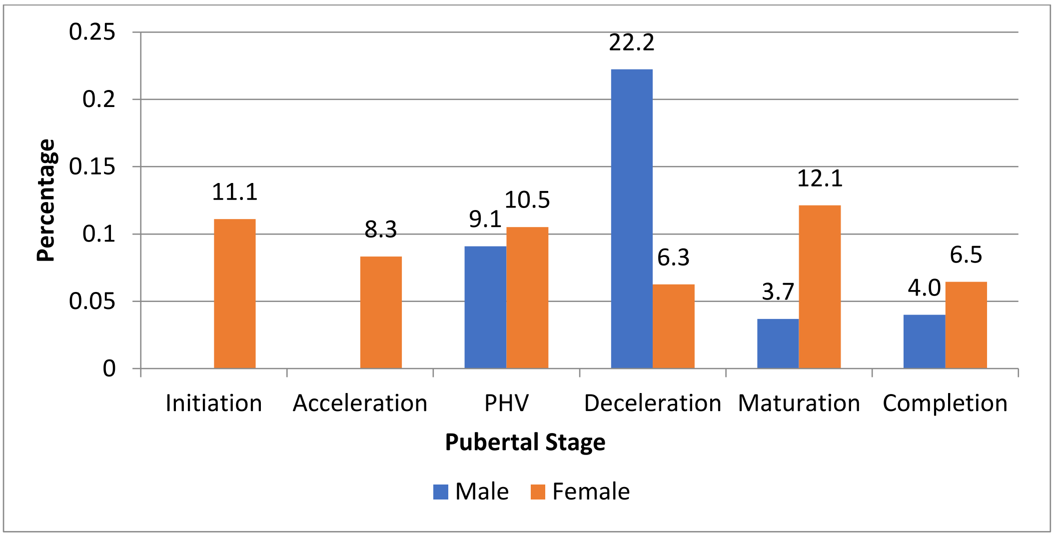

Figure 6.24: Sex and pubertal stage of adolescents with endocranial lesions

Endocranial lesions were found in all pubertal stages in the urban context while there was only a single instance of the pathology in the semi-urban. This indicated that the infirmary context had significantly (X^2=10.16, P=.005 at 1 d.f) more than the semi-urban context as did the urban context (X^2=8.53, P=.005 at 1 d.f). The infirmary context had the highest percentage (18%, n=3) of any site type but it was not present in the first two (initiation and acceleration) phases (Table 6.23, Figure 6.25).

Table 6.23: Pubertal Stage and site type of adolescents with endocranial lesions

Age Categories	Infirmary			Urban			Semi-Urban			Total		
	n	%	N	n	%	N	n	%	N	n	%	N
Initiation	0	0.0	7	1	10.0	10	0	0.0	10	1	3.7	27
Acceleration	0	0.0	14	1	9.1	11	0	0.0	8	1	3.0	33
PHV	2	11.1	18	2	11.1	18	0	0.0	5	4	9.8	41
Deceleration	3	18.8	16	2	14.3	14	0	0.0	4	5	14.7	34
Maturation	3	10.7	28	1	4.5	22	1	10.0	10	5	8.3	60
Completion	2	6.5	31	2	6.3	32	0	0.0	19	4	4.9	82
Total	**10**	8.8	**114**	**9**	8.4	**107**	**1**	1.8	**56**	**20**	7.2	**277**

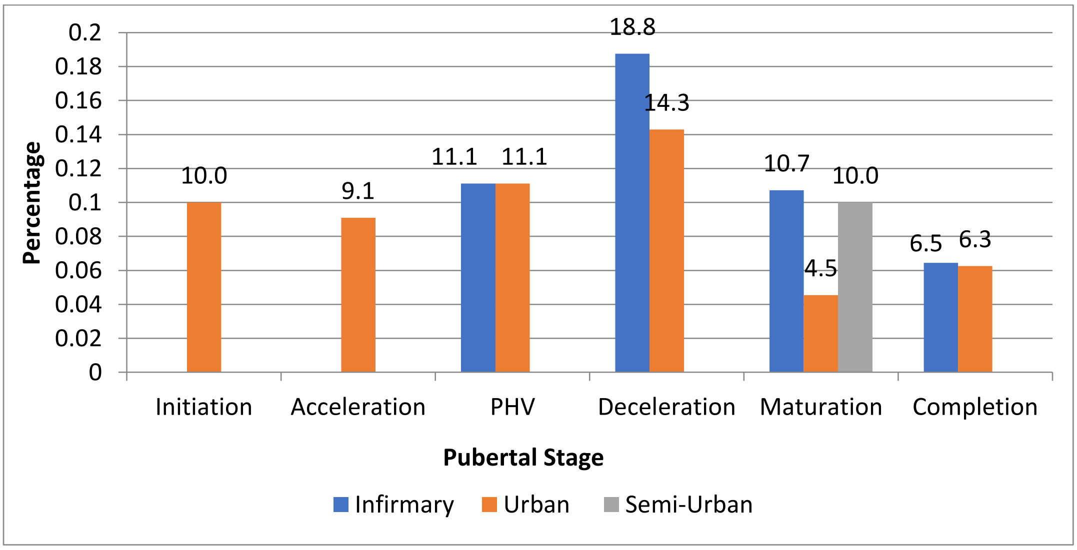

Figure 6.25: Pubertal Stage and site type of adolescents with endocranial lesions

Chapter 7 –Discussion

7.1 LIMITATIONS OF THE STUDY SAMPLES

The patterns of ill-health, stress, and disease that we observe in adolescents provide valuable information on a period of life marked by physiological and psychological changes (Shapland and Lewis 2013, 2014). The analysis of adolescent skeletons in bioarchaeology is often hindered by small sample sizes, as the mortality rate for adolescents is lower than that for younger children. Sample sizes are further reduced by the need to have most of the skeleton represented to carry out detailed assessment of pubertal status or to be sure that pathology is present, or indeed absent. The lack of large rural assemblages of post-medieval adolescents means that it is impossible to compare or contextualise the impact of an urbanised environment over a rural one on adolescent development and health.

The primary sample included two infirmary sites, Radcliffe and Plymouth. Radcliffe was a regional hospital in Oxford serving individuals in the immediate area, with patients from a diverse range of economic backgrounds. The military nature of the Plymouth Naval Hospital meant that the majority of the sample was male. These individuals would have been recruited from many different backgrounds, but with the opportunity to travel widely across the world. The sample was also biased in terms of age of admittance, and the prevalence of chronic pathology. Due to the distinct nature of these sites, the Infirmary group was analysed separately, before being compared and contrasted with the more representative cemetery data.

7.1.1 The secondary sites

The secondary sample, while useful for a broader understanding of adolescent health and demography in post-medieval England, does not provide the same resolution as the primary sample. As most current archaeological excavations are undertaken as part of construction projects, the majority have been focused in high density urban areas such as London. This meant that gaining a deeper understanding of health from individuals in suburban or more rural locations was not possible, and the entirety of the secondary sample comprises of urban sites. Hence, any comparisons between the primary and secondary samples only address urban patterns.

Difficulties with the sex estimation of younger non-adults meant that that 30% (n=122) of the adolescent secondary sample (i.e. those under 17 years) was unsexed. In addition, the broad age categories provided by previous researchers (i.e. 7-11 years, 12-17 years, and 18-25 years) were different to those devised for the primary sample, limiting the opportunities for direct comparisons. The truncation of the 7-11 year old age category to fit with the primary data also resulted in a restricted one-year age category at the start of the secondary study sample (10-11 years).

The use of Birmingham in the secondary sample provides a distinct context that had its own observer bias. It is possible that there was a greater focus on recording enamel hypoplasia as 81.5% (n=44) of the individuals with hypoplasia came from Birmingham. Nevertheless, despite the interests of the original researchers on metabolic diseases, there was no significant difference in the prevalence of these conditions at this sample, when compared to the other sites.

7.2 MORTALITY PROFILES

Overall, there was an even distribution of ages and sexes across the cohorts, with fewer individuals falling within the shorter 20.0-21.9 year age category. This suggests that males and females were equally at risk of mortality across the adolescent period. It was possible that a lack of females in the Plymouth naval sample was skewing this result, but when this sample was removed the sex distribution did not differ.

When age at death was analysed by site type, there were significantly fewer 17-19 year olds in the semi urban sites than urban or infirmary. The semi-urban sample had greater numbers of 10.0-13.9 year olds, but this peak was not significant (Table 7.1, Figure 7.1). When the infirmary sites were compared, the Radcliffe profile was flatter, indicating that children were being admitted as early as 10 years old, compared to Plymouth where the youngest individuals were aged 14 years. Plymouth has an artificial mortality profile, and likely reflects the age of recruitment into the Navy and a period of time children would have spent at sea before becoming sick and injured and entering the hospital.

Table 7.1: Age distribution of Radcliffe, Plymouth, Urban and Semi-Urban sites

Age Categories	Radcliffe		Plymouth		Urban		Semi-Urban		Total	
	n	%	n	%	n	%	n	%	n	%
10-13.9	18	11.1	4	2.5	32	19.9	41	35.7	95	21.7
14-16.9	20	12.4	15	9.3	32	19.9	21	18.3	88	20.1
17-19.9	25	15.4	30	18.6	47	29.2	21	18.3	123	28.1
20-21.9	16	9.9	7	4.4	15	9.3	10	8.7	48	11.0
22-25	20	12.4	7	4.4	35	21.7	22	19.1	84	19.2
Total	**162**	37.0	**161**	36.8	**161**	36.8	**115**	26.3	**438**	

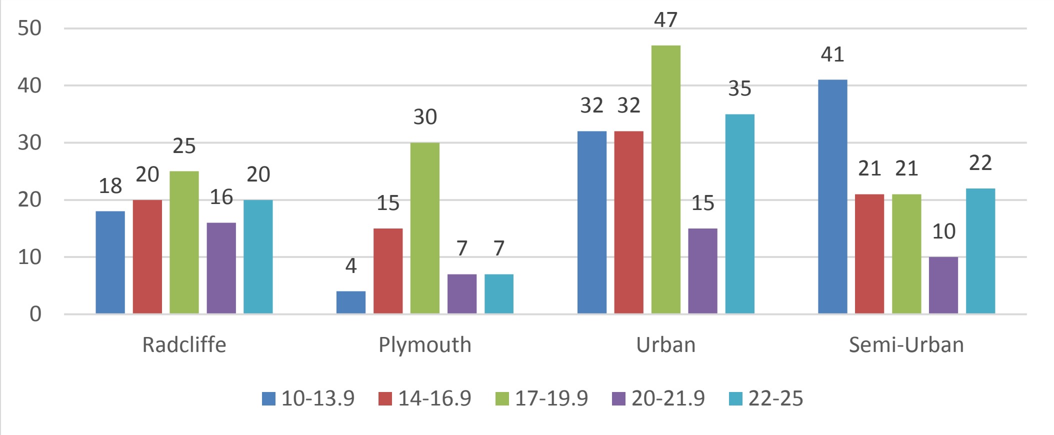

Figure 7.1: *Age distribution of Radcliffe, Plymouth, Urban and Semi-Urban among the primary sample*

The majority of individuals in the secondary sample were aged 18-25 years with an absence of 10-11 year olds in the high and low status urban samples. Where males and females could be compared, in the 18-25 year age group, again there was an even distribution of sexes in the mortality profile.

