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The effects of Industrialisation on the state of health and disease of a Victorian Urban Population:

A case study from St Hilda's Church, South Shields (Newcastle)

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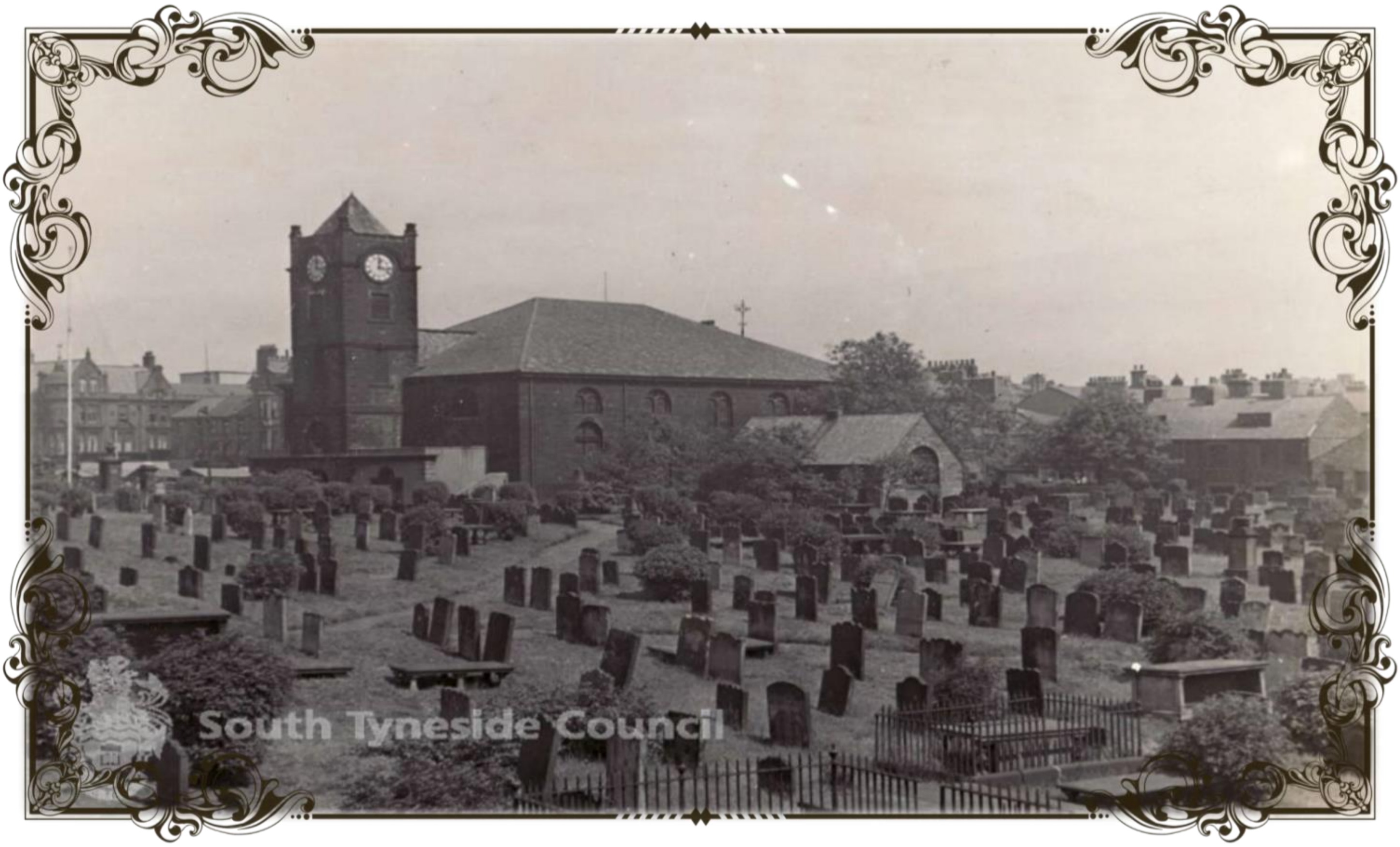

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ABSTRACT

The Industrial Revolution in the 18th and 19th centuries is one of the most prolific societal changes to have affected humanity. The rapid urbanisation and unprecedented population growth in industrialised centres led to the fast deterioration of living and working conditions. Air, water, and space restrictions due to the lack of early public health precautions resulted in a number of problems, affecting the country's demography as well as its health and disease profile. According to historical accounts, poor living and working conditions, low life expectancy, malnutrition and infectious disease were common. This research has confirmed these accounts through the osteological and palaeopathological records.

This thesis is a comprehensive analysis of the demography, health and disease status of urban populations of 18th- and 19th-century England. The analysis results of the working-class skeletal assemblage at St Hilda's burial ground (1763-1855), South Shields, were contrasted with the data from fifteen contemporary comparative sites of various socio-economic and geographic backgrounds. The aim of this undertaking was twofold; to assess the demographic structure and health and disease profile of the case study and, therefore, determine if this sample was following the general demographic and health and disease profile of the historical period; and to determine the general impact of the Industrial Revolution. Some of the criteria used to assess and contrast the health and disease status of the population and identify conflicting patterns in health stress and longevity between the various population groups include – but are not limited to – increased early life mortality, trauma patterns and congenital disorders. No major geographic divisions were observed across sites throughout England, but a certain degree of socio-economic status dependency was revealed.

Increased mortality was observed in early life between birth and age six and then middle adulthood. Males across sites were more likely to die earlier due to gender disparities as they were exposed to various occupational and lifestyle hazards. Females had increased chances of reaching senior ages after overcoming certain dangers of earlier adulthood (e.g. pregnancy, childbirth) due to life style differences but also due to indoor-based living. A potential association between an increased prevalence of congenital disorders in middle adults and early death was identified in St Hilda's, suggesting a reduction in longevity associated with early life stress due to poor maternal health and exogenous factors during gestation that

shortened the life course in adulthood. Genetic defects and exposure to harmful factors via the mother's environment were also evident as the increased prevalence of preterm and neonatal deaths in St Hilda's and comparative sites shows. Similar rates of specific and non-specific indicators were revealed across sites indicating morbid conditions throughout England. The morbid conditions as well as poor maternal health, exogenous factors and poor diet were also revealed through the presence of early life metabolic and hematopoietic disorders across sites. Unlike geographic location, a degree of socio-economic status dependency was revealed for the mortality profile, with a few sites of higher status exceeding middle adulthood; showing that the socio-economic circumstances, influenced the longevity of these individuals. A socio-economic status denominator also existed for particular conditions (e.g. maxillary sinusitis and fractures) among adults. Residual rickets in some assemblages showed some socio-economic dependency, demonstrating that it was status which helped these individuals to overcome these episodes in early life. At the same time, this could also be indicative of different childrearing practices. Despite these differences in mortality and morbidity, no significant differences were observed in adult stature across sites.

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To my Parents: My Father who would be happy to see my progress despite all the oddities of life and my mother who overcame the oddities and learned to be both Father and Mother to support me through life!

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List of Abbreviations

NE: North-East

MOH: Ministry of Health

SHS: Seamen's Hospital Society

BABAO/IFA: British Association for Biological Anthropology and Osteology/ Institute of Field Archaeologists

BARC: Biological Anthropology Research Centre

TPNB: Tibial Periosteal New Bone Formation

TB: Tuberculosis

OD: Osteochondritis Dissecans

OA: Osteoarthritis

SD: Spondylosis Deformans

DISH: Diffuse Idiopathic Skeletal Hyperostosis

GA: Gouty Arthritis

RA: Rheumatoid Arthritis

AS: Ankylosing Spondylitis

SA: Septic Arthritis

PH: Porotic Hyperostosis

CO: Cribra Orbitalia

DEH: Dental Enamel Hypoplasia

PD: Periodontal Disease

AMTL: Antemortem Tooth Loss

MNI: Minimum Number of Individuals

CPR: Crude Prevalence Rate

TPR: True Prevalence Rate

SPSS: Statistical Package for Social Science

CSV: Comma Separated Values

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CHAPTER 1

INTRODUCTION

The socio-economic environment in which a population functions can affect the structure of its composition. Population composition provides a framework against which we can examine and interpret health status, lifestyle and population behaviour (Hunter 2000; McIntyre 2013). Various inter-related socio-economic parameters such as health and diet can affect this composition (Hunter 2000; McIntyre 2013). Such parameters can be studied in relation to past populations with the utilisation of human osteology. Often, however, the association between socio-economic environment and those parameters is not always straightforward. This is due to the complexity of the mechanisms by which the socio-economic environment influences population composition. The purpose of this thesis is to osteologically investigate the effects of these parameters during the Industrial Revolution (*c.*1750-1840) in regards to the composition of the population sample of St Hilda's from the primarily working-class town of South Shields, in the northern-eastern part of England (Foster 1974). This investigation is complemented by combining the physical evidence (i.e. skeletal remains) with different kinds of data sources of the late 18thand early 19th century (i.e. historical burial registers and governmental accounts).

1.1 Brief Introduction to the Site Description and Setting

The archaeological exhumation of 204 articulated skeletons and numerous deposits of charnel and disarticulated material from part of a former burial ground on Coronation Street, South Shields, South Tyneside, England was carried out in the mid-2000s ahead of a development of a super-market and car-park by Henry Boot Development (Raynor *et al.* 2011; Proctor *et al.* 2016). The development site incorporated the southern portion of the church's cemetery which was in use between 1763 and 1855 as was indicated by the study of burial registers by the author and supported by surviving tombstones and a few readable *depositum* plates. The interments at St Hilda's represented a cross-section of the South Shields' population during the Industrial Revolution and according to the burial registers the working class made up the largest section of the population. Prior to the development, it was identified that the modern route of Coronation Street, which was created in the 1970s, ran through the southern part of the cemetery separating the small southernmost portion of the burial ground in an area of verge that later became the northern wall of the supermarket (Raynor *et al.* 2011, 5). The site of St Hilda's cemetery on Coronation Street is found in the North-East town of South Shields. South Shields is situated within the borough of South Tyneside, approximately 12km north-east of Newcastle-upon-Tyne. Coronation Street runs from the centre of South Shields westward to a junction with Station Road, opposite the south-east bank of the River Tyne (Figure 1.1). St Hilda's church with its graveyard is oriented to the north, while to the south carparks and an abandoned warehouse (Gibson et al. 2009, 6; Rainor et al. 2011) occupy the land. The solid geology of the area is one of Carboniferous (280-350 million years ago), Coal Measures and Magnesian Limestone, overlain by deposits of Devensian (73,000 to 10.000 BP) glacial till (Gibson *et al.* 2009, 6). As approaching the River Tyne, the depth of boulder clay increases, and can be as much as 12m deep (Gibson *et al.* 2009, 6; Rainor *et al.* 2011). However, this was not always the case as a great portion of the proposed development area, possibly including Coronation Street, was initially covered in water and connected to the no longer existing Mill Dam (Foster 1974; Gibson *et al.* 2009). By 1827 the Mill Dam had been completely infilled and had started to be built upon, but it can be seen on 18th-century cartographic sources (Foster 1974; Gibson *et al.* 2009, 7; Rainor *et al.* 2011). This natural geology and geographical location allowed South Shields to play such a significant role in the thriving of the coal industry especially during the Industrial Revolution.

Figure 1.1: Distance between South Shields and Newcastle-upon-Tyne.

1.2 Research Aims and Objectives

The purpose of this study is to investigate the composition of the north-eastern working-class population sample of the Industrial period which was derived from St Hilda's burial ground (1763-1855), South Shields. The primary aim is to explore the effect industrialisation had on this population by establishing their general health status, which includes providing a demographic profile and a profile of the diseases that they suffered from. Through this study, deeper insights into a primarily working-class urban community will be gained. These insights can be used to enhance the understanding of working-class life in the North-East (NE) during the study period, and also allow a comparison with working- and non-working-class sites in the rest of England. In order to gain insights into this working-class community, different kinds of data sources will be used to produce a comprehensive account of the people and the living conditions in the Industrial NE. These data sources combine historical burial registers and governmental accounts from various years in the 18th and 19thcentury together with osteological information as well as archaeological evidence of funerary rites. This will enable generalisation of the sample results and produce a holistic picture of the South Shields population during this period of study. Consequently, the approach of this study uses multiple lines of evidence, where different kinds of data sources will be combined in order to gain an optimal understanding of the community under study.

In order to achieve the aim of this thesis, three main research questions are addressed. First, what effects did industrialisation have on the health and lifestyle of the working-class population in South Shields. This will be addressed by exploring the demographic, health and disease profiles of the population sample from St Hilda's. The results will be placed in context and the population sample will be characterised by comparing the results to the burial registers of St Hilda's and historical accounts of the health of a working-class community, during the late decades of the 18th century and the earlier decades of the 19th century in the NE. This analytical step will allow the demographic profile of the osteological sample to be compared with the evidence derived from the burial registers in order to determine if the sample is biased or representative of the whole population that resided in South Shields and interred in St Hilda's cemetery. This step is important, as it will allow the generalisation of the osteological results and their projection to the entire population of South Shields. Second, who was buried in the cemetery in terms of demography and social status. This further exploration of the demography and social status of the cemetery's population will be accomplished by examining the burial registers in conjunction with the coffins and available personal effects. This step is essential as lack of grave goods is not always indicative *per se* of low social status such as for instance in the case of Quakerism (Proctor *et al.* 2016). Consequently, there is not always a relationship between the lack of burial evidence and socio-economic status as proved. Thus, by comparing the recorded demographic (age, sex, and cause of death) and socio-economic data (job description) of the burial registers to the coffins and personal effects, it is possible to ascertain their class status with near certainty even where personal effects were sparse or absent. The overall approach not only attempts to place the morbidity and mortality profiles of this assemblage into context, but also identifies through the use of different sources the negative effects on health frequently associated with urbanisation (Mahoney-Swales 2012, 8). The final focus will be to determine if there were any skeletally observable geographical differences in health and lifestyle between working-class populations throughout Industrial England. This will be achieved by comparing the results to similar available osteoarchaeological publications on the working class during this period. As a final step the results will be compared to populations of different socio-economic backgrounds from the same period, which will determine if there were any differences in health and lifestyle between different classes. Consequently, these comparisons will define the human biogeography as specified by Terell (1974, 5), for this particular population along with the state of physical health and by extension lifestyle of the individual population in comparison to other populations.

1.3 Current State of Knowledge

In order to fully understand why the present study is necessary, and why St Hilda's skeletal assemblage is an excellent case to use for this type of study, this section will outline the current state of knowledge in regards to skeletal assemblages from this time period. Though recent work has been done in the way of comprehensive osteological study of populations from the Industrial period, particularly in the north of England, there is still more to be done.

1.3.1 The Comparable Assemblages

There are numerous post-medieval burial grounds from the Industrial period in Britain (*c.*1750-1840), yet relatively few have been archaeologically excavated. Quite large numbers of burial sites, both historically and in recent times, have been cleared for development by exhumation companies with little or no archaeological recording (Mosley 2002; Raynor *et al.* 2011; Proctor *et al.* 2016). This practice has resulted in the loss of valuable information, resulting in significant gaps in the archaeological recording and research of such funerary assemblages (Powers and Miles 2011; Renshaw and Powers 2016). These gaps in the literature are the result of certain viewpoints and attitudes towards contemporary archaeology. Until the 1980s early modern archaeology and excavation of historical burial grounds was subject to neglect as it was viewed as of inferior value due its contemporary nature (Richmond 1999, 156; Mosley 2002, 3). However, a very slow but progressively increasing osteoarchaeological interest in the study of post-medieval and Industrial period populations arose after the publication of specific projects in the mid-nineties such as that at Christ Church, Spitalfields (Mosley 2002). Despite this slow increasing interest, the number of archaeologically excavated and studied sites of this burial context remains relatively low when compared to other time periods (Powers and Miles 2011; Renshaw and Powers 2016). Certainly, post-medieval funerary practices have not received nearly as much scholarly attention as their prehistoric counterparts (Renshaw and Powers 2016).

Additionally, developmental pressures in certain parts of the country 'favoured' the archaeological excavation of specific geographical regions and types of burial populations in terms of social class, thus leaving other regions unexplored (Petts and Gerrard 2006). Disparities in relatively recent development pressures in parts of Britain resulted in bias towards urban samples in the South. Therefore, the already relatively small collection of excavated and published post-medieval and Industrial period burial excavations centred around Greater London, where greater developmental pressures for land reuse existed. These skeletal collections from London largely contain burial populations comprising the Georgian and Victorian middle to upper classes, such as Christchurch, Spitalfields (Molleson and Cox 1993), All Saints, Chelsea Old Church, Kensington (Cowie *et al.* 2008), St George's Church, Bloomsbury (Boston *et al.* 2009), St Marylebone (Miles *et al.* 2008), and St Luke's, Islington (Boyle *et al.* 2005). Published collections from other regions in England are also available; however, they are only a few when compared to London. Examples include the Methodist Chapel, Carver Street, Sheffield (Witkin and Belford 2002) and St Martin's-in-the-

Bull Ring, Birmingham (Brickley *et al.* 2006). Consequently, this south-centric focus overshadowed scholarship from the north of England.

On the whole, there is not an abundance of osteological evidence on health and lifestyle for the population of England during the period of study. It is apparent that post-medieval funerary practices and population compositions are under-represented, from an osteological perspective, when compared to other time periods. This is especially true for the North and the working class in general throughout the country with regards to the research of the Industrial period.

1.3.2 Regional Context

While there is a general scarcity of osteologically-studied Industrial period skeletal assemblages the NE region is particularly underrepresented. Burial studies have always had a relatively low profile in the NE compared to other parts of the country (Gibson *et al.* 2009, 10; Raynor *et al.* 2011). The vast majority of evidence on health and lifestyle pertaining to the Industrial period in the NE primarily exists as historical accounts. Therefore, historical accounts of the 18th and 19th centuries are our primary research means of investigating this geographic region and its working-class population during this period. This is largely due to the continued use of post-medieval cemeteries, which prevents archaeological excavation and research of these grounds (Gibson *et al.* 2009, 10). The gradual development of the North did not require the reuse of the land in comparison to their fast-developed southern counterparts, especially the Greater London area (Raynor *et al.* 2011; Proctor *et al.* 2016). Another potential reason behind the skewed research interest that overshadowed research in the northern region is the involvement of more grant-providing institutions in the preservation of skeletal remains in the South (Petts and Gerrard 2006, 188). In recent years, after the excavation of St Hilda's, only a few post-medieval skeletal assemblages have been archaeologically excavated in the NE of England. Just across the river from Coronation Street lies a Quaker burial ground at Coach Lane, North Shields (Proctor *et al.* 2016). While another archaeological exhumation of a crypt took place at the Bethel Chapel, Congregationalist (or Independent) chapel in Villers Street, Sunderland in 2010 with over 400 skeletons removed. This last collection is currently curated at the University of Bradford; however, the post-excavation assessment report is in the preparation stage (Proctor *et al.* 2016). Prior to the excavation and post-excavation analysis of St Hilda's in South Shields, only one other substantial assemblage of human remains had been archaeologically excavated from the NE of England: the remains recovered from the former Newcastle Infirmary (Boulter *et al.* 1998; Nolan 1998; Gibson *et al.* 2009). These remains consist of 'unclaimed hospital patients, many of whom had been dissected by early anatomists for the advancement of science', and are thus very different in nature to non-hospital assemblages such as those of South and North Shields (Gibson *et al.* 2009, 11).

Increased population density, poor living and working conditions, low life expectancy, malnutrition and infectious disease, and increased rates of trauma and work-related-accident deaths are the most commonly cited effects of industrialisation in historical accounts of the 18th and 19th centuries (Wohl 1983; Woods and Woodward 1984; Rees 2001; Lewis 2002a and 2002b; Mays *et al.* 2008). The NE appears to be no exception to these negative effects of industrialisation suffered by the rest of the country; however, as opposed to the South, it lacks of great amount of osteological evidence on health and lifestyle of the population during this period to support this profile (Petts and Gerrard 2006; Proctor *et al.* 2016). With limited physical evidence to support or disprove the above cited effects of industrialisation, the knowledge about the population profile in the NE is currently restricted.

The fact that there is plenty of contemporary historical evidence pertaining to the NE of England, but only a few post-medieval skeletal assemblages have been archaeologically excavated there, serves to highlight the fact that St Hilda's human skeletal assemblage is a significant source of evidence from an important urban centre in a region where osteological evidence is lacking in comparison to the South (Mahoney-Swales 2012). The assemblage has the potential to contribute to the growth of the data corpus of bioarchaeology by providing a deeper insight into the lives of the working classes, in terms of population composition, health, morbidity and mortality (Petts and Gerrard 2006, 188; Gibson *et al.* 2009, 11; Newman 2015, 178). According to burial registers and other documentary accounts of the period, many of those interred in St Hilda's grounds would have been workers engaged in the local industries such as collieries, alkaline production, shipyards and the port of South Shields (Gibson *et al.* 2009, 11). Through insights into the lifestyle and health of a primarily poor urban community, the relatively limited bioarchaeological understanding of working-class life during this period will be enhanced. The analysis of St Hilda's skeletal material and its comparison to

Quaker burial ground at Coach Lane, North Shields and Infirmary Newcastle is also a valuable opportunity, as it will enable comparison between three growing industrial centres within the same region and potentially move the greater Newcastle area into the same league as the Greater London area for the range and breath of its industrial period cemetery data. It will also enable a comparison with working-class life in the rest of the country. This will determine if St Hilda's and the NE regions follow the general health and lifestyle profile established by the study of available urban working-class assemblages throughout the country, but also the working-class profile as established through historical accounts. Generalisation of the results alone for the skeletal samples of this region may be problematic as they might not be representative of the whole population who lived in the region but a sample of it, and for that reason it is important that the results be enhanced through their interpretation in the context of the historical record. This combined approach, will define if health inequalities existed between social strata and/or different geographical regions in England.

1.4 Research Approach

The central methodology of this research is a biocultural investigation, where osteological evidence will be combined with evidence from the burial registers and burial record to obtain information on the target population (Wiley and Cullin 2016). This approach aims to define how the surrounding socio-economic environment and its challenges to human biology affected the health profile of the target population by showing how these challenges were manifested upon their skeletons. This approach will provide a mortality and morbidity profile of the working-class population and subsequently determine if the biological profile of the population sample corresponds to its socio-economic status profile inferred by the burial evidence and burial registers.

Demographic data (sex and age) will be collected to reconstruct mortality profiles. Two mortality profiles will be reconstructed; one derived from the osteological data and the other from the analysis of the burial records. To address the lifestyle and well-being of the study population, a detailed picture of health status will be collected by way of recording skeletal indicators of disease and ill health. Data of disease and ill health will allow reconstruction of the morbidity profile and determine whether the study population had a healthy or unhealthy response to the impoverished environment in which they lived and worked (Foster 1974;

Barnsley 2015). The skeletal indicators of disease and ill health associated with the effects of industrialisation include: *non-specific infection* (maxillary sinusitis, inflammatory periosteal reaction and tibial periosteal new bone formation); *specific infection* (tuberculosis and treponemal disease); *biomechanical stress indicators* (spinal and extra-spinal degenerative joint disease and skeletal manifestations of physical trauma); *metabolic diseases* (scurvy, rickets, osteomalacia and osteopenia)*; non-specific environmental stress* (immature growth, adult stature, dental enamel hypoplasia, cribra orbitalia and porotic hyperostosis) and *dental health indicators* (calculus, carious lesions, periodontal disease, abscesses and ante-mortem tooth loss). For the examination of well-being, there will be a focus on the in-depth investigation of the following combined topics of pathology.

1. ***Correlation between adult stature and dietary deficiency.*** The connection between diet and achieved height in this population will be explored by analysis of dietary deficiency skeletal markers such as dental enamel hypoplasia, cribra orbitalia and porotic hyperostosis, scurvy, rickets and osteomalacia.
2. ***Specific and non-specific infections.*** High prevalence of these indicators may reflect exposure to a polluted environment and poor hygiene standards.
3. ***Spinal joint disease as indicators of occupational stress.*** High prevalence of these lesions, especially at very young ages, could be indicative of early exposure to strenuous work.
4. ***Trauma patterns as indicators of working and living conditions.*** Visual examination can identify potential trauma that the study population has experienced.
5. ***Dental health.*** Gathered dental information allows inferences about diet, oral hygiene and general health status.
6. ***Increased infant mortality as an indicator of poor living standards***. Biological factors such as the length of life or the survival of infants are commonly used as measures to gauge living standards (Huck 1993). In this respect, osteological analysis in conjunction with the study of documentary resources, including registered births and burials, will be used to determine if South Shields was affected by increased rates of infant mortality and therefore to indirectly determine poor living conditions.

7. ***Patterns in male-versus-female health, adult-versus-immature health and health of different adult age categories.*** Differences in lifestyles based on sex, different age groups and adult age categories will be studied by examining skeletal health patterns between different groups. This will allow inferences about how different groups experienced disease and therefore morbidity.

After the detailed assessment of the above indicators, any other identified skeletal pathological lesions will be assessed to determine the prevalence of other conditions such as for instance congenital diseases. The objective with this work is to gain an osteological insight into the health and disease of a poor urban community and determine if any other pathological trends outside the general health and disease pattern existed. It is envisaged that the study of St Hilda's will give deeper insights into the working-class populations of Northern England. A detailed picture of the morbidity profile will also be collected by studying the burial registers (i.e. cause of death). The aim of creating two sets of mortality and morbidity data (osteological and burial registers-based) is to not only contrast the one to the other, but also use one to supplement the other due to various limitations accompanying osteological as well as burial-register data that will be identified in the discussion section (e.g. osteological paradox and social stigma).

For comparative purposes, osteological data from other collections from throughout England will be used to contrast the findings from St Hilda's skeletal assemblage. The biocultural profile of St Hilda's cemetery population will be compared to other contemporary sites of similar or different social backgrounds. These sites are representative of major urban-industrial towns of the period. The results of these comparisons will be used to determine if the St Hilda's assemblage follows the general profile of the period. Sites such as those of the upper middle classes from St George's Church, Bloomsbury (Boston *et al*. 2009), St Luke's, Islington (Boyle *et al.* 2005), Christ Church, Spitalfields, London (Molleson *et al.* 1993; Reeve and Adams 1993) and one of the wealthiest parishes in London, St Marylebone (Miles *et al.* 2008); the middle- and lower-class sites of St Martin's-in-the-Bull Ring, Birmingham (Brickley *et al.* 2006), Infirmary Newcastle-upon-Tyne (Boulter *et al.* 1998), and Quaker burial ground, North Shields (Proctor *et al.* 2016) and the lower working-class sites from Cross Bones burial ground, London (Brickley *et al.* 1999) are amongst the many that will be utilised for comparison; all of which will be seen in detail in chapter 2. Comparisons between the focal case study and the osteoarchaeological reports from these sites of known social context will identify any similarities in mortality and morbidity between St Hilda's assemblage and these sites.

1.5 Thesis Outline: Chapter Organization

This thesis consists of eight chapters. In the current chapter, South Shields is briefly introduced to set the scene for the reader, along with the aims-objectives and the research questions, as well as the importance of the study with regards to previous studies and the research approach. The excavation and historical background to the thesis is presented in chapter 2. Chapter 2 covers the Industrial period by reporting the social and health and disease challenges that prevailed in England with the commencement of industrialisation. An overview of the living and working conditions and the new health and disease challenges introduced throughout the country is initially presented. This is followed by a summary of St Hilda's focal case study in Chapter 3 and the comparative sites, detailing the type of population that each was serving, in terms of socio-economic perspective. At the same time the individual living and working conditions and health and disease challenges that each population faced are also examined. After the excavation overview, St Hilda's cemetery is placed in context by providing specific background information on the topography and industry of the town during the Industrial Revolution. This information incorporates archaeological and documentary information to present what is known about the cemetery and the nature of the population who buried their dead therein. Then the research conducted on similar skeletal assemblages follows. In particular for each site a brief excavation overview is given, followed by lifestyle and industry differences for each site based on the geographic and socio-economic environments. These differences are drawn by using historical accounts of the period.

In chapter 4 the anthropological and statistical methods used to identify and quantify the expression of health and disease indicators are presented. The chapter commences with a description of the methods employed to assess the preservation and the demographic profile of the study population, including sexing, ageing, and stature estimation methods, as well as the methods employed for the estimation of the minimum number of individuals for the charnel material. In the last part of the chapter the methods applied to determine palaeopathology are presented along with the employed statistical methods for the analysis of the osteological results and burial registers recovered from the case study cemetery.

There are two result chapters. In chapter 5, the results of the demographic and palaeopathological statistical analysis of the case study are presented. In chapter 6, comparisons of the demographic parameters and the prevalence rates of the health and disease indicators are made between the focal case study and published archaeological sites from the same period in order to draw conclusions. These statistical comparisons were conducted to determine if it is possible to infer the type of socio-economic community by their types of mortality and morbidity profiles. Chapter 7 discusses the research findings of these comparisons and situates them into the context of Industrial England by using historical accounts on health and disease of the period. St Hilda's demographic results are initially placed into the wider context of South Shields by being compared to the burial registers and findings and discussed in relation to historical accounts focused on the town of South Shields and surrounding area during the 18th and 19th centuries. This step is necessary in order to determine if the population sample follows the same demographic and health and disease profiles as the entire population of South Shields. At the same time the mortality and morbidity profiles of St Hilda's are discussed in relation to the comparative sites, both case study and comparative sites, are situated in a broader context in England by being considered in parallel with historical accounts of the period. Finally, chapter 8 brings everything together by presenting the overall conclusions. It also discusses whether the reconstructed mortality and morbidity profiles can be indicative of the type of socio-economic community they were derived from. Lastly, the limitations of this study as well as the potential for future research are discussed in this chapter.

CHAPTER 2

HISTORICAL BACKGROUND: AN OVERVIEW OF LIFE CONDITIONS DURING THE INDUSTRIAL REVOLUTION c.1750-1840

> *Between 1780 and 1850, in less than three generations, a far-reaching revolution, without precedent in the history of mankind, changed the face of England. From then on, the world was no longer the same. Historians have often used and abused the word revolution to mean a radical change, but no revolution has been as dramatically revolutionary as the Industrial Revolution, except perhaps the Neolithic Revolution* (Cipolla 1975, 7).

2.1 Introduction

The purpose of this chapter is to offer a historical background in order to contextualise the osteological data by placing them within the appropriate socio-economic setting and circumstances of the 18th and 19th centuries. Herein the technological and economic changes that gave rise to the Industrial Revolution will be overviewed. The societal changes that led to urbanisation, the subsequent population growth and the making of a wide scale operating class, which lived in less than ideal conditions will also be addressed. With the migration of large quantities of people into industrialised centres, it did not take long for living and working conditions to deteriorate. The pressures upon the necessary elements of air, water, and space, brought on by this demographic revolution will be presented; paying particular attention to public health issues such as poor sanitation, air pollution, inadequate ventilation and limited access to water and sunlight. Along with these prevailing deteriorating conditions due to overcrowding, the subsequent risk of infection and contagion will be given. The massive numbers of people in towns, sent the country to a more primitive age of plagues, as it encouraged the systematic emergence and constant cultivation of pathogens and spread of infectious diseases due to close proximity. This problem was further aggravated by extensive population movements. Consequently, the infectious diseases that became an immense public health issue and inevitable part of industrial-environment life (i.e. cholera, measles, typhus, typhoid, tuberculosis, smallpox) will be summarised. While, the role of poor nutritional status and malnutrition through limited food access which subsequently caused further susceptibility to infectious diseases will also be introduced (McCarrison 2012, 42).

For the synthesis of this background chapter and the contextualisation of the results throughout this thesis different forms of evidence were brought together (archaeological, historical scholarships and contemporary documents). The combination of different sources was necessary, especially in cases where historical documents were used to contrast the osteological data. Historical documents cannot be accepted uncritically as they are associated with certain limitations (Humphries 2010). Although they could possibly offer a relatively accurate picture of the period of interest, they could also prove problematic as they are products of the times they were produced and hence might lack accuracy to some extent, since they might have been manipulated deliberately. For instance, in the first decades of the 19th century, public health reports lacked standardisation as no established recording criteria existed (Hardy 1994; Kirby 2014). Historical documents could also reflect the views and attitudes of the people who compiled them, the purposes they were serving and what they were aiming to promote through them (for instance to make the conditions appear worse or better than they actually were). They could also reflect certain reticence such as in the case of certain infections that might have been left deliberately unrecorded, but could also be reflective of the lack of expertise of the 'specialists' who recorded the conditions; reports were frequently compiled by inspectors who had no medical training. (Humphries 2010). Consequently, historical documents often bear only an approximation of the truth and they should be approached with a high degree of caution and scepticism (Luckin 1986; Hardy 1994).

2.2 The Incentive of Industrial Revolution and the Working Conditions

The Industrial Revolution, which started in Britain before sweeping through Europe and other parts of the world, is traditionally viewed as the most prolific societal change ever known to have affected humanity since the Neolithic (Cipolla 1975; Neuss 2015, 1). The Industrial Revolution to some extent was 'the birth certificate' of the modern world as it marked a period of change and dynamic redefinition of how humans lived and interacted with nature (Neuss 2015, 1).

The industrial and economic developments of the era brought significant social changes, primarily, the transformation of the economy from one based on small scale rural, agrarian societies into urban ones dominated by industry and machine manufacturing (Cipolla 1975; Hudson 1992; Neuss 2015). It was this economic transformation and the subsequent urbanisation of small towns into large industrialised centres to support the fuelling of a growing workforce, and expanding industry, which prompted a change for both urban and rural societies in order to produce and support a new consumer lifestyle (Cipolla 1975; Hudson 1992; Neuss 2015; Newman 2015; O'Donoghue *et al.* 2021). These changes 'shaped the face of new industrial and economically successful societies by modifying their social and economic structures and destabilising all established hierarchies' (Neuss 2015, 1). Eventually industrialisation and urbanisation influenced every aspect of people's lives.

It was, however, the contemporary scientific advances with the rapid technological changes that gave rise to the Industrial Revolution which changed society and boosted the economy of Britain (Engels 1987). The industrialised economies, equipped with new technologies, were able to quickly produce large quantities of products for lower costs, with only a small expenditure of human energy (Engels 1987; Neuss 2015). Thus, this answered the basic needs of a fast-growing population defined by 'new consumption habits and aspirations' (Neuss 2015, 1). These technological changes, along with the invention of novel machinery for mass production (e.g. spinning jenny and the power loom) had three major effects (Hudson 1992).They introduced the new usage patterns of basic materials (e.g. iron and steel), changed energy consumption patterns for existing resources as well as introduced new energy sources which included both fuel and motive power (e.g. coal and the steam engine) and resulted in extensive development of the transport infrastructure (roads, canals and railroads); all of which contributed to expanding the markets and accelerating the commercial flows (Hudson 1992; Neuss 2015).

With the innovation of such technological advancements and the use of local natural resources available from town to town, it did not take long for different regions to be heavily industrialised and develop different trades and manufacturing such as silk, flax and wool in Preston, Blackburn, Macclesfield, Leek, Coventry, Bradford and Leeds; lace making in

Nottingham, Redford and Basford; hosiery at Leicester and Nottingham; earthenware and china in Stoke-on-Trent; button making in Birmingham and Aston; watchmaking in Coventry; tin mining, copper mining, coal mining, iron-mining and lead-mining at Redruth, Penzance, Wolverhampton, Merthyr Tydfil, Pateley, South and North Shields and Newcastle; and metal-smelting, instrument-making Wolverhampton, Sheffield, Birmingham, Aston (Rosen 1973, 644; Wohl 1983, 261). The great movement of people from rural areas and foreign countries to urban areas in search of employment began with the creation of new work opportunities in these industries thus resulting in urbanisation (Wohl 1983).

This urban growth provided the industrialised centres with workforces, thus allowing cities to keep pace with new developments and allowed the continuation of this revolution. As a result, the Industrial Revolution witnessed a huge growth in size of the British industrialised centres, which happened progressively (Hudson 1992; Jackson 2015). Before the Industrial Revolution, specifically between 1700 and 1750, the population of England and Wales remained almost static with little change in birth rates (Khan 2008). According to data from baptism, burial and marriage entries the probable population estimation increased from 6,045,008 to 6,517,035 for the fifty-year period prior to 1750; however, these are only an estimation, as the first nationwide census had yet to occur (Hudson 1992, 133). The population calculations for the periods prior to the first census were gleaned from returns of baptisms, burials, and marriages obtained by extracts from the registers of parishes (Great Britain-Census 1801). However, parish registers for these periods present major discrepancies between baptisms and births and between burials and deaths (Hudson 1992, 133-134). Despite the rough nature of the calculations for the population prior to the first census, the population of Britain and Wales went from an estimate of 6,517,035 in 1750 to 8,872,980 in 1801 when the first census occurred, clearly displaying a rapid population increase in only fifty-one years (Great Britain-Census 1801). According to the first census in 1801, the population of Britain, which was defined as England, Wales, Scotland, citizens abroad serving in the military both army and navy and convicts serving on the Hulks (prison ships) was almost 11 million (Great Britain-Census 1801). By 1841 the population had jumped to almost 19 million; this represents over a 70 percent growth in just forty years (Great Britain-Census 1841). In the metropolis (of London) alone the population grew from 864,845 in 1801 to 1,690,084 in 1841 (Great Britain-Census 1841; Wrigley and Schofield 1981; Wrigley *et al.*

1997; Humphries 2010). As with any other historical documents from this period, caution should be exerted when taking the numbers of these first censuses into account as there is little reliable census information on age, marital status, occupations or place of birth before 1851 as the recording process was new and lacked of standardisation (Hudson 1992, 133).

The population increased substantially between 1750 and 1841, a time period coinciding with the first Industrial Revolution. Therefore, it is reasonable to assume that there is a correlation between these two phenomena. However, it should not be assumed that migration alone (and also immigration, but to a lesser extent, as people also relocated from overseas) was responsible for the dramatic urban increase. Though people moved to urban centres to pursue employment or avoid long commutes to the workplace, there may have been some other internal contributory factors to this population growth. Instead, this population increase could also be associated with societal changes and health improvements (Hudson 1992; Humphries 2010). According to the Registrar-General Report (1842, 138) the population of the country 'may have increased by an augmentation in the number of marriages and births and prolongation of life by diminution in the number of deaths'. Consequently, it would appear that the annual number of births may have increased in two ways; by an increase of the number of individuals married, perhaps initially more people could afford to get married revealing also an economic component, and by earlier marriages by lowering the minimum age of marriage, which shorten the interval elapsing between successive generations (Registrar-General 1842, 138; Hudson 1992, 135; Humphries 2010 38-39). As a result, people were able to get married at a younger age, and therefore expanding the fertility range of women and improvements in health and living standards which increased lifespan; both of which could lead to more children being born and surviving until adulthood (Wohl 1983; Hudson 1992, Humphries 2010).

One might have expected that with the creation of new job opportunities in the industrialised centres there would have been less unemployment among the social strata that made up the working-classes (e.g. artisans, tradesmen or unskilled labourers); however, this was only true to a certain extent and limited time frame. As the urban centres became more heavily industrialised and overpopulated the new technology prompted a substitution of mechanical devices for human skills and inanimate power, in particular steam, took the place of human and animal strength (Landes 1969, 1: Bessen 2000). As a result, machinery could perform the work of many people, resulting in unskilled lower-cost labourers being favourable and skilled labourers made redundant in favour of people being employed purely for manpower purposes, this combined with the increased price of food and decreasing of working hours and wages led to considerable stress within the operating class (Commission for Inquiring into the State of Population-Parliament Papers XXXV 1842, 79). By several measures, ordinary factory workers were unskilled and had a rough living; compared to workers in craft and professional occupations, factory workers earned lower wages as they possessed no skills and knowledge (Bessen 2000, 1). The living difference between skilled craftsmen and unskilled labourers could mean the difference existed between middle- and working-class strata in terms of incomes (Brickley *et al.* 2006). Also, 'factory jobs did not require formal education, training periods were brief, factory work was monotonous and factory workers lacked both social status and market power' (Bessen 2000, 1). Consequently, the unskilled operative class was subject to seasonal employment and sometimes suffered chronic underemployment or unemployment (Burnett 1974; Sullivan 1983; Wohl 1983; Humphries 2010 218-219). The unskilled operative class when not subject to unemployment was subject to rough work suffering the burden of fetching and carrying, preparatory and rough work such in the case of manual labourers whose picks and shovels created railway embankments, cuts, and tunnels (Burnett 1974; Sullivan 1983; Humphries 2010).

Another reason behind the distress of the operative class was the practice of many industries such as the mills to gradually 'dispense with the labour of males, but particularly grown-up men; so that the burden of maintaining the family had rested almost exclusively upon the wife and children' (Commission for Inquiring into the State of Population-Parliament Papers XXXV 1842, 79; Humphries 2010; Goose and Honeyman 2013, 4). During this period children and women became more desirable than male workers because they could be paid less (Commission for Inquiring into the State-Parliament Papers XXXV 1842; Lindert and Williamson 1983; Hudson 1992, 227; Honeyman 2007, 163; Humphries 2010). Unexpected death or impairment of the 'breadwinner' due to work accident, disease or any other reasons such as episodes of war, could have also resulted in loss of the family earner. The subsequent loss of the only source of income often led to dropping into the ranks of pauperism and the stigma of social relief (Commission for Inquiring into the State of Population-Parliament Papers XXXV 1842; Wohl 1983, 117; Humphries 2010, 172); inevitably forcing children and women to work outside the domestic environments. Orphans and abandoned children were in an even less fortunate position, compared to children who had to work, as they could be more easily exploited as they had no one to look after them (Hopkins 1994, 161; Honeyman 2007, 103; Humphries 2010, 10). Consequently, much of the labour was provided by pauper apprentices (Humphries 2010; Honeyman 2013; UK Parliament 2020). The children of paupers, orphans and abandoned children, who were sent into employment by the Poor Law authorities before the age of ten (Hopkins 1994, 161). Some had to travel long distances to serve their terms, the majority within a few miles of their homes (Commission for Inquiring into the State of Population-Parliament Papers XXXV 1842; Humphries 2010).

Children as young as five or six years were known to work in various industries and environments such as manufacture, coal mines, chimney sweeping, agriculture and apprenticeships with the latter being the most desirable form of employment (Humphries 2010, 7; Kirby 2013, 150). Given that the coal mining industry was one of the most difficult environments for adults to work in, it must have been especially hard for children. Despite that in the regions of Durham, Lancashire, Cumberland and Oldham, the employment of children in this industry was known to have commenced as young as five or six years of age (Kirby 2013) (Figure 2.1). Something that was also witnessed through the study of St Hilda's burial registers. These young children were taken down into the pits and continued doing this job throughout their adulthood (Commission for Inquiring into the Employment and Condition of Children in Mines and Manufactories 1842, 16; Humphries 2010).

Extract from the Report of the Commission for Inquiring into the Employment and Condition of Children in Mines and Manufactories (1842, 24):

Robert Harle, Gosforth Colliery aged sixteen says aged sixteen said:

'Has been down in pits eleven and a half years at this pit and Seghill.'

while William Hays, age fifteen, Gosforth Colliery said:

'Has been down this pit ten years; went down, therefore, at five years old.'

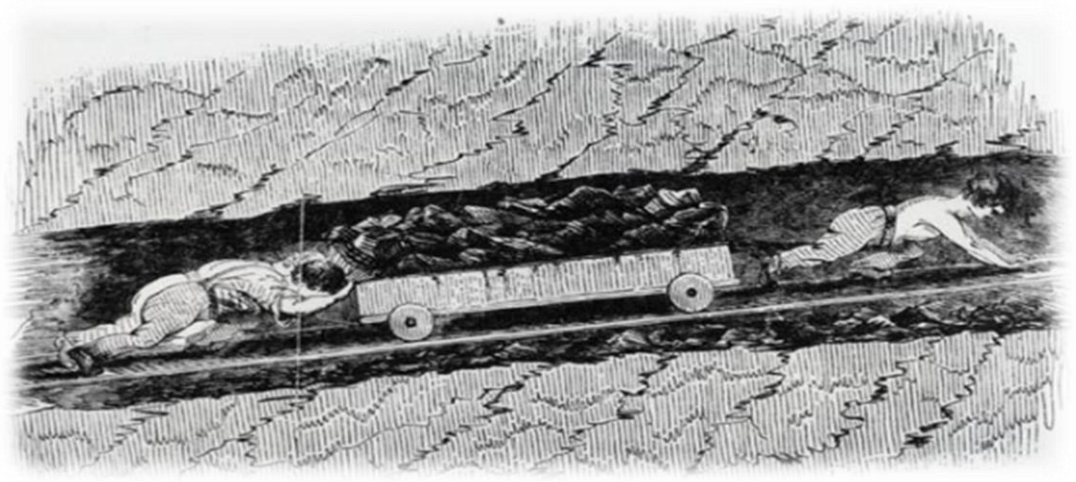


Figure 2.1: Illustration of Children in the Mines. From the report The Condition and Treatment of the Children Employed in the Mines and Collieries of the United Kingdom, 1842, 47.

One might assume that the majority of the employees in the mining industry were males. However, young girls and adult women working in collieries were not an uncommon sight in many regions (Commission for Inquiring into the Employment and Condition of Children in Mines and Manufactories 1842, 24-30; Kirby 2013, 149-153). In some colliery districts, such as in Yorkshire and Lancashire, there was no distinction of sex, instead the labour was distributed indifferently among both sexes. Thus, younger and older female children along with teenage and adult women were ‘allowed to descend into the coal mines and regularly perform the same kinds of underground work, and to work for the same number of hours, as boys and men’ (Commission for Inquiring into the Employment and Condition of Children in Mines and Manufactories 1842, 24-30; Humphries 2010; Kirby 2013 149-153).