7.3 GROWTH AND DEVELOPMENT

Growth is regarded as an indicator for the overall health of a population and reflects an individual's ability to adapt and thrive in a specific environment. The main cause of delayed or stunted growth within the same social context is most often poverty, and its significant effects have been identified in both modern and past populations (Cavigelli and Chaudhry 2012). It is necessary when discussing growth and final height attainment that factors such as catch-up growth, social inequality, and cultural buffering are addressed (Redfern and Gowland 2012).

In the primary sample, 70 dentally aged individuals were examined for growth attainment using femoral diaphyseal lengths. The data included one older male in the urban sample with open epiphyses (aged 20.0-21.9 years). Overall, for males (n=48) the infirmary sample had the best growth profiles. The semi-urban males fell behind their urban and infirmary peers, but this trend was not significant. For the females (n=22), the majority of girls in the infirmary sample had completed their maturation meaning their growth profiles could not be analysed. When this group is removed, in contrast to the males, the females from the semi-urban and urban sites had very similar growth profiles. The analysis of the growth profiles between the sexes and site types again suggest that similar to the mortality profiles, there was very little difference between males and females in the primary sample.

Research into the impact of long-term developmental stress indicated that there is a significantly increased risk of mortality for adolescent males and females with smaller TR diameters (Clark et al. 1986; Watts 2011, 2013a, 2015). Newman and Gowland (2015) found that there were significantly smaller TR dimensions in their post-medieval archaeological sites compared to modern data. Due to the broad age ranges (0-17 years) that include children and a lack of sexual differentiation (Newman and Gowland 2015) the vertebral measurements were compared within general age categories. While the TR dimensions in the primary sample were smaller in the 10.0-13.9 year olds than the 17.0-19.9 year olds, this may have been the result of continued growth of TR dimensions after initial fusion (Newman and Gowland 2015), rather than reflecting increased mortality risk.

Previous vertebral growth stress research in the later medieval adults from the Barton assemblage (Watts 2013a) showed that a restricted VNC was significantly associated with an earlier death. In the current study, there were no indications that smaller VNC sizes caused earlier death in the post-medieval adolescents.

Nevertheless, similar to Newman and Gowland's (2015) study, the TR measurement the majority of the adolescents fell below modern values provided by Hinck (1966), suggesting that they were being exposed to health insults during their development. The exception is for the combined 14.0-16.9 year female cohort (n = 24) where values exceeded both those of Hinck (1966) and Newman and Gowland (2015) (Figure 7.2). While the exact cause of this pattern is unknown there is the possibility that the 14.0-16.9 year females had less stress or that they had developed more quickly to an adult size as they were found from all three site types indicating that the trend was not confined to one environment.

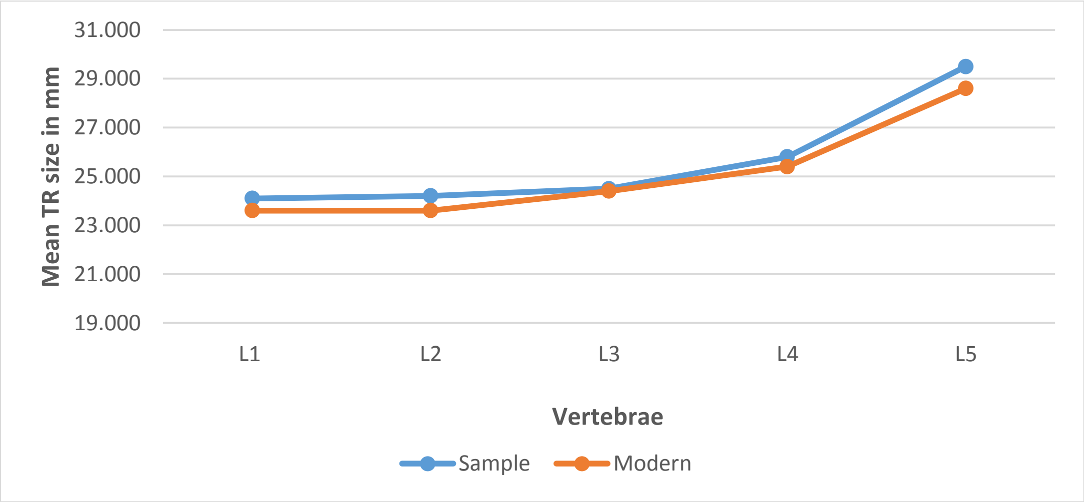

Figure 7.2: Mean TR vertebral measurements in the combined 14-16.9 year female sample and modern data (Hinck 1966)

Body height can continue to increase between 18-25 years of age (Bogduk, 2005), meaning body height may also undergo catch-up growth and/or extended growth periods into early adulthood. The vertebral body heights in post-medieval adolescents increased in size with each age category, similar to those found in Newman and Gowland (2015).

7.3.1 Stature attainment

When stature estimates were compared in individuals with fused epiphyses, the pattern changed. Here, the semi-urban males and females were the tallest (169.8cm and 159.1cm respectively) and the urban females were the shortest (157.6cm). This appears to suggest that despite lagging behind urban and infirmary groups in their growth profiles, delayed epiphyseal fusion in the semi-urban groups allowed them to 'catch-up' growth and eventually overtake their peers. The short stature of the infirmary males was in contradiction to their advantageous growth in the younger individuals. When the infirmary sites were analysed separately, it is clear that the Radcliffe males are depressing the stature averages (mean stature = 166.5 cm) and that the Plymouth males are the tallest (172.3cm). During the post-medieval period the Navy had no specific height requirements for adolescents, only that they were to be of "able body". The caloric and nutritional rations provided by the Royal Navy in 1770 were on average 4880 calories and consisted of 7 pounds of biscuits, 7 gallons of beer, 4 pounds of beef, 2 pounds of pork, 2 pints of pease, 3 pints of oatmeal, 6 ounces of butter, and 12 ounces of cheese a week (Mcdonald, 2014). These calories were supplemented when possible with fresh fruits and vegetables (Humphries and Leuning 2009) and overall the nutrition available in the Navy would allow for greater growth than those on land.

In the secondary sample, the tallest (172.4cm) males were from Birmingham with similar heights to the Plymouth sailors (172.3cm), while the shortest males were from low status London sites (165.6cm). Despite the male stature results suggesting favourable conditions in Birmingham, the females were not the tallest in the female sample and they were shorter than the semi-urban female. When

London was compared to the other urban sites (non-London) in the secondary sample, London females had the shortest means (Figure 7.3) particularly the low status (153.9cm).

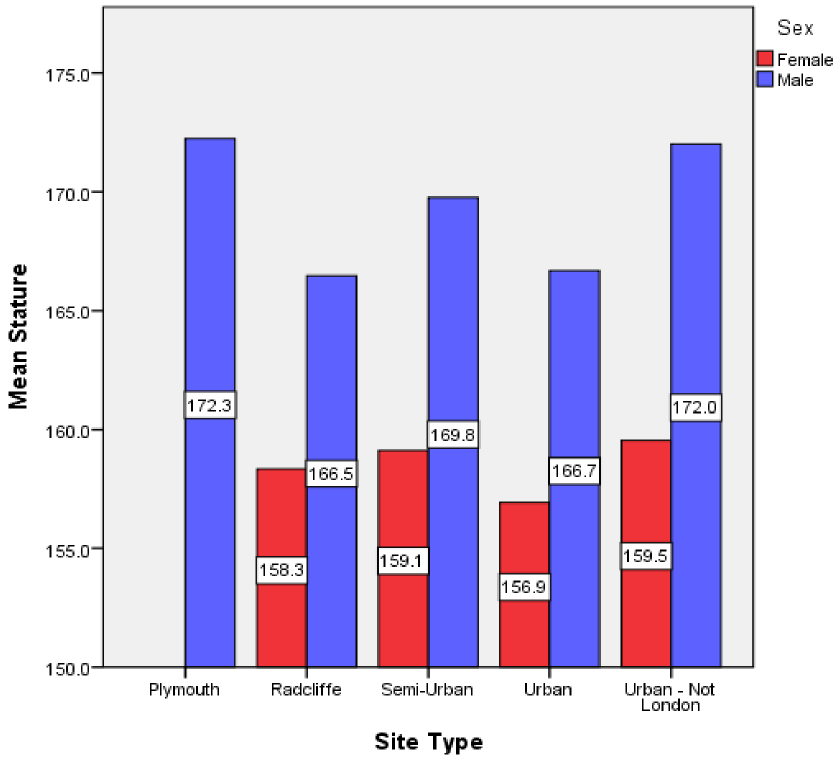

Figure 7.3: Mean femoral lengths (cm) of Plymouth, Radcliffe, Semi-urban, London and Non-London Urban sites

7.3.2 Osteological paradox and growth

The osteological paradox first introduce by Wood et al. (1992) detailed the fundamental difficulties with the paleopathological analysis of archaeologically excavated past populations of human skeletons. It should be noted that the frequency-based approach used in palaeodemographics is particularly susceptible to hidden heterogeneity and selective mortality when examining population-level trends or those that produce relative inferences and as such brings great caution when examining these trends. The three primary difficulties described by Wood et al. (1992) include demographic nonstationarity, hidden heterogeneity in frailty, and selective mortality. The first of these, demographic nonstationarity, is the issues of a populations growth or decline because of changes in fertility, mortality, or migration (Wood et al. 1992). Due to the variable and diverse nature of migration and apprenticeships during the post-medieval period that have been previously mentioned (Section 2.4) this issue was not a focus in this project but was still present in the researchers mind. This is because the period and adolescents were by their very nature non-stationary in their environment.

A large issue in regards to adolescents is hidden heterogeneity in frailty which could potentially distinguish certain adolescents as more susceptible to pathology. In order to assess this heterogeneity, potential sources (like sex, age or social status) must be controlled (DeWitte and Stojanowski 2015). The issue lies with "hidden" heterogeneity and the lack of observable frailty. Marklein et al. (2016) attempted to quantify this stress in archaeological samples and establish a frailty index from which stress and skeletal frailty could be measured through an aggregate score of multiple skeletal biomarkers. While this project does not go into as much depth in the examination of frailty or the incorporation of a customized frailty index, it is discussed with regards to pathological load and susceptibility in regards to the different stages of puberty (in section 7.8.3).

Selective mortality is the theory that adolescents who die at a given age are unlikely to be representative of the entire living population at risk of dying at that age. In regards to post-medieval adolescents in the secondary sample, their individual lifestyles and social class could be related to selective mortality. The fact that the high status London urban sample (n=54, 7.6% of the total secondary sample) was consistently found with the lowest rates of pathology could likely be due to a better overall lifestyle and health. They were not found with any DEH that would indicate early childhood stress likely due to good and consistent nutrition at a young age. This group had some of the lowest prevalence of trauma yet the highest prevalence for instances of medical intervention. Unsurprisingly in contrast the low status adolescents had the highest rates of pathology. It should be noted that the high status secondary sample did not have any of the youngest group (10-11 years of age) of adolescents present. The trends in pathology among the sexes though do not follow the same trend as there are more females with pathology found in the High and Middle status contexts while the opposite is the case for the Low, Mixed, and Birmingham contexts. This could potentially indicate selective favorability for males in the wealthier and more able households in which resources were presented preferentially to males (Molleson et al. 1993).

The primary sample indications of selective mortality and lifestyle could be best seen in the prevalence of contextual differences in pathologies that will be further expanded upon based upon each type in the subsequent sections.

7.4 NON-SPECIFIC INDICATORS OF STRESS

7.4.1 Dental enamel hypoplasia

Dental enamel hypoplasia provide a record of stress during dental development up to around 8 years of age, excluding the third molar (Liversidge 2009), containing information about physiological stress before adolescence. A total of 66 individuals or 15% of the primary sample had enamel defects, with a TPR of 59.5%. In the female sample, there were significantly higher rates of defects at Radcliffe (TPR = 8%) when compared to females in the urban and semi-urban groups. This might be expected given that these girls come from a hospital site and probably suffered from long term chronic conditions, however the same pattern was not observed for the males (Radcliffe TPR = 5.7%, Plymouth 0.8%). For the males, it was the urban group that had the highest prevalence rates (TPR = 9.3%), which was significant when compared to the semi-urban males. Crude prevalence rates for the secondary sample were comparable to the primary group at 16.7%, but the majority of individuals with defects (81.5%) came from Birmingham. In the small sample that could be sexed from this site (n= 12,), males had a trend for more defects compared to females (22% and 15% respectively).

7.4.2 Non-specific infections

Of the 33 (12.3%) individuals identified with endocranial lesions in the primary sample, 61% were urban females, which was significant when compared to the lower rate in the females from Radcliffe infirmary. There was a significance difference in the rates of cranial lesions (X^2=10.87, P=.001 at 1 d.f.) between the two infirmary sites with Plymouth having 17% more cases than Radcliffe. The presence of the endocranial lesions at Radcliffe infirmary might have been expected to be higher if they were the results of tuberculosis meningitis. However, higher rates in the male sailors may suggest their endocranial lesions were related to the higher rates of treponematosis or scurvy at the site. Endocranial lesions were not consistently recorded in the secondary sample, with only 5 of the 323 individuals in the sample recorded as having these lesions. In comparison to medieval adolescents (10-25 years) endocranial lesions were considerably higher in post-medieval adolescents, both overall (0.6% to 23.9%) and between males (0.4% to 11.8%) and females (0.8% to 32.5%) (Lewis 2016b). The fact that endocranial lesions were present in less than 1% of teenagers from the medieval period indicates a significantly (X^2=496.88, P=.001, at1 d.f.) higher presence of the infections in the post-medieval period.

In the primary sample, 107 individuals or 25% had subperiosteal new bone formation indicating infection or trauma. The highest rates (54%) were at Radcliffe Infirmary. The Radcliffe females (n=25, 61%) had significantly more new bone formation than the males and females from all other site types. There is an expectation that a medical hospital would have a high level of infection, and this may have been related to their admittance into the hospital, although most of the lesions were healed at the time of their death. However it is not clear why the females were bearing a greater portion of the pathological load.

In the secondary sample, prevalence of sub-periosteal new bone formation was slightly higher than for the primary group at 32%. There were more cases in the male sample (39%). The highest number of cases was in the oldest age group at 72% suggesting a cumulative effect for the infection. There were no significant differences between site types or social status groups.

The overall prevalence of new bone formation was 15.9%, significantly (X^2=102.39, P=.001, at1 d.f.) higher than the medieval adolescent rates of 9.1% (146/1270) presented by Lewis (2016b). Medieval males (12%) and females (8.3%) were significantly less susceptible to non-specific infections (Lewis 2016) than males (29.8%) and females (33.1%) in the post-medieval period. This suggests a higher rate of infectious disease and greater exposure to infections during the post-medieval period due to a decline in hygiene from densely populated urban settings, denser living spaces, and more pollution.

7.5 CHRONIC RESPIRATORY INFECTIONS

Respiratory infections include maxillary sinusitis, visceral rib lesions and tuberculosis. The levels of sinusitis and visceral rib lesions suggest that all the post-medieval adolescents were exposed to high levels of air pollution that had detrimental effects on their respiratory health. Figure 7.4 shows the prevalence rate of respiratory disease in the Infirmary sites, compared to the combined primary and secondary urban groups to provide further clarity on the changes between the two Infirmary sites, non-London urban sites, and urban London. Compared to later medieval data (Lewis 2016a), urban females had significantly more chronic respiratory infections than their medieval counterparts. The highest rates of respiratory diseases come from the infirmary sites, with Radcliffe showing the greatest percentage of visceral rib lesions associated with chronic chest infections (Figure 7.4). Given the rules for admittance against the admittance of patients with tuberculosis (Selby-Green, 1990), it is surprising that the rate of visceral rib lesions was so high and would indicate that this population of adolescents served by the hospital were disproportionally affected by respiratory infections. Plymouth had the highest rates of TB which was not significant and maxillary sinusitis which was significant in comparison to London (X^2=4.98, P=.05, at1 d.f.), the latter suggesting an increased exposure to air pollution (Merret and Pfeiffer, 2000; Lewis 2015). This could be attributed to the confined and densely populated living quarters of ship-based life that provided ideal conditions for the spread of infectious diseases like tuberculosis and smallpox (Brown 2011) in the post-medieval period. Despite smallpox also being indicated in the historical records, there was no osteological evidence for it in the primary sample (i.e. osteomyelitis of the distal humerus).

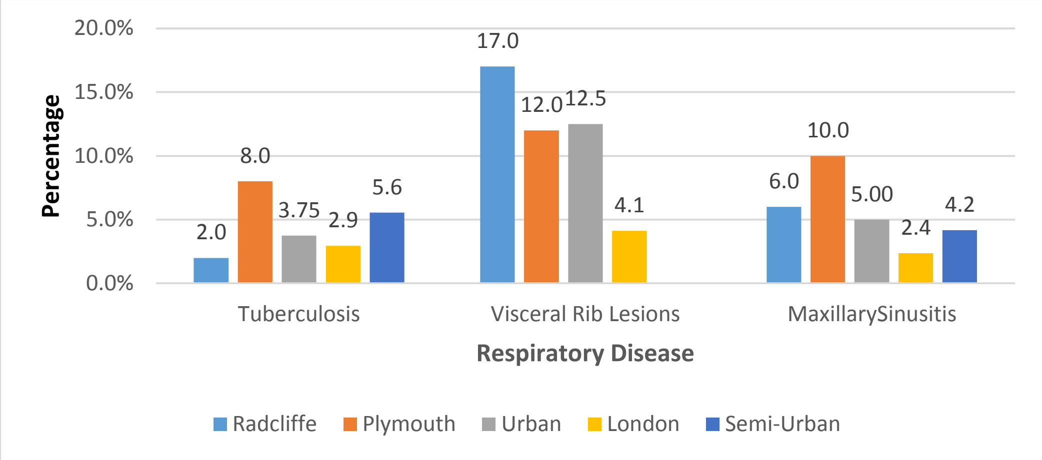

Figure 7.4: Respiratory infections in Radcliffe, Plymouth, the non-London urban group, London, and Semi-urban group

The overall rates of chronic respiratory infections in medieval adolescents (5.2%) (Lewis 2016b) were lower than the post-medieval adolescents (15%) in this study, indicating worsening air pollution and the rise of tuberculosis. Some causes of the increase in tuberculosis are likely tied to the increase in poverty, overcrowding, industry, and shifting diet (Roberts and Buikstra, 2003). London had some of the lowest rates of respiratory infections in both samples; this is surprising given the historical accounts and documentation of the poor air quality of London (Dirby 1658). In fact, the non-London urban sites had significantly more evidence for these conditions (X^2=11.99, P=.001 at 1 d.f).

Lewis (2016a) demonstrated that females carried the burden of respiratory infection in later medieval England with double the rates of TB in the females compared to the males. Here, 15 individuals or 10% of the primary sample had evidence for TB. Twice as many females were affected than the males (4 and 8 individuals respectively), suggesting this pattern of infection is continuing from earlier periods. In modern populations with TB, other than the single instance of modern Japanese women, the sex ratio is in fact the inverse with males being found with the disease twice as often (Nhamoyebonde and Leslie 2014).

Archaeologically, the gendered expectation is also the same (Roberts and Buikstra, 2003). Some possible occupational causes for increased exposure could be the access to urban farms and contaminated milk or the presence of women working as servants, while the greatest contributing factor is likely to be poverty and the densely urbanized living conditions that would accompany it. The earliest cases of TB were in the 14.0-16.9 year cohort with a steady increase until the age of 20.0-21.9 years. In the secondary sample, 15 (4.6%) of individuals had evidence for TB but more than double were male (9 and 4 respectively). TB was present in all site types and social status groups but the male predominance for TB in the secondary data comes from the low status urban groups. There were no low status groups in the primary sample suggesting that the sex ratios of TB are affected by social status, at least in London.

7.6 METABOLIC DISEASES AND BLOOD DISORDERS

The presence of metabolic diseases in the post-medieval period is well documented (Ives and Brickley 2014, Brickley et al. 2014; Mays, 2013; Gerber and Murphy 2012), with deaths as a result of scurvy and rickets documented in the London Bills of Mortality (Roberts and Cox, 2003). There were no differences between the rates of cribra orbitalia in the samples, and this may be the result of including Grades 1 and 2 within the samples to allow comparisons with the secondary data (Figure 7.5). When examining the most severe grades (4-5) there were only 7 (2%) adolescents from the primary sample with cribra orbitalia and they were from the infirmary (n=4, 1%) and urban (n=3, 0.8%) cohorts with no presence of the most severe cribrous lesions from the semi-urban cohort.

The Radcliffe adolescents had the lowest rates of metabolic diseases (1%) while in contrast, Plymouth had among the highest rates for rickets (4%) and the highest for scurvy (6%). All of the Plymouth males were found with resolved rickets indicative of a childhood deficiency and not active forms of the pathology. The high rate of residual rickets in the Plymouth sailors indicates the need for male sailors at the time despite any previous maladies or shorter stature they may suffer from. These data suggest that the Radcliffe adolescents were both well-nourished and had access to good levels of light, this probably reflects the wealthier status of these patients who had to pay to enter the hospital (Selby-Green 1990), and their better living conditions. The link between scurvy and sea travel is well documented (Lind 1772; Roger 1988) and the results reinforce the higher levels of vitamin C deficiency at sea. The lower rates of scurvy in the general population may reflect the introduction of potatoes, rich in vitamin C during the 17th century (Roberts and Cox, 2003) which contributed to the low (0.2-0.5%) death rates from scurvy described in the London Bills of Mortality. In the current study, the lower rates of scurvy in the combined London sample suggest a greater availability of vitamin C in comparison to the non-London areas.

The highest rates of healed childhood rickets overall were from adolescents living in London (7%). These rates were significantly greater than in the semi-urban (X^2=4.88, P=.05, at 1 d.f.) and Radcliffe (X^2= 6.22, P=.025, at 1 d.f.) groups, which again, is in line with historical accounts and reflects high levels of air pollution in the city.