Although child labour might appear as an extreme phenomenon brought about by industrialisation, it was really not a new phenomenon; what was new however, was the extent of exploitation that occurred during the period of study (Honeyman 2007, 114; Humphries 2010). Exploitation of these young workers certainly happened with enforcement of long working hours and minimum pay and cases of abuse were widely reported (Commission for Inquiring into the Employment and Condition of Children in Mines and Manufactories 1842; Humphries 2010). With this increase in child labour and its subsequent exploitation, some protective measures eventually had to be taken. In 1819 the first official attempt to regulate the hours and conditions of work for children in the cotton industry was made with the passing of the First Factory Act, but there were no effective means of its enforcement. In 1833 another Factory Act was passed by the government, the Act required that no child under the age of nine was to be employed in cotton mills; a maximum working week of 48 hours was set for those aged 9 to 13, limited to eight/nine hours a day; and for children between 13 and 18 it was limited to 12 hours daily. The Act also required children under 13 to receive elementary schooling for two hours each day (Cooke-Taylor 1894, 77; Humphries 2010, 175; Honeyman 2013; Gowland *et al.* 2018). But once again the means of enforcing such legislations were challenging. Later on, the regulation of working hours was extended to women and another Act was passed by the government in 1844. The regulations applied to the cotton mills industry were eventually applied to other industries (Hansard, 5 July 1833)

A reasonable question that might arise is why so many children existed in the working environments during the Industrial Revolution. It would appear that apart from the lower cost of using children, there was a more pragmatic reason. According to Hopkins (1994, 161) the cause behind the existence of so many children in employment was '…the growth of the population at a previously unparalleled rate, resulting in a predominantly youthful society, and great floods of children'. Children under the age of fourteen comprised at least a third of the total population and nearly forty percent for most of the period (Hopkins 1994, 161; Hudson 1992, 162; Honeyman 2007, 3). Thus, urbanisation led to people having more children and consequently, a large part of the country's population was composed of children from the poorest sectors of society (Honeyman 2007). When these increased birth rates are seen in combination with the increased mortality and morbidity rates, especially those for young and middle adulthood, it is clear why so many children existed inside and outside work environments. Life expectancy in England and Wales as a whole for 1841 based on the Registrar General's Annual Report for the same year was estimated by the office of National Statistics at 40.1 years (ONS 2014). Based on the same evidence, life expectancy in London alone was at 35 years and in other industrial areas such as Sheffield and Manchester, life expectancy was even lower with 33 and 29 years respectively, displaying the hazards that the working-class faced (Wohl 1983, 329; Szreter and Mooney 1998, 88-90). Under these conditions, the employment of children in various industries would have been the norm and not the exception; a necessity of survival for less fortunate families (Humphries 2010). This was especially true for those who had experienced, as it was discussed above, the loss of the head of the family or both parents due to the increased mortality experienced during the 18th and 19th centuries (Wohl 1983; Hopkins 1994; Humphries 2010).

2.3 Living Conditions during the Industrial Revolution

The Industrial Revolution was undoubtedly an Era of unprecedented changes, however many of these changes also contributed to enormous suffering for many people; something that has already been witnessed through the description of working conditions experienced by the operating forces, especially the unskilled workers (Humphrey 2010).

With the migration of large quantities of people into industrialised centres, it did not take long for living and working conditions to deteriorate, as the industrial centres were ill-prepared for such a large influx of people (Longford 1966; Wohl 1983). This urban demographic revolution was accompanied by pressures upon air, water, and space, resulting in severe overcrowding, poor sanitation, and inadequate ventilation, leading to low life expectancy and increased morbidity and mortality (Engels, 1987; Commission for Inquiring into the State of Large Towns and Populous Districts, 1845a; Newman and Gowland 2016).

As the Industrial Revolution and the tremendous population explosion continued, the British cities significant to the Industrial Revolution, such as London, Birmingham, Liverpool, Leeds, Sheffield, and Manchester needed cheap houses to accommodate the urban-working class. However, minimal regulations and enforceable policies on housing existed, and even when they did exist, they were often ignored. As a result, builders had the freedom to build as they wished with profit being their only priority; thus, houses were cheaply built and put up as quickly as possible (Beresford 1971; Wohl 1983; Rudge 2012; Jackson 2015).

The connection between poor quality housing and bad health has been known since the early stages of public health movements in the 1830s and 1840s and with obvious justification, as bad housing meant non-existent or faulty plumbing, irregular unsanitary or inconvenient supplies of water, and rudimentary excrement removal (Chadwick 1843; Dara 1910; Rudge 2012; Harisson 2017, 104). Moreover, these poor-quality structures were unsanitary not only because they lacked certain basic amenities, but because they were, by their very own construction, unsafe to be occupied (Wohl 1983, 285).

Housing during the Industrial Revolution was atrocious, but also limited in availability due to the great demand for housing around the workplace, in order for people to be closer to their jobs (Foster 1974; Clark 2002). As a result, more houses had to be slotted in and built in small spaces, next to the various workshops or other businesses; while existing buildings were modified to accommodate as many people as possible (Rudge 2012). Owing to space limitations, the construction of back-to-back housing in the inner-city areas of the Pennine Yorkshire towns, Manchester Birmingham, Bradford, Leeds, Liverpool, Salford, Sheffield and Nottingham became very common (Wooler 2015, 313-314; Harrison 2017, 101; Harrison 2019). This type of housing was popular among the lower classes and for many health reformers was seen as the least acceptable type of accommodation as a high number of deaths from diseases of the chest such as bronchitis and pneumonia as well as diseases associated with defective growth and development of the young children occurred there (Harrison 2017; Harrison 2019). These back-to-back structures, in particular, suffered from poor illumination and ventilation, as three of the four walls were shared with other buildings and the properties were two or three stories high (Darra 1910, 9-10; Simon 1929; Wooler 2015; Harrison 2017; Harrison 2019). The bottom room served the dual purpose of a living room and kitchen, whilst the two rooms upstairs were used as bedrooms (Harrison 2017). These houses had no backyard and their only wall not connected to another house was the front, acting as the only entrance except for those fortunate enough to stay on the edge of the terrace (Figure 2.2-2.3). These houses were generally cheap to build and hence of poor quality. Toilets and water supplies were shared with multiple households in enclosed courtyards (about one privy for every four houses) (Wooler 2015). Underneath many of these 'unfit' dwellings were cellars, which were let separately to the poorest section of the population, who could not afford one of the above-ground structures (Thompson 1984, 121; Harrison 2017). These consisted of one underground, damp and poorly ventilated room. Moisture and leaked sewerage waste would simply leak in their floorboards, proving that back-to-back houses were not the worst type of dwellings (Wohl 1983; Harrison 2017). Houses were often situated close to or incorporated the walls of adjacent mills, stables and even burial grounds (Thompson 1984, 121).

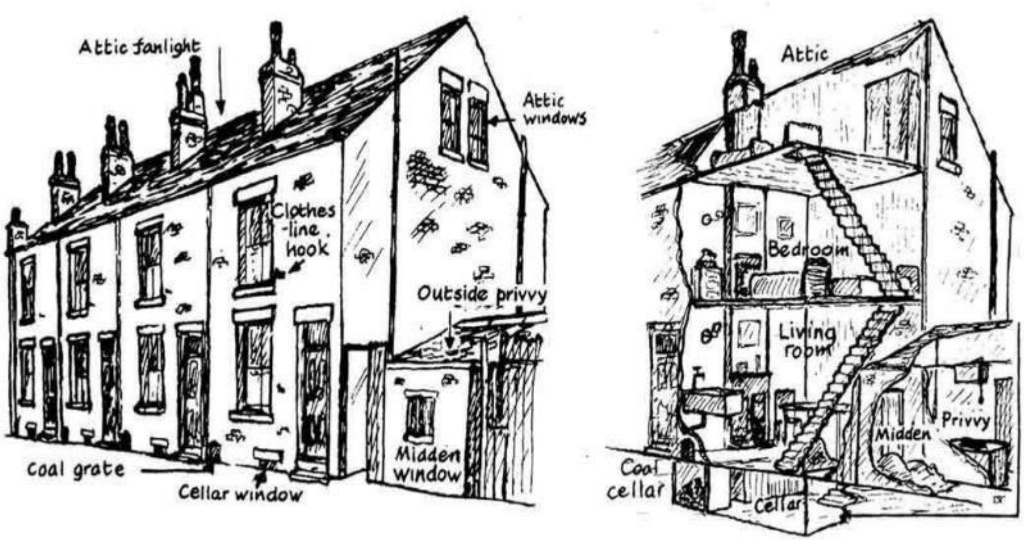


Figure 2.2: Unknown. 2019. Illustration of back-to-back housing. Source the Thoresby Society-The Historical Society of Leeds and District (Back-to-back houses - Thoresby Society).

Figure 2.3: Back-to-back houses in Birmingham, 1883. Source Birmingham Mail (www.birminghammail.co.uk).

The problem of defective and unsanitary housing was exacerbated by the fact that large families or even multiple families were house-sharing in these tenements (e.g. back-to-back houses), which did not have the appropriate facilities to accommodate the needs of an increased number of individuals, as they were meant to accommodate small families and not large extended families (Harrison 2017). Taking one case as an example, in the mid-19th-century Manchester, eighteen people, both adults and children, lived on Ludgate Street in a damp cellar. This cellar space comprised a single room, 'the dimensions of which were 17ft. by 18ft. floor and 6ft. 3in. high' (Waters 1853, 14; Harrison 2017, 104).

But even without overcrowding within houses, the intense concentration of the burgeoning population within towns would still have created a severe health hazard, placing an enormous strain upon the inadequate water, drainage and sewer facilities, saturating the sub-soil with its waste products, breathing the same adulterated air within the city, and spreading the risk of infection and contagion (Wohl 1983, 291). For most of the 19thcentury access to running water took far more effort than just turning on a tap to keep oneself clean. Access to water was outdoors via communal pumps or taps located on the street, factors that exposed water to various assaults from numerous types of pollutants (Robson 1935). In the lack of proper water and sewer facilities, drinking water was contaminated with raw sewage and other substances, which led to diseases such as cholera and typhoid with fatal consequences on entire communities (Beach and Hanlon 2018). Water was by no means universally lain, even at the end of the century. In the 1840s, only about twenty percent of the houses in Birmingham had piped-in water, while in Newcastle it was less than ten percent (Robson 1935, 313). In London at that time some 30,000 inhabitants were without piped water, even from communal street taps. While in Bolton, Chester and Liverpool for instance, the poor had to beg or steal for water or even rely on collecting rainwater (Robson 1935, 314). Even where water was lain the service was often erratic, with waterworks companies turning off the water supply between 7 pm and 5 am or no water supply on Sundays (Wohl 1983, 62). The lack of privies and drainage meant that excrement and other waste products such as rubbish were disposed of in overflowing cesspits or out on the streets which were already full with horse dung which could not be removed effectively due to the increased number of working horses (Commission for Inquiring into the State of Large Towns and Populous Districts 1845a and b; Engels 1987; Jackson 2015). As a result, the streets were not more hygienic than the housing itself (Newman 2015).

In addition to overcrowding and poor sanitation, the population also had to cope with air pollution generated by coal, which supplied domestic hearths and powered steam engines which turned the wheels of industry and transport (Commission for Inquiring into the State of Large Towns and Populous Districts 1845a and b; Fynes 1873; Bailey *et al.* 2016; Beach and Hanlon 2018). The changeover to coal as a primary fuel source resulted in extremely high levels of atmospheric pollution, with the resulting smog and soot having adverse health effects on the residents of the urban growing centres (Fynes 1873; Bailey *et al.* 2016; Newman 2015; Beach and Hanlon 2018). The detrimental effects of the atmospheric pollution on the respiratory system, were known as early as 1733, when the physician Arbuthnot (1733, 208-209) observed that the mortality of children under two years was associated with the deleterious effects of the polluted air in the city of London. While as early as the 1850s, higher coal intensity and subsequent outdoor and indoor air pollution were associated with higher death rates from respiratory diseases due to carbon particles, especially among the old and very young (Bailey *et al.* 2016; Beach and Hanlon 2018). It would appear that during the Industrial Revolution every district was affected with environmental pollution due to coal emissions, by one way or another. Those located downwind from a coal intensive district suffered from their neighbour's pollution and those surrounded by hills suffered more deaths by their own smoke emissions as they became trapped in smoke (Bailey *et al.* 2016; Beach and Hanlon 2018). Coal was by far the most important pollutant in Britain during the Industrial Revolution, however, it was not the only air pollutant affecting the various districts, alkali manufacture began in the mid-1820s and it was also deleterious in its effects on atmospheric pollution (Foster 1974; Wohl 1983; Bailey *et al.* 2016). These effects included difficulty breathing, coughing, choking, smarting of the eyes, and nausea for those exposed to it (Foster 1974). The thick shroud of pollution would have also prevented the sun from penetrating the narrow alleys of the overpopulated industrial centres, resulting in severe deficiencies such as vitamin D deficiency due to lack of exposure to ultraviolet light (Mays 2008).

Under these conditions and all the subsequent health problems, the mortality rates of both adult and foremost children rose dramatically in the urban centres (Thompson 1984). The simple arithmetic of more people meant more deaths, which led to a greater demand for burial places in churchyards which were soon full (Jackson 2015). These burial sites, many of which had been accommodating bodies for hundreds of years, were also suffering from space restrictions. The increasing need for more houses and workshops left cemeteries with no possibility to expand their borders; eventually resulting in another major public health problem; the creation of overflowing foul-smelling cemeteries due to population explosion. Bodies were often piled atop each other in vast pits with the wooden coffins tossed aside and burned for firewood. In fact, there were so many burials that in many churchyards the grounds were raised considerably above street level (Walker 1842, 21). It was not until the Burial Grounds Act for preventing overcrowding of cemeteries that this problem was progressively solved. These series of Acts from 1852 to 1885, which prohibited burials within the city limits, led to closure of existing burial grounds in the cities and the building of new ones outside the city borders.

The increased mortality rates and the serious unsanitary conditions became the concern of many social reformers of the time, who fought to improve the water supplies, drainage systems, and overcrowding of burial grounds which primarily improve public health (Wohl 1983). However, despite the gradual passing of various sanitary acts to improve drainage and general hygiene of the streets, the progress was slow and frequently problematic (Engels 1987).

2.4 New Health and Disease Challenges

The urbanisation of England brought on by the Industrial Revolution meant that there were more jobs, a wider range of social contacts, and broader cultural diversity, but it also sent England to a more primitive age of plagues due to the lack of early public health precautions; leaving everyone to some extend exposed to poor health despite any socio-economic divisions (Wohl 1983, 80). During this period of population expansion and human migration the propensity for disease became more frequent. Along with international trade wares, bacteria were also 'traded' regularly with epidemics and endemics spreading quicker with the introduction to new hosts (McNeill 1976; Duncan *et al.* 1994). As human populations grew and became better integrated through trade and migration in the 18th and 19th centuries, then disease introduction became more frequent and regular and the accumulation of hosts more rapid, sustaining regular epidemics and endemics (McNeill 1976; Duncan *et al.* 1994). This is because of the way in which infectious diseases are transmitted between humans, overcrowding in towns resulted in a greater opportunity for the bacilli to be passed quickly between individuals (McCarisson 2011, 42). The massive numbers of people in towns encouraged the systematic emergence and constant cultivation of pathogens due to close proximity within deteriorated living and working conditions. This problem was further aggravated by extensive population movements. On the one hand this movement injected new waves of healthier and younger country men and women into the towns, thus raising the general health standards, but on the other hand it placed immigrants who had little resistance or immunity to a variety of diseases which flourished in the densely packed industrial towns into close proximity to one another (Wohl 1983, 135 and 288).

Limited or lack of space, poor ventilation and limited access to sunlight as well as poor sanitation created unhygienic conditions; making people, especially those from lower socio-economic status and those that had little immunity to industrial environments such as people born in rural environments, more susceptible to pathogens (Roberts and Buikstra 2003, 59; McCarisson 2011, 42). Poverty also resulted in undernutrition and malnutrition through limited food access which subsequently caused further susceptibility to infectious diseases due to immunodeficiency (McCarisson 2011, 42; Mansukoski and Sparacello 2018). Moreover, low socio-economic status also limited the access to health care.

The most sensitive group to the deleterious effects of industrialised environments, were the young children who exhibited increased mortality from infectious diseases (Thompson, 1984). According to the Registrar-General report (1842), children below the age of five were more frequently affected by mortality and morbidity than any other group in big cities such as London, Manchester and Bradford (Pooley and Pooley 1984; Thompson 1984). From all the various infectious diseases, diarrheal diseases were one of the leading causes of death, during the period of interest, among children younger than 5 years (Registrar-General 1842, 226); while today they are the second leading cause of mortality worldwide where housing is overcrowded and water and sanitation are poor or where natural disasters have led to the collapse of the water, sanitation and healthcare systems (Amicizia *et al.* 2019, E271).

2.4.1 Infectious Disease

The major infectious diseases were conveyed in a variety of ways; by contaminated water, foodstuffs, clothes, utensils, by body lice, flies or mouth droplets; indicating that there were all influenced by cleanliness, diet, personal hygiene, public sewerage or domestic living arrangements (Wohl 1983). Consequently, infectious diseases such as cholera, measles, typhus, typhoid, tuberculosis, smallpox, became an inevitable part of industrial-environment life.

From the infectious diseases listed above, only tuberculosis and smallpox are skeletally identifiable and this is to a limited extent, providing that the individuals lived some time in order for the lesions to affect their skeletons. Thus, it is impossible to osteologically assess the prevalence of the rest of the diseases. However, despite the fact that these conditions are not skeletally identifiable it is possible to determine the risk to their exposure, by the evidence of other skeletal conditions associated with industrialised environments (e.g. nutritional deficiencies such as rickets). This can help to indirectly determine the immunological susceptibility of those individuals to those infections due to poor nutritional status and/or other factors.

Despite the lack of direct skeletal involvement in these conditions, brief description of some of them follows for contextual purposes, as according to various historical accounts (e.g. burial registers, registrar general report) these infectious diseases were rife and accounted for a large number of deaths, especially among the immature immune systems, which were vulnerable. During the use of these historical accounts a consistent attempt was made to identify the conditions and cluster them under a single name as frequently they appeared in different regions and historical documents under different names such as in the case of tuberculosis, for instance, which was frequently quoted as ‘consumption’ and ‘phthisis’. This step was necessary in order to avoid any confusion to the researcher as well as the readers.

Of all fatal diseases of the period, cholera had a disproportionate impact as it spread incredibly fast, leaving behind huge numbers of fatalities (Wohl 1983, 118). Cholera is a highly contagious disease caused by the water-born bacterium *Vibrio Cholerae* (Ramamurthy *et al.* 2020). It spreads primarily via water contaminated by faeces; thus, the transmission route is faecal oral. Although mild cholera can be indistinguishable from other diarrheal illnesses, severe cholera is distinct, with pronounced diarrheal purging. Vomiting is also a common feature in the early stage of the illness (Harris *et al.* 2012, 1-4).

Following an inexorable progress from Asia to Europe, cholera first struck in England in October 1831, during its second pandemic wave which originated in India in 1826 and lasted till 1832. The first incidence of cholera in England occurred in Sunderland, when a ship from the Baltic States, carrying sailors who had the disease, docked at the port (Jackson 2015, 56). From Sunderland, the disease made its way northwards into Scotland and southwards toward London. Before it had run its course, the disease had claimed some 50,000 lives (Greenhow 1832). Vessels from Sunderland were put in quarantine by the end of November 1831, soon after cholera had arrived there. These measures, however, were not completely effective as the first cases for London had arrived, not from international vessels but from domestic sources more specifically the colliers from the Tyne River region (Jackson 2015). Consequently, sea port towns such as Sutherland, Newcastle, Gateshead, and North and South Shields, due to their geographical location, were at higher risk as ships arrived daily from areas such as Hamburg in Germany where cholera was extensively prevalent (Greenhow 1832). After the first strike in England three more followed; the second one in 1848-49 and the third and fourth in 1853-54 and 1866-67 with diminished virulence (Wohl 1983, 118).

Cholera was contracted by swallowing water or food infected by the cholera vibrio. Cases were reported to be dead within 24-48 hours of the first apparent symptoms, but more generally the victim could die several days after onset, suffering from violent stomach pains, cramps, diarrhoea, and vomiting (Jackson 2015, 55). While the association of the virus with water contaminated with raw sewage and other substances might seem more obvious for us nowadays, it was not until London physician John Snow published his famous Essay, *On the Mode of Communication of Cholera,* in 1849 that the link between contaminated water supplies and cholera transmission was made (Snow 1855). Between 1849 and 1854, Snow proposed the theories that cholera was a communicable disease and that stool carried infectious material; in his essay he suggested that this infectious material could contaminate drinking water supplies, resulting in transmission of cholera (Snow 1855, 1-32; Harris *et al.* 2012). In 1854 Snow proved his theories when he traced cholera deaths to houses supplied by the suspect water of the Southwark and Vauxhall water company. After managing to convince the authorities to lock the handle of a pump in Broad Street in Soho, an area where fifty people per day were dying of cholera, the deaths there came to a sudden halt (Wohl 1983, 125; Harris *et al.* 2012); thus, proving the role of water supply on the prevalence of cholera or other waterborne diseases. As it was already seen in an earlier section, the distribution of water was not universally laid throughout the century, with the presence of waterworks ranging from rudimentary to non-existing for many communities. The fact that many communities had to rely on water sources on the street left the community members exposed to the dangers of widespread bacterial infections. For instance, in Newcastle in 1831-32 there were no waterworks at all and spring water was used instead, which generally had to be carried some distance in pans to the houses (Robson 1935; Wohl 1983).

Another condition similar in origin to cholera but less contagious was typhoid. Typhoid is caused by the bacterium *Salmonella Typhi* and is transmitted by the consumption of water or food that has been contaminated by the urine and faeces of an infected carrier (Maskalyk 2003, 132). The victims of typhoid experience fatigue, headaches, diarrhoea or constipation, high fever, stomach pain, poor appetite, rash and confusion (Maskalyk 2003, 132). In the 1800s, the primary source of transmission was via contaminated water such as in the case of cholera. Although typhoid was typically rife among poor communities, the disease affected everyone regardless of socio-economic status due to the common unsanitary conditions such as poor drainage and sewage system (Beach and Hanlon 2018). Although it remains a subject of debate, typhoid seems to have affected several members of the royal family. Prince Albert is believed to have contracted the disease succumbing shortly afterwards; while Queen Victoria had also contracted the disease when she was sixteen. Additionally, one of her children manifested 'bowel fever' symptoms ten years after the death of Prince Albert; luckily both overcame the danger (Longford 1964; Wohl 1983).

For London inhabitants a large portion of the community relied on the River Thames for both water supply and sewage disposal (Jackson 2015, 55; Newman 2015, 68). In November 1835 it was reported in *The Times* that water companies in South London were still drawing water from between Southwark and Lambert Bridge where the great common sewers of London discharged their contents. In fact, 7,000 families that occupied the densely inhabited borough of Southwark continued to receive water from that spot (Wright 1835, 3) (Figure 2.4). Before London embarked on its great sewerage scheme in the late 1850s, prompted by the *Great Stink* incident in London during the summer of 1858, some 250 tons of faecal matter daily found their way into the Thames. The Thames, like other rivers, also served as a convenient depository for the victims of murder, infanticide and suicide. Compared with all the ebb and flow of human excrement, dead humans and animals and discarded objects, the industrial pollution from substances such as carbonate of soda and lime was not seen as a major problem (Wohl 1983, 234). With all these various sources of water pollution and the filtration systems not being sufficiently implemented, there is no wonder how entire communities were decimated by infectious diseases such as cholera and typhoid during this period (Snow 1849).

Water, however, was not the only mode of transmission. Contaminated food, cow milk for instance, was a significant source of transmission not only for typhoid, but also for other infectious diseases such as gastrointestinal tuberculosis, scarlet fever and diphtheria; placing children, irrespective of socio-economic status, at a significant risk of infection (Wohl 1983; Newman 2015). Despite the uncertainty and ignorance surrounding the origins and transmissions of typhoid, improvements in water supply and sewerage did succeed in reducing its virulence by the early 20th century (Wohl 1983, 128).

Figure 2.4: Chruikshank., G. 1832 "Salus Populi Suprema Lex" (The welfare of the people is the supreme law). Satirical Illustration of the polluted River Thames illustrating the poem "Royal Address of Cadwallader ap-Tudor ap-Edwards ap-Vaughan, Water-King of Southwark"; a satire on water pollution of the River Thames featuring sickly residents of Southwark pleading for clean water from the chief of the Southwark water company. Source Science Museum Group Collection, UK ([Science Museum Group Collection]).

As it has been mentioned, the contraction of specific infectious diseases in childhood was responsible for a large number of fatalities especially below the age of five (Registrar General 1842, 230). Some of these childhood diseases, however, such as measles and smallpox were not exclusively confined to childhood, as they could also affect adults with compromised or alternated immune systems such as pregnant women or people in convalescence (Sappenfield *et al.* 2013).

Childhood disease outbreaks of infectious origin, such as measles, whooping cough, scarlet fever and consumption were most commonly transmitted through airborne droplets of saliva in overcrowded confined spaces. Just as today, there is a greater incidence of the common cold and flu in the winter, not only because the viruses survive longer in the cold temperatures, but also because people spend more time indoors. In this manner, overcrowding increased the chances of contracting influenza, consumption and the host of childhood diseases such as measles, scarlet fever, whooping cough and any disease conveyed by droplets of saliva. The risk of infection in overcrowded environments and the subsequent close contact were worsened by the prevalence of one-roomed living and poor ventilation within the household thus aggravating the problem of airborne disease (Wohl 1983, 288).

When the mortality of these infectious diseases is under consideration the nutritional status of the individuals is also a crucial factor (Duncan *et al.* 1996; 1997; 1998; Beach and Hanlon 2018). Along with the overcrowded conditions, a compromised nutritional status seems to play a crucial role in the spread of these infectious diseases, especially where the immune system of the immature individual is still developing or when health status is already compromised by prior infection (Schaible and Kaufmann 2007; McCarrison 2011; Newman 2015). The role of malnutrition in the spread of infectious diseases can also be demonstrated through the fact that one infectious disease may have been closely followed by another (Newman 2015, 71). Childhood diseases are frequently followed shortly by another episode of childhood disease, for instance whooping cough outbreaks often followed measles epidemics in the 19th century (Hardy 1993; Schaible and Kaufmann 2007). This happens because an episode of disease may reduce the nutritional status of an infant or child; therefore, exhausting the energetic resources needed for recovery and immune resistance (Mansukoski and Sparacello 2018). As a result, the patient is left vulnerable to contract another disease and even worse being at a higher risk of mortality (Hansen 1938; Hardy 1993).

Further supporting the importance of nutrition, the study of London's Bills of mortality, which were weekly mortality statistics which monitored burials in London, noted a lethal correlation between the price fluctuation of wheat in the 17th, 18th and 19th centuries and bacterial diseases such as measles, whooping cough and scarlet fever (Duncan *et al.* 1996; 1997a, b; 1998). Susceptibility to these bacterial diseases at this time was found to be strongly correlated with fluctuating levels of malnutrition directly associated with oscillations in wheat prices (Duncan *et al.* 1996;1997a and b; 1998). The results from the study of historical accounts were also in accordance with modern clinical studies which confirm that malnourished individuals and especially children, as a result of immunodeficiency, suffer in greater proportion from respiratory infections, infectious diarrhoea, measles, and malaria, characterised by a protracted course and exacerbated disease (Schaible and Kaufmann 2007, e115; Mansukoski and Sparacello 2018, 43).

Measles is a highly contagious disease which is caused by the *Measles morbillivirus,* it is transmitted via droplets from the mouth, nose or throat of an infected person and the symptoms appear ten to twelve days after infection. Symptoms include runny nose, high fever, bloodshot eyes, inner mouth spots, and a rash that spreads from the face; while further complications involve hearing loss, diarrhoea, brain swelling, and pneumonia (WHO 2019). As mentioned above, during the 17th, 18th and 19th centuries measles mortality was found to be cross-correlated with the annual wheat prices and also found to be correlated with low autumn temperatures (Duncan *et al.* 1997a). Whooping cough, or according to Victorians 'hooping cough', also known as 'pertussis', was also found to be highly associated with oscillations in wheat prices in 18th-century London and 19th-century Liverpool with increased number of fatalities (Duncan *et al.* 1997b; Duncan *et al.* 1998). Whooping cough is a highly contagious respiratory disease caused by the bacterium *Bordetella Pertussis* and even today is a life-threatening disease with the most serious cases and fatalities being observed in early infancy (Newman 2015). Typical manifestations include several weeks of coughing which gradually develop into severe coughing fits, ending in a characteristic 'whoop', often with cyanosis and vomiting. In young infants, the cough may be absent and the disease may manifest with spells of apnoea. Major complications involve pneumonia, bronchitis, encephalitis and malnutrition caused by repeated vomiting (WHO 2019). In modern clinical cases it has been reported that many infants are infected by older siblings, parents or caregivers who might not even know they are carriers of the disease (Bisgard *et al.* 2004).

Although both measles and whooping cough made no social status exceptions, the conditions exhibited higher incidence among the lower strata due to poor living conditions, such as overcrowding and poor ventilation, frequently within one-roomed living that made it impossible to keep infected family members away from the rest of the family (Wohl 1983; Hardy 1993; Newman 2015; O'Donoghue *et al.* 2021). But among the many causes of infant mortality, the most important factor that resulted in the spread of disease was the attitude of the parents towards infant diseases. Reluctance to incur medical cost, fear and awe of the doctors, distrust of doctors and reliance on traditional folk medicines and home remedies where common attitudes of the poor, but the most shocking attitude that the Ministry of Health (MOH) found when discussing the spread of measles and whooping cough was the 'culpable indifference' and 'gross ignorance' among parents. A common philosophy among parents was 'the children like to ave it' and 'children must die-you can't prevent them'. The MOH for Sunderland told the Sanitary Institute in 1882, mothers frequently took the children with them when visiting neighbouring houses, where there was an infectious disease and often placed the healthy children in bed with the sick, so they could get the nursing over and done with all at once. Consequently, necessity (lack of separate bedrooms and even beds), ignorance, or fatalism and malnutrition or a combination of all, made the poor resistant to doctors and their offspring susceptible to mortality (Harris 1832-33, 120-130; Wohl 1983, 18). Duncan and co-workers (1997b, 449) proposed that the sharp increase in whooping cough mortality and probably in susceptibility after 1785 was directly linked to the malnutrition of the poorer classes which stemmed from the rising grain prices.

Very similar where the findings pertaining scarlet fever, scarlet fever or 'scarlatina' or 'scarletina' is an infectious disease that can result from the bacteria group *A Streptococcus.* The disease was viewed with great dread, for the chances of a child who contracted it to survive was rather low with 95 percent of the cases who contracted the disease being children under the age of ten (Wohl 1983, 129). The signs and symptoms include fever, sore throat, headaches, swollen lymph nodes and rash beginning from the neck area. The infection spread through the aerial route, but it also spread through contact with contaminated clothes. The risk of infection was higher in overcrowded environments, especially when there was a person who had already developed the symptoms. For that reason, lower classes appeared to be more affected, although the condition made no exceptions. Analysis of the mid-19th-century registration details for scarlet fever deaths in England and Wales, revealed a significant increase in scarlet fever mortality. A positive correlation between epidemics and an oscillation in wheat prices was revealed, suggesting that maternal malnutrition during pregnancy caused increased susceptibility in the offspring which interacted synergistically with seasonal dry conditions (Duncan *et al.* 1996, 497). In parallel with the falling wheat prices after 1880, scarlet fever mortality sharply dropped indicating that the period of high scarlet fever mortality (1840-1880) was dependent on poor nutritive levels. Unlike the dynamics of whooping cough and measles, no significant correlation was revealed between the low seasonal temperatures of autumn and winter and the epidemics of scarlet fever. However, the scarlet fever epidemics between 1847 and 1880 appear to be positively correlated with dry conditions in spring/summer in England and Wales (Duncan *et al.* 1996, 493). The explanation behind this could be that *Streptococcus pyogenes* may survive better and be more active in dry weather as opposed to wet conditions (Mahara *et al.* 2016, 11).

Another condition that highlighted the crucial role of nutrition in the body's ability to resist disease, where sanitary conditions were rudimentary and disease was endemic, was typhus (Wohl 1983, 56; Mansukoski and Sparacello 2018). It is very likely, however, that many of these cases were misdiagnosed cases of typhoid (Mazumder *et al.* 2009). Typhus known also as 'Irish fever', 'goal fever', 'ship fever', 'putrid fever' and 'camp fever', is a rickettsial disease caused by the bacterium *Rickettsia prowazeki* and spread mainly by scratching the bite, which can further open the skin, allowing the bacteria greater access the bloodstream, but it can also be transmitted via inhalation of dust infected with faeces of the body louse. Conditions of overcrowding greatly encouraged the spread of the disease, which was most prevalent in the winter months and was rife among the lower strata as it was a disease of filth (Wohl 1983, 125). The point of nutrition clearly emerges in the case of Irish famine in the 19th century, where typhus deaths jumped from over 7,000 in the year before the famine occurred to over 17,000 in the first year of the famine and over 57,000 as the famine deepened. As in the case of cholera and typhoid, the sanitary changes introduced by the reformers in the second half of the 19th century, limited the spread of typhus (Salaman 1949, 308). Ironically, though the provision of sewers, which no doubt helped to reduce the number of fatalities from typhus may have increased the number of typhoid deaths, for all too often the sewers poured contaminated filth into the rivers which was a major source of drinking water (Jackson 2015).

Another infectious disease dreaded in England from the final visitation of bubonic plague in 1666 until the end of the 19th century, when it ceased to be endemic, was smallpox (Duncan *et al.* 1994, 255). Smallpox is one of the most lethal of all human pathogens (Davenport *et al.* 2018, 75, with epidemics throughout the period of study accounting for between 300 and 4,000 deaths only in the metropolis, with the infection being one of the five major infections inflicting mortality (Registrar-General 1842, 226; Miles *et al.* 2008, 134). Even those lucky enough to survive were often scarred for life because of the disfigurement (Miles *et al.* 2008, 133). Smallpox is caused by one of the strains of the orthopoxvirus *variola* (VARV) with the circulated variant in Europe before the 20th century belonging to the most lethal strain, *variola major* whose virulence and case fatality rate, according to evidence, was gradually but significantly increased from the later 16th through to the end of the 19th century (Davenport *et al.* 2018, 75). In the middle and later decades of the 17th century, the particular strain began to afflict people of all social statuses and ages. By the first half of the 18th century, almost everyone had contracted smallpox at some point and it was considered to be directly, or indirectly, responsible for one death in five (Duncan *et al.* 1994, 255).

This acute virus was a classic ‘crowd disease’ transmitted mostly through aerosolised nasal secretions between individuals in close proximity and less commonly via infected objects (Semba 2003; Davenport *et al.* 2018). Consequently, the condition was dependent on relatively large populations of susceptible hosts for continued transmission (Davenport *et al*. 2018, 75). Although difficulties existed in the diagnosis of specific infectious diseases, smallpox symptoms were relatively distinctive in nature and the viral infection was only misdiagnosed as chickenpox, which was rarely lethal (Davenport *et al.* 2018, 75). Smallpox was characterised by an extensive rash that spread over the face and the rest of the body, which after one to two days developed into pustules which eventually crusted and scabbed nine to ten days after the initial exposure (Guharoy *et al.* 2004, 441; Newman 2015, 73). Some common further complications included ocular complications such as eye infections which can even result in loss of sight, respiratory problems such pneumonia and bronchopneumonia and extensive scarring (Martin 2002; Semba 2003). Cytopathic alterations could induce great danger of mortality from smallpox to infants, pregnant women and older individuals; consequently, a large number of the affected victims would not survive due to these alterations (Martin 2002; Semba 2003; Guharoy *et al.* 2004). Those who survived smallpox conferred lifelong immunity (Martin 2002; Semba 2003). Bone complications were also reported occasionally, such as arthritis and osteomyelitis variolosa with higher predilection for the elbow (Martin 2002, 550; Miles *et al.* 2008, 134), allowing in some cases the identification of the condition in human skeletal remains. A rare possible osteological example is a four-year-old child from St Marylebone cemetery in London which exhibited osteomyelitis variolosa of the distal elbow (Miles *et al.* 2008, 134; McCarrison 2011). The elimination process of smallpox was progressively achieved after the introduction of the Vaccination Act in 1853, which made it compulsory for all children born after 1st August 1853 to be vaccinated against smallpox during their first three months of life, with fines to parents who failed to get their children vaccinated. By the 1860s, two-thirds of babies were vaccinated, and as a result there was a fall in the smallpox death rate (Wolfe and Sharp 2002, 430).

Another infectious disease with a great number of fatalities among the various social strata during the period of study was tuberculosis also frequently quoted as ‘consumption’ or ‘phthisis’ (Wohl 1983). Tuberculosis is caused by one of the species of Mycobacterium, two strains of which may affect humans, *Mycobacterium tuberculosis hominis* responsible for the pulmonary type and *Mycobacterium tuberculosis bovis* responsible for the gastrointestinal type (Roberts and Manchester 1997). Pulmonary tuberculosis is confined in the lung area and the mode of transmission is via inhaling droplets containing the bacteria. Gastrointestinal tuberculosis spreads mostly via consumption of infected meat or drinking infected milk, immediately placing infants at a higher risk of infection during the period of study; however, it can also spread via droplet infection (McCarrison 2011, 31). Another form of tuberculosis is ‘scrofula’, which affects the lymph nodes, especially of the neck. The condition is also spread via unpasteurised milk from infected cows, placing infants up to the late 1800s (when pasteurisation of milk commenced) at a higher risk. Despite the different strains of the condition that exist, it was the pulmonary type that caused an increased number of deaths during the 18th and 19th centuries (Registrar General 1842; Wohl 1983). Of all the killer diseases of the period, respiratory tuberculosis was the greatest one, perhaps accounting for one-third of all deaths from disease during the period of interest (Registrar-General 1842; Wohl 1983).

Because of the mode of transmission of the pulmonary type, overcrowded and poor living conditions during the period of interest, promoted the spread of the disease from one infected individual to another. As it has already been seen with the course of the spread of the other infectious diseases above, a limited or lack of space, ventilation and sunlight as well as poor sanitation encouraged emergence and development of pathogenic organisms (Roberts and Buikstra 2003, 59; McCarrison 2011).

The oral traditions of medicine and public health have it that malnutrition is also an important risk factor for the onset of active tuberculosis (Cegielski and McMurray 2004, 286). This notion, however, is largely based on historical reports such as also was in the case of the infectious diseases we have seen already. A historical example is the Danish tuberculosis epidemic during the First World War. Tuberculosis could be explained by widespread malnourishment, since the export of meat, fish, poultry, and dairy products meant that food was scarce inside the country. This tuberculosis epidemic plummeted once the German blockade of Denmark was established and food became available to the Danish population again, but the epidemic continued in other countries (Schaible and Kaufmann 2007, 0808). Apart from historical accounts, the synergistic relationship of malnourishment, although it is complex and difficult to explain clearly, has also been demonstrated through experimental animal studies (Cegielski and McMurray 2004; McCarrison 2011). In these studies, protein calorie malnutrition, '...compromised several components of the cellular immune response that are important for containing and restricting tuberculosis' (Chan *et al*. 1996, 14857). When the diet was restored to a full protein diet, the infection was reversed (Chan *et al*. 1996). It is generally accepted that malnutrition is a risk factor for tuberculosis development because of lowered cell-mediated immunity (Cegielski and McMurray 2004; McCarrison 2011; Mansukoski and Sparacello 2018). Extensive clinical evidence in humans, however, is necessary and more details are required in order to fully understand how tuberculosis and malnutrition are associated (McCarrison 2011). The contribution of a compromised nutritional status in the contraction of tuberculosis has also been demonstrated through Vitamin D deficiency. Vitamin D deficiency has been linked with tuberculosis in studies, where it was demonstrated that vegetarian diets may contribute to deficiencies in Vitamin D and subsequently create a greater susceptibility to tuberculosis (Ustianowski *et al*. 2005; McCarrison 2011); while the deficiency is also positively linked to the contraction of other infectious diseases such as whooping cough and bronchopneumonia because of immunological vulnerability induces by the lack of the vitamin (Hansen 1938).

Occupational exposures also promoted the spread of tuberculosis among the labouring strata. Specific occupational environments appeared to promote the spread of the disease. The high prevalence among tailors, potters, miners, and hosiers had attracted the attention of the Privy Council although it is hard to chart the course of the disease with any confidence, for it was frequently confused with other diseases such as pneumonia (Wohl 1983, 130). Nevertheless, it seems that between 1851-1860 and 1901-1910 tuberculosis mortality was roughly halved due to improvement of social conditions (Wohl 1983, 130). A study, however, into the relationship between the decline of tuberculosis and improving social conditions during the Victorian period in England and Wales supported that along with the improving living conditions, other factors must have played a role, of which natural selection was the most significant (Davies *et al*. 1999; McCarrison 2011). Natural selection in this case, assumed that tuberculosis primarily affected young adults, those susceptible to tuberculosis and of child bearing age, and thus the morbidity and mortality rates of the disease would limit the number of children born to those susceptible to tuberculosis, or would deprive young children of susceptible parents so that child mortality rates would increase. Ultimately this would result in fewer children born of people susceptible to tuberculosis, and would leave others naturally resistant to the disease to reproduce (Davies *et al*. 1999, 91; McCarrison 2011, 41).

2.4.2 Poor Nutrition and Dietary Deficiencies

During the 18th and 19th centuries, the industrial urban centres were notorious not only for the spread of diseases, but also for the presence of malnourished and undernourished individuals (Wohl 1983; Thompson 1984; Rees 2001; Mays 2008; Jackson 2015). The increased prevalence of nutritional deficiencies such as rickets-Vitamin D and scurvy-Vitamin C was indicative of poverty and poor living conditions, but also provided indirect evidence on immunological deficiencies and poor resistance to infections. Their presence in early infancy was indicative of how genetically ill equipped these individuals were to resist infectious diseases and subsequent death (Roberts and Buikstra 2003, 59; Beach and Hanlon 2018).

As it has already been established through different studies the nutritional status plays an important role in the function of the immune system, leaving the individuals vulnerable to slow recovery of infectious diseases, recurrent infections and slow healing of wounds (Hansen 1938; Hardy 1993; Muhe *et al.* 1997; Thornton *et al.* 2013; Newman 2015; Bourke *et al.* 2016; Rosen *et al.* 2016; Ngari *et al.* 2018; Ives 2018). While only a small percent of infectious diseases is skeletally identifiable, the presence of nutritional deficiencies in skeletal remains is a key to define the vulnerability of the past populations to infections.

Assessment of sunlight nutritional status can, therefore, help to indirectly determine the immunological susceptibility of individuals to those infections due to poor nutritional status and other factors. Consequently, the increased numbers of deaths, especially in early life when combined with the increased presence of metabolic disorders such as rickets and scurvy may be suggestive of the morbid effects of malnutrition and undernutrition in the morbidity and subsequent mortality of the industrial population(s) despite the lack of direct evidence for infectious diseases (Mays *et al.* 2007; Mansukoski and Sparacello 2018).

However, it was not only the diet per se that resulted in these nutritional deficiencies and subsequently immunological vulnerabilities to contract infections, but a combination of other factors. This can be clearly understood through the case of rickets, which is the result of failure to obtain vitamin D in children, while its adult form is known as osteomalacia (Figure 2.5). Only a small amount of Vitamin D is obtained through the diet from food sources such as eggs and oily fish, while the rest is mainly synthesised epidermally via sunlight exposure; therefore, sun is pivotal in acquiring the needed amount of Vitamin D (Roberts and Manchester 1997; Mays 2008; DeLuca 2014). Consequently, although rickets was one of the more obvious external signs of malnutrition among the labouring classes, it was also a major indicator of other parameters such as the conditions and circumstances that the individuals lived in (Mays 2018; Watts and Valme 2018).

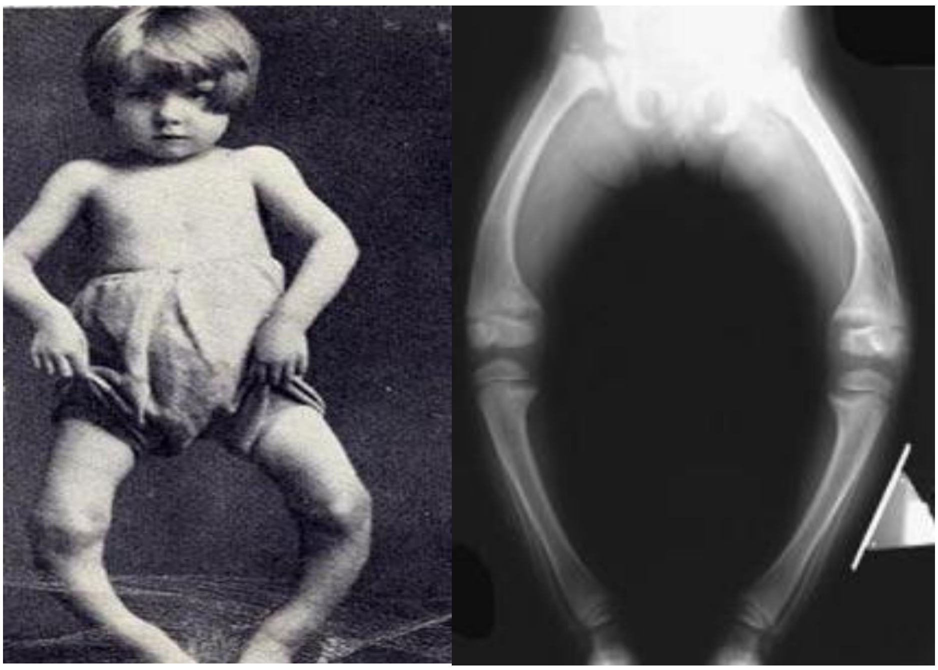


Figure 2.5: Victorian child with rickets, exhibiting the typical bow legs and an X-ray showing these characteristic changes induced by lack of Vitamin D. Source University of Bristol (www.chm.bris.ac.uk).

The rise of rickets or as it was colloquially known 'the English disease' became an alarming public health issue during the Industrial Revolution (Bikle 2012; Zhang *et al.* 2016; Mays 2018). Various factors such as social, economic, environmental, geographical and geological distribution challenges, combined with dietary deficiencies seem to have had an impact on this metabolic disease (Zhang *et al.* 2016, 4). With the shifting of the economy from agriculture to manufacture, family members of the labouring class now had to work in indoor environments during the daylight hours, this way preventing children and adults from spending some time outdoors in the sun, which further prevented them from vitamin D synthesis. Spending most of the time indoors, however, was not the only problem; even when the individuals had the opportunity to stay outdoors, the synthesis of vitamin D was problematic in the industrial cities. In part, the high prevalence of rickets during this period was due to inability of the sun to break through the canopy of smog and the overcrowded densely built slums (Wohl 1983, 219; Mays 2018, 93; Watts and Valme 2018, 60). Northern latitudes seem to be another parameter that may have contributed to the high prevalence of rickets. Although the condition existed throughout the country during the Industrial Revolution, the Northern latitude of certain industrial regions seems to have created specific areas of concentration where the prevalence was elevated due to less hours of sunlight (Wohl 1983; Mays 2018; Watts and Valme 2018; Veselka 2019). Poor child rearing practices also played an important role in the prevalence of the condition (Wohl 1983; Bivins 2007). Rickets during this period of interest were most common between six months to two years of age, showing the effects of childrearing practices such as premature cessation of breastfeeding, while the presence of the condition in younger infants was also not unusual indicating maternal deficiencies that led to prenatal exposure (Mays 2008; Morrone *et al.* 2021). Consequently, the high prevalence of rickets among children of urban centres is attributable to the long working hours in indoors environments, the thick coal smoke that prohibited sunlight from penetrating in the overcrowded slums, the natural latitude, the improper diets and childrearing practices of the period as well as the poor maternal diets and health (Hardy, 2003; Roberts and Cox, 2003; Veselka 2012; Mays 2018; Watts and Valme 2018; Morrone *et al.* 2021).

The presence of rickets, in the 18th and 19th centuries became a public health issue not only because it was an obvious external sign of malnutrition, but because the effects of vitamin D deficiency could stunt children from birth and continued to be a scourge throughout life for thousands of people (will be discussed further below). Vitamin D and its metabolism plays an important role in the regulation of the immune system and the fighting of infections (Morrison and Regnault 2015; Olmos-Ortiz 2015; Zhang *et al.* 2016). Interventional and observational epidemiological studies provide evidence that vitamin D deficiency may confer increased risk of influenza virus, rhinovirus and respiratory system infections such as pneumonia and tuberculosis (Yamshchikov *et al.* 2009, 438; Beard *et al.* 2011, 194; Stokes and Rimmer 2016, 23). Cannell *et al.* (2006) have argued that vitamin D status may contribute to determining the population susceptibility to seasonal epidemic outbreaks and the degree of associated morbidity and mortality. Thus, possibly enhancing the effects of increased indoor confinement and circulating accumulations of respiratory viruses during wintertime (Yamshchikov *et al.* 2009, 440). It is well proven that it is often the immune response of the host, rather than the viral pathogen itself, that determines the clinical severity and mortality risk associated with viral diseases such as influenza (Yamshchikov *et al.* 2009).

The role of vitamin D in fighting infections was also known in the 19th century, although not fully understood. As early as in 1867, Samuel Gee of the Great Ormond Street Hospital, one of the few children's specialty hospitals, discovered that one-third of the sick admitted children less than two years of age also suffered from rickets (Wohl 1983, 56). Nonetheless, despite the early association of the condition with ill health, it was accepted as the normal, if unfortunate, condition of the masses – 'the English disease'. As a consequence, the majority of English children grew up ill-formed and ill-equipped for the rest of their lives, if they were lucky enough to survive the various childhood dangers and reach adulthood (Wohl 1983; Bivins 2007; Zhang *et al.* 2016).

Consequently, the presence of vitamin D deficiency and therefore rickets in past non-adult populations could offer an insight not only on the levels of exposure to the sun and the diet of the individuals, but shows how ill equipped these individuals were to fight infections and subsequently to survive mortality. Rachitic children would have been more susceptible to influenza and common cold, common childhood diseases such as whooping cough and pulmonary conditions such as tuberculosis, due to reduced immunological resistance associated with rickets (Hansen 1938). Those who demonstrated both rickets and another disease such as whooping cough for instance were less likely to survive the course (Hansen 1938; Newman 2015; Ives 2018).

During this period adults were also subject to vitamin D deficiency, despite the growth cessation. The long working hours away from the sun also had negative effects on adults, especially females of child-bearing age. Vitamin D deficiency in pregnant women often caused contracted pelvises making childbirth difficult (Wohl 1983, 13). Vitamin deficiency during pregnancy could also affect the offspring making them deficient before birth with debilitating effects on the immune system and increased risk of mortality (Mays 2008 Olmos-Ortiz *et al.* 2015). Specifically, hypovitaminosis D in pregnant women has serious implications for both the mother and her child, with the implications having a lifelong effect on the child's health. Maternal and child infections, preeclampsia, gestational diabetes, preterm delivery, being small-for-gestational age, as well as genomic imprinting on the child for chronic diseases are among the health implications linked to hypovitaminosis D (Olmos-Ortiz *et al.* 2015, 443).

The role of vitamin D for a strong immune response against infections is apparent; however, the detection of rickets is also accompanied by certain limitations, such as in the case of catch-up growth where the individual recovered from an incident or in cases of mild forms of rickets (Newman 2015). Cases of rickets varied from mild to severe, as a result the cases we see manifested in skeletal remains are the extreme examples. Individuals with milder forms had fewer changes, making them less identifiable (Wohl 1983).

Another nutritional deficiency that exhibited increased prevalence during the period of study was scurvy. Humans are unable to synthesise their own vitamin C, so diet is their primary source for acquiring the vitamin. Fresh fruits and vegetables are the main source, while smaller amounts can be found in fish and dairy products (Ortner 2003; Mays 2008). Prolonged lack of vitamin C is the primary aetiology behind the formation of scurvy; however, other less common aetiologies include increased requirements for Vitamin C, malabsorption of vitamin C, and genetic predisposition to lowered vitamin C levels (Halcrow and Buckley 2014). As in the case of vitamin D, modern clinical literature has suggested that vitamin C plays an important role in the regulation of the immune system. However, more research needs to be done on humans. As Hemilä (2017, 21) concluded after reviewing the bulk of medical literature existing on the effects of vitamin C on infections, 'From a large series of animal studies we may conclude that vitamin C plays a role in preventing, shortening, and alleviating diverse infections. It seems evident that vitamin C has similar effects in humans'. Controlled studies have demonstrated that vitamin C prevents colds under specific conditions in restricted population subgroups and shortens and alleviates the common cold. Five controlled trials found significant effects of vitamin C against pneumonia. There is some evidence that vitamin C may also have effects on other infections, but there is a paucity of such data (Hemilä 2017, 21). Vitamin C has also been found to be involved in the way the human body regulates and manages energy; as metabolism regulator vitamin C helps the body to absorb iron much more effectively when it's present as well (Darius and Richardson 2014).

Although scurvy was not a major killer in the 19th century, it occasionally produced serious debility among certain groups, thereby significantly reducing the functional reserve of individuals resulting in further complications such as low immunodeficiency to pathogens or anaemia due to prolonged bleeding or even death in extreme cases (Cook 2004, 224). During the period of interest, scurvy was a significant health risk for particular groups such as mariners or prison inmates where fresh fruits and vegetables formed no part of their diets. With the embankment of long voyages in sailing vessels, scurvy became a major health hazard in mariners of all nations. By 1800 the disease had been virtually eliminated from Britain's Royal Navy with the introduction of citrus and lime juice given to the mariners (DeLuca 2014, 1; Mays *et al.* 2015, 336). However, it continued in the merchant navies until the latter half of the 19th century because the sailors were living on board the ship in substandard conditions. In 1867, the Merchant Shipping Amendment Act was passed by the British Parliament largely as a result of an effort by the Seamen's Hospital Society (SHS) for improvement of the conditions in the merchant service. Examination of the SHS records before and after this event demonstrated a marked reduction in the prevalence of scurvy in the Port of London. Although other factors such as the introduction of steam ships, which resulted in faster voyages, were clearly important, the compulsory administration of genuine lime juice under supervision in the merchant service seems to have exerted a significant effect along with a general healthier diet (Cook 2004, 224-225). By the mid-19th century, the disease had also largely disappeared from the land-based British population; however sporadic exceptions did continue to occur every now and then, for example in workhouses and prisons, but also on board the ship.

Away from isolated social groups such as sailors and prison inmates, it would appear that scurvy made no exceptions in 'outside' society between different social strata. Although one might think that the lower strata and the poor were more prone to it; seems that everyone was affected to a certain extend but for different reasons, for instance in the case of the lower strata and the poor the reason was the limited access they had to fresh fruits and vegetables due to financial restraints. The rising prices of fresh products, the sinking wages and the seasonality of fruits and vegetables made readily available cheap foods popular among the lower strata. Bread, potatoes, tea and sugar became the working-class's staples of the period and although filling to suppress hunger, they did not have much nutritional value and frequently were adulterated; apart from potatoes which could be a rich source of vitamin C when not overcooked (Wohl 1983; Shammas 1984; Sinnott 2013).

Food adulteration (deliberate or not) as well as poor preparation and preservation techniques such as overcooking were constant problems affecting all the social strata during this period, leading to a poor diet with little nutrients, especially to the growing individuals, while at the same time resulted in other health complications. Poisonous adulteration had the most harmful effects due to additives which could physically harm the consumer; fraud adulteration also existed but it did not actually harm the consumer but rendered the product impure, such as adding water to beer or milk (Fisher 2012). An example of adulteration related to the 'battle' against scurvy was the presence of additives in lemon and lime juice after their introduction as a cure for scurvy (Mays *et al.* 2015). In particular, it was observed that at some point the high prevalence of scurvy among certain groups made a comeback (Cook 2004). In January of 1866 it was revealed *in Times* with regard to the continuing high prevalence of scurvy in the merchant service in the mid-19th century that lime juice was *'manufactured from tartaric and other acids, at a cheap cost, and flavoured with essence of lemon …'* (Anonymous 1866, 9).

The childrearing practices of the period also seem to have worsened the problem of vitamin C deficiency for all the children irrespective of social status. Vitamin C deficiency can be indicative of premature cessation of breastfeeding as well as whether the mother herself was deficient. Infants who are breastfed by healthy and well-nourished mothers rarely develop the deficiency before the fourth month of life as mother's breast milk contains sufficiently high levels of vitamin C (Mays 2008).

During the 18th and 19th centuries, the increased cost of living and poor wages forced many women to work outside domestic settings, which made it virtually impossible for many mothers to breastfeed and attend to their children. As a result, the weaning process was accelerated for the lower strata, while among the higher classes although weaning did not have to start early, women were opting in for premature beginning of the practice. Higher strata mothers saw breastfeeding as unfashionable and inconvenient as it prevented many women from wearing the socially acceptable clothing of the time and it interfered with social activities such as playing cards and attending theatre performances (Stevens *et al.* 2009, 34). Due to various socio-economic circumstances and mentalities, more and more infants were being denied the nutritional support and passive immunity provided by the mother's breast milk (Stevens *et al.* 2009; Newman 2015). Before the times of bottle feeding and formula, wet nursing was the most common and safest substitute to the natural mother's breast milk (Stevens *et al.* 2009, 32). In the 19th century, artificial feeding began slowly, but steadily, to substitute wet nursing with improvement of the feeding bottle, the advances in formula development and widespread availability of animal's milk. The use of animal's milk before the era of pasteurisation, however, created further problems; cow's milk for instance provided a good mode of disease transmission such as bovine tuberculosis and typhoid (Wohl 1983, Stevens *et al.* 2009; Newman 2015).

Considering the role of vitamin C in iron metabolism, where the body absorbs iron much more effectively when vitamin C is present as well (Darius and Richardson 2014), scurvy is also likely to develop alongside anaemia. Collagen is an essential component of soft tissues such as the blood vessels, as a result inability to synthesise collagen due to lack of Vitamin C leads to vessel fragility with the constant bleeding reducing the capacity of iron absorption (Ortner 2003; Wapler *et al.* 2004).

During the 19th century anaemia was an active cause of death among certain groups with children below five (especially below one) and women above 25 being at higher risk of death (Registrar-General 1875, 151), showing the importance of iron in groups with increased turnover such as growing children and women at childbearing ages. The aetiology behind anaemia, however, frequently lies not simply on a diet deficient in iron that results in acquired forms, but also in other aetiologies that are frequently complex to understand and separate. For instance, a diet could also be sufficient in iron, but the body might not be able to withhold any nutrients (e.g. vitamin C and D) and minerals (e.g. iron) such as in the case of diarrheal diseases and parasitic infections which were a significant health problem and common cause of mortality during this period, indicating poor sanitation standards (Registrar-General reports 1842; 1845; 1850; 1859). This is because the diarrheal diseases would have been responsible for nutrient losses as the food would have passed through the gut too quickly for nutrients and minerals to be absorbed. While, parasitic and bacterial infections would have induced anaemia due to internal bleeding compromising the iron levels of the affected individuals (Wapler *et al.* 2004*;* Walker *et al.* 2009, 119). Mild anaemia could have also been an adaptive response to prevailed unsanitary conditions and infections overload by lowering the blood iron levels to a high pathogen load (Blom, 2005); this way the iron deficiency would have worked as a protection against infectious diseases by creating an unfavourable environment for bacterial growth (Roberts and Manchester 1997). Another possible aetiology behind mild forms of anaemia would have been chronic diseases such as cancer or chronic infections. Lastly, as it was indicated through the high prevalence of anaemia in women at childbearing ages and infants, the compromised mother's health status and inadequate diet were also possible causes that would have affected the iron supply of the infant. In clinical literature, maternal anaemia is associated with elevated pre- and postnatal infant mortality. After infancy growing children are also very susceptible to anaemia (Abu-Ouf and Jan 2015).

It is, therefore, apparent that the presence of anaemia in Victorian populations can be evidence of not only poor diet, but can also reflect poor hygiene standards and unsanitary living conditions. The large numbers of people that lived in close proximity in the urban centres favoured the spread of diseases by direct transmission. The contaminated water supplies due to lack of sewerage and drainage and poor sanitation and hygiene favoured gut infections or parasites to thrive among these non-mobile urban populations (Commission for Inquiring into the State of Large Towns and Populous Districts 1845a and b). Consequently, anaemia is not only the result of a diet poor in iron, but of increased sedentism, aggregation, and population density which resulted in greater exposure to pathogens (Kent 1986).

Through the study of nutritional deficiencies (i.e. rickets, scurvy and anaemia) as factors of exposure to infections we have seen that the immune system and metabolism are co-dependent. A poor metabolism can hinder the immune function leaving the individuals exposed to poor immune response manifested as infections, and vice versa. These findings should not come as a surprise as a strong immune response relies on how the body regulates and manages energy as the result of the lack of certain vitamins and minerals such as vitamin C, D and iron affect how the metabolism functions.

2.4.3 Industrial Diseases

The Industrial Era was marked by numerous factories producing a variety of new products (Satu *et al.* 2019, 73). These products, however, were frequently accompanied by debilitating health effects for those who were involved in their production. As a consequence, specific occupations came with their own burden of risks of exposure to industrial diseases (Wohl 1983; Pollock *et al.* 2015). These diseases were caused either by the effects of work processes or the working conditions such as in the case of miners or by exposure to specific hazards such as chemical substances involved in the work process such as for instance the use of phosphorus in match production (Pollock *et al.* 2015). Industrial diseases were simply an accepted part of working life during the 18th and 19th centuries, as inevitable and as unpleasant as the long hours or uncertainty of employment (Wohl 1983, 264). 'Phossy jaw, 'miner's phthisis', 'potter's asthma', 'cutlery grinder's asthma' and 'chimney sweep's cancer', were only a few of these diseases, which along with many more were all 'part and parcel' of the Industrial period vocabulary (Wohl 1983, 264). Variations of these terms existed between regions and historical documents, something that was already noted with the names of other diseases (e.g. tuberculosis). A thorough attempt was made to identify all the possible variations of names and include them under one name that is more commonly known in modern times. This step was necessary in order to avoid any arising confusion to the researcher as well as the readers.

Unfortunately, within skeletal remains the identification of pathological alterations directly linked to industrial diseases is mostly difficult because the individuals were not only exposed to poor working conditions, but also poor living conditions which could have the same effects on the body (Roberts and Manchester 1997). Subsequently, it is difficult to separate out the effects of occupational and habitational environments. A few exceptions, however, occurred such as in the case of 'phossy jaw' where some cases of this occupational disease have been identified among 19th-century individuals involved in handling of white phosphorus (Roberts *et al.* 2016; Satu *et al.* 2019).

'Phossy jaw' and its effects upon the thousands of factory and domestic workers in the match industry attracted more widespread attention than any other occupational disease because of its debilitating and gruesome effects (Wohl 1983; Pollock *et al.* 2015). The impetus for 'phossy jaw' was the desire to create strike anywhere matches (Marx 2008, 2356). Strike anywhere matches contained more white phosphorus than was absolutely required, making them subject to spontaneous ignition. Nevertheless, the overwhelming convenience of lighting a fire anywhere and under almost all conditions made them one of the most significant inventions of the industrial age and extremely popular in Britain and other countries (Marx 2008; Roberts *et al.* 2016; Satu *et al.* 2019). Match factories sprang up in 19th-century Britain, with the largest areas of manufacturing in the industrial centres of London, Gloucester, Birmingham, Liverpool, Leeds and Newcastle (Reports to the Secretary of State for the Home Department 1899, 132-144; Roberts *et al.* 2016, 44; Marx 2008, 2357; Valoriani *et al.* 2019, 73). Match factories employed workers for ten to fifteen working hours per day, while a great amount of work was also happening in domestic settings (Marx 2008; Valoriani *et al.* 2019). Because the work did not require any special skills and knowledge possession it attracted the poorest of the poor and the desperate such as unskilled male workers on lower wages and women, children and adolescents, with the later three groups comprising the greatest amount of the workforce in this industry (Molleson and Cox 1992; Harrison 1995; Roberts *et al.* 2016). Half of all employees were children between the ages of 6 and 12, each of whom could be required to work twelve hour a day. Consequently, matchmaking was one of these industries where women and minors were the most desirable employees (Commission for Inquiring into the State of Population-Parliament Papers XXXV 1842; Parliamentary Papers XI 1900; Gowland 2018).

'Phossy jaw' is osteonecrosis of the jaw after chronic exposure to white phosphorus during the match manufacturing process specifically, exposure to the dipping mixture which contained high levels of white phosphorus (Kamboj 2007; Pollock *et al.* 2015; Valoriani *et al.* 2019). Factory workers known as 'dippers', 'mixers' and 'boxers' were exposed to fumes from the white phosphorus during mixing and spreading of the dipping material, and the drying and boxing of the matches due to the crammed and ill ventilated conditions within the working facilities (Kamboj 2007; Marx 2008; Valoriani *et al.* 2019). Match manufacture was, however, not the only industry in 19th-century England that used white phosphorus. A number of other industries also used phosphorus in the manufacturing process including those producing; fireworks, munition, and brass.

Medical reports of a disease involving slow progression of exposed jaw bone began to appear as early as 1858, with the lesions being the result of chronic phosphorus poisoning (Marx 2008). In 1863 in a public report compiled by Simon, the first detailed clinical description of 'phossy jaw' was noted. The report publicly linked the conditions to exposure to fumes emitted during match production. The effect of the exposure after 3-5 years resulted in gingivitis, sequestration of alveolar crest bone, and bone necrosis of the mandible or maxilla Pollock *et al.* 2015, 264). Oral and orocutaneous fistulae, osteolytic lesions and thickening and alteration of the bone due to subperiosteal bone formation were common in the afflicted. In the more unduly exposed, the trachea-pulmonary tree became a second end point of toxicity, and cough, sputum production, and haemoptysis were common (Simon 1983). Systemic toxicity developed in the more chronically afflicted, provoking seizures and causing leukopenia and anaemia (Pollock *et al.* 2015, 265).

About eleven percent of those exposed to phosphorus developed the disease in an average period of five year after the first exposure (Kamboj 2007). This epidemic of osteonecrosis produced pain, swelling, debilitation, and a reported mortality of twenty percent (Marx 2008). The most commonly affected groups were women, children and adolescents, but adult men were also treated (Simon 1863). The higher predilection for the first reported groups by Simon (1863) was possibly because this was a job that was primarily done by women, children and adolescents. Various predisposing factors were assumed to exist such as dental caries as a main route for phosphorus to enter the dental pulp cavity and subsequently the alveolar bone. This correlation, however, remains debatable because individuals with perfectly healthy teeth were also found to be affected, thus showing a more systemic nature of the disease rather than a localised one (Roberts *et al.* 2016). Phosphoric vapor is generated by heating up phosphoric compounds, and is also absorbed through the gastro-intestinal tract. But it was perhaps dental decay that caused the more serious cases which exhibited periostitis and osteomyelitis (Kamboj 2007).

Along with many occupations came the constant danger of inhalation of various substances with damaging effects on the lungs that led to pulmonary diseases which often culminated in chronic respiratory diseases or even tuberculosis and lung cancer (Newman 2015, 84). An example of harmful substance was crystalline silica dust which could be found in different industries and working environments; as a result, the disease known as 'silicosis' came under different names based on the type of the occupation, such as for instance 'miner's phthisis', 'grinder's asthma' and 'potter's rot' (Wohl 1983, 264). Silicosis is the result of inhaling large amounts of crystalline silica dust, usually over many years. Silica is a substance naturally found in certain types of stone, rock, sand and clay (NHS 2018) Once the fine particles enter the lungs the immune system begins to attack them. As a result, inflammation and fibrosis, hardening and scarring of the lung tissue, is caused. People at high risk were potters, glass and ceramic makers, quarry workers, miners, stonemasons and cutters, and sand blasters. However, the accompanied skeletal manifestations such as inflammation of the pleural surface of the lungs (pleurisy) or tuberculosis were not very specific to their underlying aetiology as they could also be related to the living conditions and/or other occupations outside these environments.

CHAPTER 3

MATERIALS CHAPTER: THE CASE STUDY AND THE COMPARATIVE SITES

In total, sixteen skeletal collections were identified to represent urban populations from the post-medieval period, in particular from the 18th and 19th centuries, from a diverse range of backgrounds and geographical locations. Three sites were selected from the North-East of England (South and North Shields and Newcastle), one from the central North (Sheffield), one from the middle of England (Birmingham), one from the central South (Oxford) and ten from the South-East of England (various locations within Greater London) (Figure 3.1). The increased number of identified post-medieval sites from the South of England compared to the North, confirmed the existing disparities discussed earlier in development pressures in certain parts of Britain resulting in bias towards urban samples in the South and in particular from Greater London. The North appears to be no exception to the negative effects of industrialisation suffered by the rest of the country. A summary of the context of each site can be found in Table 3.1. The excavation background and historical context for each sample will be described below.

Figure 3.1: Map of England with the comparative sites.

Site	Period	Individuals	Status	Author
St Hilda's, South Shields	1763-1855	204	working class	Strati
Coach Lane, North Shields	1711-1829	236	(primarily) working class	Proctor *et al.* 2016
Infirmary Newcastle	1753-1845	210	lower and working class	Boulter *et al.* 1998
Carver Street Methodist Chapel, Sheffield	1763-1855	136	working class	Witkin, S. & Belford, P. 2000 Mosley 2002
St Martin's-in-the Bull Ring, Birmingham	1720-1863	505	working class	Brickley *et al.* 2006
Littlemore Baptist, Oxford	1861-1881	30	middle class and some skilled working class	McCarthy *et al.* 2012
Cross Bones, London	1800-1853	148	lower class	Mikulski 2007
All Saints, Chelsea Old Church	1712-1842	198	upper class	Cowie *et al.* 2008
St Benet Sherehog, London	Post London Great Fire (1666)	230	middle class, also some poor	Miles *et al.* 2008

St Marylebone, London	1817-1854	301	upper and middle class	Miles *et al.* 2008
Christ Church Spitalfields, London	1729-1852	968	middle class	Molleson and Cox 2003
St Luke's-Islington -named, London	1760-1850	241	middle class	Boyle *et al.* 2005
St Luke's-Islington - unnamed, London	N. Churchyard 1778-1848 S. Church. 1755-1844	655	working class	Boyle *et al.* 2005
St George's Bloomsbury - named	1804-1856	72	middle class	Boston *et al.* 2006
St George's Bloomsbury - unnamed, London	1804-1856	39	middle class, individuals of unknown identity	Boston *et al.* 2006
St Bride's Lower Churchyard, London	1770-1849	544	lower class	Kausmally 2008
St Pancras, London	1793-1854	715	London's population cross-section	Emery & Wooldridge 2011
Greenwich Tier, London	1749-1856	107	working-class	Boston *et al.* 2008

Table 3.1: List of used comparative sites along with the social status of each.

3.1 The St Hilda's Burial Ground (1763-1855): Excavation and material overview and the Town of South Shields in the 18th and 19th centuries

Excavation works at a section of St Hilda's parish church burial ground in South Shields, were undertaken by Oxford Archaeology North between 2006 and 2007. In total 204 articulated skeletons, with 87 of them classified as sub-adults, were recovered from two excavation phases with the much larger and more complete assemblage of human remains recovered in phase one between June and December 2006, from the immediate south of Coronation Street. During this phase were also uncovered, 50 deposits of charnel material and numerous disarticulated. From the watching brief undertaken during June and July 2007, 45 well-preserved skeletons recovered at Coronation Street. Coffins, metal handles, large *depositum plates* and few personal effects were also found (Gibson *et al.* 2009; Raynor *et al*. 2011). The human remains which were previously subject to commercial archaeology analysis by Oxford Archaeology North were also analysed by the author as her research project focal case study, with the analysis being conducted at the Department of Archaeology, University of Sheffield where the skeletal collection is curated. Along with the human remains, the burial registers of St Hilda's were also analysed by the author. In particular 31482 burial entries were subject of analysis. 'Name', 'surname', 'computed year of birth', 'date of death', 'age of death' and 'cause of death' (or 'place of death') were among the recorded information. The age of death, biological sex (as indicated from the recorded name) and cause of death allowed to reconstruct the mortality and morbidity profiles of South Shields to contrast the oteological profiles. The occupation of the deceased (or the father's occupation in the case of deceased children or the spouse's occupation in the case of widows) and any other descriptions such as titles allowed a relatively accurate determination of the socio-economic profile of the site.

St Hilda's Church was the only church serving the parish till 1934 and it was built in its present form in the early 19th century, but it is likely that the church has been a religious focus since the early medieval period (Figure 3.2). St Hilda's Church cemetery was in use since the early 15th century although the excavated remains relate to the excavation of the southern section, dated back to the 18th and 19th centuries as was revealed by the burial evidence such as tombstones as well as the burial registers (Raynor *et al*. 2011). In the southern section two principal burial horizons were identified, the lower and the uppermost. The lower horizon could be viewed in two halves, the easternmost and the west; the easternmost contained well-ordered burials within a southward extension to the cemetery made around the turn of the 18th and 19th centuries. While the west half, which was situated outside of the original cemetery boundaries, appeared to be an unconsecrated ground with most of the burials unearthed at that section belonging to preterm and neonatal infants, although a few adults also existed (Gibson *et al.* 2009; Raynor *et al*. 2011). The uppermost horizon was associated with the later stages of the cemetery's use prior to its closure in 1855 and was characterized by intensity of its usage, although there was a certain degree of organisation. Between these two principal strata, several skeletons have been attributed to an intermediate horizon, and may have been buried during the early 19th-century operation to raise the level of the cemetery (Raynor *et al*. 2011). The St Hilda's burial ground up to the point of its closure was the only churchyard serving the seaport town of South Shields.

Figure 3.2: Unknown c.1910. St Hilda's Church, South Shields. Source Newcastle Libraries (www.co-curate.ncl.ac.uk).

South Shields stood on a treeless wedge of land, surrounded by the North Sea and River Tyne; the Durham Coalfield stood behind it, while Newcastle was two miles upstream and opposite across the river was North Shields and the garrison town of Tynemouth (Foster 1974, 84) (Figure 3.3). Despite the town's lack of vegetation and the absence of ground suitable for the thriving of agriculture, the town's geographical location and geological features resulted in booming of its economy with the developments of the Industrial Revolution. However, little is known with certainty before the 13th century about the existence of the settlement which eventually became South Shields, but as suggested by the name 'Shields' or 'Scheles' the settlement was a humble collection of fisherman's huts, or shielings. By 1235 South Shields was recognised as a village with 24 tenants and continued to grow further by 1256 (Gibson *et al.* 2009, 7; Raynor *et al.* 2011, 10). Although South Shields location favoured its economic development and establishment as a trading centre, it also made the town a frequent target of rivalries (Foster 1974; Newman 2015). South Shields developed in parallel with North Shields across the River Tyne, with both towns' development being the result of Newcastle's attempt for a trade monopoly across the whole length of the River Tyne, which started as early as the 13th century (Simpson 1988; Newman 2015). Both South and North Shields were the targets of a lawsuit in 1279 by the burgesses of Newcastle, jealous that markets and the loading and unloading of ships were taking place at North and South Shields (Raynor *et al.* 2011, 10-11).

Figure 3.3: Unknown c. 1820. South Shields Harbour. Source Newcastle Libraries (www.co-curate.ncl.ac.uk).

During the beginning of the Industrial Revolution in the 18th century, South Shields was already a well-established shipping and manufacturing centre of considerable importance and prosperity despite being only a small town. The salt trading was at that point at its zenith as the town possessed a larger number of pans than its immediate rival North Shields, and it was one of the major factors in the growth of the town. Glass making had been added to its staple industries and the manufactory of alum which was about to develop into the great chemical trade of the following century, had commenced as well (Hodgson 1903, 115). Shipbuilding and repairing, previously a monopoly of Newcastle, also became another prominent industry and so did the coal mining and transport of coal by sea which was favoured by South Shields geological features and geographical location (Hodgson, 1903; Foster 1974). Some of the collieries in the South Shields area included Templetown (1805-1826) and St Hilda's (1810-1940) both established by Simon Temple Junior, a member of a local family of shipwrights (South Shields | Co-Curate (ncl.ac.uk)). Coal mining was a very hazardous occupation as the workers were exposed to shafts collapse and explosions. St Hilda's Colliery stood close to St Hilda's church, and its mine was the site of a pit explosion on June 28, 1839 in which 51 miners lost their lives (Gateshead Observer 1839). The names of 25 of the 51 victims of the mining accident that were buried in St Hilda's churchyard can be found in Appendix 1.

South Shields was primarily classified as a working-class population, with the burial registers from St Hilda's church incorporating various socio-economic circumstances such as paupers and employed individuals from the labouring strata. Exceptions in burial registers were also identified showing that sometimes it is hard to entirely socially isolate the lower from the higher strata, a phenomenon that was also observed in other comparative sites, introduced later on in this section. For instance, a 'doctor', few attorneys and even a 'baronet' were also interred in St Hilda's burial ground based on the study of the burial registers. Apart from these exceptions, however, the rest of the locals were employed in various local industries and working environments, such as the shipyards, ships, and the port, the local collieries, salt-works, glass industry, and chemical works, while there were also many self-employed individuals such as various artisans (Raynor *et al.* 2011; Newman 2016). Among the many occupations that existed in South Shields the most populous, was that of 'seamen' as also revealed from the burial registers; immediately dependent on them as it was reported, were the town's 200 public houses and 150 prostitutes, larger number of crimps and ship-owners (who also owned most of the pubs) (Hodgson 1903; Foster 1974, 84). The existence of prostitutes within the St Hilda's burial ground, however, was not confirmed as there was no such occupation registered in the burial registers; although many young and middle adult females were recorded among the deceased. It could have been that these women were refused church burial within consecrated ground of St Hilda's however this supposition remains unknown (Taylor 2009, 156). The west part of the lower horizon, however, revealed no female interments. The censuses of the period also appeared unspecified up-to 1841 on female occupations (Great Britain-Census 1841; Nolan 1998). The burial registers also revealed an increased number of 'labourers' existed. The full list of occupations can be found in Appendix 2.

The burial evidence from the excavated part of St Hilda's churchyard also pointed towards a working-class town with the individuals interred in supine position in typical earth-cut graves in simple coffins as described by Raynor *et al.* (2011, 90) 'the wooden coffins and iron fittings were characteristic of coffins manufactured *en masse* for the indigent'. The coffins were broadly similar to those identified from other industrial period British sites such as St Martin-in-the-Bull Ring, Birmingham (Brickley *et al.* 2006). However, a few local trends were observed that were distinct from those documented in other parts of the country, namely the presence of only a few metal handles and large metal departum plates (Brickley *et al.* 2006; Raynor et al. 2011). Limited was also the number of the deposited artefacts and appeared very simple with most of them being metallic pins, buttons and clothing rings (Raynor *et al.* 2011). Only a few exceptions exhibited more elaborate graves and/or coffins within St Hilda's (e.g. a case of a brick shaft-grave), nonetheless these were much less ornate than the coffins of most middle- and upper- class assemblages of the period such as the St George Bloomsbury crypt (Boston *et al.* 2006), suggesting that these exceptions were more for artisans/skilled workmen (Raynor *et al.* 2011, 90). Although these burial arrangements appeared simple, they were more elaborate than the plain arrangements provided to the paupers by the workhouse or parish which were possibly buried in the new extensions of the churchyard on peripheries far from the church (Richmond 1999; Raynor *et al.* 2011, 89).

The major developments of the 18th and 19th centuries in shipping, manufacturing, shipbuilding and coal mining industries of South Shields, indeed led to the booming of the town's economy but also resulted in unprecedented population growth. With the population reaching from 12,000 in the early 1800s to 75,000 thousand by the 1860s due to migration mainly from England, Scotland and Ireland with the creation of new work opportunities (Foster 1974, 88-89). Despite the town's prosperity during the Industrial Revolution and its coastal location, South Shields like most of the industrialised centres of the period was no exception to the adverse effects of industrialisation and urbanisation. The town suffered unsanitary conditions and polluted environments promoted by the population expansion and the industrial emissions (Commission for Inquiring into the State of Large Towns and Populous Districts 1845b; Hodgson 1903; Foster 1974). South Shields like any other urban part of the country had neither the public health knowledge nor the appropriate facilities to accommodate such a population expansion. As a result, sanitation became a major problem in South Shields and neighbouring towns, evident by frequent cholera outbreaks such as in late 1831 to early 1832 and 1834 (Hodgson 1903, 151); while other infectious disease outbreaks included 'measles' and 'smallpox' (source Saint Hilda's burial registers). The faced conditions reported in the industrial northern regions were so alarming that the district became a matter of concern for the rudimentary public health authorities of the period, and described the cases of South Shields, North Shields, Gateshead and Newcastle as a place that there is '…abundant evidence of the causes of the high rate of mortality which the mortuary registers evince' (Commission for Inquiring into the State of Large Towns and Populous Districts 1845b, 10). Due to the amount of disease reported in these towns by the authorities, these towns were selected as objects of particular attention (Commission for Inquiring into the State of Large Towns and Populous Districts 1845b, 23). A South Shields Committee on behalf of the Royal Commission for Inquiring into the Health of large Towns and Populous Districts in 1843, reported overcrowding in the houses of the poor with the number of families in each house varying from one to seventeen and the average number of persons to each room being three and three-fourths. Two types of houses mostly prevailed in South Shields - back-to-back along the river bank and single cottages in other parts of the town- both types were meant for single families. The houses, were also ill ventilated, had defective drainage and sewerage provisions as well as inadequate water supplies (Hodgson 1903, 52). The reported house drains were limited and where they existed were defective and comprised an active source of infectious diseases as they were choked with refuse and not properly cleansed. Houses on the sides of the bank, due to the lack of drainage and sewerage were pouring their contents freely into the river (Commission for Inquiring into the State of Large Towns and Populous Districts 1845b, 26). The water supply inside and outside the domestic sphere was also limited, with the poor purchasing water from standpipes. In 1844 there were 3,911 houses registered in South Shields and of these only 179 had the water laid on, while 977 were supplied by contract from the stand pipe (Commission for Inquiring into the State of Large Towns and Populous Districts 1845b, 26).

Despite the unsanitary conditions described above, the nuisances most strongly complained of by everyone in South Shields, were the smoke from the glassworks and manufactories and the emissions from alkali works which made the atmosphere suffocating for everyone irrespective of socio-economic divisions (Commission for Inquiring into the State of Large Towns and Populous Districts 1845b, 23 and 44; Hodgson 1903, 152). Dense black smoke suffocated the population of South Shields, which not only suffered from its own emissions, but also from those of the neighbouring North Shields, Newcastle-on-Tyne, and Gateshead. These neighbouring towns atop their own emissions, suffered from those which they conveyed to each other through the valley of the Tyne, and from the numerous steam-boats that ply upon the river (Commission for Inquiring into the State of Large Towns and Populous Districts 1845b, 44). In addition to the general problems of poor sanitation and smoke for the wider population, certain specific occupations within South Shields encountered even greater hazards. The miners for instance, along with pit explosions, shafts collapse and the long working hours, suffered silicosis of the lungs known as 'miner's phthisis' or 'miner's asthma' (Gateshead Observer 1839; Wohl 1983).

The great problem of the poor unsanitary conditions and suffocating atmosphere of South Shields was only worsened by the overcrowded St Hilda's churchyard, which was already an ongoing problem for many years as the churchyard was the only cemetery serving South Shields (Commission for Inquiring into the State of Large Towns and Populous Districts 1845b, 43; Hodgson 1903, 139; Rainor *et al.* 2011, 13). Various attempts for expansion were made to keep up with the exponential burial activity 'matching the contemporary growth of the industrialising town', until eventually the churchyard was closed in 1st of July 1855 with the passing of the Burial Grounds Act for preventing overcrowding (Hodgson 1903, 139; Gibson et al. 2009, 7; Raynor *et al.* 15). The problem at St Hilda's, however, was not unique. As it was previously seen in the second chapter the population explosion had commensurate impact on graveyards of the whole country which rapidly became overcrowded and unsanitary. Connections between such conditions in the foul-smelling churchyards of London, Manchester and Liverpool were made years prior to their closure, linking the spread of infections to close proximity of decaying corpses (Raynor *et al.* 2011, 14). The passing of the Burial Grounds Act was eventually one of the many sanitary measures for limiting the spread of infectious diseases throughout the country.

3.2 The Coach Lane Quaker Burial Ground: Excavation Overview and the Town of North Shields in the 18th and 19th centuries

Full excavation at the Coach Lane burial ground in North Shields has provided the entirety of a past Society of Friends-a Quaker burial ground which was in use between 1711 and 1829. The excavation of the site was undertaken in 2010 by Pre-Construct Archaeology Limited ahead of a residential development plan, revealing in total 236 articulated human skeletons with 156 of them classified as adults (Proctor *et al.* 2016, 1). Of this total number of skeletons only thirty-five percent was selected to be fully osteologically analysed due to preservation chosen criteria by Proctor *et al.* (2016, 50). The Coach Lane skeletal collection can be found at the Department of Archaeology, Durham University where it is curated.

North Shields is a seaport town across South Shields, located on the northern valley side of the River Tyne. During the 18th and 19th centuries, North Shields parallel developed with South Shields as a rival town and experienced rapid developments that shaped its industry and economy. With the town's geographical location and geophysical features being similar to South Shields, the rival towns exhibited many common flourishing industries and therefore sources of economy (Figure 3.4). South Shields, however, was not the only rival town competing against North Shields. North Shields due to its strategically important position for trade via the port in the estuary of the River Tyne often faced competition from the neighbouring port town of Newcastle (Newman 2015, 93). Newcastle's burgesses by applying restrictions attempted to oppose North Shields (also South Shields) economic development from as early as the 13th century when it was still a small settlement. As a result, they managed to suspend trade from the settlement, where it was forbidden to victual ships or to load and unload cargoes (Raynor *et al.* 2011, 11; Proctor *et al.* 2016, 6). Despite the near vicinity of the rival port of Newcastle, as well as South Shields, the town of North Shields flourished. The rapid developments of the 18th and 19th centuries led to the establishment of North Shields as an important centre in various industries such as shipping, shipbuilding, manufacturing and coal associated industries (Proctor *et al.* 2016, 6). In the development of North Shields -which in 1760s was described as 'a poor, miserable place', which consisted entirely of the narrow street along the bank of the Tyne- seems that its connection with the Quaker society members played a pivotal role (Boyce 1889, 115). During the 18th century the transportation of coal in Whitby vessels established strong links between Whitby and North Shields. Shipping and shipbuilding and the associated industries seem to have played an important role in the development of North Shields (Newman 2015). Whitby ship-owners, many of whom came from Quaker families, were attracted to North Shields due to its location and the shipping industry in the region. They purchased land and settled in North Shields and were instrumental in the lay-out of the town. Some of these individuals and members of their families were buried at Coach Lane (Proctor *et al.* 2016, 148).

Figure 3.4: North Shields Fish Quay in 1910. Source Chronicle Live (https://www.chroniclelive.co.uk).

Whether there was a largely middle-class population interred in this predominantly Quaker burial ground, still remains undefined due to the limited biographical documentary and burial evidence (Proctor *et al.* 2016). The documentary evidence, did reveal that a few prominent middle-class families were interred such the Walker family, which they were ship, property and colliery owners from Withby who moved to North Shields and invested money in property in Tyneside region (Proctor *et al.* 2016, 137, 156). The burial evidence could also be another potential means that social status could be attributed from, but that was also limited due to the austerity of this religion for simple living, where the burials also had to be plain and simple in keeping with the discipline of simplicity (Proctor *et al.* 2016, 142). The living conditions in North Shields were similar to those already reported in South Shields .They were health, strength and life destroying for the labouring strata; with the housing situation for families being destitute alike, with the easy access to wholesome water being absent, and the means resorted to for cleansing, drainage, and sewerage being utterly insufficient and the dense black smoke they emitted the one to the other suffocating them (Commission for Inquiring into the State of Large Towns and Populous Districts 1845b, 10, 44; Beach and Hanlon 2018). Consequently, with these prevailed conditions the effects of industrialisation would have had detrimental effects on all individuals, irrespective of socio-economic status. Therefore, it is more likely that the Coach Lane site is a mix of low and middle-status individuals (Newman 2015, 94).

3.3 The Newcastle Infirmary Burial Ground at the Forth: Excavation Overview and the Town of Newcastle-upon-Tyne in the 18th and 19th centuries

Full excavation at the Infirmary Newcastle burial ground, which was in use from 1753 to 1845, has provided numerous skeletal remains of diverse background (Figure 3.5). The excavation of the site was undertaken in 1996 by the former Newcastle City Archaeology Unit on behalf of the Tyne and Wear Development Corporation, ahead of an industrial redevelopment of the site. A total of 210 articulated skeletons were recovered from discrete graves with 191 of them classified as adults (Boulter *et al.* 1998, 1). The skeletal remains were analysed by the former ARCUS, of the University of Sheffield where part of the collection can be still found at the Department of Archaeology.

Figure 3.5: Unknown c. 1803. Infirmary Forth Banks, Newcastle upon Tyne. Source Newcastle (www.newcastle.gov.uk/tlt).