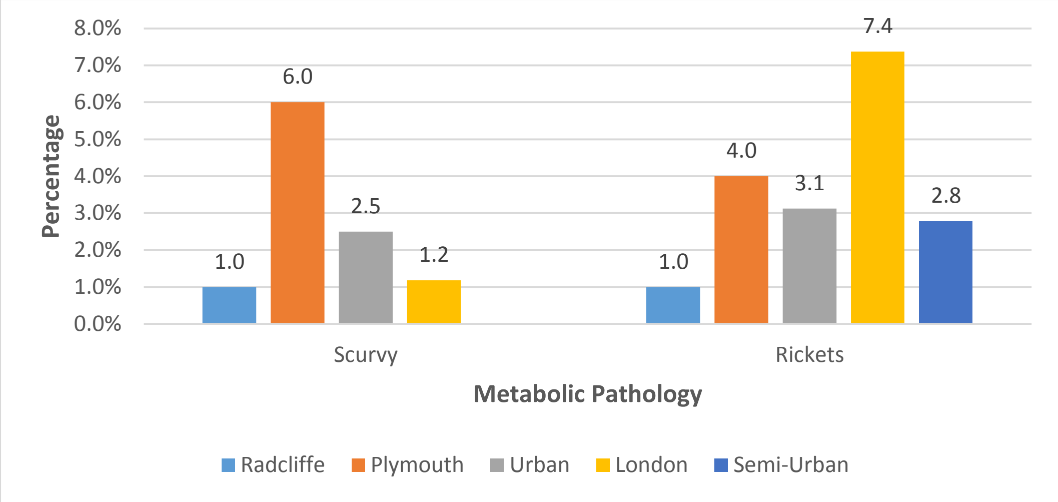

Figure 7.5: Scurvy and rickets in Radcliffe, Plymouth, the non-London urban group, London, and Semi-urban group

7.7 INFECTIOUS DISEASE

Despite previous research into post-medieval samples showing evidence for osteomyelitis as the result of smallpox and its link to sailors (Andrews and Jayan, 2001; Brown 2011), no cases were identified in the study sample. However, 12 (3.4%) individuals in the primary sample showed evidence for treponemal disease, including 3 with congenital syphilis (Figure 7.6). When considered by age, the majority (n=3; 37.5%) were aged 17.0-19.9 years, the youngest possible case was in a 13-year-old. Of the 8 syphilitic individuals that could be sexed, 6 were males. The presence of treponematosis varied throughout the different regional contexts of the combined primary and secondary sample, with the Plymouth skeletons having the highest percentage (6.2%) (Figure 7.6).

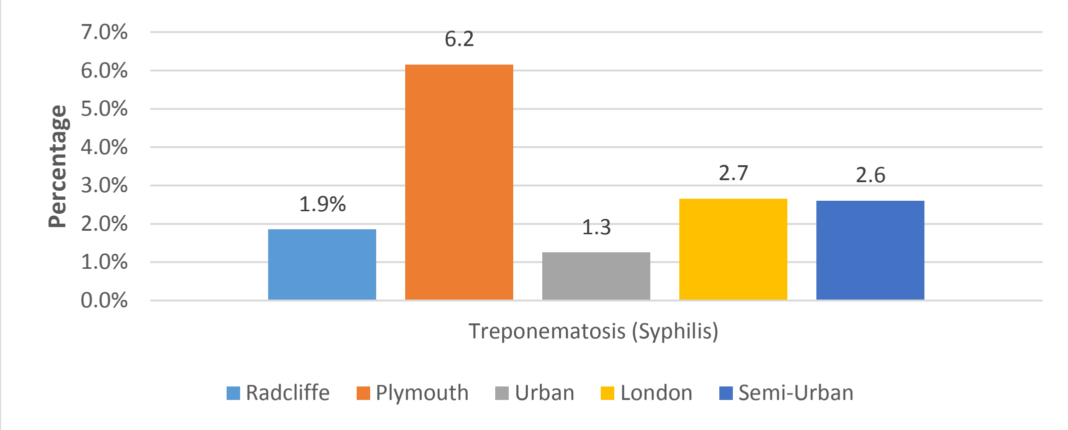

Figure 7.6: *Treponematosis in Radcliffe, Plymouth, the non-London urban group, London, and Semi-urban group.*

This includes two individuals born with congenital syphilis. The fact that the Plymouth sample included individuals with possible congenital syphilis is surprising and suggests that they were selected for service despite evidence for this chronic debilitating disease. The syphilitic young men that dominated the naval hospital reflect a subset of the population that was more prone to risky sexual behaviour. All of these sailors were over the age of 15, although the youngest case indicates delayed pubertal development as he was only in the acceleration phase, putting him roughly 3-5 years behind his peers.

In the secondary sample, 8 or 2.5% of individuals had lesions suggestive of venereal syphilis, with an even distribution of males and females. Five of these adolescents (87.5%) came from low status urban sites.

In addition to the negative health impacts of venereal syphilis, the social stigma and pressure that would be placed on those who contracted it would be noteworthy (Siena 2004, 2005). As the period progressed the social stigma of “the pox” grew from a sign of divine retribution in the 16th century, to a strong physical representation of social and sexual deviance by the mid-to late 17th century (Zuckerman 2017). The sex differences among the cases of acquired syphilis in the post-medieval period resemble those of modern patterns with males being two to three times more likely to contract the disease than females (Aufderheide and Rodriguez-Martin 1998) but it was different to the pattern found in the medieval period (Lewis, 2015). It should be noted that these numbers of individuals are only those whose infection had progressed to the point in which there was osteological evidence, and as such the actual number of individuals with the infection could be much higher.

7.8 TRAUMA AND TREATMENT

The extent of traumatic injuries in the post-medieval period shows a significant difference between the more urbanised and semi-urban locations. In the primary sample, 34 adolescents demonstrated trauma, with the majority (n=19; 10%) in the infirmary group followed by the urban cohort (n=10, 9%). The majority of trauma was located in the spine (n=16, 47%) which was highest in the urban group (n=7, 20%), which are normally associated with falls from height, or load bearing (Scalea et al. 1986; Boston, 2014). Despite the expectation that the Plymouth skeletons would have high levels of trauma due to their role as soldiers, there were only two cases, and these were all in the form of cranial trauma (n=2). This is possibly the result of these adolescents being "selected" out for further treatment at the hospital where they later died. It is a possibility that other adolescent sailors had traumatic injuries but they were not admitted to the hospital as head injuries would be more severe. The high prevalence of trauma identified at Plymouth previously by Boston (2014) was in older sailors who had survived multiple tours. Given the fact that the skeletons in this sample had previously been on ship before going to the hospital and only went up to 25 years of age, there is the possibility that they had not seen battle yet or that their injuries were soft tissue and had not had any skeletal impact.

Females in the primary sample were found with the all of the lower limb trauma recorded (n=6). While females from infirmaries had the highest amounts of trauma recorded, the variation in locations of trauma was greatest in the urban cohort. The semi-urban cohort had the lowest trauma in the sample (n=5, 14.7%) and they were all vertebral in nature. The age distribution of traumatic injuries indicated that the majority (74.3%) of trauma found was in the older adolescents (18 – 25 years). This possibly indicates that there is greater exposure to environmental and interpersonal trauma with an increase in age from child to adult.

In contrast to overall fracture rates attributed to deaths, Cox and Roberts (2003) found the greatest percentage of trauma to be focused upon the ribs unlike the vertebrae found here in this project. Unfortunately a lack of additional studies into the extent, locations, and possible causes of trauma during the post-medieval period make comparing the trauma identified in adolescents difficult to contextualize.

In the secondary sample, 58 (18%) of adolescents were found with trauma, with the majority coming from London (n=53, 87%). Of the London group, 24 (39%) were from the low status sample. The secondary sample provides a very different picture of the distribution of urban trauma, especially for London. While there were still a high number of individuals with vertebral trauma (n=7), fractures were more widely distributed across skeleton. The secondary sample had three cases of facial trauma in the low status context, as well as five cases of cranial trauma. In London, the high-status group had the lowest incidence of trauma and the low status group, the highest. In the combined primary and secondary sample, there was significantly more (X^2=5.27, P=.025 at 1 d.f) trauma in the London sample compared to any other.

The rise in population density and overcrowding created squalid living environments and post-medieval adolescent males, like their medieval counterparts (Roberts and Cox 2003), would likely be more prone to risky behaviour, and no location was more indicative of this than in London, with the presence of facial (n=3) fractures possibly indicative of interpersonal violence (Figure 7.7). The rib (n=2) stress fractures that were present could potentially have been the result of crush fractures due to machinery work or falls (Lovell, 1997; Roberts and Cox 2003). Surprisingly, half (n=2) of the facial trauma from the secondary sample was found in low status females suggesting that some females were exposed to greater trauma directed at the face. Urban males were found with high levels of each type of trauma (10% - 37% respectively). Birmingham females in contrast were only found with trauma to the upper limbs (n=2, 20%) reinforcing the belief that greater urbanization would provide greater opportunities for trauma but also the possibility that they were being exposed to greater falls or injury (Ives et al. 2017).

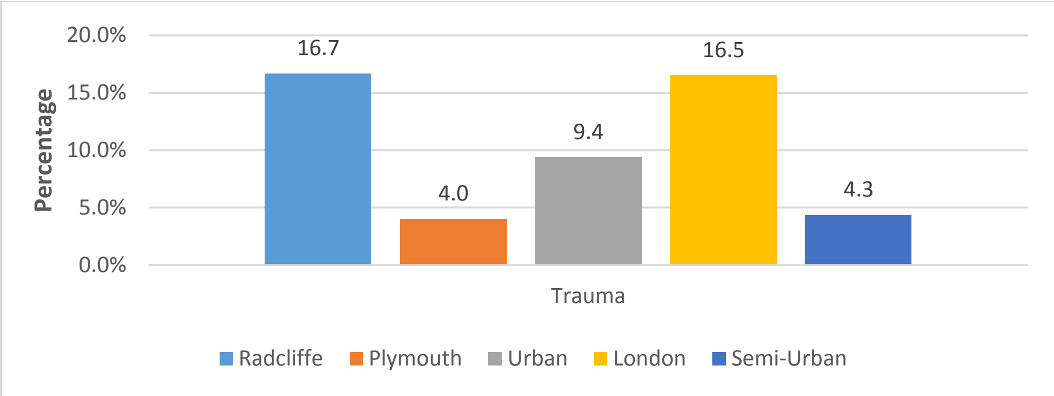

Figure 7.7 Trauma in Radcliffe, Plymouth, the non-London urban group, London, and Semi-urban group.

7.8.1 Medical Intervention

While there were several reported cases of craniotomies in the secondary sites, in the primary assemblage, trauma indicative of medical intervention was found in all locations in the primary sample and was the greatest in the Radcliffe infirmary (10%). This is due to the very nature of this regional hospital and its later development and expansion. The main difference between the two medical contexts is the type of medical interventions that were being performed. The medical interventions in Radcliffe were more diverse and exploratory in nature, encompassing craniotomies, amputations, post-mortem dissections, and trepanations. Plymouth medical intervention consisted entirely of craniotomies and amputations. The fact that all site types had some individuals with a form of medical intervention (craniotomies) is representative of an underlying growth of the medical field and the expansion of hospitals in the post-medieval period (Fowler and Powers 2012).