Funded by philanthropic donations the Infirmary Newcastle was established for treating 'The Sick and Lame Poor' of the counties of Northumberland and Durham (Boulter *et al*. 1996, 1; Nolan 1996, 36). However, the patients were technically not paupers, but rather those without the means to pay for treatment in their homes (Nolan 1996, 36). As a rule, specifically excluded from admission, at least in theory because the burial records implied otherwise, were the infectious (e.g. measles, smallpox, infectious fevers and consumption) and the incurable (e.g. incurable cancers). As well as pregnant women, children under seven years of age unless they required an operation and the mentally ill (Boulter *et al*. 1996, 1; Nolan 1996, 36). The cause of death in the burial registers never implied directly infectious diseases, though 'fever' appeared frequently with the accuracy of diagnosis appearing suspicious. Although it is also possible that cases of fever could have also occurred after admission. However, it is also possible that patients 'admitted for' and 'dying from' apparently innocent disorders may have been incubating more serious diseases as supported by the admission records which showed that some of the frequently diagnosed conditions during certain decades were 'consumption', 'dropsy', and 'palsy'. Skeletal evidence also supported the existence of infectious diseases such as tuberculosis (consumption), among the deceased. It is also unclear how many patients with sexually transmitted diseases had been treated in Infirmary Newcastle before 1830, but after 1830 it was known that the Infirmary also catered to prostitutes (Nolan 1996). No such information on the nature of the occupation or the disease of the female inmates was, however, revealed in any of the records. Where occupations were given most of the entries in the admissions book and burial registers were from artisan background, with many males being mariners, pitmen, labourers, craftsmen or soldiers. For the late 18th and early 19th centuries the patients were almost exclusively locals from Newcastle and the adjacent parts of Durham and Northumberland, after 1803 number of foreigners, Scots, Irish, southern English and a few from the continent made appearance in the surviving admissions, discharge and burial records, reflecting social and demographic changes. Many of these non-locals were possible seamen (Nolan *et al.* 1998). In Infirmary Newcastle burial ground were interred the bodies of patients who died in the hospital and whose bodies were unclaimed by relatives (Nolan 1998, 36-37). From the surviving burial registers (1803-1845) there was a period where the burial ground was closed down, probably due to overcrowding (Boulter *et al*. 1996; Nolan 1996).

Newcastle 'played a central role in Britain's coal-based Industrial Revolution as the major supplier of London and many of the outer-ports', attracting workers from other towns with the creation of new work opportunities (Ville 1998, 60); with the population reaching from 28,366 to 49,860 between 1801 and 1841 (Great Britain-Census 1801; Great Britain-Census 1841). Shipbuilding, shipping and heavy engineering were pivotal in Newcastle's prosperity, with its port being ranked during the end of the 18th century as Britain's second port after London in respect of the amount of tonnage built and registered there, along with the volume of shipping and trading at the port (Ville 1998, 60). A great percentage of these vessels registered at the port of Newcastle, however, were not per se built there, but locally at other neighbouring centres of North and South Shields and Howdon Pans. On an interesting note, of tonnage registered at the port between 1786 and 1800, 47,000 were built at South Shields, 38,000 at Newcastle, 22,000 at North Shields and 19,000 at Howdon Pans. Newcastle's status and prosperity heavily relied on its two rival towns. South Shields' growth was remarkable with the town owning five hundred vessels in 1809, in contrast to only four in 1740. This created of course an intense rivalry with the older shipping centre at Newcastle in the first half of the 19th century, as a result South Shields became a separate port of registry in 1848 (Ville 1988, 66-67).

With such heavy industries the effects of industrialisation and urbanisation would have been detrimental for the population of Newcastle. The prevailing conditions in Newcastle, however, have already been seen in the South and North Shields section, where the three towns were examined and reported together in the second Report of the Commissioners for Inquiring into the State of Large Towns and Populous Districts (1845b). It seems that these three towns, apart from competing against each other in various common industries, developed in parallel due to the geographical and geophysical features they shared; they were also competing in the prevailing detrimental conditions which were identical due to the common industries and environments.

3.4 Carver Street Methodist Chapel Burial Ground: Excavation Overview and the Town of Sheffield in the 18th and 19th centuries

Partial excavation at the Carver Street Wesleyan-Methodist chapel burial ground, which was in use from 1806 to 1855, has provided numerous skeletal remains of a non-conformist working-class population sample (Figure 3.6). The excavation works took place in summer of 1999 by ARCUS of the University of Sheffield, on behalf of Brown and Son Ltd in the process of redevelopment of the site. In total the remains of at least 136 individuals were recovered from the partial excavation of the burial ground, 93 of which were adults and 37 non-adults (Witkin and Belford 2000, 38). The human remains were analysed by ARCUS.

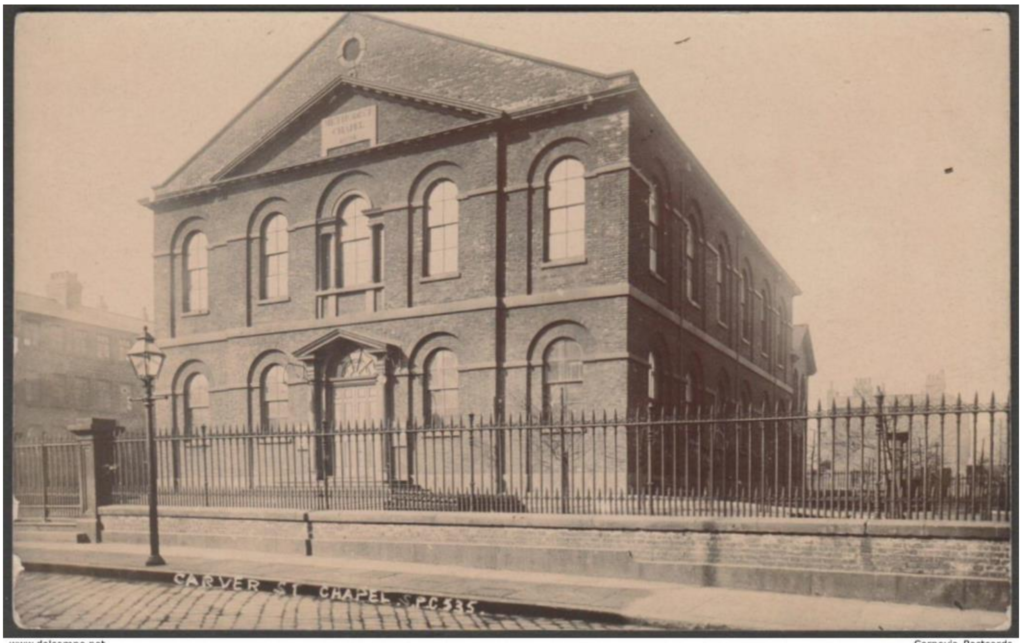


Figure 3.6: Sheffield Photo Company c. 1905. Monochrome original photographic postcard showing a view of the Methodist Chapel, Carver Street, Sheffield (No S.P.C. 535, 1905).

The Methodist Church, non-conformist Protestantism, was founded in the mid-18th century by the preacher John Wesley, with the numbers of followers increasing rapidly in the late 1800s and the religion becoming popular among labouring and manual workers in the newly growing industrial areas, a population group that was largely neglected by the Church of England (Field 1777, 199; Witkin and Belford 2000, 2; Mosley 2002, 12). Sheffield was one of the faster growing centres of Methodism with three new places of worship being built between 1780 and 1805. The Carver Street Methodist Church was built in 1804-1805 and became the principal Methodist church in Sheffield, replacing earlier places of worship at Garden Street and Norfolk Street (Witkin and Belford 2000, 2). The surrounding land was used as a burial ground from 1806-1855 with 1900 interments taking place according to the burial registers (Mosley 2002, 12).

The 18th century had seen the development of Sheffield as a small, but rapidly expanding industrial centre. Sheffield ‘was a cutlery town, long before it became Steel City’ (Hey 2005, 91). Sheffield had a long tradition of manufacturing cutlery, which comprised an important part of its economy, since the middle ages. Improvements, however, in the iron and steel trade in the late 18th century, gave a new impetus to the town’s urbanisation, creating new work opportunities, which attracted workers from other parts of the country. The population of Sheffield rapidly expanded from just fewer than 14,531 in 1736 to 31,314 in 1801 and continued growing apace, with the population reaching 68,186 in 1841 (Hey 2005, 96); By 1851 it had reached 135,310 and continued to grow reaching 380,793 by 1901 (Great Britain-Census 1801; Great Britain-Census 1851; Great Britain-Census 1901).

Sheffield during the Industrial Revolution was predominantly an industrial town, with over 300 steel furnaces alone in the beginning of the 19th century, plus myriad hearths for forges and other workshops. By the middle of the 17thcentury three out of every five men were described in the parish register as cutlers, revealing a primarily working-class population occupied in metal working and manufacture (Hey 2005). That was also reflected in the 18th burial registers from Carver Street burial ground, with the occupations of the buried individuals including 'knife grinder', 'scissor grinder', 'file smith', 'razor smith', 'cutler' and 'edge toolmaker'; although some exceptions were also identified such as 'attorney' and 'Methodist preacher' for instance. Most of the Carver Street burial ground's buried individuals were exclusively from Sheffield Parish.

With an economy heavily reliant on metal works and manufactory the poor air quality reported by many during the Industrial Revolution was not a surprise. In fact, the town was known as a 'smokey centre of industry' long before the first steel furnace was erected and before the Industrial Revolution (Hey 2005, 91). A century later Daniel Defoe (1927) during a visit observed that '…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…'. But it seems it was also the natural topography of the town which was very hilly that exacerbated the problem of poor air. In the absence of flat swampy land, the smoke was ascending to the streets instead of leaving them, making the atmosphere suffocating. In 1848 a parliamentary report on health and sanitation in the borough of Sheffield reported that the air was so heavily polluted that

> *The particles of soot floating about in the atmosphere were so numerous that people were prevented from having recourse to the most common method of ventilation by opening windows- and doors; in many places the evil is so extensive that the inhabitants find the greatest difficulty in maintaining personal or domestic cleanliness* (Haywood and Lee 1848, 68).

As well as the smoke, there were also problems with poor sanitation and hygiene; as a result, Sheffield like other predominantly industrial centres of the time, was subject to various infectious diseases outbreaks. Cholera outbreaks for instance affected Sheffield frequently, with the first outbreak noted in 1832, while there were also later outbreaks in 1849, 1854 and 1866. Parts of the town suffered more than others, these tended to be in the industrial parts where living conditions were poor and cramped (Sheffield Libraries Archives and Information 2015, 6). According to the parliamentary report on health and sanitation in the borough of Sheffield (1848, 5-11) the rooms of the houses were '…low, and the admission of light and air very imperfect, a fact plainly indicated by the pallid faces and feeble half deformed limbs of a number of unhappy children inhabitants…'. Accumulation from night soil and other filth from the privies comprised a constant cause operating to increase mortality, as in many areas public privies were used by seven to twenty families. The hilly topography of the town further exacerbated the increased mortality as stagnant pools were created, resulting in Malaria which was another common problem in Sheffield (Commission for Inquiring into the State of Large Towns and Populous Districts 1845b; Heywood and Lee 1848). In addition to the general problems of smoke and sanitation for the wider population, the grinders for instance suffered silicosis of the lungs known as 'grinder's asthma' along with the explosion of the wheels and the long working hours (Wohl 1983; Witkin and Belford 2000).

3.5 The Churchyard of St Martin's in-the-Bull Ring and the City of Birmingham in the 18th and 19th centuries

Full excavation at the former churchyard of St Martin's Church in-the-Bull Ring Birmingham, which was in use from *c.* 1720 to 1863, has uncovered 857 burials (Brickley *et al.* 2006, 2) (Figure 3.7). The majority of the burials were in simple earth-cut graves, but the remainders were buried in more elaborate graves and chambered vaults. The interred population represented a cross-section of Birmingham's population during the Industrial Revolution, with individuals in earth-cut graves broadly representing the working-class and those from the burial structures the middle-class. The excavation works took place in autumn of 2001 by Birmingham Archaeology, on behalf of Birmingham Alliance in advance of the creation of a new public square in the old Bullring (Brickley *et al.* 2006). Detailed anthropological analysis was carried out on a sample of 505 skeletons by Brickley and co-workers.

Figure 3.7: The Bull Ring in the early 20th century with St Martin's Church in the background. Source Birmingham Live (https://www.birminghammail.co.uk).

St Martin's burial ground served as the principal burial ground for the parish. Birmingham was a prosperous manufacturing and trade centre before the Industrial Revolution, (Brickley *et al.* 2006, 6). In the 19th century the industry of primary importance was metalworking, with the manufacturers producing a huge variety of articles in iron, brass and steel such as swords, knives and cutting tools, nails, wire, utensils, buckles, buttons and many others. By the 19th century a great part of the industry was involved in the making of coffin furniture, or the metal fittings and fixtures on coffins. Other prominent industries, to name just a few, included leather-based works, cloth-making, rope-making, button-making (shell- and bone-based), potting and the manufacture of clay pipes (Brickley *et al.* 2006, 6). The growing prosperity of the town attracted increased immigration into the area which resulted in a population explosion. The population rapidly expanded from just fewer than 7,000 in 1700 to 23,688 by 1750, the population continued growing apace with the population reaching 189,000 in 1845 and over 500,000 in 1901 (Commission for Inquiring into the State of Large Towns and Populous Districts 1845a, 198; Brickley *et al.* 2006, 12). It is said that Birmingham was the fastest growing industrial town in the country (Commission for Inquiring into the State of Large Towns and Populous Districts 1845a). As a result, this put enormous pressure on the market, on the church and on the churchyard, with the latter having to accommodate the dead of an increasingly populous parish (Brickley *et al.* 2006).

Birmingham was primarily made of the humbler classes, something that was also confirmed through the burial evidence of the parish. Greater than 90 percent of the analysed skeletons were classified as 'working-class' based on the earth-cut graves in which they were interred. Despite the fact that similar evils prevailed in all towns, varying in their intensity and in proportion, Birmingham was one of the few exceptions from towns of the period, although populous, the living conditions there were less detrimental. That is because Birmingham possessed many natural advantages over other towns of the Industrial Revolution—as a good site, with adequate fall for drainage; a dry and porous subsoil, and water generally of good quality and good and cheap coal supply in the vicinity. In the first Report of the Commissioners for Inquiring into the State of Large Towns and Populous Districts (1845a, 198) Birmingham was described as '…. perhaps one of the most healthy of our large towns….' The principal streets of Birmingham were generally wide, well made, and with sufficient fall; while the drains in the main streets were also well laid out and tolerably attended to (Commission for Inquiring into the State of Large Towns and Populous Districts 1845a, 198). However, the contrast between the conditions that the richer and middle- and working-class lived was stark by comparison to other industrialised centres. The houses of the richer and middle-classes appeared generally dry and airy and the water supply for these classes was good, and the drainage and cleansing were of little complaint, though susceptible to considerable improvement. The state of the habitations of the working and poor classes, on the other hand, was often widely different. Their houses varied greatly in comfort and convenience, as in size and situation (Brickley *et al.* 2006). Four types of housing were available to the working-class strata; the 'three quarter houses' which could be afforded by the skill craftsmen, the 'back-to-back' while at the bottom of the range were 'the courthouses' and lastly were the 'lodge houses' which were universally condemned (Brickley *et al.* 2006). Cellars seemed to be absent in most of the working-class housing in Birmingham, which was a very positive thing in terms of sanitation and hygiene. Inside and outside, the houses of the lower classes exhibited the same unsanitary and unhygienic problems observed throughout the country (Commission for Inquiring into the State of Large Towns and Populous Districts 1845a, 198; Robson 1935, 315). However, the living in Birmingham despite these poor conditions was not as bad as in other towns. The dry soil on which the town is situated, lessened the intensity of the evils to which the poor were exposed (Commission for Inquiring into the State of Large Towns and Populous Districts 1845a, 106).

3.6 The Baptist Chapel Burial Ground, Littlemore, Oxford: Excavation Overview and the Parish of Littlemore in the 18th and 19th centuries

Excavation works at the non-conformist burial ground of Baptist Chapel, Littlemore, at the southwest of the centre of Oxford, has uncovered a small number of skeletal remains. The excavation works were undertaken in 2009 by Oxford Archaeology, following the demolition of the chapel and prior to redevelopment of the site. Only thirty skeletons survived due to preservation issues, with the burial evidence from the grave stones indicating that the earliest burial was in 1861 and the latest in 1881 (McCarthy *et al.* 2012, 1).

The parish of Littlemore had a mostly rural character in the 19th century; it acquired a church, a chapel, two schools, and a number of gentlemen's houses. Its bleak landscape was transformed into mostly green by tree-planting undertaken in 1840. The construction of the Littlemore Hospital, a psychiatric asylum for the county of Oxford, the railway in the middle of the 19th century and other opportunities for employment attracted newcomers and the number of working-class houses increased to meet the needs of the labourers. Despite the increased number of newcomers, at the end of the 19th-century Littlemore still maintained its rural character. The village now had a few shops and four public houses which also provided for holiday-makers and fishermen. In 1848 the average number of patients in the asylum was 200, but by 1900 the number was 543. In 1883 a new chapel to seat 300 was added, together with a house for the resident medical officer (Lobel 1957, 206-214). Before the 19th century, Littlemore had no residents of distinction, but later residents were J. H. Newman, C.L. Cornish, the Tractarian, E. A. Freeman, the historian, Sir William Herschel, Baronet who also discovered the use of fingerprints in detecting crime and Henry Bloodhurst, M.P., the son of a local stonemason, who became the first direct representative of labour to be given a government appointment under Gladstone. Another Littlemore character was Joseph Ley, the first medical officer of Littlemore Hospital, to whom much of the early reputation of the hospital was due. He introduced a humane system 'beyond what was common at the time' (Lobel 1957, 206-214). It would, therefore, appear that the site was mostly a middle-class site as it was revealed by the memorial stone analysis, but there were also some artisans and skilled working-class individuals among the interments. The coffins and fittings recorded from Littlemore also pointed towards that direction, as they were broadly consistent with those of the lower to middle classes (McCarthy *et al.* 2012).

Despite the status and the rural character of the site, increased infant mortality was observed and the results were more consistent with working-class levels of infant mortality. This is perhaps due to the fact that these infants were born to individuals who initially resided in urban centres and did not reside from the beginning of their lives in this rural site; in this way reflecting the effects of genetics on the offspring. Although burial registers are not available for the Littlemore Baptist Chapel during this period, it would appear that mortality rates are closely comparable to those recorded in the burial register of the wider Baptist community of King's Lynn, Norfolk. With almost half of the population failing to reach adulthood and mortality peaked in infants below two years of age, while some individuals managed to pass the age of 45. For the comparative analysis, only the demographic data used as the palaeopathological information from the site was mostly quantitatively recorded due to the small sample of the assemblage (McCarthy *et al.* 2012). Among the recorded pathological lesions metabolic and malignant neoplastic were identified.

3.7 The Cross Bones Burial Ground, Redcross Way, Southwark, London: Excavation Overview and the Parish of Cross Bones in the 18th and 19th centuries

A number of archaeological excavations were conducted between 1991 and 1998 by the Museum of London Archaeological Service, on behalf of the London Underground Jubilee Line Extension Project, with one of the excavated sites being the Cross Bones Burial Ground in Southwark, on the South bank of Thames. The burial ground was excavated between 1992 and 1993, after tracing documentary evidence, which indicated that the Redcross Way was used during the post-medieval period as a burial ground, quoted as 'Cross Bones' (Brickley and Miles 1999; Newman 2015). The burial ground of Cross Bones, was heavily used during the first half of the 19th century, serving the parish of St Saviour's in Southwark which was one of the poorest parishes of London (Brickley and Miles 1999). The ground is thought to have originally been established at least as early as the 17th century, as a 'single women's' cemetery, a euphemism for the prostitutes whose dwellings were clustered around the theatres, ports, and industrial parts of the South bank of Thames (Roberts and Godfrey 1950, 84-86; Hayward 2008, 707). The only proof, however, which has been adduced for the truth of this tradition, is the fact that the ground remained unconsecrated, although by 1769, the unconsecrated burial ground was used as a parish burial ground for paupers and remained so until its closure in 1853 due to overcrowding (Roberts and Godfrey 1950; Brickley and Miles 1999). It would appear, however, that the actual reason for not declaring this ground 'sacred' was that the ground was held on lease from the Bishop of Winchester and that it was customary only to consecrate freehold ground (Roberts and Godfrey 1950, 84-86).

The main excavation phase at Cross Bones burial ground revealed 148 individuals, mostly buried in cheap coffins, and are thought to date to the last 50 years of use of the cemetery approximately from 1800 till its closure due to overcrowding (Brickley and Miles 1999). Of the total number of revealed individuals, 104 were non-adults with a further 34 percent being perinatal and 66 percent being equal or below five years. It remains unclear whether or not these elevated rates of premature deaths were a product of sampling strategy, which revealed the part of the cemetery that was in use for the interment of the very young, in this way skewing the demography of this sample. However, the phenomenon of burying children in unconsecrated areas outside the original boundaries of the cemeteries was not unusual during this period, as we have already seen in the case of St Hilda's (Raynor *et al.* 2011). In any case, the elevated rates of premature deaths in such a burial site which was reserved for the poorest of the society such as those receiving pauper's burials, should not be unexpected (Brickley and Miles 1999). Half of the Southwark's population was living in poverty and many of them were located in the parish of St Saviour's (Wohl 1983, 44). As it was already seen in the disease section (2.4.1), the borough of Southwark was in particular subject to various water-borne diseases, due to low-quality water supply which was contaminated with the contents of sewers (Wright 1835, 3; Commission for Inquiring into the State of Large Towns and Populous Districts 1845a, 568; Booth 1891; Wohl 1983; Brickley and Miles 1999; Jackson 2015). Thus, with such detrimental conditions the increased number of premature deaths could possibly not be a skewed product, but could be suggestive of elevated mortality risks in early life amongst the poorest (Owsley and Jantz 1985).

3.8 All Saints, Chelsea Old Church Burial Ground: Excavation Overview and the Parish of Chelsea in the 18th and 19th centuries

Archaeological excavations at the northern part of All Saints, Chelsea Old Church burial ground, which was in use between *c.* 1712 and 1842, revealed the skeletons of 290 individuals (Figure 3.8). The excavation works took place in 2000 by the Museum of London Archaeological Service, following demolition works, as a condition of planning consent for the redevelopment of the site. From the total number of revealed skeletons, 198 were selected for detailed recording as part of the Wellcome Osteological Research Database (Cowie *et al.* 2008, xi). From the analysed skeletons, 165 belonged to adults while the rest belonged to non-adults. The skeletal collection can be found at the Museum of London, Centre of Human Bioarchaeology, where it is curated. However, the excavation works at the site were not the first one, during the Second World War Chelsea Old Church was completely destroyed by bombing and the church was rebuilt in the 1950s (Cowie *et al.* 2008). In the 1960s further building work took place as part of the rebuilding works, which caused part of the 18th and 19th centuries churchyard to be exhumed and reburied (Cowie *et al.* 2008; Newman 2015).

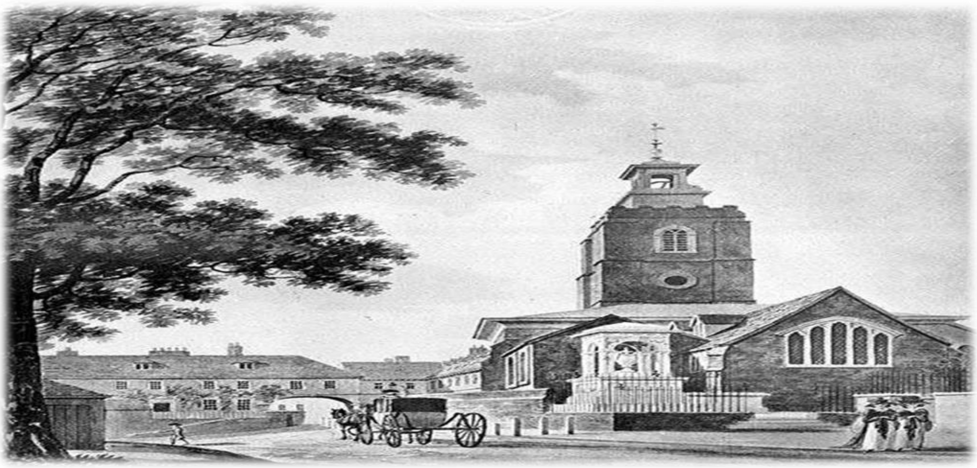


Figure 3.8: Haton, J. 1788. Chelsea Old Church, Arch House. Source Historical England (Chelsea Old Church (All Saints), Cheyne Walk, Chelsea, London | Educational Images | Historic England).

Although Chelsea today is part of central London in the borough of Kensington (south west of the city), back in the beginning of the 18th century, Chelsea still had a more rural character, located on the outskirts of the city (Cowie *et al.* 2008; Newman 2015). Chelsea's rural character was lost gradually with the beginning of the Industrial Revolution and the area transitioned from a riverside village to a suburb of London. At the beginning of the 18th century, Chelsea was a substantial settlement of about 300 houses, although it maintained a rural aspect surrounded by fields, orchards, nurseries and market gardens (Mitton 1902, 1). Until the early years of the 19th century, many of the inhabitants continued to be occupied in the land. By the middle of the 18th century, Chelsea had become a fashionable resort for Londoners, descriptions at this time suggested that Chelsea was a relatively healthy and prosperous place compared with many parts of nearby London. Nonetheless, poor existed in the parish, and in 1837 a workhouse was established there for the employment of the paupers (Cowie *et al.* 2008, 13). By the first half of the 19th century as London continued to grow, Chelsea was swallowed by the expanding city with the surrounding fields rapidly disappearing beneath streets and houses (Cowie *et al.* 2008; Newman 2015). By 1902 Chelsea had approximately reached the 74,000 inhabitants, while it is believed that the population in 1801 was around 12,000 (Mitton 1902, 1).

The population interred in Chelsea Old Church churchyard represents a cross-section of those who resided in a wealthy but diverse transitioned rural area during the 18th and 19th centuries. As Chelsea expanded progressively, the small size of the churchyard became a problem, leading to the creation of two additional parish burial grounds in 1736 and 1812 (Cowie *et al.* 2008, 19). Before May 1736, when the first additional ground was created, the churchyard in Old Church Street would have been the burial place for anyone in the parish from wealthy to parish poor, but even after this date it would appear people of varying status were interred including a number of carpenters, bricklayers, lawyers, and army officials, a 'barge builder', 'an apothecary', a 'butcher', 'a brewer', a 'pasty cook', a 'printer', 'a layer' and a 'vintner'. Most of the individuals were buried in graves, while two brick-lined graves and two burial vault structures were also identified in that section (Cowie *et al.* 2008, 21). In any case, working-class cases were interred along with the wealthier classes; the socio-economic circumstances of these working-class individuals were superior to their urban counterparts. This is simply because the working-class of this rural site would have had enough means to enjoy a comfortable living.

3.9 St Benet Sherehog Burial Ground, City of London: Excavation Overview and the Parish of St Benet during the 17th to 19th century

Archaeological excavations at 1 Poultry site in the city of London were undertaken by the Museum of London Archaeology Service between 1994 and 1996, ahead of redevelopment of the site (Cowal 2008). The archaeological works revealed 280 burials related to two faces of the burial ground, prior and after the London Great Fire in 1666, with the burials representing medieval and post-medieval populations respectively. A total of 267 skeletons was retained for anthropological analysis and analysed in two separate groups based on the period they were dating from. Of the total skeletons retrieved, only 230 will be the focus of this research as they mostly date back to the post-medieval period; of these, 212 are believed to date back to the post-fire and 18 to the pre-fire phase but late 17th century (Miles *et al.* 2008, 70). Of these individuals of interest, 165 are adults and 65 are non-adults. The collection is curated by the Museum of London, Centre for Human Bioarchaeology.

The excavated post-medieval burial ground of St Benet Sherehog is thought to have been in use from the 16th to the 19th century, it therefore represents a population sample from a wide chronological range within the post-medieval period during which this district saw great changes due to industrialisation and urbanisation of London (Miles *et al*. 2008; Newman 2015). The church was never rebuilt after being destroyed by the Great Fire in 1666, but the burial ground continued to be used for new burials for the parishes of St Benet and St Stephen Walbrook, which were united in 1670, the burial ground was closed in 1853 (Miles *et al*. 2008).

The parish of St Benet Sherehog was a small but affluent community located within the City of London. Survived evidence such as wills and the median rent for properties, indicated that the parish scored high in wealth for the 16th and 17th centuries. The dominant trade in the area by the 16th century was grocery. After the London Great Fire in 1666, the rebuilt parish remained one of the wealthier areas of the city, but by the 18th and 19th centuries a population decline was noted due to relocation of the businesses to the outskirts of the city (Miles *et al.* 2008, 14-16). From the 16th century, what was for St Benet parish a sporadic sponsorship of poor relief became systematised, showing that the parish could not only support its own poor, but could afford to support the poor in other parishes. It would therefore appear that St Benet’s sample occupied primarily the middle social ground. This, however, does not mean that everyone interred in St Benet's was relatively wealthy (Miles *et al*. 2008, 92). The parish apart from assisting its poor during life also assisted the poor after life, by covering the cost of burial. By the middle of 18th century it seemed that the parish was housing its poor adults elsewhere, but parishioners from the poorhouse were known to be 'repatriated' and buried in St Benet (Miles *et al.* 2008, 16).

Despite the wealthy status of the parish, the central location of it would have not entirely protected its parishioners from the evils of industrialisation and urbanisation of the rapidly expanding London. In the 18th and 19th centuries, the parishioners would still have experienced the unpleasant effects of atmospheric pollution and the effects of poor sanitation and hygiene that came with overcrowding. However, in the absence of burial registers before 1675 and any information in the documentary sources after 1665, pertaining to the cause of death in the parish it is hard to define how the effects of industrialisation and urbanisation affected the parishioners during the 18th and 19th centuries, the only inferences that can be drawn are those from the age distribution and the revealed osteological information (Miles *et al.* 2008, 17).

3.10 St Marylebone Church Burial Ground, City of London: Excavation Overview and the Parish of St Marylebone in the 18th and 19th centuries

Archaeological investigations by the Museum of London Archaeology Service in 1992, showed that the St Marylebone Church graveyard lay substantially undisturbed beneath a playground for the St Marylebone Church of England School for Girls, which was levelled in the 1930s on the site after the gravestones were cleared. In 2004 plans for an underground redevelopment of part of the site, allowed excavation of a sample of the burial ground and part of the church itself (Figure 3.9). Only seventeen percent of the total development was excavated and the rest was subject to a watching brief. The analysed skeletal sample which also combined data obtained from the 1992 sample was composed of 301 individuals in total, 223 of which were adults and 78 were sub-adults (Miles *et al.* 2008, 1-2). The skeletal remains can be found at the Museum of London, Centre for Human Bioarchaeology, where they are curated.

Figure 3.9: Unknown c. 1817. Parish Church of St Marylebone. Antique Engraved Print. Source Antiques Maps and Prints (St Marylebone Parish church London Antique engraved print 1817 old (antiquemapsandprints.com)).

The parish church of St Marylebone on Marylebone Street, Westminster was built in its present form in 1817. From 1400 the earlier church stood to the south, adjacent to the street. This was replaced by a small church built in 1742 on the site which served an expanding and wealthy population. This church, however, could not cope with the huge population increase in the parish in the latter half of the 18th century and was eventually replaced again by the present church to accommodate such a large congregation (Miles *et al.* 2008, 6). The parish of St Marylebone during the 18th and 19th centuries had a number of different burial areas over time, including the extramural grounds at St John's Wood and two on Paddington Street. The existence of so many different burial areas during this period reflects the significant issues of overcrowding with the population expansion that arose from industrialisation. By 1854 very few burials were taking place in ground other than St John's and those would have been in existing family plots. In the churchyard, the number of burials was down to single figures (Miles *et al.* 2008, 11).

From a high incidence of surviving documentation such as baptism registers and particularly wills relating to those buried in the cemetery, it was established that the parish exhibited a relatively high number of upper and middle-class individuals. Identified occupations in the 19th-century baptism registers, which required the father's profession to be recorded, included 'gentleman', 'army officer', 'clerk', 'architect', 'attorney', 'barrister', 'school master', 'professor of music', 'artist', 'sculptor', 'mechanic'. From wills and other sources, it also became apparent that many wealthy individuals were not locals as they had valuable properties outside the area and some had fairly recently moved to the parish. In addition to the wealthy, there were also a number of people who provided services to the wealthy such as grocers, carpenters, cabinet makers, carvers and gilders, labourers, builders, chimney sweeps and servants. The existence of servants in such a wealthy area should not come as a surprise, with so many 'strangers' arriving in London to find a job in the 18th and 19th centuries; a job like that in a wealthy area where lodging was provided, would have been mostly desirable by many newly arrived strangers who had nowhere to live (Cowie *et al.* 2008; Miles *et al.* 2008). A number of paupers was also identified, showing how difficult it can frequently be to entirely separate the wealthier from the poorer strata.

Despite the relatively wealthy status of the site, the parish's central location would have not entirely protected its parishioners from the effects of industrialisation and urbanisation of the rapidly expanding London. That was also seen by the assessment of the recorded parish burials with the number of dying children following the general increased mortality pattern among children in the metropolis as a whole and other parts of the country, recorded by the Registrar-General for various years (Registrar-General 1839; 1842; 1845; Pooley and Pooley 1984; Thomson 1984; Miles *et al.* 2008). In the absence of any recorded cause of death in any records of the parish right up to 1837, it is hard to define how the effects of industrialisation and urbanisation affected the parishioners during the 18th and 19th centuries the only inferences that could be drawn were those from the age distribution (Miles *et al.* 2008, 67).

3.11 Christ Church Spitalfields Crypt, East London: Excavation Overview and the Parish of Spitalfields in the 18th and 19th centuries

Archaeological works at the Crypt in Christ Church Spitalfields, East London, which was in use from 1729 (when the church was consecrated) to 1852, has revealed a large number of skeletons (Figure 3.10). The excavation of the site was undertaken between October 1984 and April 1986 by the Spitalfields Project Team, in advance of restoration works which first required the clearing of the crypt. About a thousand skeletons were excavated, including nearly 400 with coffin plate information giving name, age and date of death (Molleson and Cox 1993).

Figure 3.10: Ackermann, R. 1815. Christ Church, Spitalfields. Source Library of Huguenot History (Christ Church, Spitalfields (London) - Bibliothek für Hugenottengeschichte (BFHG)).

Reconstruction of the social backgrounds of the named individuals has shown that the majority were of Huguenot descent, French Protestants who were prosecuted by the French Catholic government after revocation of the Edict of Nantes and fled the country in the late 17th century during a violent period (Thornbury 1878; Smiles 2009). According mostly to baptism records but also other documentary evidence such as marriage records, a large proportion of these named individuals were involved in the silk industry. Some were prosperous master weavers, while others were hard working journeymen weavers and silk dyers who, together with surgeons, master craftsmen, artisans, merchants and tradesmen comprised the 'middling sort' of the 18th century (Thornbury 1878; Molleson and Cox 1993; Reeve and Adams 1993; Gibson 2009).

Spitalfields was the centre of the silk industry in London from the 16th century and its size and range was increased from the late 17th century as a direct result of the Huguenot immigrants settling in the area and bringing their textile manufacturing skills. The wealthy status of these individuals may have cushioned them from some of the effects of poverty, but not necessarily from everything (Molleson and Cox 1993; Roberts 2007). These people lived in the most desirable residences with spaces, gardens, street lighting, a better sewage system and good sanitation, enjoying a better quality of life. This phenomenon of superior living conditions in the wealthy quarters was not unique to Spitalfields as it was revealed through the first Report of the Commissioners for Inquiring into the State of Large Towns and Populous Districts (1845a). This status, however, would have only partially protected these individuals as it would have been as they were still sharing the same air and streets with the poor who could not constantly stay confined, eventually leading to the spread of diseases. Along with these general effects on health resulting from the poor surrounding conditions, those individuals involved in the silk industry would have also faced specific occupational hazards. Respiratory infections were known to be associated with working in the textile industry (Roberts 2007, 804).

3.12 St Luke's Church Burial Ground, Islington, London: Excavation Overview and the Parish of St Luke's in the 18th and 19th centuries

Archaeological works at St Luke's Church burial ground in Islington, which was in use from *c.* 1755 to 1848, has revealed a considerable number of skeletons. The excavation of the site was undertaken between July and December 2000 by Oxford Archaeology on behalf of ABL Cultural Consulting Limited, ahead of construction and refurbishment plans (Boyle *et al.* 2005). Osteological analysis of the skeletal material was largely undertaken on site and completed in Oxford. The exhumed skeletal sample of 896 was divided into high- and low-resolution samples. The high-resolution sample comprised 241 named individuals who were osteologically recorded in full and described as primarily 'middle-class' as most of them were buried in vaults and elaborate graves. The remainder were unnamed individuals where basic anthropological information was recovered and described as primarily 'working-class' as most of them were buried in plain earth-cut graves (Boyle *et al.* 2005, 13-57).

The church and the burial ground are situated on Old Street, north of the city of London and the church was consecrated in 1733 to relieve the City Church of St Giles-without-Cripplegate, which was reported to have 4,600 houses at the time (Riley and Gomme 1914). St Luke's was one of the fifty new churches commissioned to be constructed in the early 18th century in London and surroundings, to accommodate the needs of the growing population. From the proposed churches only, a dozen was eventually constructed including among them those of Christ Church, Spitalfields and St George's, Bloomsbury (Molleson and Cox 1993; Reeve and Adams 1993; Boyle *et al.* 2005; Boston *et al.* 2006).

The parish was laid out in numerous streets and squares, covered with buildings in every direction, and by 1840 had already become one of the most extensive, and populous parishes in the suburbs of the metropolis (Lewis 1840 cited in Boyle *et al.* 2005, 35). From the middle of the 18th century, the construction sector of the watchmaking trade was located within the parish and the adjoining parish of Clerkenwell. By the end of the 18th century the watchmakers in the parish were estimated at 1,000 (Boyle *et al.* 2005, 35). It would appear, however, that less than twenty percent of the parishioners' households classified as wealthy based on tax collection; the rest were from the lower strata with many of London's poorest of the poor who were mostly Irish, located in St Giles back settlement and some also in the parish of St Luke's (Boyle *et al.* 2005, 35-36). According to Lewis (1840 cited in Boyle *et al.* 2005, 35) the poorest and most dissolute in Spitalfields were several grades above the Irish living in St Giles back settlement and the poor quarters of St Luke's parish. Not much direct information, however, is known pertaining to the occupations of the interments in St Luke's as the studied burial registers were in microfilms and did not record the occupations of the individuals (Boyle *et al.* 2005). Despite the stark occupational and accommodation differences that the wealthier and poor of St Luke's parish might have experienced; it is certain that living in such proximity with each other, in such an overcrowded parish in the metropolis, would have affected to some extent the health of everyone. That was also confirmed by the cause of death in the burial registers where 'consumption' was reported as the most common causes of death, revealing close proximity and unsanitary conditions (Boyle *et al.* 2005, 37).

3.13 St George's Church Crypt, Bloomsbury, London: Excavation Overview and the Parish of St George's in the 18th and 19th centuries

Archaeological work at St George's Church Crypt, Bloomsbury has provided numerous skeletal remains with burials dating from 1804 to 1856, after which date the crypt was sealed (Figure 3.11). The excavation of the crypt was conducted between April and June 2003 by Oxford Archaeology on behalf of the Parochial Church, ahead of redevelopment of the crypt. The names of 86 percent of the assemblage were identified from *depositum* plate inscriptions.

Osteological analysis of 111 skeletons recovered from open lead coffins was undertaken on site (Boston *et al.* 2006). The skeletal sample was divided into high- and low-resolution samples. Where the identity of individuals was known, 'named sample with 72 individuals', detailed analysis was undertaken but where the identity was unknown, 'unnamed sample with 39 individuals', a lower level of analysis was carried out (Boston *et al.* 2006).

Figure 3.11: Unknown, 1878. Bloomsbury Square and Neighbourhood from Old and New London: Volume 4, (pp. 535-545) 1878. Source British History Online Bloomsbury Square and neighbourhood | British History Online (british-history.ac.uk).

In the early 18th century, the area of Bloomsbury comprised a growing number of residences of the 'middling sort' and a few mansions of the aristocracy. The genteel classes were attracted by its location on the periphery of the metropolis upwind from the major industry of the East End. Bloomsbury was slow in becoming urbanised in comparison to other parts of London, but the urban development in and mostly around Bloomsbury continued apace in the early 19th century, with Bloomsbury soon enclosed to the north by the parishes of St Pancras and Clerkenwell. While until the early part of the 18th century, Bloomsbury lay within the parish of St Giles in the Fields where increased social heterogeneity existed; with the workhouse of St Giles being described by philanthropists of the era as the 'greatest sink of mortality' (Boston *et al.* 2006, 61-63). Consequently, sandwiched between these less healthy areas, Bloomsbury represented a 'genteel oasis of middle-class' (Boston *et al.* 2006, 61).

Documentary research on the named individuals, confirmed that the interred population primarily represented the wealthy upper middle-classes residents of Bloomsbury, and amongst them were many lawyers, doctors, M.Ps, imperial administrators, and Army and

Navy officers (Boston *et al.* 2006). The population also included members of the staff of the nearby British Museum, including one Principal Librarian. In addition to the wealthy, there were also people who provided services to the wealthy inhabitants of Bloomsbury, who intended on improving their position in society such as a number of tradesmen including butchers, grocers, builders, wine merchants, carpenters and a servant (Boston *et al.* 2006).

It would appear that the healthful environmental effects of the location and socio-economic factors of the parish, to some extent, played their role in the mortality patterns of the crypt population (Boston *et al.* 2006). There were marked differences between the demography reflected in the London Bills of Mortality of 1848 and that compiled from the coffin plate inscriptions from St George's crypt; although, the found results could also be biased as the assemblage represented a population sample. Childhood mortality below the age of five years was much lower in the crypt sample. Similarly, mortality figures for the first 20 years of life were dramatically lower compared with those for the wider London population. Lastly, adult longevity was much greater in the St George's population, with a far higher proportion of the population surviving beyond 70 years of age. The most common recorded causes of death were 'consumption, followed by 'inflammation' and 'dropsy', together with 'old age' (Boston *et al.* 2006). The presence of infectious diseases such as consumption, however, shows that socio-economic conditions only partially protected the wealthier individuals. The close proximity of the parish with other poorer parishes would have had some impact on the spread of diseases.

3.14 St Bride's Lower Churchyard, London: Excavation Overview and the Parish of St Bride's in the 18th and 19th centuries

St Bride's lower churchyard, 75-82 Farringdon Street, forms part of the population who lived in the parish of St Bride's during the 17th-19th centuries. The lower churchyard is one of three burial locations in the parish; the other two, the main churchyard and church crypt, are associated with St Bride's Church, Fleet Street (Figure 3.12). The creation of this third burial location, which is dated approximately between 1770 and 1849, reflects the overcrowded conditions within the St Bride's Church crypt and churchyard and the constant need for more burial space (Miles and Conheeney 2005). The parish records show that in 1800 the population of the parish was 7,078 individuals while the total number of occupied houses was

830. The registrar of St Bride’s noted that between 15 and 20, and sometimes 30 people were living in one house. Lower St Bride’s Churchyard, Farringdon and St Bride’s Fleet Street, although part of the same parish population, represent two different social classes (Miles and Conheeney 2005; Mant and Roberts 2015). Parish burial grounds generally charged different rates depending upon the burial location in the cemetery; St Bride’s however, had no such differentiation and therefore it was probably the poorer members of the parish, lodgers and inhabitants of the nearby Bridewell workhouse and Fleet prison that were laid to rest in St Bride’s (Kausmally 2008; Miles and Conheeney 2005; Mant and Roberts 2015). Fleet prison was mainly inhabited by debtors, and a total of 41 former prisoners were buried in the lower churchyard (Miles and Conheeney 2005).

Figure 3.12: Unknown c. 1800. St Bride's Church in Fleet Street, London.

Excavation works in the 1950’s by Professor Grimes were carried out as a consequence of the bomb damage incurred to the church during the Second World War and revealed various archaeological information as well as large numbers of skeletal material from the three burial locations. In total 606 individuals were recovered from the Lower St Bride’s Churchyard, Farringdon, with 544 individuals available for analysis. The majority of the exhumations, 497 individuals, were recovered from the open yard and were buried in wooden coffins, mainly made of elm, stacked up to eight deep in the open yard, while 47 were found in a brick vault (Kausmally 2008). Subsequently, the densely packed burials represent overcrowded conditions and the lack of burial space due to the increased morbidity and mortality, especially among the parishes of the poorer strata. It was estimated that the skeletal assemblage available for analysis represented approximately 50 percent of the cemetery population (Miles & Conheeney 2005).

3.15 St Pancras Old Church Cemetery, London: Excavation Overview and the Parish of St Pancras in the 18th and 19th centuries

Numerous skeletal remains were revealed during archaeological investigations at St Pancras burial ground in the London Borough of Camden. The works were undertaken, between 2002 and 2003, by Gifford during construction of St Pancras International, the-new terminus of High Speed 1. The presence of St Pancras Old Church is documented from the late 12th century, with the original churchyard being subject to several extensions in the post-medieval period, culminating in the creation of the 'New Burying Ground' to the east in 1792, with the last burial taking place in 1854 (Figure 3.13). The 2002–2003 exhumation of burials and subsequent analysis was principally concerned with the study of the southernmost 'Third Ground', which lay at the southern end of the 'New Burying Ground' and was used from 1793 until its closure in 1854. From this section, 1,383 burials were recorded archaeologically (Emery and Wooldridge 2011; Redfern 2012). A total of 780 burials were retained from processing and of these, 715 individuals were the subject of full osteological analysis, 448 of which were adults and 183 were non-adults, while the rest were unknown. The human remains were reburied following recording by the Museum of London Specialist Services and Pre-Construct Archaeology (Redfern 2012). Individuals came from both ornamented coffins and a corresponding sample of plain coffins. The survival of legible inscribed coffin plates revealed a heterogeneous population buried during a time of rapid urbanisation and industrialisation. Many people were from outside the metropolis and immigrants. Identified individuals included refugees who fled the French Revolution, most notably three aristocrats and two prelates (Emery and Wooldridge 2011).

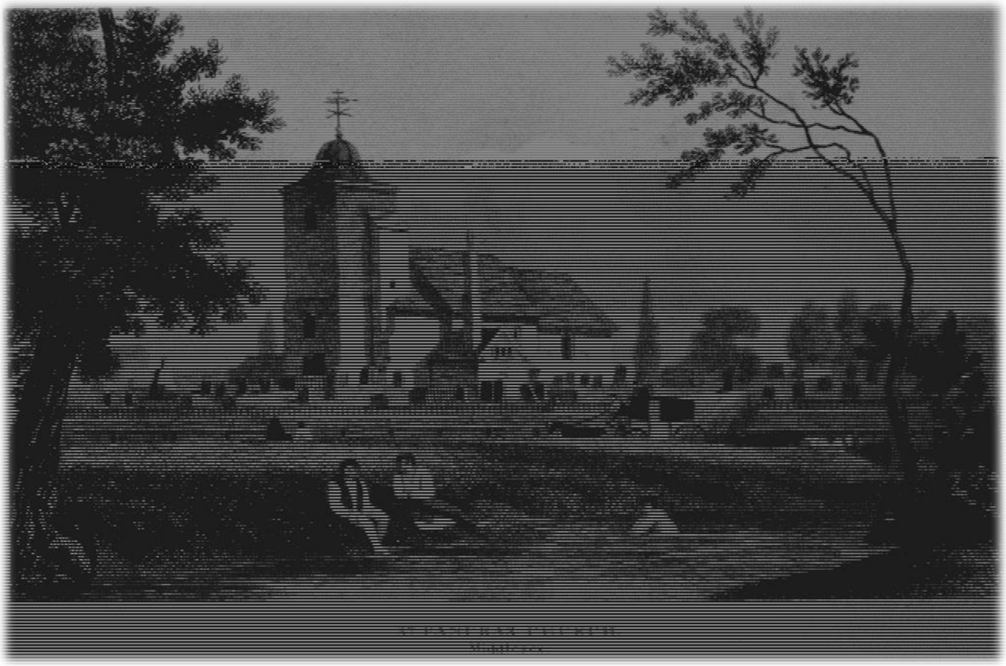


Figure 3.13: Neale, J. P. 1815. Table 30. St Pancras Old Church from Survey of London: Volume 19, the Parish of St Pancras Part 2: Old St Pancras and Kentish Town, 1938. Source British History Online (Plate 30: St. Pancras Old Church | British History Online (british-history.ac.uk).

St Pancras was often said to be the most populous parish in the metropolis (Walford 1878). Palmer (1870, 14) in his history of the parish reported that '…. its population is estimated, at the present day, at a little over a quarter of a million, its number being only exceeded of all the metropolitan parishes by Marylebone'. He also reported that the parish was estimated to contain 2,700 square acres of land, and that its circuit is twenty-one miles. From the 'Diary' of the vestry for the year 1876–1877, it was reported that the area of the parish was 2,672 statute acres and in 1871 the total number of householders was 23,739 (Walford 1878). During that period, there were 278 parliamentary and municipal boroughs in England and Wales, exclusive of the metropolis, and only five of these (i.e. Liverpool, Manchester, Birmingham, Leeds, and Sheffield) contained a larger population; and there were twenty-two counties with smaller populations in each than St Pancras (Walford 1878, 324-340). Consequently, when the described above circumstances are taken into consideration, these found individuals would have lived in close proximity irrespective of socio-economic status.

3.16 Royal Hospital Greenwich Burial Ground, London: Excavation Overview and the Town of Greenwich in the 18th and 19th centuries

Archaeological works at Devonport Buildings, King William Walk, Greenwich, London, have provided a number of skeletal remains. The excavation was conducted between July 1999 and September 2001 by Oxford Archaeology, on behalf of Mount Anvil, in advance of a redevelopment plan (Boston *et al.* 2008, vii). The proposed redevelopment area was within a location formerly used as the ratings' burial ground of the Royal Hospital Greenwich and originally had contained the remains of approximately 20,000 retired seamen and marines of the Royal Navy, interred between 1749 and 1856 (Boston *et al.* 2008, vii). The Royal Hospital in Greenwich (Figure 3.14), which operated between 1694 and 1869, was an institute for the relief and support of seamen serving on board the ships and vessels belonging to the Royal Navy, who by reason of age, wounds or other disabilities were incapable of further service and personal maintenance (Boston *et al.* 2008, 7). Most Greenwich pensioners were veterans of Britain's wars with the Dutch, the Americans, the Spanish, the French Republic and Napoleon. A total of 107 skeletons were recovered from 55 graves, with the majority of individuals being older adult males revealing the nature of the archaeological site, however, a small number of women and adolescents were also present (Boston *et al.* 2008, vii).

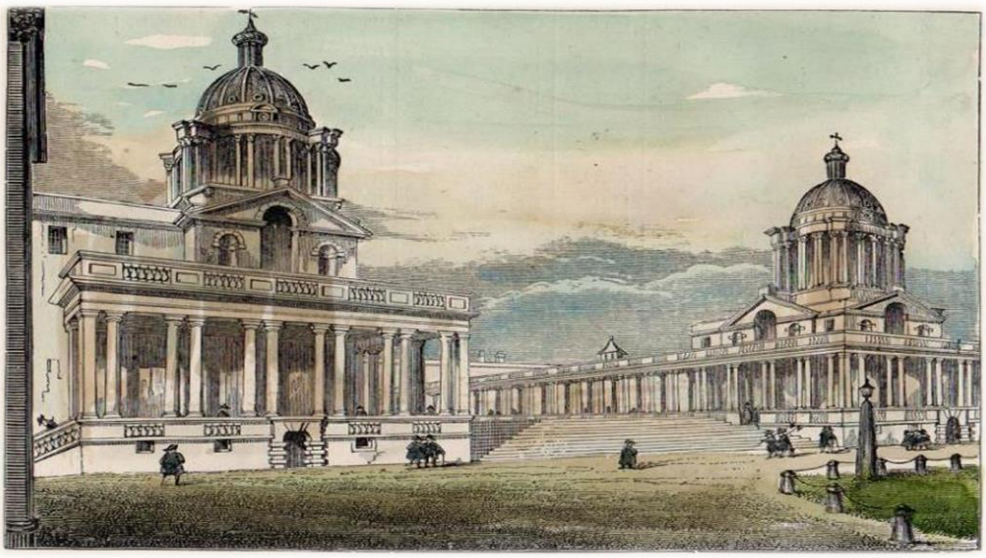


Figure 3.14: Greenwich Royal Hospital. A late 19th-century impression of a print originally published in the Penny Magazine, 1833. Source Warwick Leadlay Gallery (https://www.warwickleadlay.com).

The vast majority of the seamen and mariners serving in the Royal Navy were working-class in origin (Floud *et al.* 1990). This was evident from documentary sources that recorded the occupations of seamen and mariners before joining and after leaving the Royal Navy. These occupations included many labourers, but also skilled workmen. A few were artisans such as bakers, tailors or carpenters (Boston *et al.* 2008, 16). While there were also many sailors from seafaring families or at least that lived in seaport areas. The town of Greenwich, which was built along the bank of the Thames where the channel was both very broad and very deep, was notable for its maritime history and from the 18^{th} century was a popular resort. Greenwich was very populous, containing about 2,000 houses, and was reckoned as one of the genteel and pleasant towns in England with many of its inhabitants being persons of rank and fortune. It was greatly improved by the powers of an act passed in 1753. The dryness and salubrity of the soil and air, the conveniency of the park, the general pleasantness of the adjoining countryside, and its near neighbourhood to the metropolis, contributed to making it a most desirable residence for people of fashion and fortune (Hasted 1797, 372-420). Trying to define, however, how the surrounding environment might have benefited or negatively affected the hospitalised individuals during the long course of their lives in terms of strict geographic location (Greenwich and broader London boundaries), would not be reasonable, assuming that these individuals could be from anywhere in England, Wales and Scotland but also outside of the British mainland, for example Ireland, and were in the hospital only for a specific time after their admission. Knowing, however, that many of these individuals joined the Navy in order to escape poverty among the rural and working-classes of the period, others to escape creditors and the debtor's prison (Boston *et al.* 2008, 13); it can be assumed that they had probably experienced the general working and living conditions among the lower strata that were recorded throughout the country. Consequently, although this site cannot be bound to a certain geographic location and specific effects, it is expected that these individuals would skeletally manifest the physical effects of social deprivation that similar assemblages of working-class origin of this period such as Cross Bones, London and St Hilda's, South Shields exhibited.

CHAPTER 4

METHODS

The purpose of this chapter is to outline the methods used to identify and quantify the expression of health and disease indicators encountered within St Hilda's cemetery in South Shields. The methods for establishing the levels of preservation and completeness of the skeletal assemblages will be discussed first. This step is necessary in order to enable the identification of any biases in the data, which may result from poor preservation of the skeletal elements or from selective burial practices. Then, a summary of the methods used to determine the biological sex, age, and stature of each individual within the assemblage will follow. These demographic parameters will be used to create an overall demographic profile. In the same section, the identifying criteria for each main palaeopathological category (non-specific and specific infections, trauma, joint disease, dental disease and metabolic disease) will also be included. The criteria for recording the rest of the palaeopathological conditions, outside the main categories (e.g. congenital and miscellaneous) will be briefly described in chapter 5 along with the results of their analysis. This step is necessary as outside the main palaeopathological categories, it is impossible to predict any other possible pathological lesions beforehand. After the articulated material methods, a summary of the methods used for estimating the minimum number of individuals for the charnel and disarticulated material will be given. In the same section, a summary of the methods for recording the demographic and palaeopathological parameters of the charnel and disarticulated material is included.

Age, biological sex and stature were fully analysed and a full skeletal and dental inventory were made for each skeleton. In the course of the palaeopathological examination, detailed macroscopic examination of the skeletons for skeletal and dental pathology was the main means of calculating the crude and true prevalence rates. More specifically, a detailed description of the pathological dental and skeletal lesions was undertaken for the needs of inventories, followed by a differential diagnosis. As individuals can suffer from different diseases simultaneously and their skeletal manifestations, the process of differential diagnosis (meaning the creation of a list of potential diseases) was essential to avoid limitations by exclusions of diagnosis (Jain 2017).

4.1 Skeletal Assemblage Preservation and Composition

An important aspect of this research was to identify how well-preserved the studied material was in order to account for any bias that may have had an impact on the distribution of different sexes and age groups or prevalence rates of pathologies. A typical example of this type of bias is the under-representation of infant remains in the demographic profile of cemetery populations. Infant under-representation seems to be affected by various parameters such as poor preservation, excavation methods, and cultural practices applied to the burial process (Buckberry 2000; Sayer 2014). However, the issue of poor preservation of immature remains must be first assessed before any cultural interpretations are provided, regarding the absence or presence of juvenile burials (Buckberry 2000, 14). Such under-representations can frequently lead to false interpretations, when the preservation is not considered (Buckberry 2000).

Within this thesis, preservation and completeness were recorded for each skeleton. This enabled crude counts for the number of each surviving observable element, allowed the well-preserved elements to be observed for any pathologies, and finally for these elements to be compared with other contemporary sites.

4.1.1 Skeletal Assemblage Preservation

Preservation is defined as the degree the bone has survived the taphonomic processes of decay and external environmental factors, such as soil type and the presence of microorganisms within the soil (Bell *et al.* 1996). In order to quantify the level of preservation within these assemblages, two parameters were assessed: the *completeness* of the surviving skeletal elements and the overall *condition* of the bones (Brickley and McKinley 2004; Mahoney-Swales 2012). Within this thesis 'completeness' refers to the percentage of the skeletal remains that survived and 'condition' refers to the extent that erosion, abrasion and post-mortem damage has affected the skeleton (Brickley and McKinley 2004).

The completeness of surviving skeletal elements was recorded numerically and divided into four categories *(0-24%; 25-49%; 50-74%; 75-100%)*. To quantify the condition of each skeleton, the standards of *BABAO/IFA* criteria for recording bone surface preservation was used. Abrasion and erosion were assessed together and were assigned a grade on a spectrum of *0 to 5+* (Brickley and McKinley 2004, 15-16). Definitions of the different grades of bone surface condition are listed below (Table 4.1).

0→ Surface morphology is clearly visible with fresh appearance to bone and no modifications.
1→ Slight and patchy surface erosion.
2→ More extensive surface erosion (e.g. through root action) than grade 1, with deeper surface penetration.
3→ Most of the bone surface affected by some degree of erosion (by root action); general morphology maintained but detail of parts of surface masked by erosive action.
4→ All of the bone surface affected by erosive action; general profile maintained and depth of modification not uniform across whole surface.
5→ Heavy erosion across whole surface, completely masking normal surface morphology with some modification of profile.
5+→ As Grade 5, but with extensive penetrating erosion resulting in modification of profile.

Table 4.1: Definitions of the seven different grades of bone surface condition based on Brickley and McKinley (2004, 15-16)

In order to gain an overall impression of the condition of the cortical bone of the skeleton, the overall preservation of the assemblages was rated on a three-point grading system, *Good (1), Moderate (2), Poor (3),* which was adapted from the recording standards of Connell and Rauxloh (2003). Definitions of the three different grades of bone preservation are listed below (Table 4.2). This is important as, aside from cortical erosion and abrasion, post-mortem damage, as well as other parameters such as fragmentation and staining from organic materials can affect each bone. Each of these factors can impede the identification of sex- and age-diagnostic characteristics as well as pathological characteristics (Mahoney-Swales 2012). For instance, the shaft of a bone may have *grade 1* cortical erosion, but may have very fragmentary joint ends, which would inhibit recording of degenerative joint disease (e.g. osteoarthritis). Therefore, the overall condition of the bone for the entire skeleton would have been recorded as *Poor*.

1→ Bone surface is in **good** condition with no erosion, with fine surface detail such as coarse woven bone deposition would (if present) be clearly visible to the naked eye
2→ Bone surface is in **moderate** condition, with some post-mortem erosion on long bone shafts. Erosion of articular surfaces and some prominences
3→ Bone surface is in **poor** condition, with extensive post-mortem erosion resulting in pitted cortical surfaces. Articular surfaces missing or severely eroded

Table 4.2: Definitions of the three different grades of bone preservation based on Connell and Rauxloh (2003) standards.

4.1.2 Skeletal Assemblage Composition: Sexing and Ageing Methods

Sex is defined as the biological make-up of an individual's reproductive anatomy and secondary sex characteristics; whereas gender is defined as an aspect of a person's social identity (Diamond 2002; Little 2013; Zuckerman and Crandall 2019). Consequently, these two terms should not be used interchangeably as the former refers to a biological identity while the latter to the socio-cultural identity and involves personal preferences and societal constructs (White and Folkens 2007, 386-387). In some circumstances the assigned sex and gender of an individual does not align in life and in the burial context as in the case of the 'Red Lady' of Paviland Cave in Wales, a partial Upper Palaeolithic male skeleton, initially identified as female in 1832 based on the burial evidence (Jacobi and Higham 2008). Therefore, within this thesis the term 'sex' refers only to the biological sex and not to the 'gender' of the individual. The determination of sex was defined by the study of each skeleton and not by the study of the burial context and associated artefacts.

Two types of methods were employed for the determination of adult biological sex, morphological (shape-based) summarised by Buikstra and Ubelaker (1994) and osteometric (measuring dimensions) by Stewart (1979). The use of sexually dimorphic traits on the skeletal elements of the pelvis and skull, was the primary assessment method as it offers a high degree of accuracy, 90% and 80% respectively (Buikstra and Ubelaker 1994; White and Folkens 2005). Then, osteometric methods or the mean average of measurements of specific points on certain bones on both male and female skeletons were employed as a secondary-supportive method. More specifically, metric measurements of the vertical diameter of both femoral and humeral heads were taken in order to further support the first type of methods used (Stewart 1979). As it is not always feasible to assign a definitive sex due to certain influential factors such as age, population affinities, and state of completeness and preservation, four main sex categories were assigned. Each sexable skeleton was initially assigned to one of the following sex categories; Male (M), Probable Male (M?), Female (F), Probable Female (F?). Later on, these four categories were collapsed into two categories, Male (M) and Female (F), for easier statistical manipulation. Cases of individuals that did not display strongly male or female characteristics were recorded as 'ambiguous'. Finally, cases of individuals that were lacking diagnostic features for sex determination due to factors such as poor preservation were recorded as 'unknown'.

No attempt was made to assign biological sex for non-adult skeletons (below 18 years of age). A number of morphological and metrical methods for determining sex in non-adult skeletal remains have been developed by various authors (Schutkowski 1993; Molleson *et al.* 1998; Loth and Henneberg 2001), but unfortunately, the reliability of these methods remains controversial. Therefore, for this stated reason, no biological sex was assigned for non-adult skeletons.

After the assessment of biological sex, multiple methods were employed for age assessment and the results were compared to ensure consistency. Within this thesis, 'age' is used in terms of the biological age-related skeletal changes known to occur during periods of growth and decline of an individual's life span (Schwartz 1995, 185). Therefore, the term age here does not refer to the chronological age that is the calendar months/years of an individual. The chronological age may not always directly correlate with the osteological age. For example, a 10-year-old child may exhibit the skeletal size and features of a 7-year-old child due to developmental delays.

Adults were aged by utilising development and degenerative changes to the bones and teeth; specifically, degenerative changes to the physical morphology of the: (1) pubic symphysis (Todd 1920; Suchey and Brooks 1990), (2) auricular surface (Lovejoy *et al.* 1985; Buckberry and Chamberlain 2002), (3) sternal end of the ribs (Iscan *et al.* 1984), as well as cranial sutures obliteration (Meindl and Lovejoy 1985), late fusing epiphyses and third molar eruption (Scheuer and Black 2000). The assessment of sex before age estimation was necessary as specific ageing methods, such as the pubic symphysis (Suchey and Brooks 1990) and sternal end of the fourth rib (Iscan *et al.* 1984), have separate age phases for males and females. Miles' (1962) dental attrition method was only used as a guide, as it tends to grossly under-age skeletons of post-medieval populations. The method was developed in Anglos-Saxon skeletal samples, and thus samples with similar diets are prerequisite (Miles 1862, 886). post-medieval and early modern populations are expected to demonstrate different rates of attrition due to softer and refined diets (Roden 1997; Boulter *et al.* 1998). For that reason, the method developed by Roden (1997) on the post-medieval assemblage of Newcastle Infirmary, was employed along with Smith's (1984) method for further accuracy.

Ageing of non-adult skeletons was achieved through the use of dental and skeletal ontogenetic changes. The development of dentition is well correlated with chronological age as it is minimally influenced by external factors. As a result, dental development is less susceptible to environmental influences (e.g. periods of malnutrition and infection) than skeletal growth (Lewis and Ambika 2006). Consequently, the following dental methods were employed to estimate age-at-death for non-adult remains: (1) stages of dental calcification, (2) root extension, (3) tooth eruption and (4) apical closure of the tooth root (Anderson *et al.* 1976; Moorrees e*t al.* 1963 a,b). In addition, the following skeletal methods (1) skeletal development and epiphyseal fusion (Krogman and Iscan 1986; Bass 2005; Schwarz 1995; Scheuer and Black 2000) and (2) diaphyseal long bone length measurements (Gindhart 1973; Fazekas and Kosa 1978; Scheuer *et al.* 1980; Hoppa 1992; Scheuer and Black 2000) were used in conjunction with the dental methods and as a substitute when no teeth survived.

Detailed descriptions of age-related differences on the bones were not recorded but rather skeletons were assigned to one of the twelve following broad age categories (Table 4.3).

Age Category	Age Range
Preterm	Under 40 weeks
Neonate	Birth-1 month
Infant	1-12 months
	1-6 years

Early Childhood (Young Child)	7-12 years
Late Childhood (Older Child)	13-17 years
Adolescent	18+ years
Adult	18-25 years
Young Adult	26-35 years
Early Middle Adult	35-45 years
Late Middle Adult	46+ years
Mature Adult	60+ years
Older Adult	

Table 4.3: Assigned age categories

For the purposes of this research, the terms ‘perinate’, literally meaning around the time of birth, and ‘stillbirth’, meaning born dead, were both deliberately avoided. These medical terms are difficult to apply to skeletal remains. Instead, both terms were replaced by the term ‘preterm’ to describe those born before the usual gestation period, which is considered to be around 40 weeks, though normal gestation can length between 38-42 weeks (Beers and Berkow 1999; Scheuer and Black 2000; Raynor *et al.* 2011; Liston *et al.* 2018). Therefore, no assumptions had to be made as to whether or not it was a live birth or a stillbirth; but only that both birth and death occurred before the normal gestation period (Scheuer and Black 2000). It is possible for a foetus to be viable after seven months of gestation (28 weeks), but the terms perinatal and stillbirth are not appropriate in this context as it would denote an assumption around the survivorship of the individual.

Within this thesis, the term ‘adult’ refers to any individual including and over the skeletal age of 18 years at death. In some cases, an individual was assigned only the ‘adult’ age category with no further subdivision into a more specific age category. This is due to the poor completeness or condition of a skeleton which prevented an accurate assessment of that individual's age. However, it must be noted that these are arbitrary biological categorisations frequently associated with imprecision and approximate estimations, which may not reflect chronological age at death and have no relevance in a cultural and social context (White and Folkens 2005; Mahoney-Swales 2012). The Industrial period is a typical example that age had no relevance in a cultural and social context; on many occasions end of the childhood, started too early among the lower classes as children were often forced to work almost as soon as they could walk, something that was also corroborated in Saint Hilda's burial registers.

4.2 Skeletal Assemblage Composition: Stature Estimation Methods

Although stature is related to health and diet, it is also to a greater extent influenced by population affinities and was therefore included in the demographic section of this thesis (Mahoney-Swales 2012). In particular, the final attained stature in adults is influenced by the interplay between inherited, environmental and socio-economic factors (Boyle *et al.* 2005). Inadequate nutrition and infectious disease during developmental years, or a synergistic interaction between the two, are the most common causes of growth stunting in human populations (Mays *et al.* 2008, 85), inhibiting an individual's ability to achieve their genetically assigned potential height (Robb *et al.* 2001, 216; Dewitte and Hughes-Morey 2012, 1). Along with the physical stressors, emotional stressors during childhood and adolescence may also prevent achieving this potential. If such stressors, both physical and emotional, are too severe or prolonged for the growing body to 'catch-up' its growth later, the individual's physical development will be permanently inhibited (Boyle *et al.* 2005).

Consequently, adult stature is perceived as a good indicator that reflects the overall health of individuals and of populations, provided the genetic component of populations do not change (Boyle *et al.* 2005). Thus, a comparison of the overall average adult stature of the St Hilda's cemetery, with contemporary urban cemeteries may provide insight into the environmental and social background of the populations.

Adult stature can be calculated using ancestry-dependant sex-dependant regression formulae. More specifically for the needs of this study, two formulae were employed for the estimation of adult stature; calculations from long bones maximum length measurements (linear regression) for white males and females provided by Trotter (1970), and calculation from the maximum femoral length known as 'Femur/Stature ratio' provided by Feldesman *et al.* (1990). The latter method was used as a secondary method to support the results of the first one, in order to establish consistency. As a standard practice, the left side of the skeletal elements were used to measure the maximum length. Whenever the left side element was absent or damaged, the right side was used to substitute for the left. When the sex of the individual was unknown, the length of the long bones was recorded and values for both males and females were calculated and then averaged to provide a stature estimate. Only individuals of identified age and sex were included within the results, to enable sexual dimorphism to be identified. Comparison between estimation from the Femur/Stature ratio and estimation from linear regression followed in order to establish accuracy and give the range of the stature.

4.3 Palaeopathology Methods

In order to understand the quality of life that the working-class individuals of St Hilda's burial ground experienced, a number of health and disease indicators were observed and recorded. The main means of investigation were macroscopic assessment, although some use of x-rays was applied in order to confirm instances of healed fractures.

Health and disease indicators manifest upon the skeleton and dentition as a physiological response of an affected individual's body to extrinsic environmental influences. These extrinsic influences include inclement weather, nutrition, unhygienic and overcrowded living conditions, pollution of the air and water supply, physically vigorous activity, work accidents, and incidents of violence (Roberts and Manchester 1997). As a result, these factors manifest upon the skeleton in various forms, including (1) upper and lower tract respiratory infections (e.g. maxillary sinusitis, pleurisy and tuberculosis), (2) metabolic diseases (e.g. rickets, scurvy), (3) hematopoietic diseases (e.g. cribra orbitalia and porotic hyperostosis) as manifestations of physiological stress (e.g. intestinal parasites and diarrhoea), (4) degenerative joint disease, (5) fractures and other forms of trauma (Ortner 2003; Aufderheide and Rodriguez-Martin 2006; Waldron 2009; Roberts and Manchester 1997). The extent to which the individual is affected by these environmental stressors results from a combination of factors, such as the biologically determined level of resistance related to age and sex, as well as the socio-economic and cultural influences such as family structures, housing and income (Desai *et al.* 1970, 133).

An initial assessment of the population's health and disease status was based on the recording of all the observed pathological lesions on each of the articulated and disarticulated skeletal remains. For the needs of this thesis, the following classification system from the *Biological Anthropology Research Centre (BARC)* was used to record the infectious diseases including specific and non-specific infections (e.g. syphilis), trauma (e.g. fracture), joint disease (e.g. osteoarthritis), metabolic disease (e.g. dietary deficiencies), dental disease (e.g. periodontal disease), neoplastic disease (e.g. bone cancers), and congenital disease (e.g. bifid spine). Additionally, specific diseases associated with the occupational hazards facing workers in industrial conditions were also recorded such as phosphorus necrosis (e.g. phossy jaw).

A brief explanation of the aetiology of each health and disease indicator recorded will be presented in the next section. This step will be followed by a description of the employed methods and criteria used to record each indicator. The recording criteria are adapted from texts where photographic and diagrammatic examples of the health indicators under consideration are provided. The intention of this approach was to standardise the recording system and reduce any inter- and intra-observer errors that can occur from misinterpretation of ambiguous terminology such as 'slight', 'moderate' and 'severe'.

4.3.1 Indicators of Environmental Stress: Non-Specific Infection

Evidence of non-specific infection throughout the skeleton can give an impression of an individual's general state of health at their time of death (Weston 2008). A limitation that accompanies this type of non-specific lesions, however, is that the infection cannot be attributed to a single identifiable pathogen (Roberts and Manchester 1997). These types of lesions can, thus, provide indirect evidence of the conditions and environments to which the individuals were exposed. For example, maxillary sinusitis (see below) can be used as a non-specific infection to infer the presence of respiratory irritants and infections (Boocock *et al.* 1995; Roberts 2007).

a. Maxillary Sinusitis

Infection of the maxillary sinuses occurs primarily when an upper respiratory tract infection spreads from the nose to the sinuses. However, there are also other contributory factors, which can be divided into two groups: environmental and health related contributors.

Environmental factors include: poor ventilation, overcrowding, internal and external pollutants and irritants (e.g. polluted sooty air), low humidity, cold, damp climates, and poor hygiene. Whereas, the health-related contributors include asthmas, allergies and congenital predisposition. It can also be instigated by dental infections from carious teeth and periapical abscesses discharging through the floor of the maxillary sinuses (Boocock *et al.* 1995; Lewis *et al.* 1995; Roberts and Manchester 1997; Boyle *et al.* 2005; Roberts 2007; DiGangi and Sirianni 2017). In the dry bone, maxillary sinusitis is recognised as irregular pitting and new bone formation on the inferior surface of the sinuses (Roberts and Manchester 1997, 131). Chronic sinusitis or environmental irritants can also lead to enlargement or hypertrophy of the turbinates as a secondary complication. When the middle turbinates are affected the condition is called 'concha bullosa', where the middle turbinates are filled with air. When this happens, the conchae bullosa blocks the air flow to the sinuses (Ozturan 2013). When an individual exhibits a deviated nasal septum, it is more likely that both turbinate hypertrophy and concha bullosa are present. These pathological changes can macroscopically be observed in the dry bone, with the turbinates looking like small expanded balloons (Brunworth *et al.* 2013)

Hence, within this research chronic maxillary sinusitis and secondary complications can be used as an indicator to reflect indoor and outdoor pollution, poor hygiene standards, and overcrowded living conditions. By analysing the prevalence within the case study, inferences could be made about the living and working conditions of the population as a whole. Further detailed analysis into the prevalence of maxillary sinusitis within different population groups such as adults and non-adults, and males and females may provide information on the different conditions encountered by different demographic groups (Mahoney-Swales 2012).

In order to avoid destructive procedures by the use of an endoscope, the analysis was limited to fragmentary crania that have undergone post-mortem breakage with their cavities being already exposed. The cranium was placed under high-intensity light and a magnifying scope was used to determine the presence of remodelled bone in the maxilla; maxillary sinusitis was recorded as absent or present using the diagnostic criteria and photographs provided by Boocock *et al.* (1995, 486-9). According to Boocock's diagnostic criteria the following features were identified: (1) pitting, (2) spicules and (3) remodelled spicules (Figure 4.1 a-c). However, in order to record them as absent or present for the statistical analysis, these categories were collapsed following Merrett & Pfeiffer (2000) into 'remodelling' (indicating spicules, pits, or both were present) and no 'remodelling'. Data were also collected on dental infections in the maxillary molars (abscesses, periodontal disease and ante-mortem tooth loss) and on whether or not molars exhibited root protrusion into the maxillary sinus (DiGangi and Sirianni 2017, 159). The presence of the above dental pathologies, which may have had an impact upon the maxillary sinuses, were recorded to enable the relationship between dental health and sinus infection to be determined. Cases of odontogenic sinusitis were left outside the statistical analysis of maxillary sinusitis and were analysed separately. Lastly, in the case of non-adults the recording of maxillary sinusitis was restricted to individuals aged over three years due to the incomplete development of the maxillary sinus in infants and younger children (Lewis 2002a, 37; Roberts 2007).

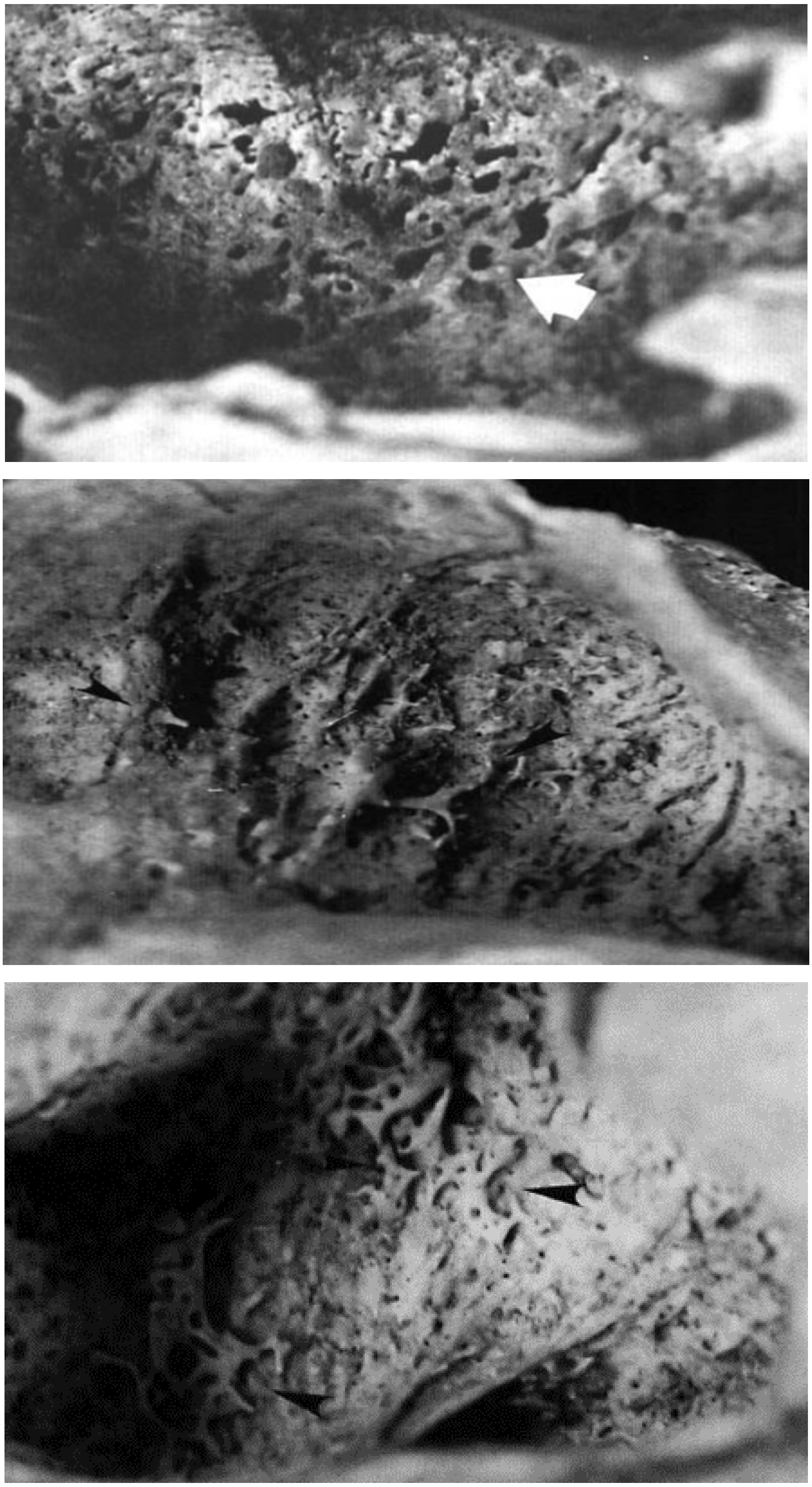


Figure 4.1 (a-c): Stages of maxillary sinusitis adapted from Boocock (2007, 486-488): (a) pits, (b) spicules, (c) remodelled spicules (order: top to bottom).

b. Rib Lesions associated with Pleurisy

Another condition associated with respiratory disease, but in this case of the lower respiratory tract is pleurisy. Pleurisy is inflammation of the tissue between the lungs and the ribcage (parietal pleura); it is a complication of several different medical conditions, but the most common cause is viral infection of the lungs (e.g. flu) spreading to the pleural cavity. Other causes of pleurisy include bacterial infections (e.g. pneumonia and tuberculosis), rib bruises or fractures which result in inflammation of the pleura, haemorrhage, and lung neoplasms (Roberts *et al*. 1998; Boyle *et al.* 2005; Davies-Barrett *et.al* 2019). The vast majority of respiratory diseases leave no trace on the bones; however, where a lesion is closely associated with the ribs, resorption or new bone proliferation on the visceral surface of the ribs may occur due to the close proximity between the pleura and the periosteum of the internal surface of the ribs (Roberts *et al*. 1998; Cappaso 2000b).

In skeletal remains, pleurisy is identified as a subperiosteal reaction on the visceral surface of the ribs which occurs during inflammation of the surface (Cappaso 2000b; Davies-Barrett *et al.* 2019). Traditionally, such skeletal lesions were associated with TB; however, Roberts *et al.* (1998, 56) concluded that no differential diagnosis was possible without the presence of tuberculoid lesions in other parts of the skeleton. Consequently, in this case other aetiologies such as pneumonia, chronic obstructive pulmonary disease, such as chronic bronchitis and emphysema, and less likely, metastatic carcinoma, non-specific osteomyelitis and syphilis cannot be ruled out (Roberts *et al.* 1998, 58; Boyle *et al.* 2005, 173; Kass *et al.* 2007, 1357)

To record the lesions, the ribs were placed under high-intensity light and a magnifying scope was used to determine the presence of remodelled bone on the visceral surface manifested as (1) porosity, (2) pitting and (3) sub-periosteal new bone formation (Matos and Roberts 2006) (Figure 4.2 a-c). However, in order to record them as absent or present for the statistical analysis, these categories were collapsed into 'remodelling', which include all the above three features and no 'remodelling'.

As in the case of maxillary sinusitis, the occurrence of rib lesions associated with pleurisy in St Hilda's sample can be used as a non-specific indicator of environmental stress, in order to elucidate the exposure of the St Hilda's sample to indoor and outdoor pollution which caused respiratory diseases. Indoor as well as outdoor environments during the Victorian period had a high degree of particulate pollution (Fynes 1873; Bailey *et al.* 2016; 2018). Consequently, further detailed analysis into the prevalence of rib lesions associated with pleurisy within different components of Saint Hilda's population sample will possibly provide information on the different conditions encountered by different demographic groups.

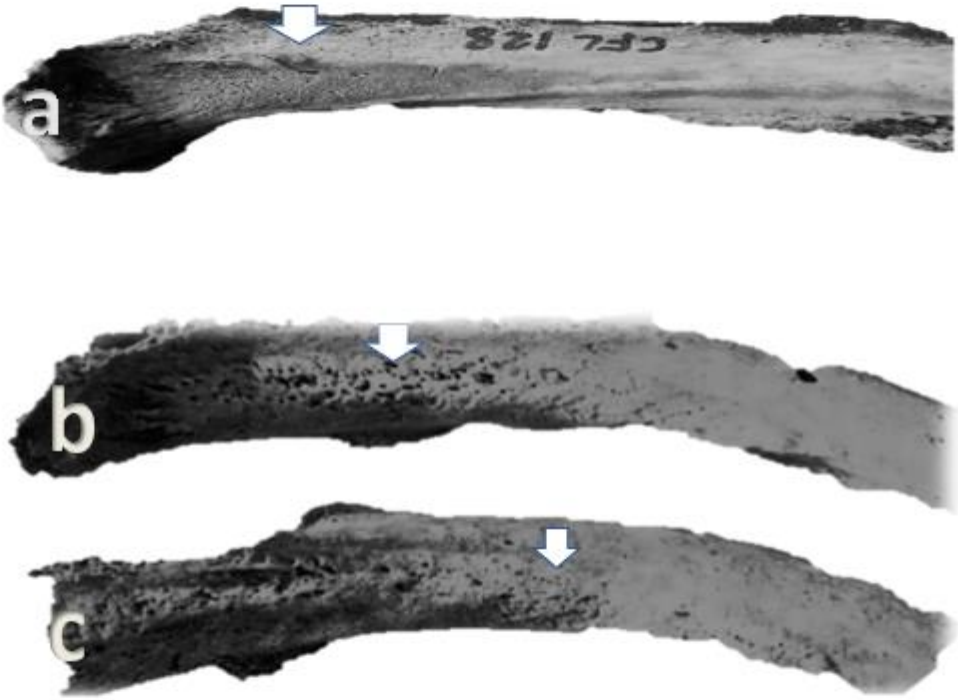


Figure 4.2 (a-c): Examples of skeletal manifestations of pleurisy: (a) new bone formation, (b) fine pitting, (c) porosity. Courtesy University of Sheffield reference material.

c. Tibial Periosteal new bone formation (TPNB)

Subperiosteal new bone formation is a skeletal response to extrinsic or intrinsic pathological or non-pathological stimuli upon the periosteum, the outer membrane that covers the external non-articular surfaces of a bone (Roberts and Manchester 1997, 127-9; Weston 2008, 48-9; Waldron 2009, 115). The formation of these non-specific bone changes has been attributed to bacteria such as *Staphylococcus, Streptococcus* and *Pneumococcus* while they spread from a primary to a secondary focus (Roberts and Manchester 1997; Larsen 1997). There can be many causes for this non-specific bone change, although non-specific and specific infections such as chronic skin ulceration in the elderly due to varicose veins or syphilis are common (Resnick and Niwayama 1981; Roberts and Manchester 1997; Weston 2008; Waldron 2009; Boel and Ortner 2011). Other causes include chronic stress injuries, trauma, minor inflammations within the soft tissues of the body, subperiosteal hematomas, bone neoplasms and underlying metabolic diseases (Roberts and Manchester 1997, 127-9; Waldron 2009, 116). It has also been argued that subperiosteal new bone formation can be generated by any friction, pressure or mild stress upon the periosteum (Weston 2008, 49). The wide range of causes makes it almost impossible to differentiate between subperiosteal bone formation due to inflammation or due to any other aetiologies. Despite the wide spectrum of aetiologies behind these lesions, TPNB has been commonly utilised in the study of human skeletal remains as one of the many 'stress' indicators reflecting the body's ability to respond to irregularities whether they are infectious, inflammatory or traumatic in origin; therefore, its utilisation is also important in the study of St Hilda's (Boyle *et al.* 2005; Roberts and Manchester 2010). The high predilection of periosteal new bone formation seen on tibia in relation to other bones is probably due to its superficial nature on the anterior aspect that can be subject to recurrent minor injury (Roberts and Manchester 1997).

For the diagnosis of TPNB the following diagnostic features were identified on tibia; longitudinal striation frequently accompanied by fine pitting and porosity, patch or patches of reactive bone, and eventually plaque-like new bone formation on the original cortical surface with cortical expansion due to extensive subperiosteal reaction (Roberts and Manchester 1997, 129-130; Steckel *et al.* 2006) (Figure 4.3 a-c). The lesions were recorded as present or absent for the statistical analysis. Individuals below three years of age were excluded to avoid confusion of pathological periosteal new bone formation and normal growth process for this age (Scheuer and Black 2000). Furthermore, only new bone formation on the tibial shafts and not on the articular surfaces was recorded. The aim of this was to prevent confusion with new bone forming in response to inflammation from osteoarthritis and other degenerative joint disease. In the lack of any multifocal new bone formation outside the tibial bone, the TPNB was recorded as non-specific.

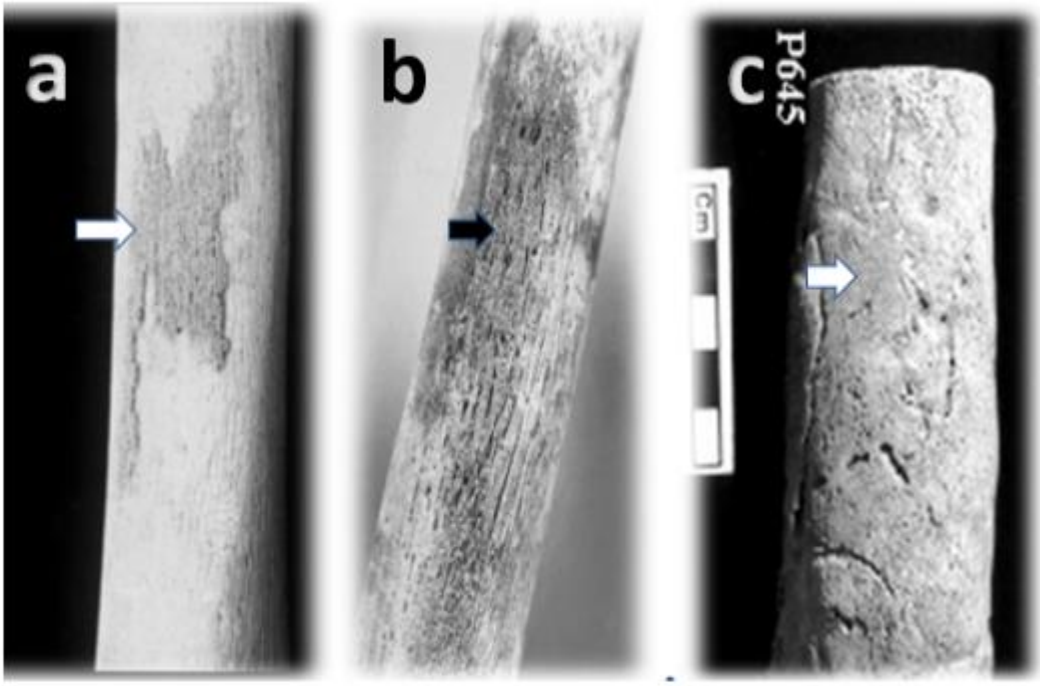


Figure 4.3 (a-c): Examples of TPNB: (a) plaque woven new bone formation (active-unhealed lesions), (b) woven porous bone with some striation and fine pitting, (c) periosteal reaction with diffuse compact bone (healed). Courtesy University of Bradford BARC reference material.

4.3.2 Indicators of Environmental Stress: Specific Infection

Unlike non-specific infections, specific infections can be more directly associated with particular living conditions and activities such as in the cases of tuberculosis or venereal syphilis. Establishing whether the new bone formation is localised or diffuse is useful in narrowing the diagnostic possibilities. Both Tuberculosis and Syphilis are infectious diseases with multiple foci with their pattern of lesions throughout the skeleton being pathognomonic for their diagnosis.

a. Tuberculosis (TB)

Tuberculosis is caused by one of the species of *Mycobacterium*, two strains of which may affect humans, *Myco. tuberculosis hominis*, responsible for the pulmonary type of disease, and *Myco*. *tuberculosis bovis*, responsible for the gastrointestinal type (Roberts and Manchester 1997; Roberts *et al*. 1998). Therefore, there are two modes of TB transmission, on the first mode the bacillus is established in the lungs if inhaled, on the second the bacillus is established in the gastrointestinal tract if ingested (Roberts *et al.* 1998). Both strains can cause skeletal changes, however, it is *Myco. bovis* which is the more likely of the two to cause skeletal changes (MacCarrison 2011, 50).

Overall, it is thought that only 3-5% of the living untreated patients will present skeletal lesions (Roberts and Manchester 1997; Ortner 2003). This is via haematogenous and lymphatic spread from either the lungs or intestines (Roberts 2015, 118). In general, the invading pathogen tends to have high predilection for areas high in red marrow content such as the spine, gradually destroying the bony tissue (Roberts and Buikstra, 2008).