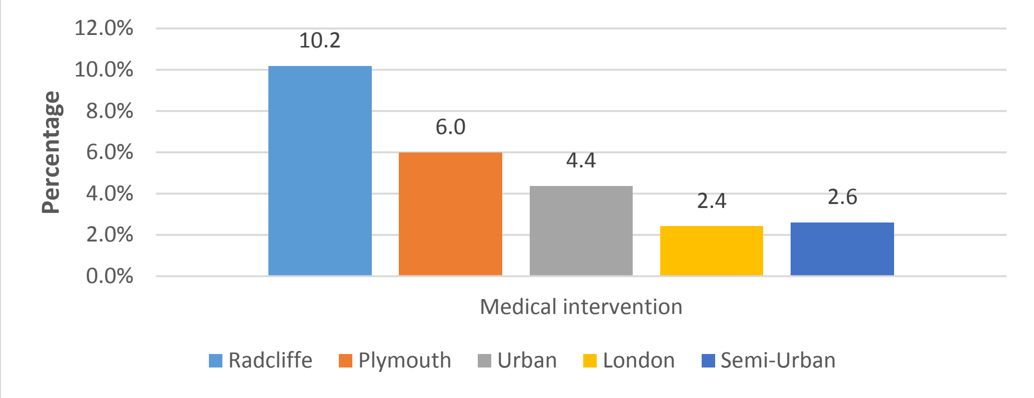

Figure 7.8 *Medical interventions in Radcliffe, Plymouth, the non-London urban group, London, and Semi-urban group.*

7.7 PUBERTY IN POST-MEDIEVAL ENGLAND

In the primary sample it was possible to score pubertal status for to 364 (79.1%) individuals. Of these 298 (81.9%) were assigned a dental age (166 males; 129 females). The average age of onset was 10-13 years for both males and females, with PHV at 14.8 years in females and 16.2 years in males. The average age of menarche was 16.2 years. No post-medieval adolescents were found to have started pubertal development (onset) before the age of 11 in contrast to the modern, medieval and Roman data which included individuals as young as 9 years at onset. There was considerable variation in the post-medieval pubertal development, including both late and early maturers, similar to modern patterns (Lewis, 2018).

When compared to previous studies on Roman and medieval teenagers, there were similar ages of onset for each stage, however post-medieval adolescents took longer to complete each stage (Table 7.2 and 7.3).

Table 7.2 Average age and age ranges of pubertal development in modern, post-medieval, medieval and roman males

Male Pubertal Development	Modern Male*		Post-medieval Male		Medieval Male**		Roman Male***	
	Age range	Mean Age	Age range	Mean Age	Age range	Mean Age	Age range	Mean Age
Initiation	9.5-13.5	12	10-13	11.2	10-12			
Acceleration	11-13	11.8	11-16	13.3	10-16	12.9	12-18	14.2
Peak Height Velocity	13-15	14.2	15-18	16.2	15-16	15.1	17	17+
Deceleration	17-18	17.1	15-18	16.8	15-17	16.8	16.5-17.5	17
Maturation			18-25	20.3	16-20+	18.7		
Completion			18-25	22.4	16-20+			

**Marshal and Tanner 1969; ** Compiled from Lewis et al. 2014; ***Compiled ages from Arthur et al. 2016*

Table 7.3 Average age and age ranges of pubertal development in modern, post-medieval, medieval and roman females

Female Pubertal Development	Modern Female*		Post-medieval Female		Medieval Female**		Roman Female***	
	Age range	Mean Age	Age range	Mean Age	Age range	Mean Age	Age range	Mean Age
Initiation	8.5-13	10	10-13	11	10-12		8-9	
Acceleration	10-12	10.2	11-15	12.8	10-13.9	11.7	10-12	11.3
Peak Height Velocity	11-13	12	13-19	14.8	15-16	15.1	11-15	13
Menarche	12.5-13.2	12.6	14-18	16.2	15-17	15	15-17	14.1
Deceleration	14.2-15.2	14.8	14-19	16.1	12-18	15.3	18-19	
Maturation			17-25	20.4	16-20	18.1	17-20	
Completion			17-25	23	16-20+			

**Marshal and Tanner 1969; ** Compiled from Lewis et al. 2014; ***Compiled ages from Arthur et al. 2016*

The average age of entry into the acceleration phase was one year later in the post-medieval males compared to their medieval counterparts, while PHV took 1 year longer for the post-medieval males to complete. The Roman males appear to be entering each stage later than their medieval and post-medieval counterparts, but this may be a reflection of the much smaller sample sizes. In the post-medieval females, the only pubertal stage in which the average age of onset was younger than the medieval females was at PHV, but they took 5 years longer to complete this stage (Table 7.3). Roman females were ahead of both of these groups at every stage.

The modern ages discussed in this section are the recorded ages of living individuals where the precise age of entry to each stage was known, while the osteological pubertal ages are all based upon age at death data and age at which each stage was surpassed, and so comparisons should be treated with caution. As non-survivors, the adolescents in this sample and the timing of pubertal development that they represent may not reflect the timings of the living population in which they were originally derived (Arthur et al. 2016). When compared to modern data, post-medieval males entered the acceleration phase 1.5 years later than their modern counterparts, with females being 2.6 years behind modern females. PHV was delayed by 2.6 years and 2.8 years for post-medieval males and females respectively.

One feature of post-medieval puberty is the large overlap in ages between the pubertal stages. This larger age range in both sexes indicates a greater variability due to environmental stresses and pathology that will be further developed in the puberty and pathology section.

Table 7.4: Pubertal timing of the Post-medieval males sample compared with Modern, Medieval, and Roman males. Black squares represent the ages at which the various pubertal stages were observed while the white numbers are the mean ages for each stage (adapted from Doe et al. 2017)

Adolescent Sample	Pubertal stage	Estimated age-at-death (years)														
		8	9	10	11	12	13	14	15	16	17	18	19	20	21	22-25
Modern (Marshal and Tanner 1969)	Initiation					12										
	Acceleration				11.8											
	PHV							14.2								
	Deceleration										17.1					
Post-medieval (This study)	Initiation				11.2											
	Acceleration						13.3									
	PHV									16.2						
	Deceleration									16.8						
	Maturation													20.3		
	Completion															22.4
Medieval (Lewis et al. 2016)	Initiation															
	Acceleration					12.9										
	PHV								15.1							
	Deceleration									16.8						
	Maturation											18.7				
	Completion															
Roman (Arthur et al. 2016)	Initiation															
	Acceleration							14.2								
	PHV										17					
	Deceleration										17					

Table 7.5: Pubertal timing of the Post-medieval females sample compared with Modern, Medieval, and Roman females. Black squares represent the ages at which the various pubertal stages were observed while the white numbers are the mean ages for each stage (adapted from Doe et al. 2017)

Adolescent Sample	Pubertal stage	Estimated age-at-death (years)														
		8	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22-25**
Modern (Marshal and Tanner 1969)	Initiation			10												
	Acceleration			10.2												
	PHV					12										
	Menarche					12.6										
	Deceleration							14.8								
Post-medieval (This study)	Initiation				11											
	Acceleration					12.8										
	PHV							14.8								
	Menarche									16.2						
	Deceleration									16.1						
	Maturation													20.4		
	Completion															23
Medieval (Lewis et al. 2016)	Initiation															
	Acceleration				11.7											
	PHV								15.1							
	Menarche								15							
	Deceleration								15.3							
	Maturation											18.1				
	Completion															
Roman (Arthur et al. 2016)	Initiation															
	Acceleration				11.3											
	PHV						13									
	Menarche									14.1						
	Deceleration															
	Maturation															

7.8.2 Menarche

The timing and onset of first menstruation is a significant milestone not only biologically but also socially (Boynton-Jarrett and Harville, 2012). The average age for females who had achieved menarche in the post-medieval period was 16.2 years. This compares to 15 years in the medieval period and 14 years in the Roman. Modern European females have their menarche at around 12 years, with post-medieval females being 3.6 years behind modern females. The age of modern males and females reports the actual age of their first period, in contrast to the archaeological data that, in the absence of an unossified iliac crest, can only record the age at which menarche had been achieved. There was a broader age range for females achieving menarche in the post-medieval sample when compared to the earlier time periods, with an extra year at either end of the range.

Between the 1840s and 1880s the average age of menarche varied by location and social status in England (Whitehead, 1847; Rigden 1869; Giles 1901). For the working women of Manchester, menarche occurred on average at 15 years and 7 months, while the "educated ladies" had their first period earlier at 14 years and 6 months (Whitehead, 1847 cited in Papadimitriou 2016: 529). In contrast, London obstetric patients from 1855, reached menarche at 15 years and 5 months (Rigden 1869; Papadimitriou 2015). The osteological data supports these reports with the average age of a female having experienced menarche by 16 years.

The possible causes of delayed pubertal development in post-medieval women when compared to modern data and earlier periods indicate they were struggling with poor nutrition. In modern populations, slow pubertal progress and menarcheal delays have been related to poor nutritional status (Goyal et al. 2012) and famine (Van Noord and Kaaks 1991). Due to a reduced peak bone mineral density at the time of maturation, women are more susceptible to developing osteoporosis at an earlier age when menarche has been delayed by two or more years (Karapanou and Papadimitriou 2010). A later age of menarche would have the further social implications that females are not yet adults and of childbearing age. While this could dampen the viability of them as a marriage partner, the average age of marriage was considerably later than the age of menarche, at 20-22 years (Mendelson and Crawford 1998).

7.8.3 Puberty and Pathology

The association between pathological conditions and pubertal development has been recently demonstrated (Lewis 2016). In the primary sample, 72 adolescents were found to be delayed in their pubertal development. Of these, 56 (20.2%) had some form of pathology (metabolic, infectious, congenital) while 16 (22.2%) had no evidence of disease. The majority of the delayed individuals were from the Infirmary context (n=31, 43%) followed by the urban context (n=27, 37.5%).

In the study by Lewis et al. (2016), syphilis was shown to have no effect on pubertal delay, and they suggested that the disease was contracted after PHV had been attained and secondary sexual characteristic were evident. As the majority of these individuals were female, it was suggested these individuals could have been employed in prostitution. In the current study while numbers are small, treponemal disease did appear to affect pubertal development. Of the 6 males with the disease, 3 (50%) showed some delay, two with venereal syphilis, and one individual with congenital syphilis. Two of the three delayed males were in the deceleration phase aged 22-25 years (mean 16.8 years) but had passed PHV and the development of secondary sexual characteristics. In contrast, the male with congenital syphilis was still in the acceleration phase at 15 (mean 13 years).

Lewis et al. (2016) found TB to be significant in delaying pubertal development in later medieval adolescents (n=10, 74%). There were five delayed adolescents with tuberculosis of which three are of distinct note. The first was a highly delayed 16-16.9 year old male from urban Manchester who was found to still be in the acceleration phase. The second was an 18-18.9 year old male from the Naval Plymouth hospital who was identified as being in peak height velocity. The third and only female was 17-17.9 years old and found in the semi-urban context having only reached peak height velocity.

When pathological lesions were correlated with delayed puberty, 4 (40%) had TB and were delayed, but 22% showed a delay with no evidence for chronic infection. The 40% of delayed individuals with TB mirrors previous studies (Lewis 2016) and suggests that TB had a detrimental effect on pubertal development. Nineteen (26.4%) of the delayed adolescents were found with some form of metabolic condition, although the majority of these (n=14; 73.7%) had cribra orbitalia. There was no evidence for a link between scurvy and delayed puberty.

Of the 190 adolescents in which vertebral stress was recorded, only 30 (15.8%) were found to have delayed pubertal development, while 34 (17.9%) were found with enamel hypoplasia. The statistical analysis comparing adolescents with and without delayed puberty and vertebral growth indicated that there was no significant difference between the anterior-posterior and transverse lengths in male adolescents but there was a significant difference between the 2nd, 3rd, and 4th lumbar vertebrae when looking at the mean sizes of the vertebral body heights.

The impact of a lower VNC on pubertal development was limited with only 16% who were delayed showing small VNC. It may be related to the timing as the transverse measurement was determined to be reduced in comparison to the average non-delayed cohort. While the fusion was complete by the beginning age ranges of this project (10-13 years of age), the AP and TR diameters have been shown to increase through remodelling of the vertebral canal and neural arch until around 15 years of age (Watts, 2013). This remodelling takes place during the early phases of pubertal development in modern samples, but given the delay in post-medieval puberty, there could be an effect on the vertebral dimensions leading to smaller canal size.

Puberty, Susceptibility, and the Osteological Paradox

There are several possibilities when examining susceptibility based upon puberty and pathology in regards to the osteological paradox. While the low numbers of adolescents made it difficult to make definitive conclusions about susceptibility and pubertal development, there are some hypotheses for the trends found.

One hypothesis for the age demographics recorded in the samples is that the adolescents were not the most susceptible within the population as those would have already perished at earlier ages before making it to 10 years. The general belief in academia is that overall susceptibility is greatest in the youngest and most vulnerable children in any population (DeWitte and Stojanowski 2015. Within the youngest age category (10-13.9 years) the presence of early life stresses (DEH) could potentially predispose the adolescents to dying young but they were still present (21.7%) and did not comprise the smallest percentage of the sample (20-21.9 years, 11% of the population). Within this sample, it can be seen that there are differences in the pathologies present between sexes with vitamin D deficiency being more prevalent in females and dying in the early life stages.

Another hypothesis for the increased rates of 17 year olds found within the sample (28.1%) is that the biological change of puberty has once again increased the overall susceptibility of the individuals. As such, adolescents with a delayed pubertal growth would be expected to be found with a higher degree of pathology. A possible example of this is in the presence of DEH in 17 – 19 year olds. Adolescents were found in this age range to be primarily in the Deceleration (22.2%) and Maturation (22.4%) phase of puberty. This is interesting that the delayed adolescents with DEH that died at this age range were nearing the end of pubertal development yet still had evidence of early childhood stress markers. As such they while they may have been more susceptible in early childhood they were able to survive and make it to the later pubertal stages but with delays. This higher disease load in females in particular could indicate an earlier selective bias in regards to nutrition during the early childhood that is common throughout the Urban and Infirmary contexts.

Puberty could be a potential cause in the increase of pathology as a result of biological, psychological, and social changes that alter the immune system, encourages greater risk taking, and social flexibility. The counter argument to this is that any delays in pubertal development could be as a result of perimortem pathological or environmental effects.

7.9 SUMMARY

Life as an adolescent in post-medieval England depended greatly on where you lived and grew up. In all areas adolescents were exposed to environmental and social stress that affected their mortality, growth and development. For females, life was markedly more difficult from an early age as they were found with more non-specific stress indicators, such as dental enamel hypoplasia, and they suffered more from tuberculosis. Males were found with more treponemal disease and trauma, although the inclusion of post-medieval sailors may have influenced the results. Living in an urban environment would have a negative impact on overall health, and it was these adolescents who showed the highest rates of residual vitamin D deficiency in the sample. Stature was depressed in both sexes of the urban cohorts but males had the opportunity to alleviate some of their childhood nutritional deficiencies through entering the Navy and receiving a stable source of nutrition. Life in the Navy had its own hardships as males would be exposed to constrained living conditions at sea that would expose them to respiratory infections, vitamin C deficiency, and social conditions that exposed them to venereal syphilis. Access to medical care was growing throughout the period but access was still restricted to those who had the funds to pay directly or were connected in some way to influential people.

Urban adolescents were found with more non-specific stress like DEH and non-specific infections than the semi-urban cohort indicating that there were nutritional deficiencies from an early age throughout the cohort. The highly populated urban setting was perfect for the propagation of respiratory infections though the semi-urban context was higher than the more regional urban locations, despite the slightly higher presence of tuberculosis in the semi-urban cohort. The semi-urban adolescents would be taller than their urban peers, have less respiratory infection, better metabolic health due to a wider availability of sunlight and nutrition and less trauma. Despite differences in the rates of specific pathologies, males and females had similar patterns of mortality.

Overall, both males and females would find themselves going through puberty at later ages and with longer durations than their modern, medieval, and Roman peers. This would impact how they interacted with each other socially and within society. As they grew up they would be exposed infectious diseases that could further delay their pubertal development.

With the average age of marriage for females being in the early to mid-20's, the majority of women would be at the end (maturation) or have completed pubertal development. Some females with delayed puberty may not have completed their pubertal development before marriage, though there is historical evidence that not yet reaching menarche was not a prohibitive factor for marriage (Mendelson and Crawford 1998).

Chapter 8: Conclusions and Future work

8.1 CONCLUSIONS

The aims of this research were to assess the health of post medieval adolescents, specifically between the ages 10 to 25 years from throughout post-medieval England to identify trends and differences in health among the population during puberty and any effects of the urbanizing environment on their pathology.

The main conclusions are as follows:

- Males and females were at equal risk of death across all age groups and in all site types.
- There were no significant differences in the growth profiles within the different site types, but the Plymouth males were the tallest and London females the shortest in the primary sample
- Spinal development did not correlate with a younger age at death
- Post-medieval sailors had the highest rates of tuberculosis and maxillary sinusitis, suggesting impact of living conditions
- In the urban cohort females carried the burden of respiratory diseases overall
- Plymouth had highest rates of scurvy, while London had the lowest suggesting availability of vitamin C in the city, compared to a deficit in access to fresh food during long sea voyages
- London had the highest rates of rickets in the post-medieval sample likely reflecting the impact of air pollution
- Syphilis was highest in sailors, and in males from low status urban centres
- There was a longer duration in each pubertal stage compared to other studies, an older age of menarche, and delayed pubertal development in adolescents with treponematosis and tuberculosis

This study represents the largest study of post-medieval adolescent skeletons from England to date. Through the examination of age, sex, stature, skeletal development, puberty stages, and skeletal pathology, this study has provided a picture of what it was like to live as an adolescent in different urban context in post-medieval England. Infectious and metabolic diseases were abundant in the living environment and their impact on overall health and pubertal timing was evident. The composition of the primary sample allowed for a detailed analysis of a broad range of urban contexts, some of which that were unique to the post-medieval period (i.e. infirmaries) that comprised a diverse range of living conditions for adolescents. Despite the desire to consolidate the entirety of the sample as one single English group the distinct nature of the different contexts makes that difficult.

With the exception of Plymouth, which was dominated by males, both sexes were at equal risk of death across all age groups and site types, with no significant differences in their growth profiles. Once growth was complete however, the Plymouth males were the tallest and London females the shortest in the sample. This suggests that once in the navy, males benefitted from access to food resources that were not so readily available to their peers.

The secondary sample provided more general insight into the nature of social status in the urban locations of London and Birmingham by accessing previously published data from excavation reports. These results show poorer health for the low status London adolescents, while rates of TB were equal in London and Birmingham. While growing up in Birmingham appears to have been stressful, with the highest rates of enamel hypoplasia at this site, by later adolescence the health of these individuals was comparatively good.

The secondary sample was also able to provide further insight into the effects of social status on trauma. Those living in low and mixed status urban contexts had higher rates of traumatic injury when compared to high status post-medieval groups. Males had twice the total number of individuals with trauma (16 to 33 respectively). Both sexes from Birmingham had the lowest amounts of trauma while the low status London cohort had the highest. While useful as a comparative database, the secondary sites lacked the resolution and up to date precision that the primary sample had and relied on other observers providing detailed and consistent findings.

The project presented some challenges. Firstly, the number of adolescents dating to the post-medieval period is limited. Many sites have been reburied, access to collections in museums was restricted over the course of this PhD study, and teenagers tend not to die as frequently as other age cohorts. The issue of preservation was more acutely felt due to the need to observe numerous locations on each skeleton to access puberty stage, age and sex, in addition to the presence of absence of disease. The issue of sex ambiguity led to the greatest care being taken when assessing the sex of the youngest skeletons due to lack of easily identifiable sexually dimorphic features.

The examination of spinal growth did not correlate with a younger age of mortality and post-medieval adolescents were found with vertebral dimensions smaller than those in healthier modern populations. Additionally, both male and females were exposed to a higher prevalence of disease and had smaller mean transverse dimensions at all ages except for the 14.0-16.9 year old cohort.

By grouping the adolescents into six pubertal stages, the project was able to identify that post-medieval adolescents had an average overall delay in the timing of puberty in both boys and girls of 2 years to modern studies. There was also a delay in the average age of menarche for post-medieval females (16.2 years) compared to Modern (12.6 years), Medieval (15 years), and Roman (14.1 years) time periods.

The overall impact of pathology on puberty indicated that 56 (20.2%) had delayed pubertal growth and had visible pathologies while the adolescents with the greatest delay from the average pubertal age for each sex were identified with tuberculosis. There were only 30 (15.8%) of the population that had both a delayed pubertal development and smaller VNC measurements.

This project has contributed new insights into what it was like to grow up in post-medieval England and the social and environmental processes that shaped health in Urban, Semi-urban, and Infirmary environments.

8.2 FUTURE WORK AND RECOMENDATIONS

While this project has expanded research into the timing of puberty in post-medieval period there are still opportunities to further the research. It would be desirable to expand the population of adolescents examined from this time period, as well as to diversify the possible locations with some infirmary sites to the north as well as more samples from developing towns. The incorporation of "rural" post-medieval adolescents would be important in differentiating the extent of pathological development and identifying whether there are distinct migratory signals. The use of stable isotope analysis can be used to identify diet and track movement while the use of epigenetics and peptides can help to explore sex and provide greater clarity into the timing of puberty. Ultimately, greater numbers of individuals from throughout the country during this period are required for the post-medieval period to expand on our understanding of what it meant to live in the post-medieval period throughout the country. The effects of sexual dimorphism in the timing of vertebral neural dimensions and body growth are not fully understood and a larger and more comprehensive dataset is necessary.

While these techniques have been very effective in determining new information about post-medieval adolescents in England, they can still be used and transferred to other urbanizing locations in the past such as continental Europe. In doing so the further research would build and provide complementary parallels in which to compare post-medieval adolescents and the lives and health in the greater context of the world.