The bone changes associated with TB may be specific to TB or non-specific, meaning they could be related to TB but could also be caused by a number of other diseases (MacCarrison 2011). The most reliable anatomical region in the skeleton for the diagnosis of TB is the spine, characterised by destructive lesions with little or no new bone formation. Tuberculosis of the spine is known as *Pott's disease* which causes angular kyphosis due to the demineralisation of the vertebra, and subsequent collapse of the vertebral bodies (Resnick and Niwayama 1995, 2462). TB of the spine usually involves the lower thoracic and upper lumbar regions with two to four adjacent vertebrae being affected mostly in the anterior portion of the body. The vertebrae become wedged shaped and collapse and subsequent bony fixation (ankylosis) follows (Figure 4.4 a-b). Differentiation between human- and bovine-type spinal collapse is impossible as both appear identical (Resnick and Niwayama 1995, 2463-2464; Roberts and Manchester 1997, 139; Ortner 2003, 233-235).

Figure 4.4 (a-b): Examples of Spinal TB-Pott's spine. Courtesy University of Bradford BARC reference material.

Osteomyelitis of the ends of the long bones and joints themselves is also another feature for the diagnosis of TB; with the joints producing septic arthritis with the destruction of the joint surfaces that progresses into fibrous fixation (ankylosis) during healing. In septic arthritis arising from TB, only a single joint is involved and is more destructive than proliferative; septic TB has a high predilection for either the hip or knee joint, outside the spine (Roberts and Manchester 2005). TB of the hip is very erosive with foci in the femoral head and neck and possibly the acetabulum (Ortner 2003; McCarrison 2011, 53). TB of the knee can cause deformities and destructive changes in the femoral condyles and/or tibial plateau, but rarely in the patella or fibula (Ortner and Putschar 1985, 154; Ortner 2003, 240; McCarrison 2011, 111). Attempting to differentiate between end stage rheumatoid arthritis and septic arthritis caused by TB can be impossible if there is fibrous or bony fixation, but limited or no bone destruction (Ortner 2003, 241).

Non-specific bone changes in TB may include bone formation on the visceral surfaces of the ribs, calcified pleura, or granulomatous lung modules. These skeletal changes in the ribs are not pathognomonic for the diagnosis of TB as any chronic pulmonary infection could stimulate similar skeletal changes (Roberts *et al.* 1998; McCarrison 2011). However, they may be considered suggestive of TB in cases that are more erosive than proliferative in nature (Roberts and Manchester 1997; Ortner 2003, 233; Roberts 2015, 117). For example, rib lesions in TB appear to be more destructive in nature, described as 'scoop-out' lesions (Figure 4.5a). The formation of such destructive rib lesions in TB results from the presence of 'bulla' or 'abscess' (Roberts *et al.* 1998; Santos and Roberts 2006).

Other possible non-specific changes include destructive lesions of the bone underlying the skin lesions of lupus vulgaris most often affecting the facial bones and/or tuberculous dactylitis of the short bones of the hands and feet and wrist joint (Ortner 2003, 247; Roberts 2015, 117-118). The shoulder joint, sternum and elbow joint can also be affected. The shafts of long bones are not usually involved but when they are, the tibia is most commonly involved (Ortner 2003, 245). TB can manifest in the ankle joint and bones of the feet; if the origin of infection is the tibia, destruction and subsequent healing ankylosis of the tibiotalar joint can occur (Ortner 2003, 241; McCarisson 2011, 50). Additionally, the cranial vault may also be involved due to TB meningitis (Figure 4.5b).

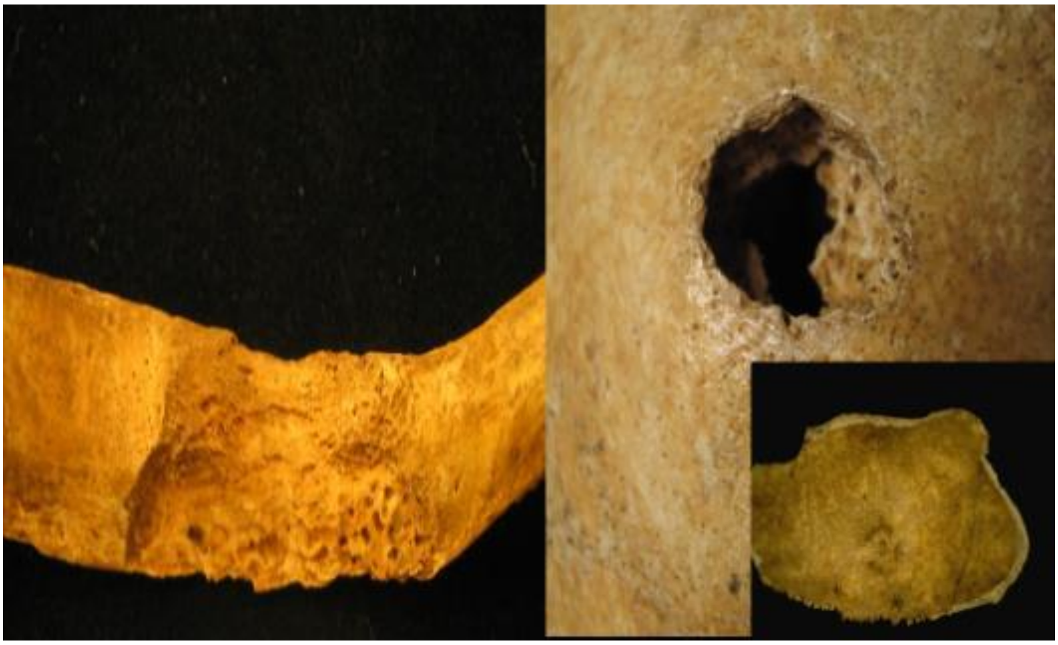
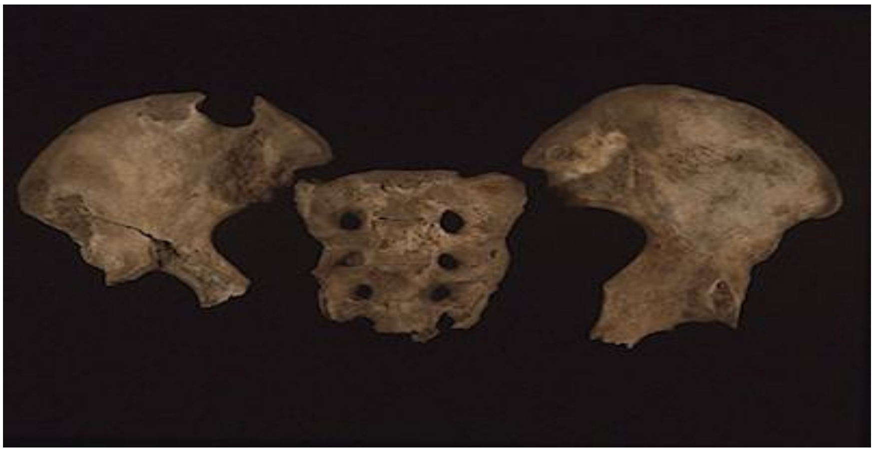


Figure 4.5a and b: 'Scoop out' rib lesions in TB and endo- and ectocranial lesions (order: left to right). *Courtesy University of Bradford BARC reference material.*

In the case of gastrointestinal TB, lytic lesions on the anterior aspect of the lumbar vertebra may be present resulting from the presence of enlarged and infected tissue mass. The pelvic bones and sacroiliac joint may also be affected usually through tracking of infection to the pelvis from the psoas muscle abscess (Aufderheide and Rodríguez-Martín 1998, 139; Ortner 2003, 239) (Figure 4.6 a-b)



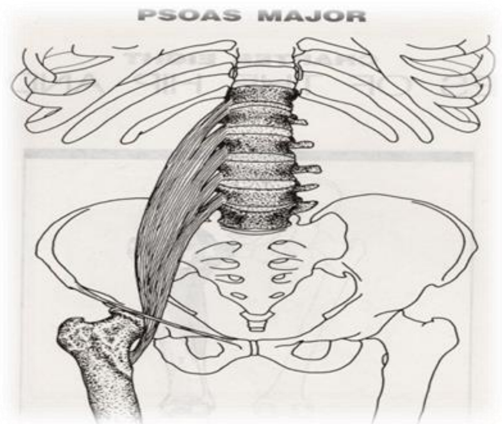


Figure 4.6 (a-b): Example of gastrointestinal TB with tracking of infection to the pelvis from a psoas muscle abscess. Courtesy University of Bradford BARC reference material.

b. Syphilis

Syphilis, transmitted through sexual contact, is known as *acquired syphilis*; this term is used to distinguish from the *congenital* variant which is transmitted transplacentally to the developing foetus of an infected mother (Ortner 2003, 278). Acquired syphilis also known as the *great pox,* is caused by the *spirochaete, Treponema pallidum.* Three other organisms within this genus are responsible for causing non-venereal or endemic treponematoses. *T. pallidum* subspecies *pertenue* is the causative agent of yaws, *T. pallidum* subspecies *endemicum* causes endemic (non-venereal) syphilis also known as bejel, and *T. carateum* causes pinta. These pathogens are unfortunately morphologically and antigenically indistinguishable. However, as Peeling *et al.* (2017, 2) defined they can be differentiated by 'their age of acquisition, principal mode of transmission, clinical manifestations, capacity for invasion of the central nervous system and placenta, and genomic sequences'.

Syphilis is mainly transmitted by contact between mucous membranes during intercourse with an infected person in the first 1-2 years after their exposure to the pathogen (Storm 2012; Peeling 2017). Following infection, there are four stages and it is usually during the tertiary stage (2-10 years) that skeletal involvement occurs allowing the diagnosis of syphilis in skeletal remains; however, only 10-12% of the affected individuals will exhibit skeletal involvement (Ortner 2003, 279).

In cases where skeletal involvement occurs, often more than one bone is affected and the skeletal changes are bilateral, affecting areas with thin skin near the surface; although the reason behind this predilection for thin skin areas remains unclear (Roberts and Manchester 1997). The most reliable anatomical region in skeletal remains for the diagnosis of syphilis is the tibia as it is the most common site of involvement; the nasal area and the cranial vault are also common locations (Ortner 2003, 280). Other bones close to the skin surface, but less frequently involved, include cancellous bones such as the ribs and the sternum. The spine appears to be an exception to the rule of the cancellous bone involvement; it is rarely involved in syphilis and when involved the focus is the cervical region. Involvement of the joints may occasionally occur in the large joints of knee, shoulder and elbow (Roberts and Manchester 1997; Ortner 2003; Storm 2012; Peeling 2017).

As with tuberculosis, two types of skeletal changes are identified in syphilis, pathognomonic bone changes or non-specific, meaning they could be related to syphilis but could also be caused by a number of other diseases (MacCarrison 2011; Storm 2012). Pathognomonic bone changes include *gumma;* in living cases the lesion is seen as a soft gummy tumour of focal infection, which results in punched-out destructive lesions, mainly on the cortical surface of the underlying bone (Ortner 2003; Strom 2012). Consequently, based on the presence of *gumma* the syphilitic lesions of long bones can be separated into non-*gummatous* and *gummatous* osteoperiostitis, meaning non-specific and specific osteoperiostitis. The *non-gummatous* syphilitic changes may leave elevated plaque-like exostoses on the cortex of bones that have a major overlying layer of muscle such as in the case of femur. Diffuse non-gummatous osteoperiostitis tends to leave the bone thick and heavy, the thick bone build-up may become firmly attached to the cortex with the outer surface appearing hypervascular.

During advanced stages the medullary canal may be completely obliterated by sclerotic trabeculae. The *gummatous* osteoperiostitis is much more characteristic, resembling a tumour-like enlargement of the affected area. In dry bone, the marked hypervascular periosteal bone build-up surrounds a scooped-out defect, extending into the cortex (Figure 4.7 a-b). Granulomatous lesions of the skull are known as *caries sicca* (Figure 4.8 a-b), the lesions initially appear as clustered pits mostly on the frontal bone and as the disease develops new lesions may occur in adjacent parietal and facial bones (Ortner 2003; Storm 2012). All skeletal bone changes in syphilis are characterised by excessive osteosclerotic bone response with thickening of the cortical bone due to endosteal and periosteal new bone formation, leading to localised swelling.

Figure 4.7 (a-b): Gummatous lesions in venereal syphilis, tibiae and femur with localized swelling due to thickening of cortical bone (order: left to right). Courtesy University of Bradford BARC reference material.

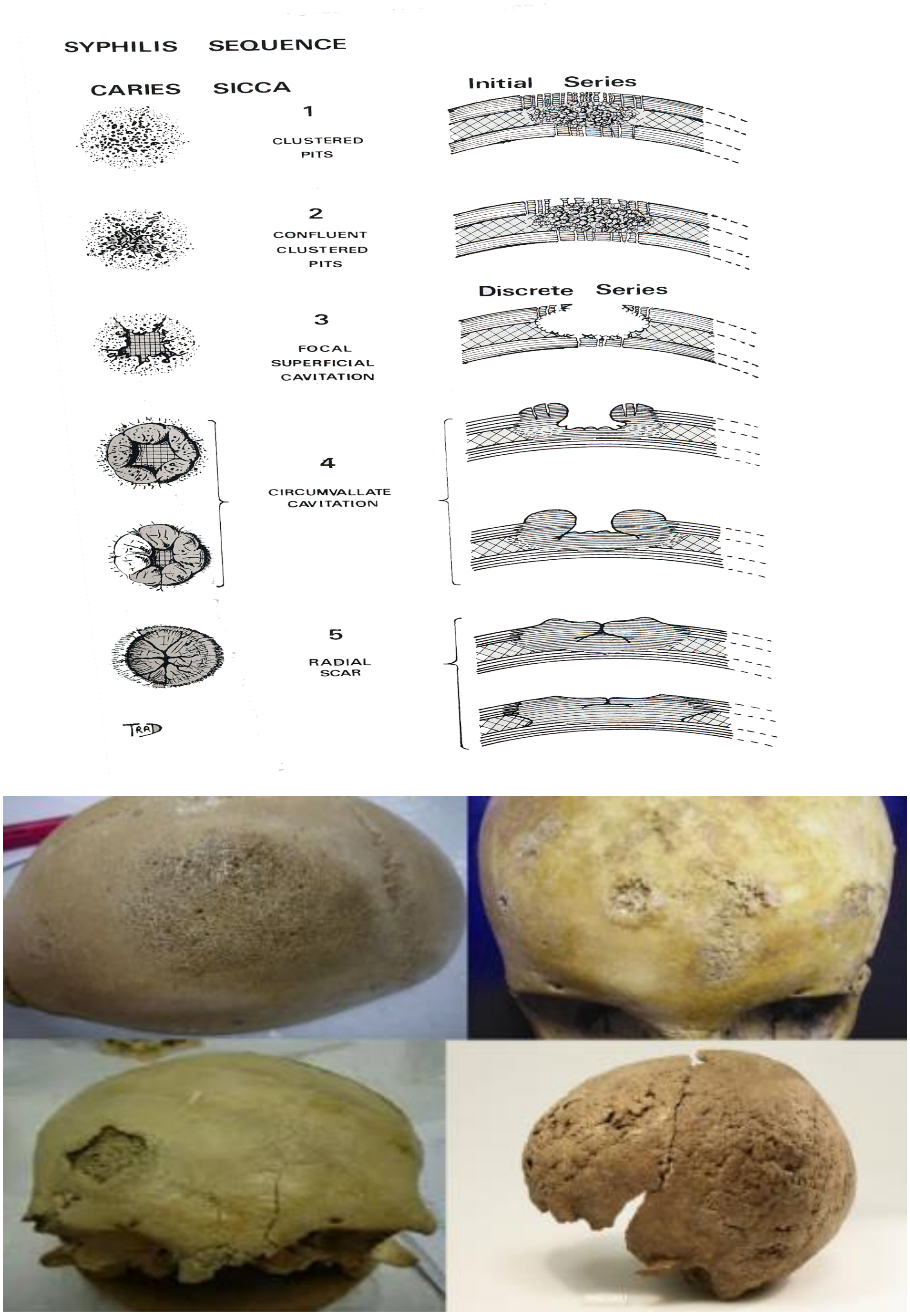


Figure 4.8 (a-b): (a) Schematic representation of various stages of caries sicca cranial lesions in venereal syphilis accompanied by (b) stages in real life specimens (order: top to bottom). Courtesy University of Bradford BARC reference material.

Congenital syphilis is transmitted transplacentally from the infected mother to the foetus during her early acute phase (Storm 2012, 6). Congenital syphilis is characterized by high foetal mortality; it can result in foetal death followed by abortion in the first half of pregnancy, foetal death with delivery of a premature or mature diseased stillborn foetus, or delivery of a living, infected infant which could potentially die in early childhood (Ortner 2003, 289). In premature and full-term stillborn, as well as in actively infected new-born living infants, skeletal changes are always in the form of syphilitic osteochondritis (inflammation of bone or cartilage). The condition affects all the areas of endochondral growth, but is more pronounced in the fast-growing metaphysis (especially distal femur and proximal tibia) and they consist of an accumulation of calcified cartilage resulting in poorly differentiated bone formation. For the diagnosis of congenital syphilis in skeletal remains, the following dental and skeletal features may be pathognomonic: frontal and parietal bossing of cranium; destruction of the nasal bones, collapse of the nasal bridge; Mulberry molars, and Hutchinson's incisors (notches in teeth); enlargement of the clavicular sternal end known as Higoumensaki's sign; epiphyseal cartilage inflammation manifested as enlarged metaphyseal zones in mature bone; gummatous periostitis and osteomyelitis in older children; saber tibia due to non-gummatous periostitis resulting in osteosclerosis with ultimate fusion of the sub-periosteal bone deposits and underlying cortex (Ortner 2003, 289-297; Storm 2012, 6).

4.3.3 Indicators of Skeletal Biomechanical Stress

a. Trauma

Trauma is acute physical injury to living tissue caused by an extrinsic force or mechanism. Most minor injuries, such as cuts, bruises and scratches leave no evidence on the bone. Therefore, trauma in skeletal remains is indicative of injuries of great severity, although certain severe or fatal injuries such as extradural or subarachnoid haemorrhage may also lack osteological manifestations (Roberts and Manchester 1997; Alexis *et al.* 2018). Trauma could manifest upon the skeleton in several ways: (1) partial or complete break or discontinuity in a bone (fracture), (2) dislocation of a bone at a joint, (3) soft tissue injuries resulting in bone tissue formation/calcification (e.g. myositis ossificans traumatica), (4) secondary complications on bones due to disruption in nerve and blood supply leading to osteonecrosis and (5) an artificially induced abnormal shape or contour of bone (Roberts and Manchester 1997, 65; Ortner 2003, 119). Trauma can be accidental or incidental and can be used as a barometer to reflect living environment conditions, socio-economic differences, lifestyle, occupational and behavioural differences, interpersonal violence, and cultural practices. Additionally, the state of healing may be indicative of diet, underlying health, availability of treatment, and occurrence of complications for the populations under study (Roberts and

Manchester 1997; Ortner 2003). For example, accidental injuries predominantly manifest in the long bones and are associated with specific occupations and day-to-day living activities, whereas high levels of physical activity are typically associated with fractures to the lower limb, distal radius, clavicles and ribs (Roberts and Manchester 1997, 73; Dandy and Edwards 1998; Mahoney-Swales 2012). Occupational traumas are the result of repetitive or sudden stress imposed upon the skeleton during an individual's working life (Larsen 1997; Dandy Edwards 1998). For example, spondylolysis (fracture/separation of a neural arch from the vertebral body) or clay-shoveler fracture (separation of spinous process from the vertebral body) are often cited as a consequence of repeated trauma imposed upon the neural arch through bending and lifting (Roberts and Cox 2003, 202). All skeletal traumas, including traumas around the time of death (perimortem), observed in St Hilda's were recorded to determine any prevalence which may be indicative of behaviours or occupations.

Fractures are the most commonly encountered types of trauma in skeletal assemblages, revealing socio-economic information on occupational, lifestyle and behavioural attitudes as well as the underlying health of the studied individuals. Fractures within St Hilda's skeletal assemblage were initially diagnosed on the basis of their morphological appearance. For their accurate diagnosis the following recording criteria from Roberts and Connell (2004, 37) were employed. These criteria focus on the following diagnostic features: (1) which bone and which part of the bone was affected, (2) the type of fracture: spiral, comminuted, transverse, oblique, greenstick, compression (e.g. vertebrae), depressed (e.g. cranial), (3) was the fracture simple or compound, (4) angular or spiral deformity, (5) apposition of the fracture fragments, (6) amount of overlap, (7) evidence of healing, (8) evidence of complications (e.g. non-union, pseudoarthrosis, necrosis), secondary complications such as infection and joint disease) and (9) determining pre- or post-fracture care (Honeycutt 2019). Whenever it was feasible the fractures were classified based on their aetiology into four causative categories: (1) sudden injury, (2) stress fractures, (3) fragility fractures or (4) secondary fractures as pathological complication (Roberts and Manchester 1997). Where the diagnosis of a fracture was uncertain, radiographic examination was utilised. The latter is an essential part of examining fractures as it offers a clear insight into the type of fracture, its extent and degree of healing, cortical realignment and compensatory remodelling within the bone (Boutler *et al.* 1998, 105).

Where dislocations were suspected, the following diagnostic criteria from Roberts and Connell (2004, 37) were employed: (1) which joint was affected and any observed changes to the joint surfaces, including new joint surface development, (2) whether the dislocation was congenital or traumatic in origin and (3) if there were any associated fractures. In the case of soft tissue injuries, the area of bone affected and the link to the muscle (myositis ossificans), tendon/ligament attachments and actions were recorded. In the case of other injuries such as spondylolysis the following diagnostic criteria by Roberts and Connell (2004, 37) were employed: (1) which vertebra was affected, (2) was the injury with or without slipping forward of the vertebra (spondylolisthesis), (3) was it unilateral or bilateral, (4) were there any other associated defects and (5) was there any evidence of healing.

In the case of surgical procedures such as amputations the following criteria by Roberts and Connell (2004, 37) were utilised: (1) affected element, (2) any evidence of healing and (3) any evidence of difference in size of bones affected and not affected (disuse-dystrophy). While in case of trepanation, the following criteria were recorded: (1) type (scrape, saw, bore and saw, gouge, drill), (2) position on the skull, (3) healed or not and (4) any evidence for head injury. Lastly in post-mortem procedures such as craniotomy, the following features were recorded: (1) record angle, position and precision of saw cut (number of attempts) and (2) whether the occipital bone was included in the seat, or merely the frontal and parietal sectors. For sawn long bones, where possible, a distinction was made between possible practice amputation and evidence for anatomical specimen preparation.

b. Joint Disease: Spinal and Extra-spinal

Joint disease can be erosive, proliferative – or both – and can be due to various aetiologies such as mechanical alterations (e.g. osteoarthritis), immune-mediated inflammatory diseases (e.g. septic arthritis) and metabolic diseases (e.g. gouty arthritis) (Roberts and Manchester 1997). Before we proceed to the employed methods for recording joint disease, it is necessary to provide a definition of the joint and, hence, the anatomical regions (articulations) that were assessed for the recording of joint disease. A joint is a structure where two or more bones make contact. Joints allow various movements and different degrees of movements to occur around this point of contact in order to provide support (Schwartz 2007, 6-7). There are several types of joints with synovial joints being the most numerous and the only ones affected by joint disease. Consequently, these points of contact between bones were assessed across each skeleton to determine the type of joint disease affecting the individuals (Figure 4.9). However, as archaeological skeletal remains are frequently affected by preservation issues such as fragmentation and are subject to poor preservation conditions; it is not always feasible to assess all points of contact. In cases, where both articulation points of contact survived, both points of contact were assessed for the presence of an alternation. In cases, however, where only the articular surface of only one bone out of two survived, then only this bone was assessed, provided its surface was not poorly preserved. This method might seem arbitrary, nonetheless, as skeletal remains are frequently far from intact, modifications of methods that were developed on living subjects are necessary.

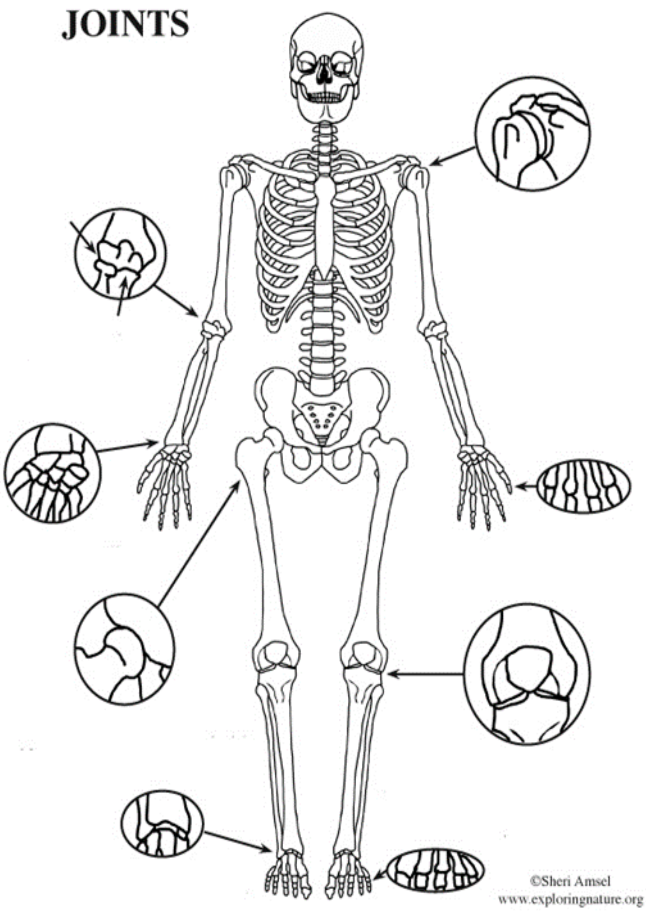


Figure 4.9: Points of contact between bones for assessing joint disease (exploringnature.org).

An inevitable consequence of the ageing process is the gradual degeneration of the joints (Roberts and Manchester 1997, 99). Other possible predisposing factors that result in the degeneration of the joints include, biological sex, hormones, genetics, body size and mass index and intense activity, especially starting at a very young age (Aufderheide and Rodriguez-Martin 2006, 97; Waldron 2009, 45). The general features utilised for the diagnosis of both spinal and extra-spinal degenerative joint diseases in St Hilda's include the following features: (1) osteophytosis and new bone growth on the joint surfaces of the synovial joints and symphyseal articulations between the vertebral bodies, (2) porosity, (3) joint contour change, (4) subchondral cyst formation or (5) eburnation with the latter being pathognomonic for the diagnosis of Osteoarthritis (OA) (Waldron and Rogers 1991). In cases where eburnation was absent the recording of two of the above-stated features was necessary for the diagnosis of OA rather than relying on a single alternation which could have simply been a result of ageing or pathological process (Roberts and Manchester 1997). Where only one diagnostic feature outside eburnation was observed the changes were classified as degenerative joint disease and not as OA. Where OA was established, two further classifications were made: primary, which is idiopathic as one-to-one causal correlations are impossible, or secondary, where an underlying cause could be established (e.g. fractures).

For the accurate recording of the degenerative changes of the appendicular articulations of the shoulder, elbow, wrist and hand, hip, knee, ankle and foot the diagnostic criteria of Waldron and Rogers (1991) described above, were used in combination with the schematic representations provided by Steckel *et al.* (2006, 32-33) and can be seen below (Figure 4.10a). Additionally, reference photos from BARC (2012) were utilised as photographic reference material (Figure 4.10b) to better understand these features.

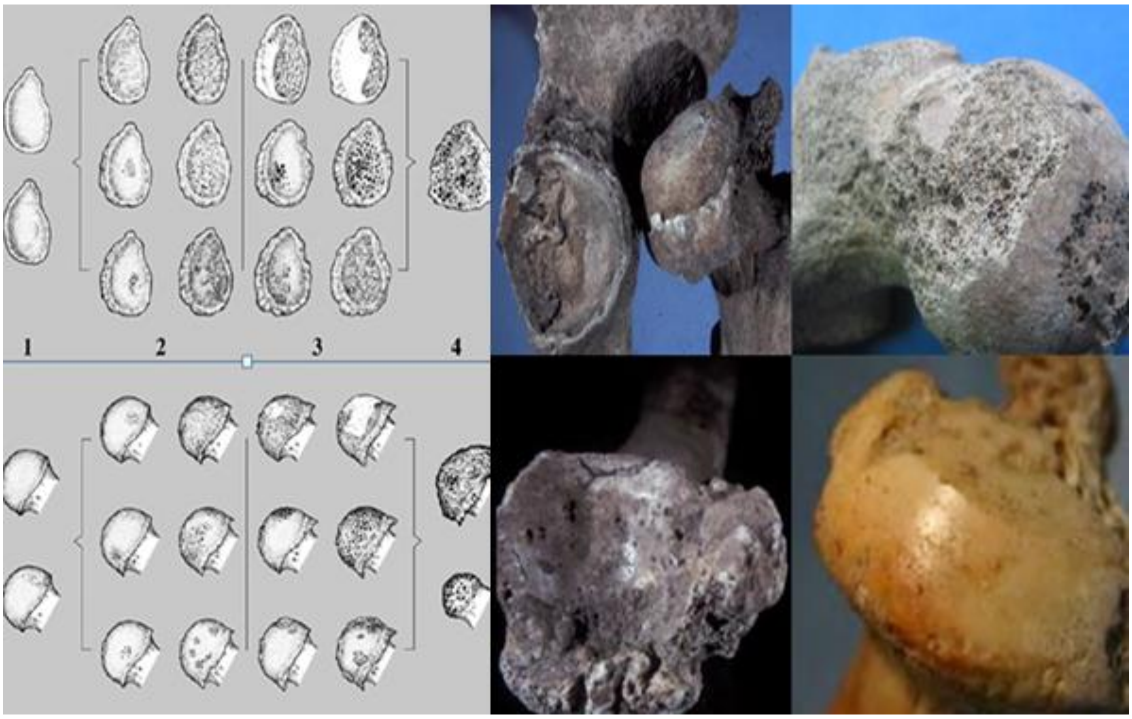


Figure 4.10 (a and b): (a) Schematic drawing of the four stages of appendicular degenerative joint disease adapted from Steckel et al. (2006, 32-33), (b) reference photos of osteophytes, porosity and subchondral cyst formation, joint contour changes and eburnation from the BARC reference collection (order: top to bottom-left to right).

In the case of degenerative joint disease of the vertebrae, however, the recording was less straightforward due to the greater complexity of the anatomy of the vertebrae which exhibit more than one type of joint. As a result, the vertebrae were examined by multiple anatomical regions based on the types of available joints. The vertebrae were systematically assessed for degenerative lesions related to OA of the articular facets, changes of the vertebral body due to degeneration of the intervertebral disc, osteophytes and Schmorl's nodes due to intervertebral disc herniation (Figure 4.11).

The above step was necessary as spinal OA refers only to the degeneration and involvement of the articular facets, leaving the rest of the vertebral joints and especially the vertebral body unexplored. Degenerations at the level of the intervertebral disc are known as spondylosis deformans (SD). SD is a process stimulated by degeneration of the intervertebral disc and thus the intervertebral space between the bodies of opposing vertebrae (Mann and David 2006, 101). SD is seen as marginal osteophytes, ranging from small to large horizontal bridging that bulge and serve to reinforce the centra and occurs as a response to this process on the margins of the superior and inferior surfaces of the vertebral bodies. Here osteophytes originate from the point of attachment of the fibres of the intervertebral disc and tend to develop horizontally, but can turn vertical if sufficiently large. Reactive new bone formation and pitting on the vertebral body surfaces is also typical (Ortner 2003, 555). Thereby, although is not clear from the term, SD is a form of OA of the vertebral body. Cases of marginal osteophytes occurring alone without pitting and densification of the vertebral body surface were considered separately for the purposes of this thesis, but may indicate an early stage of SD. Osteophytes formed without any other features were simply recorded as marginal osteophytes as the small unspecific growths could be due to generic degenerative processes.

Another less specific condition than OA was Schmorl's nodes, the lesions of which are identified as depressions on the end plates of vertebrae and formed as the result of the protrusion of the cartilage of the intervertebral disc through the vertebral body. Many theories have been proposed as possible aetiologies such as physical activity, trauma or genetic predisposition (Buikstra and Ubelaker 1994; Aufderheide and Rodriguez-Martin 2006). As males tend to be more prone to the lesions further analysis was applied in order to see if there were any differences in the prevalence between biological sexes (Diehn *et al.* 2016).

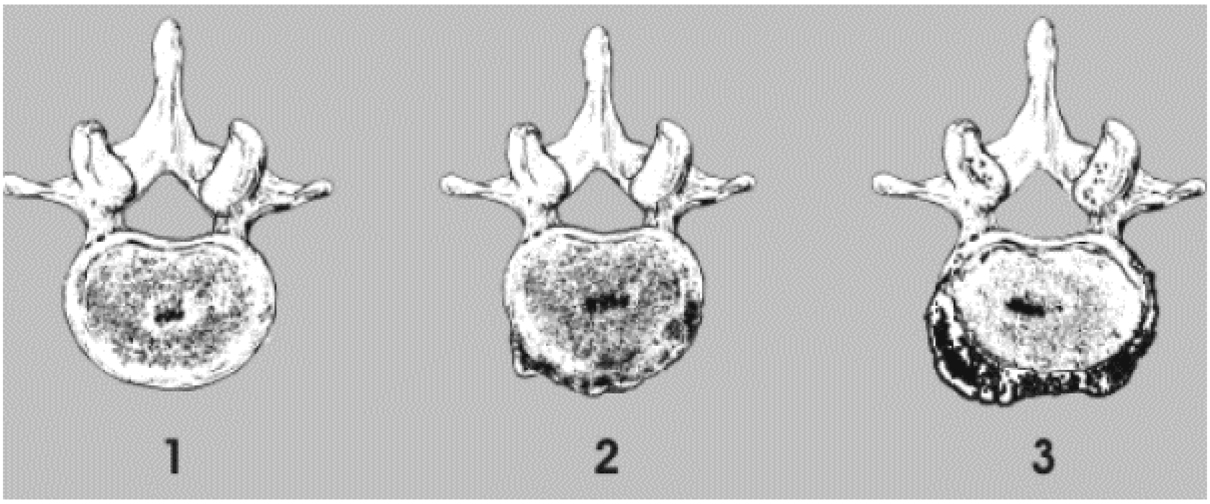


Figure 4.11: Stages of spinal degenerative joint disease adapted from Steckel et al. (2006, 33). The lesions in the middle of the vertebral bodies are Schmorl's nodes at various stages while the lesions around the margins of the vertebral body (2-3) are marginal osteophytes ranging from unspecific osteophytes to SD. Various stages of degenerative changes are also visible in the facet joints.

c. Other Joint Disease: Diffuse Idiopathic Skeletal Hyperostosis (DISH) and Gouty Arthritis (GA)

DISH is a common systemic disorder observed mainly in elderly individuals above the age of sixty-five, with a higher predilection for males than females. Despite the increase of prevalence with age, the condition often remains unrecognised (Verlan *et al.* 2007; Artner *et al.* 2012). DISH is seen as a degenerative non-inflammatory process; however, the aetiology and pathogenesis remain uncertain and sometimes complicated. DISH has been, however, linked to trauma and occupational stress, fluorosis, ankylosing spondylitis, gout, obesity and endocrine disorders associated with obesity such as type II diabetes and hypoparathyroidism, although these conditions are not the causality (Ortner 2003; Kacki and Villotte 2006). Due to its association with conditions of over indulgence and excessive diet the condition is frequently utilised in archaeological populations to identify samples of higher socio-economic backgrounds, where the access of the individuals to food resources was not limited (Jankaouskas 2013; Miles *et al.* 2018).

DISH is characterized by ankylosing formations due to candle-wax-like flowing ossifications along the anterolateral aspect of contiguous vertebral bodies, most commonly the right thoracic area, with retained intervertebral disk space (Roberts and Manchester 1997; Aufderheide and Rodriguez-Martin 2006). Diagnosis of these vertebral manifestations is supported by extra-spinal ossifications of peripheral ligaments, tendons and joint capsule insertion points (entheses) (Rogers and Waldron 1995; Steckel *et al.* 2006). For the definite diagnosis of DISH in skeletal remains, the following changes need to be identified: continuous or discontinuous ossification along the anterolateral aspect of at least four continuous vertebrae (Figure 4.12) and symmetrical and peripheral enthesopathies (>2 mm) involving areas such as the posterior heel, superior patella, or olecranon with the entheseal new bone having a well-defined margin (Steckel *et al.* 2006; Kacki and Villotte 2006). These same features apply to a probable diagnosis of DISH, with exception that two vertebrae are required instead of four.

Figure 4.12: Definite case of DISH with characteristic candlewax appearance on the right side due to ossification. Photo by Kacki and Villotte (2006).

Another condition frequently utilised in archaeological populations to determine socio-economic differences is GA (Gouty Arthritis). This condition is the result of an inflammatory response to the deposition of uric acid in the joints (Roberts and Manchester 1997; Ortner 2003). The possible aetiologies behind the formation of GA include excessive diet, alcohol consumption, dehydration, trauma, systemic illness, unusual physical exercise and hereditary factors (Roberts and Manchester 1997; Aufderheide and Rodriguez-Martin 2006). Gout seldom manifests before forty years of age and shows strong sex predilection for males (Ortner 2003, 583). For the diagnosis of GA in skeletal remains, the following criteria were used: (1) symmetric erosions in articular and periarticular tissues, (2) absence of osteoporosis in the affected joints and (3) erosions accompanied by a Martel Hook which is seen as round 'punched out' erosions with sclerotic margins and overhanging edges. The condition is characterised by no ankylosis of the joints and joint space is retained (Banton 2014, 6). GA has a predilection for the 1st metatarsophalangeal joint, while other locations include the feet, ankles, knees, wrists and hands. In general, it would appear that the condition has a predilection for small rather than large joints (Ortner 2003).

For the diagnosis of GA careful observation is required due to some similarities with Hallux Valgus which also presents bony erosions (Mays 2005, 144). Hallux Valgus or colloquially 'bunion' is defined as a lateral deviation of the greater toe. The principal cause is biomechanical, specifically the habitual use of tight and narrow footwear such as boots that constrict the toes, but it could also be the result of inherited structural defects in the foot as the condition has also been found in individuals who do not wear shoes (Mays 2005; Trujillo-Mederos *et al.* 2012). This process usually develops over many years and is accompanied by changes at the first metatarsophalangeal joint (Trujillo-Mederos *et al.* 2012). Diagnostic criteria include: (1) lateral deviation of the first phalanx accompanied by a medial deviation of the first metatarsal bone with subluxation of the metatarsophalangeal joint, (2) marked sagittal groove (sulcus sagitalis) in the medial margin of the articular surface of the metatarsal head, (3) lateral subluxation of the sesamoid complex and (4) presence of erosions and exostosis in the metatarsal head due to chronic medial deviation of the first metatarsal (Mays 2005; Mafart 2007; Trujillo-Mederos *et al.* 2012). Trujillo-Mederos *et al.* (2012), suggest that the use of Hallux Valgus in archaeological remains could partially determine socio-economic status differences based on the presence or absence of footwear and type of shoes used.

Some other joint diseases that could potentially be encountered within St Hilda's include rheumatoid arthritis (RA), ankylosing spondylitis (AS) and septic arthritis (SA). RA is an autoimmune condition; however, the trigger is unknown, although there are some predisposing factors such as the age of an individual (>40), genetics, hormones, obesity, and smoking (Roberts and Manchester 1997; Ortner 2003). For the diagnosis of RA, Banton's diagnostic criteria (2014, 17) were employed, and include: (1) symmetrical marginal erosions of the small joints of the hands and/or feet, (2) minimal new bone formation, (3) no inflammation of the sacroiliac joint, (4) absence of spinal fusion and (5) sometimes evidence of osteoporosis in affected joints. Ankylosing Spondylitis (AS) is an erosive joint disease, combined with inflammatory enthesopathies. The aetiology of AS is unknown, it is idiopathic although it also has a genetic component. The axial skeleton is mainly affected with smooth spinal fusion (bamboo spine) due to the formation of syndesmophytes (vertical outgrowths of bone due to ossification of annulus fibrosus) and symmetrical fusion of both sacroiliac joints; fusion of ribs may also occur (Roberts and Manchester 1997; Ortner 2003).

Septic Arthritis (SA) usually affects a single joint and is the result of a specific infection (blood borne) such as TB with the hip and knee being the most commonly affected joints in this condition. Alternatively, it may be the result of a direct infection (trauma) due to non-specific organisms such as *Staphylococcus spp.* or *Streptococcus spp*. The condition is characterised by erosion of bone around the edges of the joint, sometimes leading to ankylosis (Roberts and Manchester 1997; Ortner 2003)

4.3.4 Metabolic and Hematopoietic Disorders

Metabolic bone disease may be defined as a disease that causes disruption to normal bone formation, remodelling or mineralisation or a combination of these (Roberts and Manchester 1997; Ortner 2003; Mays 2008). Metabolic diseases are direct indicators of dietary stress, socio-cultural practices, as well as underlying health conditions (Mays 2008; Lewis 2010). Within St Hilda's the following metabolic conditions were considered: rickets and osteomalacia, scurvy, osteoporosis, and dental enamel hypoplasia. Cribra orbitalia and porotic hyperostosis, whilst both being hematopoietic disorders, were also included with the metabolic disorders as they represent bone marrow disturbances.

a. Rickets

Vitamin D plays a major role in calcium homeostasis; in its absence there is reduced absorption of calcium and phosphorus by the small intestine which is necessary for the mineralisation of osteoid, the organic matrix of bone and cartilage (Bouillon and Suda 2014, 1; Carmeliet and Bouillon 2018, 13). Failure to obtain this vitamin in childhood results in the formation of rickets which can be classified as either active or residual (Roberts and Manchester 1997; Ortner 2008; Brickley and Ives 2008; Mays 2008). Skeletal changes in rickets are induced when walking is commenced (Ortner 2008).

The classic skeletal changes for the diagnosis of rickets include bowing of the major weight-bearing bones (femur and tibiae and forearm), flaring and swelling of the distal metaphysis, coxa vara where the angle of the femoral neck appears diminished, and in case of healed rickets, fractures of thickening. Some other features include porosity of the epiphyseal plates (growth plates), new bone formation, enlargement of costochondral rib junction, contracted pelvis, porosity of cranial bones, delayed eruption of deciduous and permanent teeth, and dental enamel hypoplasia as evidence of a stressful episode (Brickley and Ives 2008, 103-105). Evidence of residual rickets is indicative that the individual overcame severe episode(s) of deficiency in childhood; however, the condition left a permanent record in their skeleton especially on long bones, leaving gross deformities particularly of the legs. The most frequent expression of residual rickets is medial-lateral bending in the tibiae, but also anterior-posterior bending of the femora (Brickley *et al.* 2010). The femur is frequently buttressed by a bar on the concave surface (Waldron 2009, 129). A number of features visible in active rickets will be still visible in a skeleton who overcame the active stage(s) (Veselka 2012).

The development of vitamin D deficiency after the completion of endochondral growth is termed osteomalacia, and is characterised by brittle bones that trigger the appearance of the following pathological alterations: pseudo-fractures (primarily on the ribs, scapulae, pelvis, and long bones), collapse of the vertebral bodies, pelvic deformities, and some long bone bending deformities (Ives and Brickley, 2008; Newman 2015). In cases of osteomalacia, the result of demineralisation is mostly manifested as collapse and deformity, for example in the cases of the vertebrae under weight-bearing stress, and the deformity of the pelvis, and less as bending of the bone which is characteristic of rickets (Roberts and Manchester 1997).

The identification of rickets and osteomalacia in St Hilda's sample can be used as an indicator to determine the prevailed outdoor conditions such as sun-blocking smog that kept a good portion of sunlight from reaching an individual's skin; socio-economic circumstances such as employment of working-class children that forced many of them to stay indoors (e.g. in factories or workshops) from a young age; and the childrearing practices of the period (e.g. swaddling and keeping of children indoors for prolonged periods) (Brickley and Ives 2008; Mays 2008). Further detailed analysis into the prevalence of active and residual rickets within different population sectors such as adults and non-adults and males and females may provide information on the different conditions encountered by different demographic groups.

b. Scurvy

Scurvy is the outcome of prolonged vitamin C deficiency. Vitamin C is involved in the synthesis of collagen, the structural protein of connective tissues, as well as bone. The newly formed bone may appear osteopenic in deficient individuals. Vitamin C deficiency also causes weakening of the blood vessels walls, and subsequent haemorrhage (Aufderheide and Rodrieguez-Martin 1998, 310-312; Mays 2008, 223). When the haemorrhage occurs adjacent to a bone it may initiate an osteological reaction and this is how the deficiency is diagnosed

(Aufderheide and Rodrieguez-Martin 1998, 31; Mays 2008, 223). The deficiency is osteologically identified as porosity and new bone formation, induced by haemorrhaging blood vessels in areas adjacent to bones in which frequent movement occurs (e.g. joints, eye orbits, the mandible and maxilla) (Ortner and Ericksen, 1997; Newman 2016). Other affected areas include the cranial bones, with the sphenoid being the primary focus, and other post-cranial bones such as the scapula. Ante-mortem tooth loss can also be another feature due to prolonged bleeding of the gums. Scorbutic lesions are generally more prominent and relatively 'easier' to diagnose in infants and young children. In adults, skeletal scorbutic lesions tend to be relatively minor and non-specific, making the diagnosis rather difficult. As already described, bleeding and swelling of the gums due to scurvy results in ante-mortem tooth loss and inflammatory changes of the alveolar bone (Ortner 2003, 387). However, the use of ante-mortem tooth loss and periodontal disease, especially in adults, to infer the presence of the deficiency can be problematic due to the association of these dental conditions with a complex array of other conditions and old age (Hillson 2002; Mays 2008).