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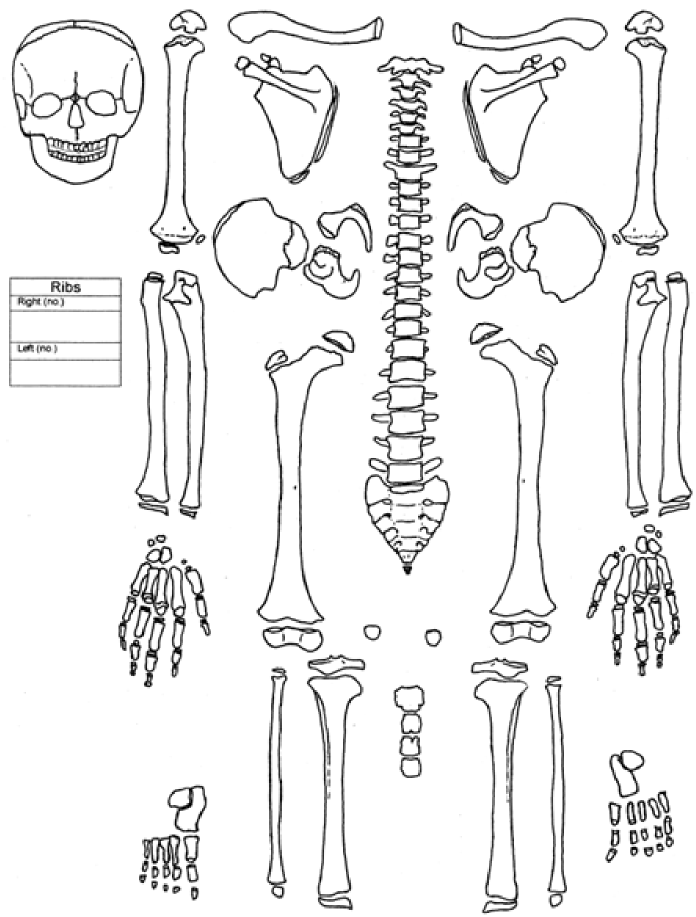
Appendix 1

Recording Form

Recording Form			
Site Code:	Site Name:		Skeleton No:
Age:		Sex:	



Dentition

R	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	L
	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	

Pathology Key: Calculus - C, Carries - Ca, DEH, Tooth formation stage:

Sex Determination

Sub 15 - Distal Humerus		**Pelvis 15 years and older**	
Trochlear constriction		Greater Sciatic Notch	
Trochlear symmetry		Subpubic Angle	
Olecranon fossa shape		Subpubic Concavity	
Angle of the medial epicondyle		Ventral arc	
Mental eminence		Ischiopubic Ramus	
Auricular elevation			
Sciatic notch angle			
Sciatic notch depth			
Sex:			

Age Determination

Fusion/Development	**Stage**	**Age**	**Comments**
Dental Calcification			
3rd molar state			
Vertebral annular rings			
Fusion of the Ischial epiphysis			
Basilar Synchondrosis			
Sacral fusion			
Medial Clavicle			
Long Bone fusion			

Age:	**Comments:**

Pubertal Stage

Canine Mineralization	Iliac crest Fusion	Phalanges and Distal Radius	Hamate hook development	CVM

Overall pubertal stage:		Estimated age:	

VNC and Vertebral Body Height

Vert.	**Anterior Posterior length (AP)**	**Transverse Length (TR)**	**Vertebral Body Height (VBH)**

Appendix 2

Primary Sample skeleton list

Gaps in Project numbers are due to skeletons omitted due to preservation or age. Further information can be seen in the digital database cd attached.

Project Number	Site Type	Sex	Age Category	Pubertal Stage:	Path	Stature	Vert
1	Urban	2	14-16.9	3	0	163.274	1
2	Urban	5	14-16.9	3	1	147.118	1
3	Urban	2	22-25	6	0	169.819	1
4	Urban	4	10-13.9	2	0	153.992	0
5	Urban	1	14-16.9	2	1		0
7	Urban	3	14-16.9	2	1		0
8	Urban	2	17-19.9	6	0		0
9	Urban	2	14-16.9	3	1		0
10	Urban	5	22-25	6	1		1
11	Urban	5	22-25	6	0		1
13	Urban	4	22-25	6	0		0
14	Urban	4	14-16.9	3	0	163.274	1
15	Urban	2	14-16.9	2	0	163.274	1
16	Urban	1	17-19.9	4	1		1
17	Urban	1	17-19.9	4	1	169.7	1
18	Urban	5	17-19.9	5	1		1
19	Urban	5	17-19.9	5	0		1
21	Urban	1	20-21.9	4	1	163.75	1
22	Urban	5	20-21.9	6	1		1
24	Urban	1	20-21.9	6	1		1
25	Urban	1	22-25	5	1		1
26	Urban	1	22-25	5	1		0
27	Urban	4	22-25	5	1		1
29	Urban	5	22-25	6	0		0
30	Urban	1	22-25	5	1		1
32	Urban	1	22-25	6	1	163.512	1
33	Urban	5	22-25	5	1		1
34	Urban	1	22-25	6	1		1
36	Urban	1	22-25	6	1		0
37	Urban	2	10-13.9	2	1		1
41	Urban	4	14-16.9	4	1		1
42	Urban	4	17-19.9	4	1		0
43	Urban	5	20-21.9	5	0		0

44	Urban	5	17-19.9	6	1		0
45	Urban	5	17-19.9	5	1		1
46	Urban	1	17-19.9	3	1		0
47	Urban	4	17-19.9	3	1		0
48	Urban	1	22-25	6	1		0
49	Urban	1	22-25	6	1		1
50	Urban	1	22-25	6	1		1
52	Urban	4	10-13.9	1	1		0
56	Urban	1	22-25	5	1		0
57	Urban	2	10-13.9	1	1	140.902	0
60	Urban	2	22-25	6	1		1
62	Urban	4	17-19.9	6	1		0
63	Urban	5	17-19.9	4	0		0
64	Urban	1	20-21.9	6	0		1
66	Urban	4	10-13.9	1	1		0
69	Urban	2	10-13.9	1	1		1
70	Urban	4	10-13.9	1	1		1
71	Urban	4	10-13.9	2	1		0
74	Semi-Urban	4	10-13.9	2	0		0
76	Semi-Urban	3	10-13.9	1	1		0
78	Semi-Urban	1	17-19.9	5	1	169.7	0
79	Semi-Urban	5	17-19.9	5	1	169.101	1
80	Semi-Urban	4	22-25	6	0		0
81	Semi-Urban	1	10-13.9	2	0		1
82	Semi-Urban	1	22-25	6	1	178.506	1
83	Semi-Urban	1	22-25	6	1	160.418	0
84	Semi-Urban	1	17-19.9	5	1	170.89	1
88	Semi-Urban	2	10-13.9	1	1	137.808	1
89	Semi-Urban	1	22-25	6	0	177.554	0
90	Semi-Urban	5	10-13.9	2	0		0
91	Semi-Urban	5	14-16.9	4	1	149.835	0
92	Semi-Urban	4	14-16.9	3	1		0
93	Semi-Urban	5	14-16.9	3	0		1
96	Semi-Urban	4	10-13.9	1	1		0
97	Semi-Urban	5	22-25	6	1	155.022	0
98	Infirmary	4	22-25	5	1		0
99	Infirmary	4	10-13.9	3	1		0
100	Infirmary	1	17-19.9	3	1		1
102	Infirmary	2	20-21.9	6	1		0
103	Infirmary	2	17-19.9	5	1		0
105	Infirmary	2	17-19.9	3	0		0

108	Infirmary	3	17-19.9	3	0		0
109	Infirmary	1	14-16.9	2	1		1
112	Infirmary	2	20-21.9	6	0		1
114	Infirmary	2	14-16.9	2	0		0
115	Infirmary	3	22-25	6	1		0
116	Infirmary	1	22-25	6	0		0
117	Infirmary	2	14-16.9	4	0		0
118	Infirmary	1	22-25	6	1		0
119	Infirmary	1	22-25	6	1		0
122	Infirmary	1	14-16.9	3	1		0
123	Infirmary	1	17-19.9	6	0		0
126	Infirmary	2	20-21.9	6	1		0
127	Infirmary	1	14-16.9	3	1		1
129	Infirmary	2	10-13.9	1	1		0
130	Infirmary	2	20-21.9	6	1		0
131	Infirmary	2	14-16.9	2	1		0
132	Infirmary	2	10-13.9	1	1	144.234	0
133	Infirmary	1	20-21.9	5	1		0
136	Infirmary	1	17-19.9	4	1		0
137	Infirmary	1	17-19.9	4	1	176.126	1
138	Infirmary	2	17-19.9	4	1		0
142	Infirmary	1	17-19.9	3	0		0
144	Infirmary	2	17-19.9	4	1		1
145	Infirmary	1	14-16.9	3	1		0
147	Infirmary	2	17-19.9	5	0		0
148	Infirmary	1	17-19.9	5	1	166.606	0
149	Infirmary	1	17-19.9	6	1	167.082	0
150	Infirmary	1	17-19.9	5	1		0
151	Infirmary	2	17-19.9	3	1		0
152	Infirmary	2	17-19.9	3	1		0
153	Infirmary	2	17-19.9	4	1		0
156	Infirmary	1	20-21.9	6	1	178.744	0
157	Infirmary	1	17-19.9	4	1		0
158	Infirmary	2	14-16.9	3	0		0
160	Infirmary	2	17-19.9	5	1		0
162	Infirmary	2	14-16.9	3	1	168.51	0
163	Urban	5	22-25	6	1	147.612	1
164	Urban	1	10-13.9	2	1		0
165	Urban	5	10-13.9	1	1		0
166	Urban	1	17-19.9	3	1		1
168	Urban	1	10-13.9	1	1	147.328	0

169	Urban	2	14-16.9	2	1	148.756	1
170	Urban	3	17-19.9	4	1		1
171	Urban	2	10-13.9	2	1		1
172	Urban	1	14-16.9	4	1		1
173	Urban	3	10-13.9	1	0		0
174	Urban	1	14-16.9	3	1	163.274	1
175	Urban	4	14-16.9	3	0	160.456	0
176	Urban	4	10-13.9	3	1	148.042	1
178	Urban	4	17-19.9	5	1		0
179	Urban	2	17-19.9	6	1	174.535	1
180	Urban	5	22-25	6	1	151.378	1
181	Urban	1	22-25	6	1	167.558	1
182	Urban	1	17-19.9	5	1	177.078	1
183	Urban	4	17-19.9	5	1	172.559	1
184	Urban	4	17-19.9	4	1		0
185	Urban	1	22-25	6	1		1
186	Urban	2	20-21.9	6	1		0
187	Urban	1	20-21.9	5	1	177.554	1
188	Urban	5	17-19.9	5	1	160.703	1
189	Urban	4	14-16.9	2	1		1
190	Urban	2	14-16.9	4	1		1
191	Urban	2	10-13.9	2	0		1
192	Urban	4	17-19.9	5	1		0
193	Urban	1	17-19.9	5	0		0
194	Urban	1	20-21.9	6	1		0
195	Urban	5	17-19.9	5	1		0
198	Urban	5	14-16.9	4	1		0
199	Urban	3	17-19.9	5	1-dent		0
201	Urban	3	17-19.9	6	0		0
202	Urban	3	17-19.9	6	0		0
204	Urban	3	14-16.9	5	1 -dent		0
206	Urban	1	17-19.9	4	1	165.892	0
207	Urban	3	14-16.9	3	0		0
208	Urban	5	17-19.9	5	0		0
209	Urban	4	17-19.9	4	1		0
210	Urban	1	22-25	6	1	170.672	1
211	Urban	4	14-16.9	3	1		0
212	Semi-Urban	2	10-13.9	1	1	134.074	1
213	Semi-Urban	4	10-13.9	1	1		1
214	Semi-Urban	2	10-13.9	1	1		0
216	Semi-Urban	4	10-13.9	1	1	145.142	0

217	Semi-Urban	1	10-13.9	1	1	137.57	0
219	Semi-Urban	1	10-13.9	1	0	148.994	0
220	Semi-Urban	3	10-13.9	2	1		1
221	Semi-Urban	2	10-13.9	2	0		1
222	Semi-Urban	4	10-13.9	2	1	156.134	1
223	Semi-Urban	2	10-13.9	1	1	154.825	0
224	Semi-Urban	4	10-13.9	2	1		0
225	Semi-Urban	4	10-13.9	2	1		0
226	Semi-Urban	4	10-13.9	2	1		1
227	Semi-Urban	4	10-13.9	1	1		0
228	Semi-Urban	1	10-13.9	2	1	162.56	1
230	Semi-Urban	4	10-13.9	2	1		1
231	Semi-Urban	2	10-13.9	2	0	172.08	1
232	Semi-Urban	4	10-13.9	2	0	163.35	0
235	Semi-Urban	5	10-13.9	2	0		0
236	Semi-Urban	4	10-13.9	2	1		1
237	Semi-Urban	1	14-16.9	3	1		0
239	Semi-Urban	2	14-16.9	2	1		1
241	Semi-Urban	3	14-16.9	2	1		0
242	Semi-Urban	4	14-16.9	2	0	153.787	1
243	Semi-Urban	2	14-16.9	2	0		0
244	Semi-Urban	2	14-16.9	2	0	143.758	1
245	Semi-Urban	5	14-16.9	3	0		0
246	Semi-Urban	5	14-16.9	4	0	156.751	0
247	Semi-Urban	4	17-19.9	3	1	155.763	1
248	Semi-Urban	2	14-16.9	3	0	152.326	0
251	Semi-Urban	4	14-16.9	4	1		0
252	Semi-Urban	4	17-19.9	6	1	154.034	0
255	Semi-Urban	5	20-21.9	6	1	154.034	1
256	Semi-Urban	4	17-19.9	5	1	156.504	1
258	Semi-Urban	4	17-19.9	4	1		0
259	Semi-Urban	4	17-19.9	6	1		0
260	Semi-Urban	1	14-16.9	5	1	183.028	1
261	Semi-Urban	1	20-21.9	6	1	166.13	0
262	Semi-Urban	4	22-25	6	0	172.34	1
264	Semi-Urban	3	14-16.9	3	0		0
266	Semi-Urban	5	17-19.9	5	1	160.209	1
267	Semi-Urban	1	17-19.9	5	0	157.562	1
268	Semi-Urban	4	17-19.9	4	0		0
269	Semi-Urban	5	17-19.9	3	0	161.9	1
270	Semi-Urban	4	20-21.9	6	0		1

271	Semi-Urban	5	20-21.9	6	0		0
272	Semi-Urban	5	14-16.9	4	0	164.408	0
273	Semi-Urban	5	22-25	6	1	161.444	1
274	Semi-Urban	1	20-21.9	6	0	176.602	0
275	Semi-Urban	1	22-25	6	1	170.89	1
276	Semi-Urban	1	22-25	5	1	171.842	1
277	Semi-Urban	1	17-19.9	4	1	170.652	1
278	Semi-Urban	2	20-21.9	5	1	160.18	0
279	Semi-Urban	4	20-21.9	5	1	155.516	1
280	Semi-Urban	1	22-25	6	1	166.606	1
281	Semi-Urban	4	22-25	6	0	154.775	0
282	Semi-Urban	1	22-25	6	1	167.082	1
283	Semi-Urban	5	22-25	6	1	150.082	1
284	Semi-Urban	5	22-25	6	0	155.269	1
285	Semi-Urban	4	22-25	6	1	161.608	0
286	Semi-Urban	1	22-25	6	0	172.08	0
287	Semi-Urban	1	22-25	6	1	161.846	0
288	Semi-Urban	4	17-19.9	3	1		0
289	Semi-Urban	4	22-25	6	1	163.35	0
292	Semi-Urban	4	14-16.9	3	1		0
293	Semi-Urban	1	10-13.9	1	1		0
294	Semi-Urban	5	22-25	6	1	168.36	0
296	Semi-Urban	1	20-21.9	6	1		0
297	Semi-Urban	1	22-25	6	1	173.984	0
302	Semi-Urban	1	14-16.9	3	0		0
303	Semi-Urban	5	17-19.9	5	1	164.655	0
304	Semi-Urban	1	17-19.9	6	1	168.986	0
305	Infirmary	2	17-19.9	4	1	159.94	1
306	Infirmary	5	20-21.9	6	1	161.197	1
307	Infirmary	1	10-13.9	2	1	156.372	1
308	Infirmary	4	14-16.9	3	1	166.137	0
309	Infirmary	1	20-21.9	5	1	169.462	0
310	Infirmary	1	17-19.9	5	1	160.42	1
311	Infirmary	1	14-16.9	3	1	172.556	1
312	Infirmary	5	20-21.9	5	1	148.02	1
313	Infirmary	4	17-19.9	5	1	158.94	1
314	Infirmary	4	17-19.9	5	1		0
315	Infirmary	1	20-21.9	6	1	156.43	0
316	Infirmary	5	17-19.9	3	1	169.348	1
317	Infirmary	2	17-19.9	5	1	168.99	0
318	Infirmary	5	20-21.9	5	1	169.45	1

319	Infirmary	1	20-21.9	5	1	169.63	1
320	Infirmary	2	14-16.9	3	1	157.8	1
321	Infirmary	4	14-16.9	3	1	157.8	1
322	Infirmary	5	22-25	6	1	161.05	1
323	Infirmary	1	17-19.9	5	1	170.18	1
324	Infirmary	4	14-16.9	3	1	127.605	1
325	Infirmary	1	22-25	6	1	170.89	1
326	Infirmary	2	10-13.9	2	0	157.8	1
327	Infirmary	4	14-16.9	3	1		0
328	Infirmary	4	14-16.9	2	1	151.07	0
329	Infirmary	1	10-13.9	2	1		1
330	Infirmary	2	22-25	5	1	164.23	1
331	Infirmary	2	22-25	6	1	174.46	1
332	Infirmary	4	22-25	6	1	163.77	0
333	Infirmary	1	17-19.9	5	1	169.462	1
334	Infirmary	1	14-16.9	4	1		0
335	Infirmary	5	20-21.9	6	1	160.06	1
336	Infirmary	3	10-13.9	2	1		1
337	Infirmary	4	17-19.9	5	1	150.44	1
339	Infirmary	2	20-21.9	5	1	173.43	0
340	Infirmary	3	17-19.9	6	1		1
341	Infirmary	1	10-13.9	2	1	150.184	0
342	Infirmary	2	10-13.9	1	1	156.134	1
343	Infirmary	1	22-25	6	1	103.96	0
344	Infirmary	4	22-25	6	1	164.26	1
345	Infirmary	1	14-16.9	3	0	167.082	1
346	Infirmary	5	20-21.9	5	1	154.88	0
347	Infirmary	4	20-21.9	5	1	167.8	1
348	Infirmary	1	17-19.9	6	1	171.47	0
349	Infirmary	1	22-25	6	1	172.08	1
350	Infirmary	1	10-13.9	2	1	153.278	1
351	Infirmary	4	22-25	6	1	158.77	0
353	Infirmary	5	10-13.9	2	1	154.034	1
354	Infirmary	5	20-21.9	5	1	156.85	0
355	Infirmary	4	22-25	5	1	153.64	0
356	Infirmary	1	14-16.9	4	1		0
357	Infirmary	4	17-19.9	4	1	156.85	1
358	Infirmary	4	22-25	6	1		1
359	Infirmary	4	14-16.9	4	1		1
360	Infirmary	2	10-13.9	1	1	143.52	0
364	Infirmary	2	20-21.9	6	1	166.84	1

365	Infirmary	1	10-13.9	3	1	164.702	1
366	Infirmary	1	14-16.9	3	1	166.606	1
368	Infirmary	1	22-25	6	0	172.09	1
369	Infirmary	1	14-16.9	2	1		1
373	Infirmary	5	22-25	6	1	154.14	1
374	Infirmary	1	10-13.9	2	1		0
375	Infirmary	5	22-25	5	1	156.85	0
377	Infirmary	5	17-19.9	5	1	157.98	0
378	Infirmary	1	10-13.9	1	1		1
379	Infirmary	5	17-19.9	6	1		0
380	Infirmary	2	17-19.9	4	1	169.22	1
381	Infirmary	5	17-19.9	4	1	157.84	1
382	Infirmary	5	22-25	6	1	157.59	1
383	Infirmary	5	22-25	5	1		0
386	Infirmary	2	14-16.9	2	1		0
387	Infirmary	5	17-19.9	4	1	161.28	1
389	Infirmary	2	17-19.9	6	1	166.606	1
390	Infirmary	2	10-13.9	2	1		1
391	Infirmary	5	17-19.9	4	1	163.27	1
392	Infirmary	1	20-21.9	6	1	172.09	0
393	Infirmary	5	17-19.9	4	0	157.59	1
395	Infirmary	2	10-13.9	2	1	159.466	1
396	Infirmary	5	22-25	6	1	161.05	1
398	Infirmary	5	20-21.9	6	1	159.32	1
399	Infirmary	1	10-13.9	1	1		1
400	Infirmary	2	22-25	6	1	187.31	0
401	Infirmary	5	17-19.9	5	0	157.84	1
402	Infirmary	2	17-19.9	5	1	170.18	0
403	Infirmary	2	10-13.9	1	1		1
404	Infirmary	2	17-19.9	4	1	180.89	1
405	Infirmary	1	20-21.9	6	1	177.55	1
406	Infirmary	1	20-21.9	6	1	166.13	1
407	Infirmary	2	22-25	6	1	163.51	1
408	Infirmary	4	14-16.9	3	1	168.607	1
410	Infirmary	1	17-19.9	5	1	173.75	1
411	Infirmary	2	14-16.9	2	1	158.633	1
414	Urban	4	17-19.9	5	1	155.763	1
415	Urban	5	17-19.9	4	1	153.787	1
416	Urban	4	10-13.9	2	1		0
417	Urban	2	17-19.9	6	1	162.084	1
418	Urban	3	17-19.9	5	1		1

419	Urban	2	14-16.9	3	1	165.178	1
420	Urban	2	20-21.9	6	1	156.848	0
421	Urban	5	14-16.9	4	1	155.269	1
422	Urban	5	17-19.9	5	1	160.703	1
423	Urban	4	14-16.9	3	1	167.619	1
424	Urban	4	14-16.9	3	1	154.528	1
425	Urban	4	10-13.9	3	0	153.787	1
427	Urban	5	10-13.9	1	1	139.708	0
428	Urban	1	22-25	6	1	161.846	1
430	Urban	5	22-25	6	1	156.751	1
431	Urban	4	14-16.9	3	1	149.835	1
432	Urban	5	17-19.9	5	1	159.221	1
433	Urban	2	10-13.9	1	1	143.52	1
434	Urban	5	14-16.9	4	1	149.835	1
435	Urban	2	10-13.9	1	1	146.614	1
436	Urban	2	14-16.9	3	1	170.89	0
437	Urban	2	17-19.9	5	1	166.844	0
438	Urban	2	10-13.9	3	1		0
439	Urban	4	17-19.9	6	1	162.679	0
440	Urban	4	10-13.9	3	1		1
441	Urban	5	17-19.9	6	1	150.823	1
442	Urban	2	10-13.9	2	1	142.33	1
443	Urban	4	14-16.9	2	1	154.775	0
444	Urban	4	20-21.9	5	1	149.094	1
445	Urban	4	17-19.9	5	1	152.552	1
446	Urban	2	20-21.9	6	1	168.272	0
447	Urban	2	10-13.9	2	1		1
451	Urban	1	10-13.9	3	1	138.046	1
452	Urban	1	14-16.9	3	1	177.792	1
454	Urban	1	22-25	6	1	171.604	1
455	Urban	1	10-13.9	2	0		0
456	Urban	4	22-25	5	0	161.691	1
458	Urban	1	22-25	6	1	163.988	0
459	Urban	5	22-25	6	1	143.907	1
460	Urban	4	22-25	6	0		1
461	Urban	1	17-19.9	3	1	177.316	1
462	Urban	5	17-19.9	5	1	163.914	1