Extreme care should be taken when using cranial lesions of the orbits to diagnose scurvy as these lesions can be found in other conditions such as anaemia induced by infections (e.g. gastrointestinal) (Ortner and Ericksen 1997; Zuckerman *et al.* 2014). Overlapping gross lesion expressions have frequently led to an over diagnosis of anaemia and an under diagnosis of scurvy (Zuckerman *et al.* 2014, 27). Lesions of the orbits are subperiosteal hematomas of multiple aetiologies (e.g. scurvy, anaemia, micro-trauma) (Walker *et al.* 2009). In the absence of marrow hyperplasia of the orbits (cribra orbitalia) the diagnosis of scurvy is easier; the problems however arise when the lesions are porous in nature and healed making the lesions indistinguishable (Wapler *et al.* 2004). This is not to say that individuals could not have suffered from multiple deficiencies or conditions such as cribra orbitalia due to both anaemia and scurvy. However, in the case of scurvy its co-occurrence with cribra orbitalia should not come as a surprise due to the documented association between scurvy and anaemia, as vitamin C deficiency induced haemorrhaging reduces the capacity for iron absorption (Ortner 2003; Wapler *et al.* 2004).

c. Osteoporosis

Osteoporosis is the most common cause behind osteopenia observed in contemporary populations arising from an imbalance between bone resorption and bone formation; however, osteopenia does not always lead to porous bones (Ortner 2003, 411). Ageing and general factors such as diet, lack of exercise, sex, circulating sex hormones, prolonged lactation and a high number of pregnancies have been implicated in the occurrence of osteoporosis (Roberts and Manchester 1997). Widespread osteoporosis may also be secondary in other conditions that affect the formation and resorption of bone such as osteogenesis imperfecta. Osteoporosis can also be localised instead of diffuse, arising as the result of the removal of mechanical stresses due to disuse, pain, trauma, infection or disturbed intervention (Ortner 2003, 412). As osteoporosis is a disease associated with ageing, it usually does not manifest before the fifth decade in both sexes, but is more frequent and severe in females. This partially reflects the hormonal imbalance in females which accompanies menopause with the sharp drop in oestrogen as opposed to the more gradual decrease of testosterone in ageing males (Ortner 2003; Mays 2008).

For the diagnosis of osteoporosis, a series of features were used including diminished bone mass and density (osteopenia) and microarchitectural deterioration, one or more fractures, especially compression fractures of the vertebrae (codfish vertebrae), diminished trabecular structure of cancellous bone, and thinning of cortical bone from the endosteal surface (Mays 2008, 227). These features were also combined with general considerations of age and sex of the individuals. Diminished bone mass and density are pathognomonic for the diagnosis of the condition, which is disproportionally allocated in the skeleton because the greatest physiological turnover of bone occurs in cancellous bone. As a result, bones rich in spongiosa such as vertebrae, ribs, sternum and pelvis, were first examined, as they are the most frequently affected by osteoporosis; without that meaning that long bones cannot be affected. The most severe skeletal changes are usually observed in the vertebrae, where the normal density of the vertical and transverse trabecular becomes reduced. Compression fractures resulting in flattened or wedged vertebrae may be commonly seen, frequently resulting in secondary kyphosis. The rest of the non-long bones affected also exhibit pronounced cortical thinning, with rib fractures being frequently common as well. Long bones are less affected due to their much slower turnover, with the resorption of the cortex identified in two manifested patterns; endosteal resorption, which leads to increased diameter of the medullary cavity and intracortical resorption, resulting in increasing prevalence of unfilled or partially filled spaces. Of the long bones, the femoral neck with its trabecular structure seems to take most of the biomechanical loading, showing the most characteristic changes, with secondary fractures being commonplace (Ortner 2003, 41-412). Where only diminished bone mass was observed without any other features, the cases were diagnosed with the generic condition of osteopenia. Osteopenia, however, can be caused by a series of abnormalities including not only osteoporosis but also osteomalacia (and rickets), severe malnutrition, hyperparathyroidism and cancer (Ortner 2003, 410).

d. Porotic Hyperostosis (PH) and Cribra Orbitalia (CO)

PH and CO are lesions identified as porosity on the diplöe of the skull and on the orbital sockets respectively (Angel 1966; Stuart-Macadam 1985; 1987a, b; 1992; Lewis 2002a). However, the two are not always causally related (Cole and Waldron 2019). The most commonly reported origin of these lesions is iron deficiency anaemia in childhood that results in marrow hyperplasia to stimulate the red blood cells production, while the state of healing may be indicative of ongoing stress in adulthood (Stuart-Macadam 1992; Walker *et al.* 2009). Skeletal and radiographic data suggest that active lesions seen in young individuals represent a state of acute anaemia at the time of death (Keenleyside & Panayotova 2006).

Acquired anaemias, genetic anaemias, depleted maternal B12 reserves, nutrient loss through gastrointestinal infections due to unhygienic living environments, malaria and conditions associated with vitamin deficiencies (e.g. scurvy, rickets) could be possible aetiologies (Wapler *et al.* 2004*;* Walker *et al.* 2009, 119; White 2018, 1). Unfortunately, the occurring bone changes are the same for both genetic and acquired types of anaemia, a fact that makes it difficult to identify the cause of each type in archaeological remains but the high occurrence of lesions suggests that it is impossible they were caused by genetic iron deficiency alone (El-Najjar *et al.* 1976; Hengen 1971; Roberts and Manchester 1995; Blom *et. al.* 2005; Walker *et. al.* 2009). This is because it would be unlikely for so many people in the past to suffer from genetic anaemia, but this does not mean that genetic anaemia did not occur in some of the identified cases (Stuart-Macadam 1992). Consequently, this frequent occurrence of the lesions combined with the fact that genetic anaemia is rare in modern day Europe suggests that the lesions were a consequence of acquired anaemias, regardless of the underlying aetiology (White and Folkens 2007). Yet, it is important to mention that healed lesions indicate only episodes of acquired anaemia. Lesions caused by genetic diseases remain unhealed until the end of the individual's life (Stuart-Macadam 1992; White and Folkens 2007).

Within this thesis, the cranial vault and orbital roof were assessed macroscopically for the presence of CO and PH, and lesions were recorded for both non-adult and adult skeletons. At the same time, it was observed whether or not the affected individuals also exhibited Dental Enamel Hypoplasia (section e) as there is a significant association between them (Keenleyside and Panayotova 2006). If CO lesions were present, they were assigned to a morphological classification system of two types of lesions by Steckel *et al.* (2006, 13-16). Type 1 lesions were 'capillary like impressions' and Type 2 were 'scattered fine foramina' with a tendency to cluster together (Figure 4.13a). Caution was, however, exerted in the diagnosis of CO because simple porosity on the orbital roof, with no convex change from the normal concave curvature is a normal developmental variation, probably the result of the interaction between bone and vascular development (Cole and Waldron 2019, 620). In the case of PH, if the lesions were present, they were assigned to two types of classification by Steckel *et al.* (2006, 13-16). Type 1: 'Presence of slight pitting or severe parietal porosity' and Type 2: 'Gross parietal lesion with excessive expansion and exposed diplöe' (Figure 4.13b). In the case of PH, the changes are most frequently seen on the squamosal portions of the occipital and the parietal bosses, and less commonly on the frontal, temporal, sphenoid, and maxilla.

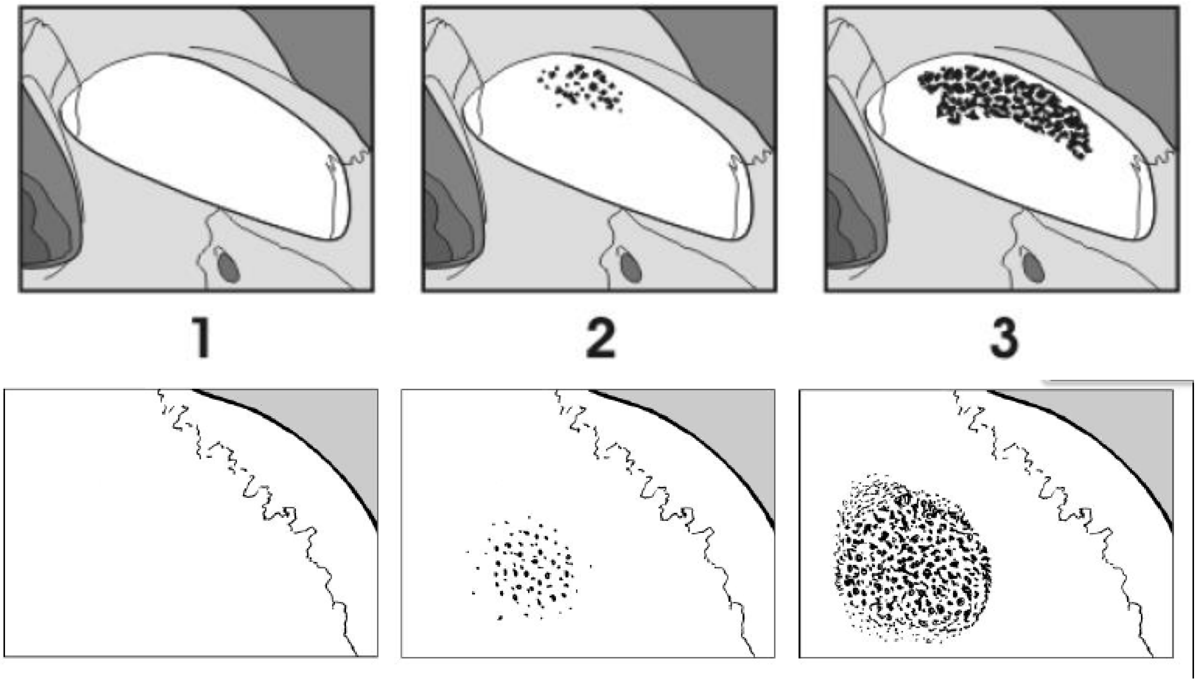


Figure 4.13a and b: Stages of cribra orbitalia and porotic hyperostosis adapted from Steckel et al. classification standards (2006, 13-14) (order: top to bottom).

e. Dental Enamel Hypoplasia (DEH)

Growth disturbances of enamel formation in developing teeth provide a permanent record of systemic physiological stress experienced in early life. Some of the cited stressors behind this growth interruption include episodes of disease (e.g. infections), general undernourishment and the resulting physical stress from it, nutritional deficiencies (e.g. Vitamin D) and factors associated with weaning (Hillson 2002; Steckel *et al.* 2006; Ogden *et al.* 2007; McIntyre 2013). Thinning of the enamel caused by these interruptions or slowing of the normal deposition of enamel during crown formation is responsible for the lesions; they are often seen as localised transverse lines, pits, or grooves on the enamel surface around the circumference of the crown, and visible on the buccal, lingual, mesial and distal surfaces (Goodman and Rose 1990; Hillson 2002; Mays 1998). Unlike bone, enamel does not remodel during the lifespan. Thus, it presents a permanent record of childhood stress experienced in the first eight or nine years of life or up to approximately thirteen years if the third molar is incorporated into the analysis (Roberts and Manchester 1997; Hillson 2002).

For DEH, the recording standards as outlined by Steckel *et al.* (2006, 13) were employed (Figure 4.14). The age at which the growth disruption occurred was estimated from the position of the band of defective enamel on the crown (Goodman and Rose 1991; Mays 1998;

Reid and Dean 2000; Primeau 2015). Determining the age of disruption of enamel formation allows the identification of the developmental stages at which individuals experienced the greatest levels of physiological stress. For the adult skeletons, the sex of the individual was taken into consideration to see if any patterns could be inferred about the health of males and females. Due to significant association of DEH with CO, rickets, hereditary vitamin D-dependent rickets and scurvy, individuals with DEH were also examined for the presence of these conditions (Nikiforuk and Fraser 1981; Hillson 2002; Facchini *et al.* 2004; cited in Keenleyside and Panayotova, 2006). Their examination, in a combination with other skeletal stress indicators, aimed for a successful interpretation of the causative factors behind the formation of these dental defects in the studied individuals. However, one-to-one correlations were frequently impossible; for that reason, the lesions were interpreted as evidence of interplay between dietary and non-dietary factors, depending on each individual case (McIntyre 2013)

To calculate the prevalence of DEH the number of enamel-hypoplastic defects on all the available incisors and canines were recorded. In order to prevent misidentification of perikymata (transverse lines of growth resulting from normal enamel apposition) or enamel defects resulting from localised trauma as dental enamel hypoplasias, only transverse lines forming a continuous band around the tooth crown and into which the tip of a dental probe can be inserted were recorded (Mahoney-Swales 2012, 125). Worn teeth, with no surviving occlusal enamel, were excluded from DEH age formation calculations. The lesions were recorded as present or absent, with present including one or more hypoplastic lines present on the examined tooth.

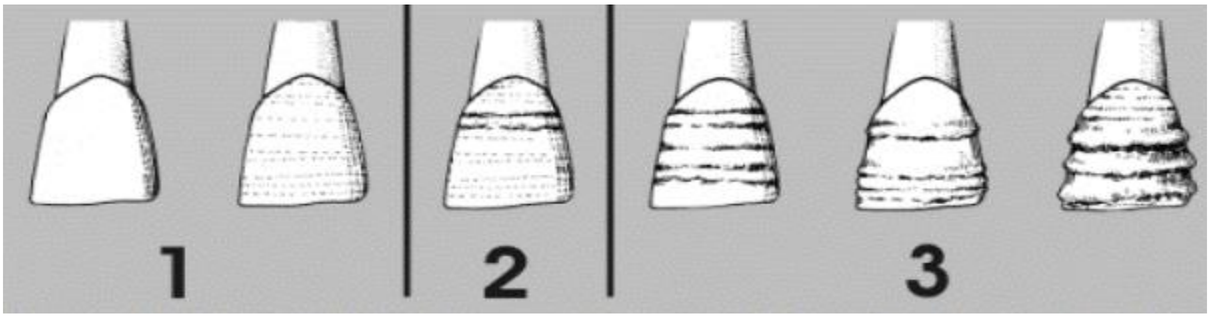


Figure 4.14: Stages of dental enamel hypoplasia adapted from Steckel et al. (2006, 13-14) standards.

4.3.5 Dental Disease

Dental health is intrinsically linked to systemic and general health status (Hillson 2002). Thereby, through the recording of dental disease in skeletal remains, it is possible to quantify dental health levels, providing valuable evidence not only on dental as well as general and systemic health, but also on oral hygiene, diet, food preparation techniques and cultural behaviours of the past populations (Goodman and Rose 1990; Roberts and Manchester 1997; Hillson 2002; Bekvalac 2010). Two types of dental pathologies were observed in St Hilda's assemblage: infectious diseases such as calculus, dental caries, periodontal disease and dental abscesses, and degenerative diseases such as ante-mortem tooth loss and dental wear (Roberts and Manchester 1997, 44-45). Infectious conditions are most informative about oral health and diet, whereas degenerative conditions are more informative about activity and age-related changes to the occlusal surface of the teeth. Infectious and degenerative dental diseases, however, are often mutually dependent processes making one-to-one correlations impossible. Despite this limitation, their use in studying the health of past populations is nonetheless informative (Roberts and Manchester 1997, 44-5).

a. Calculus

Dental plaque accumulates on the tooth surface during lifespan and is mineralised by components of saliva to form dental calculus (Lieverse 1999; Hillson 2002). Dental plaque consists of microorganisms such as bacteria, which accumulate in the mouth, emended in a matrix partially composed by the organisms themselves and partially derived by proteins in the saliva (Hillson 2002). Initiation of mineralisation is linked to the extent of plaque, and thus also to those contributory factors that lead to increased plaque accumulation such as poor oral hygiene, oral environment, a diet high in carbohydrate consumption, fluid consumption etc. (Lieverse 1999, 224-225; Hillson 2002, 259). Consequently, the aetiology of calculus formation is multifactorial and for that reason the mechanism behind its formation remains not fully understood thus far (Radini *et al.* 2017).

It is generally accepted that calculus formation is favoured by an alkaline oral environment, which increases the precipitation of minerals from the surrounding oral fluids (saliva and gingival crevice fluid) (Lieverse 1999; Hillson 2002; McIntyre 2013). It is also accepted that diets high in protein increase the alkalinity of the oral environment, thus contributing to the formation of dental calculus (Hillson 2002). However, little clinical research has been conducted on living humans, but studies on living animals such as rats have suggested that 'diets high in protein, carbohydrates and fat are conducive to calculus formation;' (Lieverse 1999, 224). While the same studies have found that high consumption of water resulted in decreased calculus formation (Lieverse 1999, 224).

Two forms of calculus are generally identified, supra- and sub-gingival, depending on whether the calculus is on the crown of the tooth or the exposed roots (Roberts and Manchester 1997; Hillson 2002; Waldron 2009). Calculus tends to develop most commonly on the lingual side of lower incisors and buccal side of upper molars, a common pattern that is also observed in archaeological populations (Roberts and Manchester 1997). The frequency and extent of calculus deposits is an age-increasing process which can lead to further complications. For instance, in extreme cases calculus deposits can lead to periodontal disease where alveolar bone inflammation affects the bone and can lead to subsequent tooth loss in senior adults (Roberts and Manchester 1997; Hillson 2002). Therefore, the condition is frequently accompanied by further dental complications, especially in the elderly, such as tooth loss. Within St Hilda's assemblage, the condition was simply recorded as present or absent and the extent of dental calculus formation was recorded using the diagrams presented in Brothwell (1981) (Figure 4.15). For the statistical analysis these categories were limited to 'absent' or 'present'.

O. Unrecordable

1. No calculus

2. Slight calculus build-up

3. Medium calculus build-up

4. Considerable calculus build-up

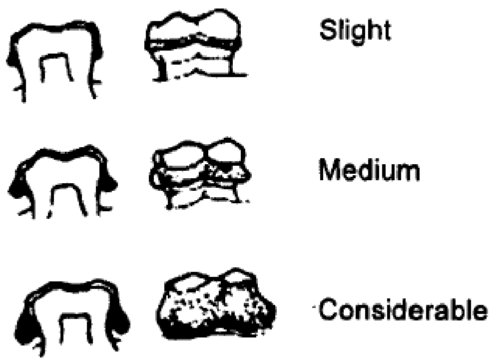


Figure 4:15: Levels of calculus accumulation accompanied by schematic representations adapted from Brothwell's (1981, 153) standards.

b. Dental Caries

Dental caries is a disease process characterised by progressive focal demineralisation of enamel or dentine, the lesions are caused by bacterial decay, and therefore infectious in nature and transmittable (White and Folekns 2005, 329; Humphrey *et al.* 2014). Mutant groups of microorganisms of the genus *streptococcus* such as *mutants* and *sorbinus* are the aetiological agents (Hillson 2002). The process of demineralisation of dental hard tissues is caused by acids produced by the bacteria due to fermentation of dietary carbohydrates, ultimately leading to formation of a cavity in the crown or root surface (Hillson 2002; Steckel *et al.* 2006). Several bacterial mechanisms from this process could contribute to the pathogenesis of periodontal disease. In periodontal disease induced by bacteria, a good immune response may be beneficial (Ali *et al.* 2011; Nair *et al.* 2014; Strauss *et al.* 2019).

The aetiopathogenesis of caries, however, is complex and therefore it is impossible to make one-one correlations, but diet tends to be a central factor in its cause. Typically, populations with high fermentable carbohydrate consumption (e.g. sugars and starches) express the highest prevalence of carious lesions, therefore, increased prevalence of the lesions may be indicative of diets rich in these foods (Steckel *et al.* 2006; Humphrey *et al.* 2014). Other factors that have an impact on the formation of the lesions include oral hygiene, trace elements in food and water supply (e.g. fluoride), pathogenic factors (e.g. bacteria), and the shape and structure of the teeth. Other predisposing factors may include enamel composition and structure, tooth morphology and position, and saliva composition (Roberts and Manchester 1997; Hillson 2002). Clinical studies have suggested that biological sex differences may also exist, with females being more frequently affected than males. Factors such as earlier eruption of teeth, hence longer exposure to the cariogenic oral environment, easier access to food supplies and frequent snacking during food preparation, as well as hormonal related changes due to pregnancy are three of the possible aetiologies that make females more prone to this condition (Roberts and Manchester 1997; Lukacs and Largaespada 2006). However, in archaeological populations this pattern is not always present.

The lesions are seen as cavities on the tooth crown and according to the stage of their severity can range from white opaque areas and brown discoloration spots to clearly observable cavities (Hillson 2002). Ante-mortem tooth loss might be one of the further complications of extensive carious lesions (Roberts and Manchester 1997; Hillson 2002; Waldron 2009). In St Hilda's, for the needs of statistical analysis the carious lesions were recorded as 'absent' or 'present'. This analytical step was necessary in order to quantify the prevalence rates and enable comparisons across sites. A brief description, however, was provided with each individual and the lesions were described as 'small' (up to 2mm), 'medium' (up to 50% of a single surface) or 'large' (over 50% of a single surface) (Lukacs 1989, 267) (Figure 4.16). This brief description was provided in order to determine the degree of tooth damage and subsequently assess the level of oral hygiene and type of diet.

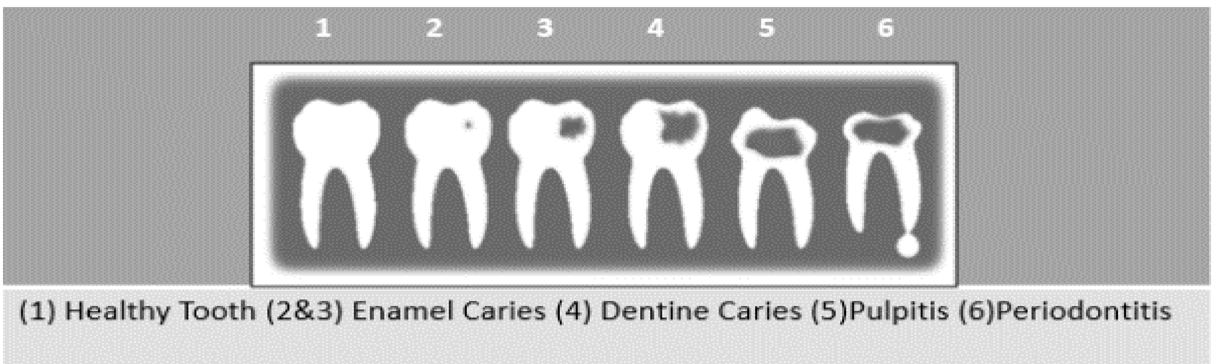


Figure 4.16: Carious lesions, different degrees of severity accompanied by schematic representations.

c. Dental Wear (DW)

Dental wear is a degenerative disease process occurring on the dental hard tissues throughout life and is the result of attrition, abrasion and erosion. Attrition (tooth-tooth contact) is the result of masticatory forces and parafunctional activities such as bruxism (the grinding of teeth in sleep). Attrition is identified as wear of the incisal and occlusal surfaces, whilst abrasion (tooth-body-tooth contact) is the result of external bodies used between the teeth resulting from processes such as pipe smoking, nail biting or use of the teeth as vices; the lesions are identified as shallow concave or wedged shaped notches. Erosion is the loss of dental hard tissues by chemical action not involving bacteria. There are two sources of chemical action both involving erosion by acids, intrinsic or extrinsic. The intrinsic sources originate in the stomach and are associated with acid reflux and regurgitation, or eating disorders such as anorexia and bulimia nervosa. Extrinsic sources are acids contained in dietary components, such as fruit, fruit juices and carbonated soft drinks (Lopez-Frias *et al.*2012, 48). Consequently, whilst dental wear can be age related it is not always, as it can also depend on the lifestyle, type of diet, culinary practices, food processing, occupational and domestic activities, as well as long standing social practices which create stress upon the teeth (Boston *et al.* 2002). Thus, the recording of the lesions in past populations can be very informative about their lives. For the recording of DW in St Hilda's assemblage, the categorical standards for epidemiological studies pioneered by Bardsley *et al.* (2004) and simplified by Lopez-Frias *et al.* (2012) were employed (Table 4.4). Then the categories were collapsed to 'present' or 'absent' for easier statistical calibration. As increasing age-at-death could increase DW prevalence due to long-term use of teeth, in cases of older individuals with severe DW, DW was also compared to the mean age assigned by the pubic symphysis and auricular surface (Steckel *et al* 2006; McIntyre 2013: Swales-Mahoney 2012).

Score	Criteria
0	No wear into dentine
1	Dentine just visible (including cupping) or dentine exposed
2	

3	Dentine exposure greater than ⅓ of surface
	Exposure of pulp or secondary dentine

Table 4.4: Stages of dental wear by Lopez-Frias et al. (2012, e52) classification system

d. Periodontal Disease (PD): Periodontitis

PD was already encountered as a possible complication to calculus deposits due to bacteria accumulation. The deposits irritate the dental tissues resulting in inflammation of the periodontal tissues that surround and support the teeth, including the alveolar bone (Hillson 2002, 260). PD is extremely common and in its mildest form during life is manifest as gingivitis, which implies involvement of gingivae only. However, if gingivitis is left untreated it can spread from the gums to the rest of the periodontal tissues, including the alveolar bone, resulting in periodontitis (Hillson 2002, 262). Periodontitis can cause weakening of the periodontal ligament and resorption of the alveolar bone initiated by soft tissue pockets formed between the gums and the tooth roots, which lead to loosening of the tooth and subsequent tooth loss (Roberts and Manchester 1997, 50; Waldron 2009, 240). Both inflammatory conditions are caused by pathogenic bacteria in the dental plaque; however, bacteria themselves are not a sufficient cause - a susceptible host, due to lowered immune response, is also required (Ali *et al.* 2011; Nair *et. al.* 2014).

Periodontitis upon the skeleton is recognised as either horizontal resorption of the alveolar bone or vertical irregular resorption with pockets or wells expanding to the cancellous bone of the jaws (White and Folkens 2005, 330; Hillson 2002, 264-265; Waldron 2009, 240). Evidence of inflammation, remodelling including pitting, new bone formation, and formation of a cylindrical cavity around the roots of affected teeth may also be observed (Waldron 2009). The condition was recorded as ‘present’ or ‘absent’ along with whether it was horizontally or vertically developed (Figure 4.17 a-b).

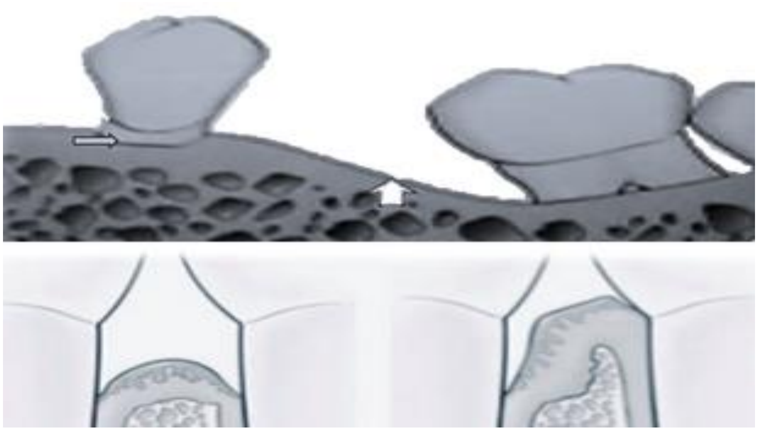


Figure 4.17 (a-b): Two types of alveolar bone lowering in skeletal remains adapted from Hillson (2002) standards. First arrow represents the horizontal type and second the vertical type. Drawings on the bottom are close-ups of the horizontal and vertical type respectively (order: left to right).

e. Ante-mortem Tooth Loss (AMTL)

The loss of permanent dentition before death is the final result of several disease processes and their relationship is not always straightforward (Boston *et al.* 2008; Gibson et al. 2009). Teeth may be lost for various reasons, including periodontal disease, dental caries, heavy dental wear with ageing, extraction, trauma or scurvy, but periodontal diseases accounts for the majority of the cases (Steckel *et al.* 2006, 15; Waldron 2009, 239). AMTL is generally considered a degenerative disease where the main contributory factors are old age and poor oral hygiene (Boston *et al.* 2008). Thus, AMTL does not only provide information about periodontal disease, but also the effects of oral hygiene, dietary deficiencies, and masseteric activity, which subsequently provide information about the type of diet, ageing, occupation, cultural practices, and trauma. In the case of AMTL, the condition is easily recognisable as the tooth socket(s) of the missing tooth exhibit evidence of remodelling (resorption) as opposed to post-mortem loss, where there is no evidence of remodelling in the tooth socket. The number of missing teeth can be used to assess the severity of the condition. In many cases of AMTL and also in cases of older edentulous individuals, resorption is accompanied with bone remodelling which fills the empty tooth socket, showing that the tooth was lost well before the time of death.

f. Dental Abscess

A chronic dental abscess is the final product of an inflammatory process, a suppurative collection associated with the structures surrounding the teeth, seen as dentoalveolar voids in skeletal remains (Ogden 2008b). The development of a dental abscess, however, may be initiated by many causative factors such as bacteria that may enter the pulp cavity through progressive caries, tooth wear or trauma as well as tooth surgery (Roberts and Manchester 1997, 50; Ogden 2008b, 51). An abscess may also develop if an individual develops periodontal disease and a periodontal pocket is formed by the accumulation of bacteria within the pulp cavity, and infection tracks down the root apex (Roberts and Manchester 1997, 50; Boston *et al.* 2002, 65). This is initiated by dental plaque accumulation, which can displace the soft tissue surrounding the tooth creating the periodontal pocket. The resultant pus drains from the infected area through the alveolar bone forming a cavity near to the alveolar margin (Roberts and Manchester 1997). Abscesses can be life threatening, or can diminish resistance to disease and can affect dietary intake even more than caries (Steckel *et al.* 2006, 136).

Many of the palaeopathological periapical voids diagnosed as dental abscesses, are actually symptomless periapical granulomas or cysts (Dias and Tayles 1997; Ogden 2008 b: Mahoney-Swales 2012). A periapical granuloma is a soft tissue sphere primarily of epithelial composition filled with inflammatory cells and is a response to chronic infection, frequently forming a bony cavity due to osteoclastic activity (Ogden 2008b). A periapical granuloma can frequently develop into a cyst whereby the granulation tissue of the former is replaced by fluid surrounded by a layer of epithelial tissue lining the walls of the cavity (Dias and Tayles 1997, 549; Ogden 2008b). In order to diagnose a granuloma, the periapical void should usually be 2-3mm in diameter and smoothly rounded in shape, whereas a void larger than 3mm is more likely to be internally developing cyst (Dias and Tayles 1997, 551; Dias *et al.* 2007, 626). Periapical cysts are characterised by lining of epithelial cells and have porous walls which enable a blood supply. Porosity of the lining of the void is also observed in granulomas, but less so in cysts (Ogden 2008b, 54). A chronic abscess on the other hand, lacks of the epithelial composition lining and has clearly defined rounded or thickened margins due to remodelling and often exhibits a halo of new bone, whereas both granuloma and cyst often exhibit sharp edges around the cavity exposed by taphonomic damage to the overlying eggshell thickness of bone (Ogden 2008b, 53-54).

An increased number of periapical voids within a population may indicate a lower immune response which may result from various environmental factors such as nutrition and health

(Dias and Tyles 1997, 548). Therefore, the lesions can be used to assess the levels of dental health and environmental stressors. Most of the comparative sites utilised in this research did not differentiate between the different forms of periapical voids as most of the reports were written prior to 2007, when differentiation standards started to be established (Mahoney-Swales 2012, 136). Therefore, it is probable that many periapical voids have been recorded as dental abscesses. Within the case study, periapical granulomas and cysts were distinguished from chronic abscess voids during recording using the diagnostic features described above (Figure 4.18). In order to enable comparative analysis, however, and since they all represent immune responses to infection, they all had to be grouped together under the description 'dental abscess'.

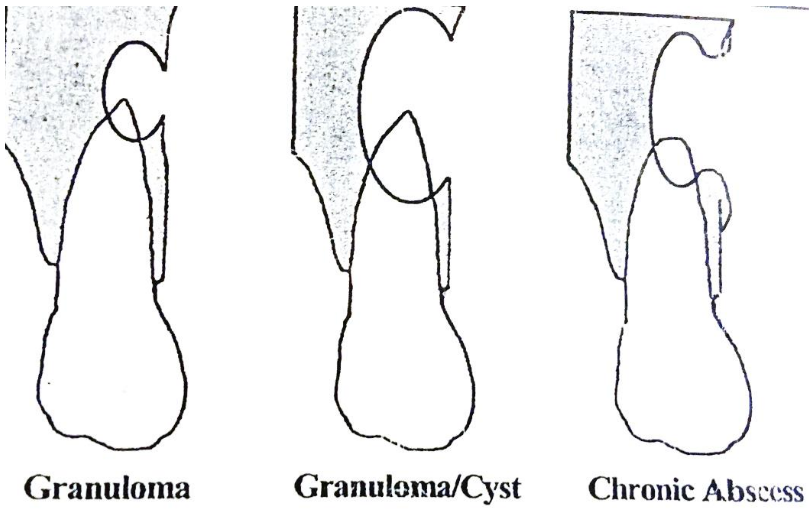


Figure 4.18: Schematic drawing of the three types of dental voids adapted from Ogden (2008b, 54).

4.4 Minimum Number of St Hilda's Individuals for Charnel and Disarticulated Material

The estimation of the minimum number of individuals (MNI) was based on the highest number of an individual bone that represented the most frequently counted skeletal element in the charnel and disarticulated material (Ringrose 1993; Lyman 1994; Orchard 2000). As an example, an individual can only have one right femur and if two right femurs are recorded from a single burial context then that suggests that at least two individuals are represented.

An essential requirement to achieve the most accurate assessment of MNI was to avoid over-enumeration caused by a simple count of entries for each type of skeletal element. Consequently, the completeness of each skeletal element had to be considered for the process of MNI estimation (Boulter *et al.* 1998). As a result, in cases where many of the bones were not complete but were instead a fragment of a whole bone, only one entry-counting was made. As an example, based on what was described above, only one recording should be made for a present distal right femur and the head of another proximal right femur as both fragments could potentially have come from the same skeletal element.

The estimation of MNI was also based on common sense observations regarding, age, sex, dimensions and morphological characteristics of the encountered disarticulated bones and charnel material. For example, although they might be counted as two pelvic bones of opposite sides, this does not necessarily imply that they came from a single individual. It is the observation of the sex related traits on these two elements, the age-related degenerative changes in the pubic symphyses and auricular surfaces along with the dimensions and other characteristics that will determine whether or not they belong to one or more individuals. Therefore, in order to achieve an accurate estimation of MNI, multiple factors had to be considered.

For the analysis of charnel and disarticulated material a combination of quantitative and qualitative methods was employed. The methods used for assessing the biological sex and age-at-death of these individuals were the same as those used for the articulated material (section 4.1.2). As the nature of the material was mostly commingled and the most commonly encountered long bone was femur due to the more compact nature that possess, the stature estimations were primarily based on the maximum femoral length method by Feldesman *et al.* (1992). In the case of pathological conditions, due to the nature of the material that was commingled and in poorer state of preservation, it was not within the scope of the thesis to record any prevalence rates and identify how different groups were affected by. Instead, a more qualitative approach was taken to determine whether the material exhibited the same pathological trends observed in the articulated material. The employed methods for recording the pathological conditions were the same as those used for the articulated material (section 4.3).

4.5. Data Analysis Protocol

In order to allow easy calibration of the data and analysis of the raw numbers and percentages for inter- and intra-site comparisons, the demographic, pathological and burial data were inputted into a Microsoft Excel spreadsheet. Basic statistical comparisons were made using crude and true prevalence rate calculations. Crude and True Prevalence Rates of all skeletal and dental diseases for the articulated material were calculated on Excel and some demographic figures and frequency graphs were produced. Typically, the prevalence of a specific condition/disease is quantified by calculating the 'Crude Prevalence Rate' (CRP) and 'True Prevalence Rate' (TPR). CPR is the number of individuals affected by a particular pathological condition from the total number of individuals in the population, whilst TPR is the number of skeletal/dental elements affected by this pathological condition out of the total number of elements available for observation (Roberts and Cox 2003; Waldron 2009; McIntyre 2013). Both CPR and TPR were necessary to be calculated for each pathological category due to inconsistencies in the recording methods among different published osteological reports. TPR tends to be more accurate in the calculation of disease prevalence in skeletal remains as it considers individual skeletal elements and not the skeleton as a whole; however, it is frequently not available as it is a time-consuming process that requires examination of individual skeletal elements that are involved in specific conditions. Consequently, for comparison with other assemblages where TPR was not available CPR was used instead. CPR was calculated using the following equation:

CPR%= (Number of affected Individuals/Total number of individuals observed) *100

In palaeopathological literature, TPR usually refers to the number of skeletal elements affected by a palaeopathological condition (e.g. osteoarthritis on each recordable vertebra) relative to the total number of present skeletal elements (e.g. total recordable vertebrae) on which the condition could possibly occur (Roberts and Cox 2003; Waldron 2009). Consequently, TPR was calculated using the following equation after Roberts and Cox 2003:

TPR% = (Number of skeletal elements affected (e.g. teeth, teeth socket, vertebrae, femoral head etc)/ Total number of skeletal elements observed) *100

Example: TPR%= (2000 affected teeth/5000 observable teeth) = 40%

However, variability in quality of TPR data available from the comparative literature may exist based on different authors' preferences. Consequently, the TPR can also be seen as the number of affected individuals as a proportion of the number of individuals upon whom the pathology could be recorded if it was indeed present (Roberts 2007). For that reason, within St Hilda's the second variation of TPR also had to be calculated for occasional comparison with sites that seemed to prefer this second type. This second variation of TPR appears to be a combination between the CPR and TPR equations described earlier in this section.

For the purposes of CPR and TPR calculations, pathological conditions were broadly categorised according to aetiology: specific and non-specific infections, trauma, spinal and extra-spinal joint disease, metabolic disorders, congenital conditions and neoplastic disease. Most of the comparative sites had calculated the CPR prevalence for conditions such as rib lesions, trauma and spinal and extra-spinal joint disease, with only a few exceptions that had also calculated the TPR values for some specific conditions (rib lesions, spinal OA and Schmorl's nodes). For that reason and based on an initial assessment and the post-mortem condition of St Hilda's material, no perplexed methods had to be employed for recording TPR. In the case of these few comparative sites which provided TPR it was unclear how these conditions were recorded with regard to any potential fragmentation issues; as no descriptions were provided it was impossible to replicate their method. In any case, within St Hilda's a method replication would not have been necessary, as on average most of the bones appeared intact and where post-mortem fragmentation occurred, the anatomical parts of the long bones such complete diaphysis and proximal and distal epiphyses and the bodies and ventral and dorsal articulations in the case of ribs and vertebrae were also retrieved during excavation, allowing the adequate assessment of the bones despite their fragmentation. In cases where only the body or diaphysis survived then the assessment was based on that, with full appreciation that some information might have been missed as the rest of the bone was not present. Hence, the common method where bones are divided in three to five segments for the recording of fractures or other lesions was not utilised here as the recording was a relatively straight-forward process due to the completeness of the skeletal elements.

The calculations of CPR and TPR values were a necessary step in order to understand St Hilda's data and see if they exhibited a similar morbidity profile to other sites of the same period and background of interest. To allow further statistical analysis, the data sets were transferred from Excel into SPSS (Statistical Package for Social Science) version 24.0 by being converted first to comma separated values (.csv) files in order to allow compatibility with SPSS formatting. The data analysis within this thesis focused on cross-tabulation of biological and social variables, with significance testing to assess the probability of the relationship between the two.

As the variables within St Hilda's were mostly categorical (nominal), non-parametric tests (distribution-free) were applied and in particular the chi-square (χ^2) test of independence (Kinner and Gray 2000). The chi-square (χ^2) test was used to identify basic correlations between categorical groups of data such as biological sex, age-at-death and pathology (Chamberlain 2007; McHugh 2013). In each case, the null hypothesis that there was no relationship between the categorical variables of demography and pathology was used. The threshold for rejection of the null hypothesis was set to 0.05. When the chi-square test result reached or approached statistical significance after having used a two-by-two contingency table, a Yates correction for continuity was automatically applied by SPSS to ensure the result was significant (Kinnear and Gray 2000). Where the sample size was small, such as in the case of specific infections or grave types, Fisher's Exact test was automatically applied by SPSS instead of chi-square (Kinnear and Gray 2000; Pallant 2013). Specifically, when counts for a specific variable were less than 5, a Fisher's exact test was applied (Gould and Gould 2002).

For tables greater than two-by-two, post-hoc tests were required after chi-square to confirm where the differences occurred between groups. This step was necessary as a statistically significant result means that there is indeed a difference between two categorical groups; however, if the table is greater than two-by-two, the chi-square does not show where the differences occurred between groups. Consequently, in order to ascertain which groups contributed to the statistical significance in the chi-square test for tables greater than two-by-two, the standardised residual test by Beasly and Schumacker (1995) was performed. In this test the usual p-value (0.05) for significance was adjusted using the Bonferroni correction to allow for the number of multiple pairwise tests to be carried out.

For numerical values with normal distribution, the data were analysed using parametric tests such as t-tests in order to compare two groups of variables of interest (Pallant 2013). The parametric t-test was used to compare the means of two independent groups in order to determine whether there was statistical evidence that the associated population means are unrelated (different) such as the mean statures between males and females (Kent State University Libraries 2017).

After the primary analysis of St Hilda's assemblage, a comparative quantitative analysis between the case study and the sites of known context was applied. Each available health and disease indicator were compared independently by using CPR and TPR values. This comparison was necessary in order to determine the extent to which the living conditions experienced by the study population had a specific impact on their skeletal health compared to other sites of various socio-economic backgrounds. This step will enable identification of where similarities and differences between the sites arise and whether the populations experienced the effects of industrialisation similarly or differently. For this quantitative comparative analysis between the case study and the sites of known context, the employed statistical tests were z-tests for proportions and means, as opposed to t-test (*n <30*) that was used for the primary analysis of St Hilda's results. Z-test is used to determine whether two population means are different when the variances are known and the sample size is greater than 30 (Harvey 2016). This analytical step was necessary as a frequent issue in comparative literature is that the comparison of prevalence is qualitative, meaning that the study fails to consider sample size differences (how small or large a sample size is) between sites. A small sample size that is too small increases the likelihood of a type II error, skewing the results, which decreases the power of a study. Type II error occurs when the results confirm a null hypothesis on which the study was based when, in fact, an alternative hypothesis is true (Kinnear and Gray 2000; Pallant 2013). For example, two skeletal assemblages might exhibit the same mean of stature despite the one being much smaller than the other. To avoid such errors, a systematic quantitative literature review was employed, instead of a qualitative one, by running multiple z-tests of proportions and means.

CHAPTER 5

RESULTS OF SAINT HILDA'S SKELETAL ASSEMBLAGE ANALYSIS

This chapter presents the demographic, health and disease profile of the 204 articulated skeletons from Saint Hilda's, which underwent osteological analysis. The results from the analysis of the charnel and disarticulated skeletons are also documented here. In the first parts of the chapter, after the preservation parameters, the results of the biological sex and age-at-death assessment of the articulated skeletons are presented in order to determine the demographic composition of the population sample. A detailed osteological assessment of sex and age-at-death was necessary, as the biographical evidence derived from *depositum plates* was limited. The results of the adult stature assessment are also documented in order to determine the extent to which the living conditions experienced by the studied population had an impact on skeletal growth in comparison to other similar assemblages. The adult stature is also compared between males and females to determine the extent of sexual dimorphism, which may be indicative of disparities in health, diet and environmental influences upon the two sexes. In the later parts of the chapter the results of the crude prevalence rate (CPR) and true prevalence rate (TPR) of each stress related palaeopathological condition are then presented. Prevalence comparison of the health indicators, between adults and non-adults, is the next analytical step. Within the adult group of the studied skeletal assemblage, the prevalence rate of each indicator is discussed in terms of different sex and age categories. This is to determine if different groups of the population under study experienced levels of physiological stress differently. This process is mostly followed for the adult group of the population as the non-adult group seem to have suffered very low rates of disease; however, whenever possible the prevalence rate of each indicator is also discussed between different non-adult age categories. In the final part of the chapter the results from the analysis of the charnel and disarticulated material are presented

5.1 Skeletal Assemblage Preservation

The level of preservation for every articulated skeleton, 113 adult, 4 adolescent and 87 non-adults (sub-adults), within this assemblage was quantified by assessing the *completeness* of the surviving skeletal elements and the overall *condition* of the bones. According to the standards of Connell and Rauxloh (2003, 2-3) that were modified for the purpose of this research, over half of the total assemblage exhibited *Good (1)* preservation (*52.5%; 107/204*), while almost equal percentages showed *Moderate (2)* (*25.5%; 52/204*) and *Poor (3)* (*22.1%; 45/204*) (Figure 5.1a).

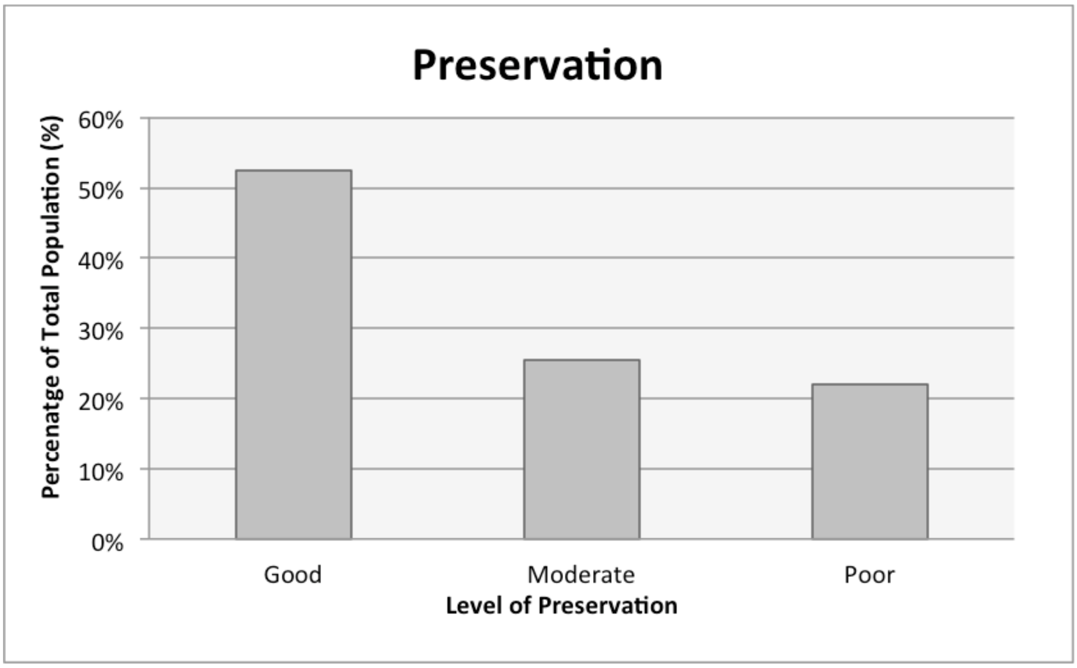


Figure 5.1a: Preservation distribution in St Hilda's assemblage, represented by percentage of the total population (n = 204).

When the total assemblage was divided in two sub-assemblages, adult and non-adult, the following observations were made. Over half of the adult proportion exhibited *Good (1)* preservation (*58.1%; 68/117),* while the rest of adult skeletons exhibited *Moderate (2)* (*26.5%; 31/117*) and *Poor (3)* (*15.4%; 18/117*). In the case of non-adults, almost half of the total non-adult assemblage exhibited *Good (1)* preservation (*44.8%; 39/87*)*,* followed by *Poor (3)* (*31%; 27/87*) and *Moderate (2)* (*24.1%; 21/87*) (Figure 5.1b). Although the percentage of good preservation of non-adults might seemingly appear low in relation to adults, it is in not when is considered that destructive post-depositional effects frequently have greater impact on bone preservation of growing children than adults (Gordon and Buikstra 1981, 569). Taphonomic factors such as soil acidity, temperature, burial depth and water level contribute to bone preservation (Brickley and McKinley 2004, 15). The low mineralisation of bones and subsequent increased porosity in growing children also mean that the remains of non-adult individuals are more likely to be affected by these factors to a greater degree (Guy *et al.* 1997, 225).

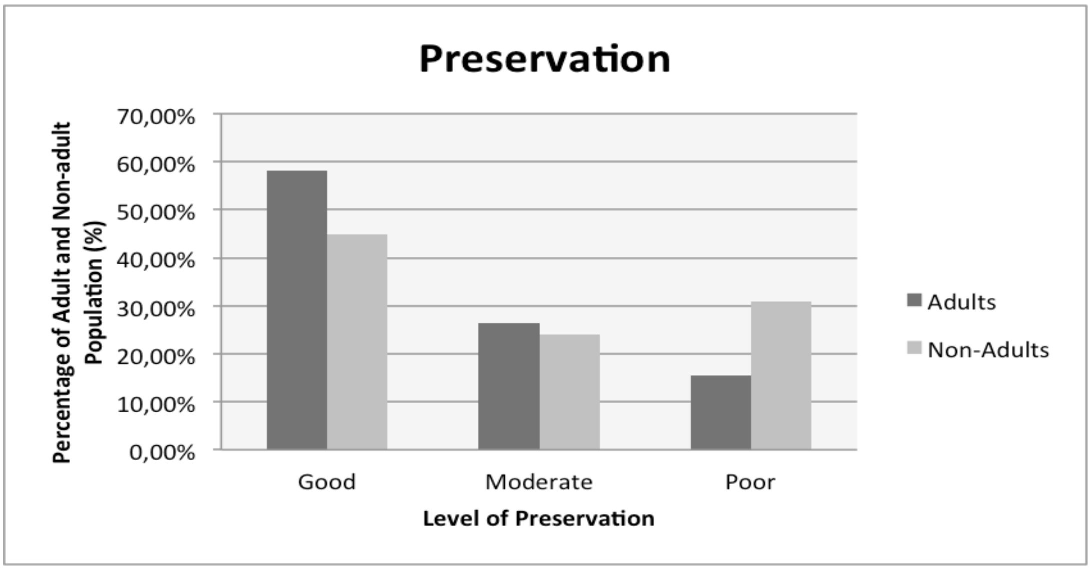


Figure 5.1b: *Preservation distribution in St Hilda's assemblage*, *represented by percentage of the total adult (n = 117) and non-adult population (n = 87).*

Within the St Hilda's skeletal assemblage, less than half of the total skeletons (*40.7 %; 83/204*) were more than *75%* complete; while the next more commonly encountered levels of completeness were *25-49%* (*22.1%; 45/204*) and *50-74%* (*21.6%; 44/204*) and less commonly ≤ *24%* (*15.7%; 32/204*) (Figure 5.2a).

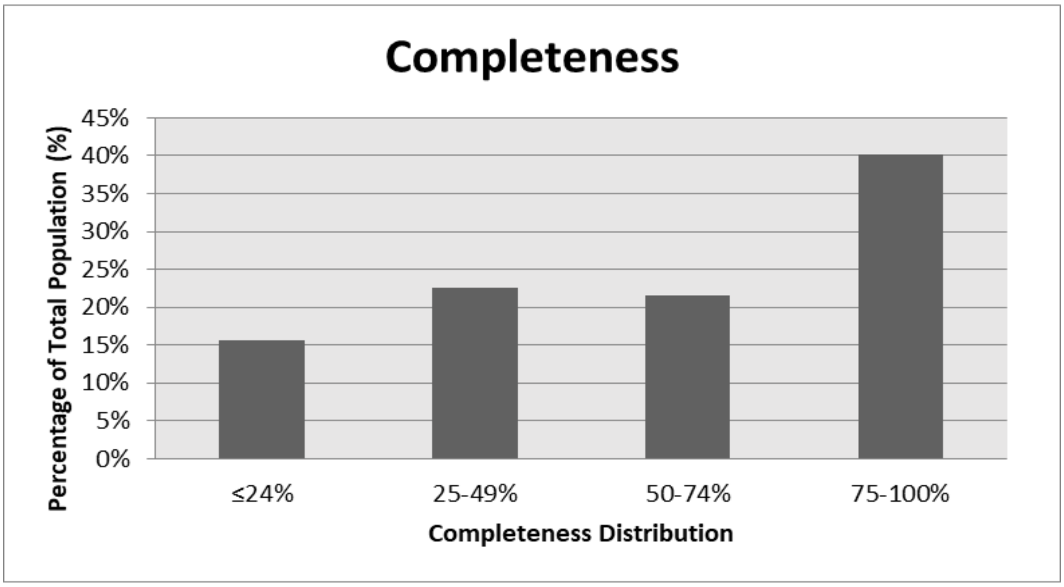


Figure 5.2a: *Completeness distribution in St Hilda's assemblage, represented by percentage of the total population (n=204).*

Within the adult population, almost half of the skeletons *(47.9%; 56/117)* were more than 75% complete, while the next more commonly encountered level of completeness was *50-74%* (*23.1%; 27/117*) and less commonly were *25-49%* (*14.5; 17/117*) and *≤24%* (*14.5; 17/117*). These figures indicate a high frequency of complete skeletons. Within the non-adult proportion, a substantial number of individuals exhibited good preservation levels. The most commonly encountered levels of completeness were ≥75% (*31%; 27/87)* and 25-49% (*32.2%; 28/87)* respectively. Less encountered were 50-74% (*20%; 17/87*) and ≤24% (*17.2%; 15/87*) (Figure 5.2b).

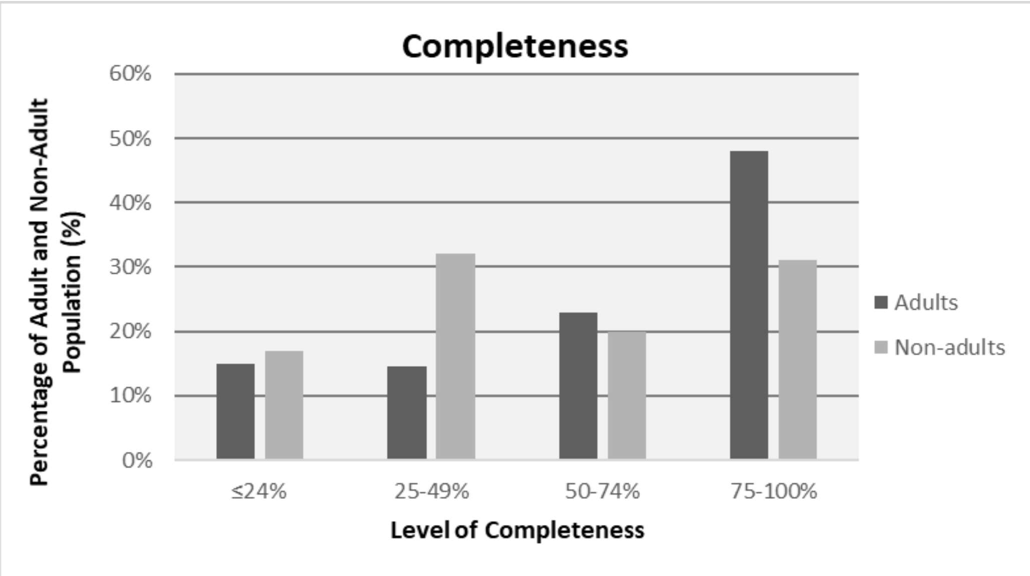


Figure 5.2b: Completeness distribution in St Hilda's assemblage, represented by percentage of the total adult (n=117) and non-adult population (n=87).

The total assemblage showed little evidence of severe cortical erosion. A high proportion of the population sample (*91.2%; 186/204*) displayed *grade 1-3* cortical erosions according to the Brickley and McKinley standards (2004, 15-16), which corresponds to a slight to moderate erosion of the skeletons within the assemblage overall. Only a nominal percentage (*8.8%; 18/204*) of individuals exhibited destruction of the cortical bone represented by *grades 4, 5* and *5+* (Figure 5.3). Within the adult total assemblage, the most commonly encountered grades of cortical erosion were 1 (*59%; 69/117*) and 2 (*21.4%; 25/117*); the same observation was made for the total non-adult assemblage (*32.2%; 28/87* and *40.2%; 35/87*). The next most commonly encountered grades of erosion for both adults and non-adults were *grade 3 (11.1%; 13/117* and *18.4%; 16/87)* and grade 4 (*5.1%; 6/117* and 8.0%; *7/87*). The rest of the grades were only a nominal percentage; with four adults in total exhibiting *grade 5* and *5+ (3.5%; 4/117)* and one non-adult exhibiting *grade 5 (1.1%; 1/87).*

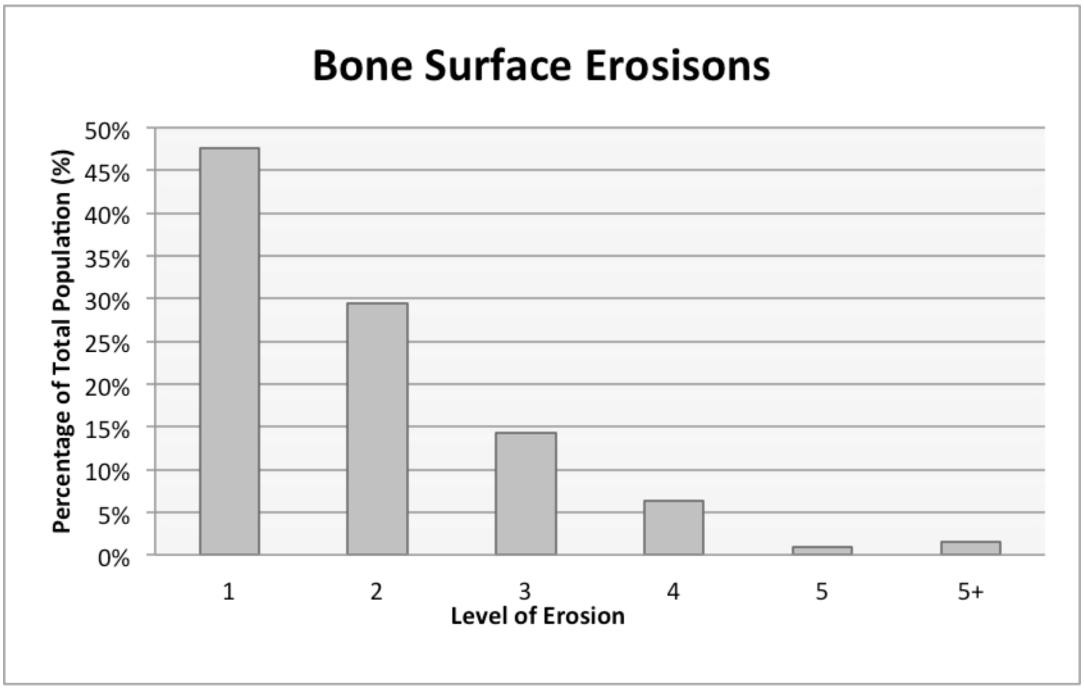


Figure 5.3: Level of erosion distribution in St Hilda's assemblage, represented by percentage of the total population (n =204).

Overall, the osteological information available through macroscopic analysis of St Hilda's assemblage was good. In regards to the non-adult proportion, St Hilda's assemblage did not suffer the same percentages of degradation frequently reported in other archaeological cemeteries.

5.2 Demographic Composition: Biological Sex and Age-at-Death

Of these 204 skeletons that underwent osteological analysis, 87 (*42.6%*) were non-adults, 4 were adolescents (*1.96*%) and 113 (*55.3%*) were adults. The four adolescents exhibited features between end years of adolescence and early adulthood. These four individuals although were described as 'adolescents' were paleopathologically analysed as part of the adult population as growth delays and disturbances were suspected as the reason behind the mixed features; a process that was initially employed for the assessment of their preservation and completeness. No attempt, however, was made to assess their biological sex as frequently they exhibited mixed features. Additionally, no stature assessment was attempted due to the possible observed delays. Within the adult population (adolescents are here excluded), 65.5% (*74/113*) were assigned a definite biological sex. To maximise the numbers of 'assigned a sex' individuals available for analysis and to make the analysis more consistent with other studies, the probable males (males?) and females (females?) were replaced with definite male and female categories for the purposed of the statistical analysis. From this adult population, 7.0% (8/113) could not be sexed using standard osteological methods, due to lack of diagnostic elements necessary for sex determination; while 0.9% (1/113) was determined as ambiguous. No attempt was made to sex the 87 non-adults and 4 adolescents as sex cannot be osteologically determined with certainty before full maturation. These individuals were described as 'unsexed'. The proportion of males (*25%, 51/204)* and females (*26%, 53/204)* constituting the total adult population was virtually the same (Figure 5.4). When only the adult individuals recorded during skeletal analysis, for which sex could be determined were considered, 49% (51/104) were male and 51% (53/104) were female.

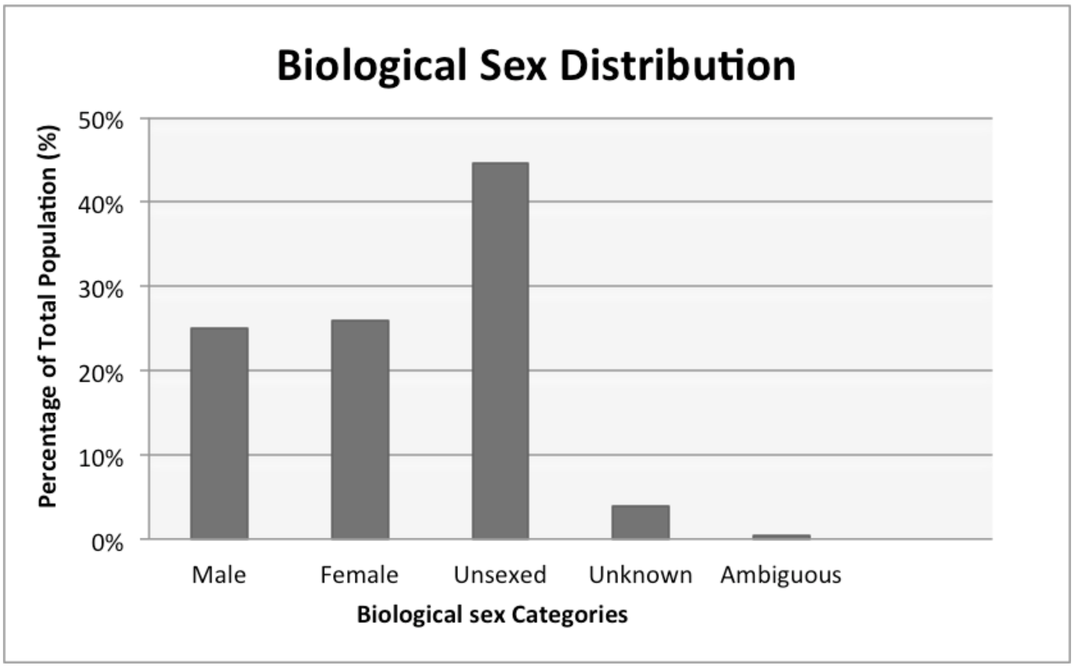


Figure 5.4: Summary of biological sex distribution in St Hilda's assemblage, represented by percentage of the total population (n =204).

The ratio of male to female individuals within the adult assemblage was 1:1.04, achieving almost precise parity of the sexes. The greater proportion of females than males was also confirmed with the study of St Hilda's burial registers. Both skeletal and burial register data agree that the burial population was roughly equally split between males and females. According to the burial registers, during the total period of use of the cemetery there were interred 15.688 males and 15.770 females, giving a 1:1.01 male to female ratio (Figure 5.5). The burial registers ratio could be considered representative as it was based on the whole population (longitudinal study) of South Shields during this period and provided information not only on the sex of adults, but also on the sex of non-adults.

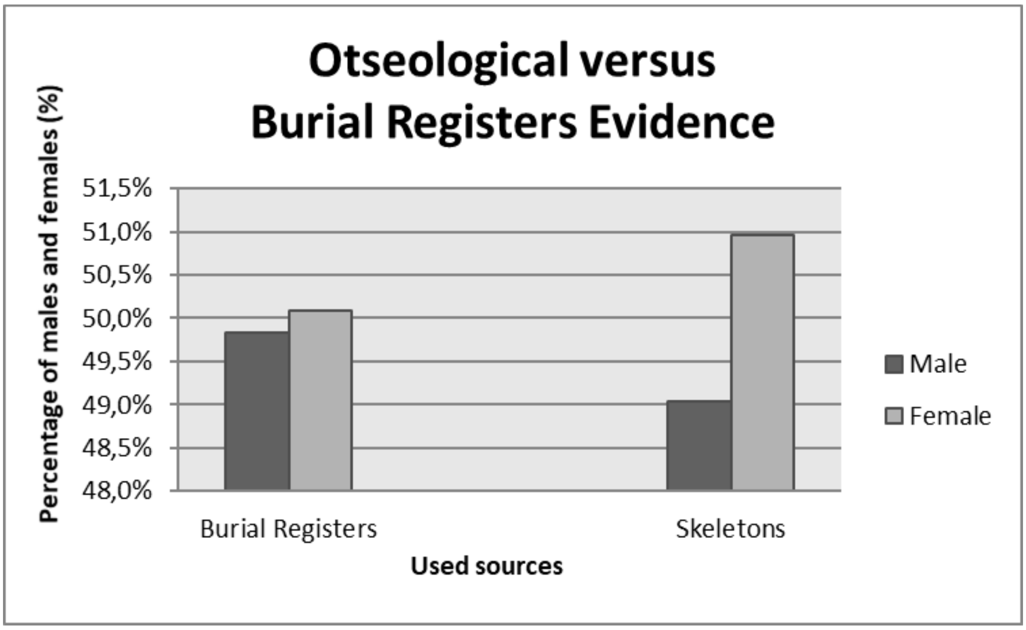


Figure 5.5: Summary of biological sex distribution between St Hilda's skeletal assemblage and burial registers represented by percentage of the population that biological sex was recorded or known.

The mortality profile showed an increase from birth peaking in the first month(s) of life and early childhood age category, followed by a reduction in older childhood, adolescence and young adulthood, and then increasing to a peak in middle adulthood followed by mature and older adulthood (Figure 5.6a). In other words, many individuals who managed to survive the crucial point of early childhood between birth and 6 years of life managed to live up to middle adulthood between 26 and 45 years of life and those who managed to overcome this second crucial point managed to reach senior adulthood categories. The general mortality profile was partially consistent with the study of burial registers. St Hilda's overall osteological mortality profile exhibited some similarities with the overall burial mortality profile. The increased number of deaths in early childhood followed by a decrease in late childhood reaching young adulthood, followed by a second increase in middle adulthood was a pattern in common (Figure 5.6b). After middle adulthood, however, there were some observed differences linked to the accuracy of the osteological methods when ageing senior adults, these encountered differences will be further addressed in the discussion section (Figure 5.6c).

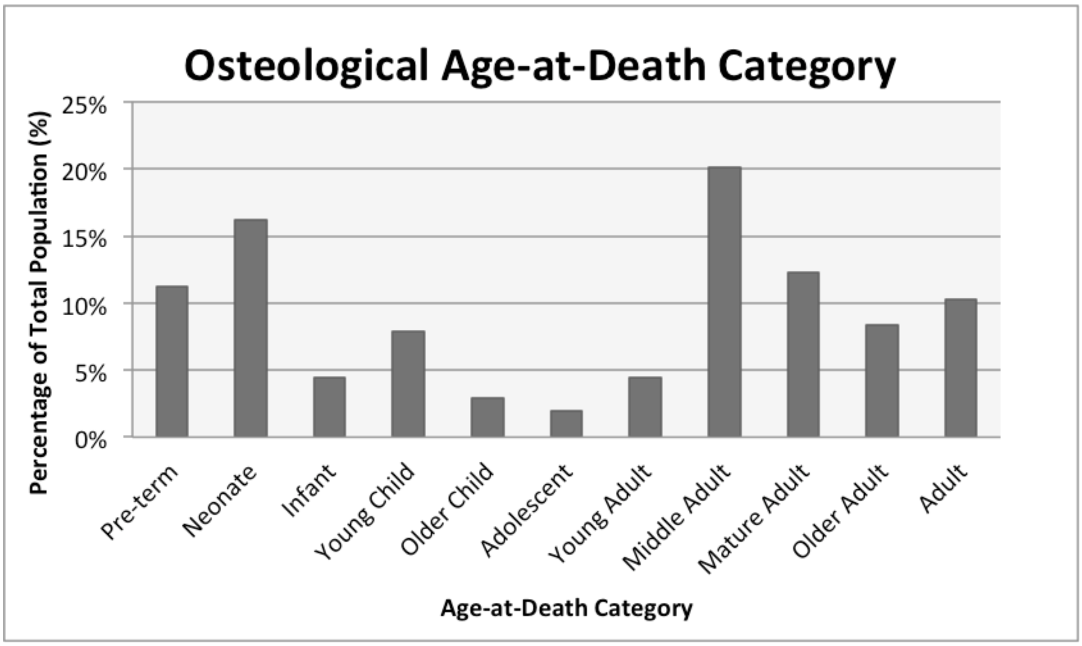


Figure 5.6a: Summary of age-at-death distribution in St Hilda's assemblage, represented by percentage of the total population (n =204).

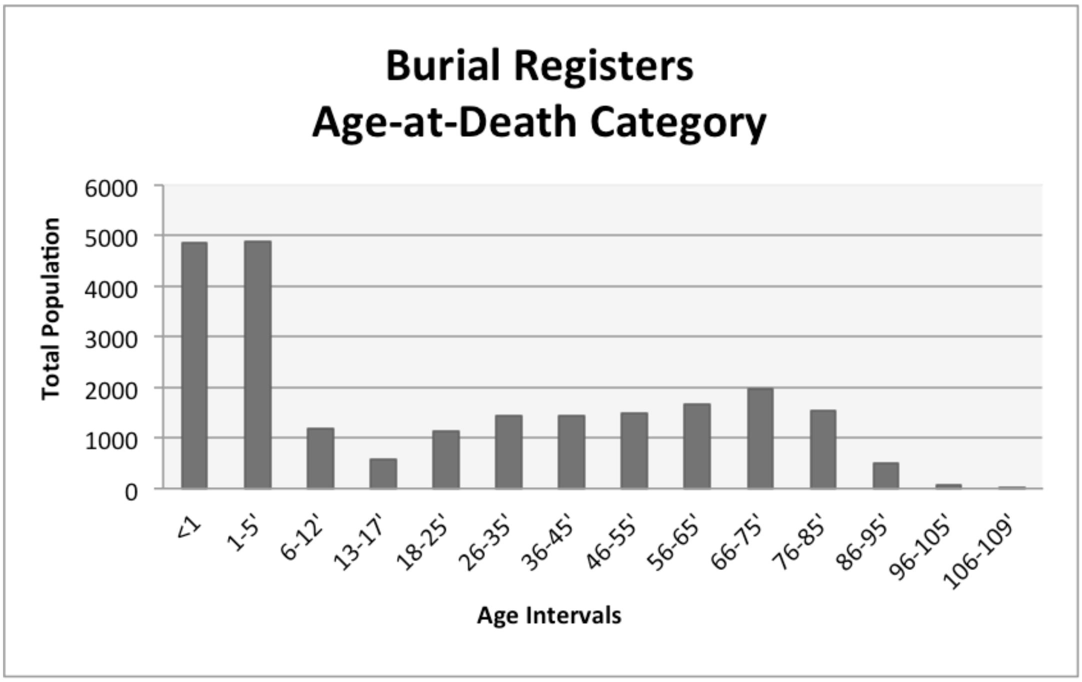


Figure 5.6b: Summary of age-at-death distribution in St Hilda's burial registers, represented the total population (n=31.481).

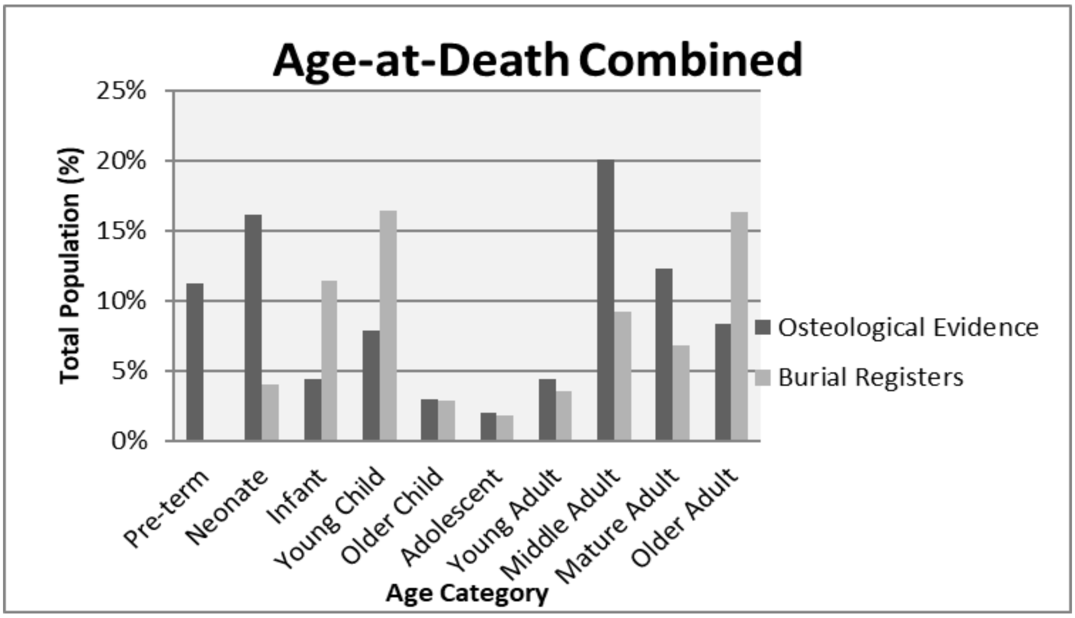


Figure 5.6c: Summary of age-at-death distribution in St Hilda's assemblage and burial registers combined, represented by percentage of the total population.

In order to further determine how mortality impacted different adult groups, the various age groups were split by biological sex and new categories were created. For example, with the new categories, death rates were higher for young adult females (*6.7%; 7/104)* in comparison to young adult males (*1.9%; 2/104*). Once a female overcame this crucial stage between 18 and 25 years of age, she had higher chances to reach the senior adult stages of mature (13.5%*; 14/104*) and older adulthood (*9.6%; 10/104*) when compared to their male mature *(10.6%*; *11/104*) and older adult *(6.7%; 7/104*) counterparts. Males who survived young adulthood had less chances to reach senior adulthood, since they exhibited high rates of death occurring in middle adulthood (*27%; 28/104*) when compared to their female counterparts (*11.5; 12/104*) (Figure 5.7).

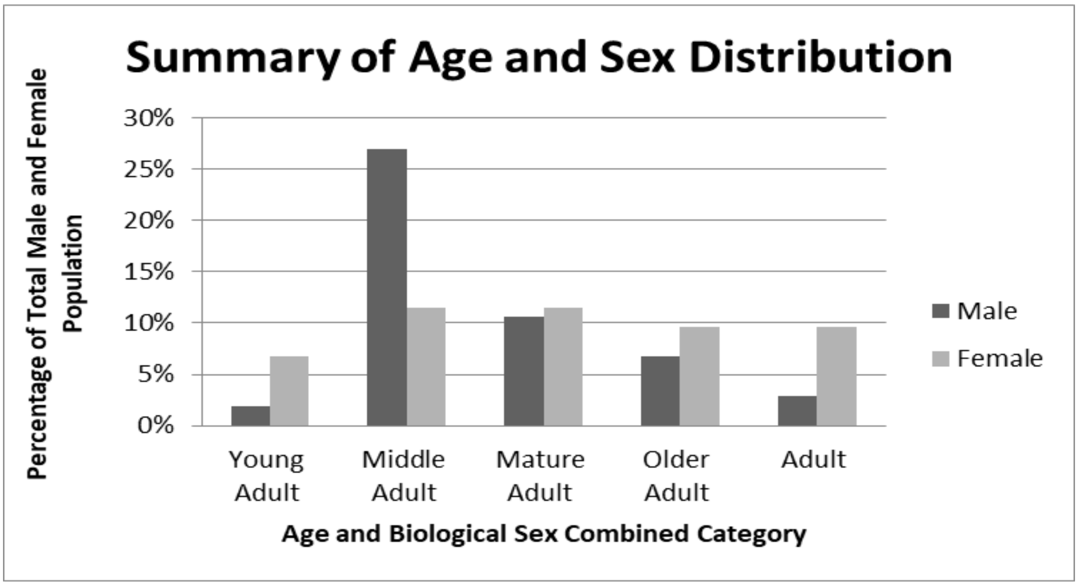


Figure 5.7: Summary of age and sex distribution in St Hilda's assemblage, represented by percentage of the total sexed population (n =104).

In order to determine, if indeed middle adult males or any other male age group experienced mortality differently than their female equivalent age group and therefore the observed difference described above did not happen by chance, a chi-square (χ^2) test of independence was applied to the age groups split by sex and a null hypothesis of no relationship existing between the categorical variables was made (Chamberlain 2007). The chi-square was statistically significant ($p = 0.008$), indicating that there was a difference between the groups; however, since the table was greater than two by two, post-hoc analysis was required to confirm where the differences existed. Consequently, in order to ascertain which groups contributed to the statistical significance in the chi-square test, a standardised residual test was performed (Beasly and Schumacker 1995). In this test, the usual p-value (≤ 0.05) for significance was adjusted using the Bonferroni correction to allow for the number of multiple pairwise tests to be carried out. After the completion of this step, the test returned a statistically significant result ($p = 0.0004$) indicating that middle adult males had indeed suffered higher mortality when compared to their female counterparts. None of the other groups presented statistical significance. Consequently, only the death of middle adult males (26-45) was statistically significant, although females initially appeared to have also experienced a higher number of deaths during young adulthood (<25) and senior adulthood categories (>46).

5.3 Estimation of Adult Stature

Stature calculated from long bone lengths was recordable for 88 observable adults (male = 45, female = 39 and unknown or ambiguous = 4). The mean adult stature for the total number of observable adults was 164cm with a range of 140-182.5cm. While, the mean stature for males alone was 170cm with a range of 140 -182.5cm and for females alone was 158cm with a range of 145-169.5cm (Table 5.1; Figure 5.8). In order to determine whether there was a statistical difference between the means in the two unrelated groups of males and females a two t-test was applied between them. The difference in stature observed between males and females was statistically significant ($t = 6.16$; $p = 0.000$).

Males		
Stature Banding	**Count**	**Percentage**
Under 145	1	2.22%
145-150	0	0.00%
150-155	0	0.00%
155-160	3	6.67%
160-165	5	11.11%
165-170	9	20.00%
170-175	13	28.89%
175-180	11	24.44%
Over 180	3	6.67%
Total	**45**	**100.00%**

Females		
Stature Banding	**Count**	**Percentage**
Under 145	0	0.00%
145-150	3	7.69%
150-155	7	17.95%
155-160	15	38.46%
160-165	10	25.64%
165-170	4	10.26%
170-175	0	0.00%
175-180	0	0.00%
Over 180	0	0.00%
Total	**39**	**100.00%**

Table 5.1: Stature distribution for St Hilda's analysed males (n=45) and females (n=39).

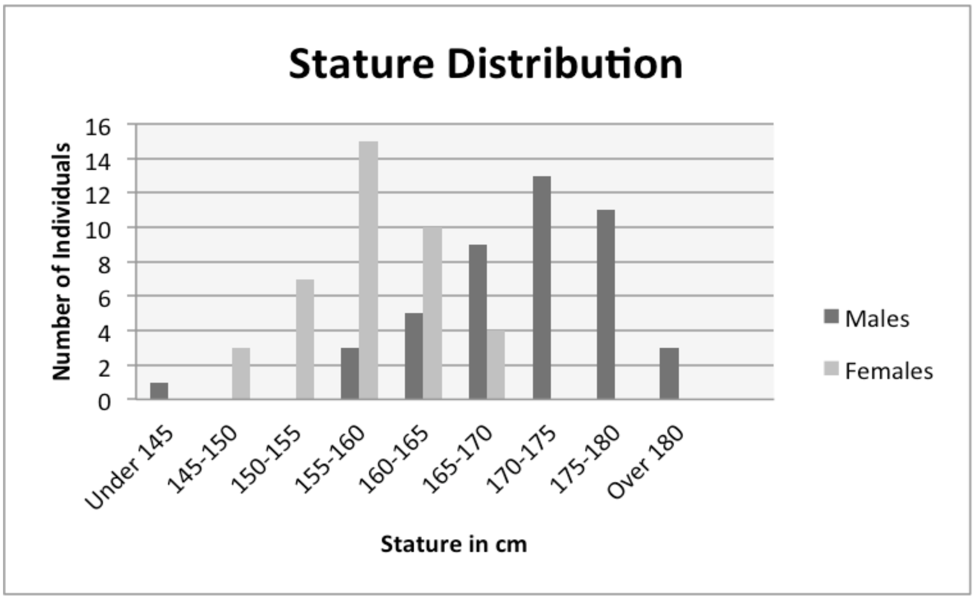


Figure 5.8: Stature distribution in males and females.

5.4 Palaeopathology

In this part of the chapter the CPR and TPR calculations of each stress related palaeopathological condition are presented. The aim of these calculations was twofold; to enable as a first step the comparison of prevalences of pathological lesions within the different population groups of St Hilda's (e.g. adults and non-adults) and as a further step to enable comparison between different populations. The comparison of the pathological rates between St Hilda's and other sites, will allow determining if differences existed between geographical regions and socio-economic backgrounds.

5.4.1 Indicators of Environmental Stress: Specific Infections

Lesions indicative of specific infections such as tuberculosis and syphilis were identified in a few individuals. Given the nature of specific infections that involve the distribution of lesions in more than one skeletal element, only the CPRs for TB and syphilis were calculated. The CPR of TB for the total population was 0.98% (*2/204*). The CPR for adults alone was 1.70% (*2/117*) while non-adults showed no evidence of the lesions. The most convincing case of TB was that of an adult female that exhibited features pathognomonic for the diagnosis of Pott's spine. The individual exhibited lytic lesions on the inferior surface of the eighth and ninth thoracic vertebrae, resulting in spinal collapse with secondary kyphoscoliosis and secondary osteoarthritis at the zygapophyseal joints. However, conditions such as metastatic carcinomas and multiple myelomas can also produce spinal lytic lesions. In the second cases of TB, the lack of spinal lesions made impossible to put forward a definite diagnosis. This second possible case could alternatively be compatible with conditions such as pulmonary bronchitis, fungal infections such as histoplasmosis and blastomycosis, inflammatory conditions such as sarcoidosis, septicaemia as well as neoplastic conditions such as lung cancers and metastatic carcinomas.

The CPR of venereal syphilis for the total population was 1.47% (*3/204*) with all the affected individuals being adults 2.56% (*3/117*). A forth probable adult case was suspected, but it was not included in the CPR calculations of the disease as the individual exhibited only a skull lesion which was not exactly pathognomonic for the diagnosis of the specific infection. Syphilitic lesions were identified in a male middle adult, who presented clustered pits and radial-like lesions of the frontal bone, inflamed alveolar bone below nasal spine, inflammatory reaction on the left side of the mandible as well as gummatous osteomyelitis of the right and left tibiae (saber tibia) and femora. Further skeletal changes included diffuse subperiosteal reaction with pitting of the left clavicle and localised subperiosteal reaction near medial condyle of the left humerus. A second possible case was a mature female who exhibited mediolateral bowing of the tibiae and bilateral subperiosteal reaction on both femoral shafts, tibiae and fibulae with the lesions exhibiting striated appearance indicating they were still active at time of death. A third possible case was a middle adult female who exhibited abnormal bone loss on mid-line of cranial vault transversing the sagittal suture and perforation at the focus of depression, resembling early stages of caries sicca. Non-gummatous and gummatous lesions on left tibia (saber tibia), fibulae and ulna were also noted. The fact that the affected individuals were middle and mature adults and that the disease takes up to 2-10 years for skeletal manifestation indicates that these individuals managed to survive for quite a while with the disease, reflecting a strong immune response.

A possible case of congenital syphilis was also identified in a preterm of 30-32 weeks of gestation, the CPR for the total population was 0.49% (*1/204*) and for the non-adults 1.15% (*1/87*). The disease is transmitted in gestation by syphilis bacteria entering the placenta of the pregnant woman and its most commonly transmitted during the early acute stage of mother's condition. The recorded changes included increased porosity of the rib shafts (externally), fusiform appearance (enlargement) of both clavicles due to osteitic development and flaring/destruction of their metaphyses. Both radii, ulnae and tibiae appeared enlarged to due to osteitic development and their metaphyses appeared flared and pitted. The nasal region and alveolar bone of mandible appeared very porous (fine pitting) and the skull exhibited endocranially some porosity as well as the orbits too. Conditions such as maternal deficiencies (Vitamin D deficiency and scurvy) and intrauterine infections were proposed as differential diagnoses.

5.4.2 Indicators of Environmental Stress: Non-Specific Infections; Maxillary Sinusitis, Rib Lesions associated with Pleurisy, Tibial Periosteal New Bone Formation and Endocranial Lesions

The most commonly encountered non-specific indicators of infection within the St Hilda's skeletal assemblage were maxillary sinusitis, rib lesions associated with pleurisy and tibial periosteal new bone formation reflecting generic poor living and working conditions.

a. Maxillary Sinusitis

Without the use of an endoscope, fragmentary crania allowed limited observation of the paranasal sinuses. Within the St Hilda's skeletal assemblage, a total of 104 individuals possessed at least one maxillary sinus suitable for analysis, of these 10 were non-adults (aged 3 years and over) and 94 were adults. A total of 45 individuals displayed new bone formation in their maxillary sinuses giving a CPR at 43.3% (*45/104*). The TPR of maxillary sinusitis for the total number of fully developed recordable sinuses in individuals aged 3 and above was 39.02% (*80/205*) (Figure 5.9). The TPRs for non-adults and adults were 35.0% *(7/20)* and 39.5% *(73/185)* respectively, this corresponds to 4 affected non-adults and 41 affected adults. The application of a chi-square (χ^2) test revealed that there were no statistically significant differences between the TPR's of the two major groups of non-adults and adults. In order to determine, if different age categories experienced maxillary sinusitis differently, a chi-square (χ^2) test was applied to the various categorical ages. The application of the test revealed no statistically significant differences in the TPRs of maxillary sinusitis between different age categories for either the total population or the adult population alone.

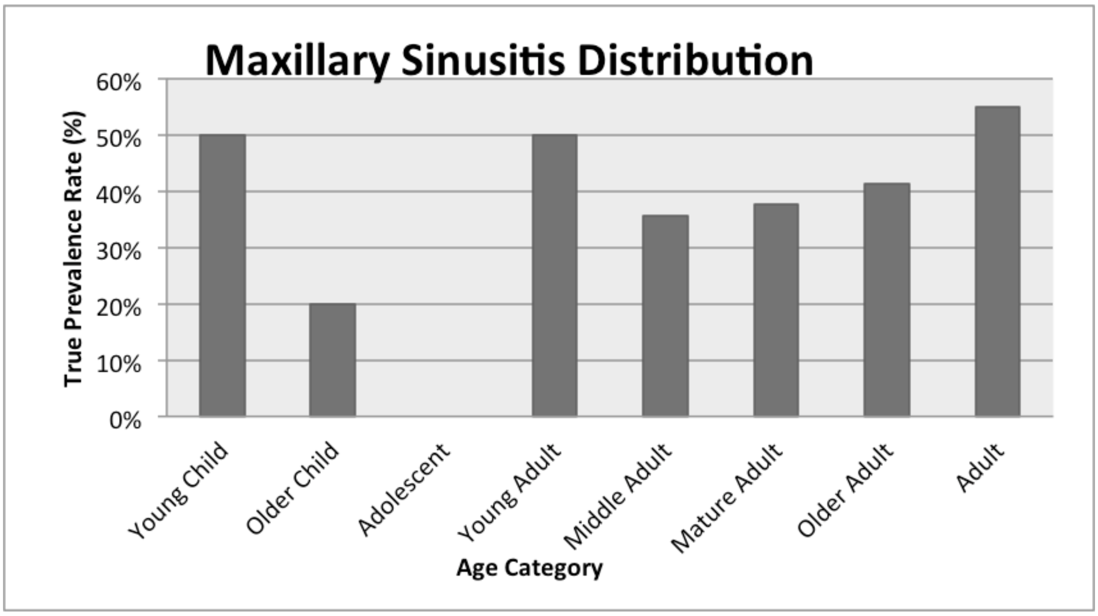


Figure 5.9: True prevalence rates in percentages for distribution of maxillary sinusitis for each age category within St Hilda's (n= 104) individuals with recordable maxillary sinuses.

The application of a chi-square (χ^2) test between biological sexes revealed that the prevalence of maxillary sinusitis was statistically higher in females than males (*p= 0.002*), the TPRs for females and males were 53.7% *(51/95)* and 23.8% *(20/84)* respectively (Table 5.2; Figure 5.10). This corresponds to 28 affected females and 12 affected males from the total number of affected individuals; whilst one affected adult of ambiguous sex had to be excluded from this last comparison. It is possible that the peak in maxillary sinusitis observed in females represents occupational or behavioural differences between sexes. As we have seen, however, the prevalence rates of maxillary sinusitis were independent of age-at-death making it more likely to reflect the surrounding environment and lifestyle. The fact that over half of the affected individuals, 53.3% (*24/45*), exhibited active lesions at time of death was indicative of constant exposure to these irritants. No statistical difference was also observed for age groups split by sex when a chi-square test was applied.

Age Category	Females (TPR %)	Males (TPR %)
Young Adult	7 (58.3%)	0 (0.00%)
Middle Adult	12 (54.6%)	12 (24.5%)
Mature Adult	10 (41.7%)	7 (33.3%)
Older Adult	11 (57.9%)	1 (10.0%)
Adult	11 (61.1%)	0 (0.00%)

Table 5.2: Number of affected sinuses with maxillary sinusitis for each male and female age category within St Hilda's.

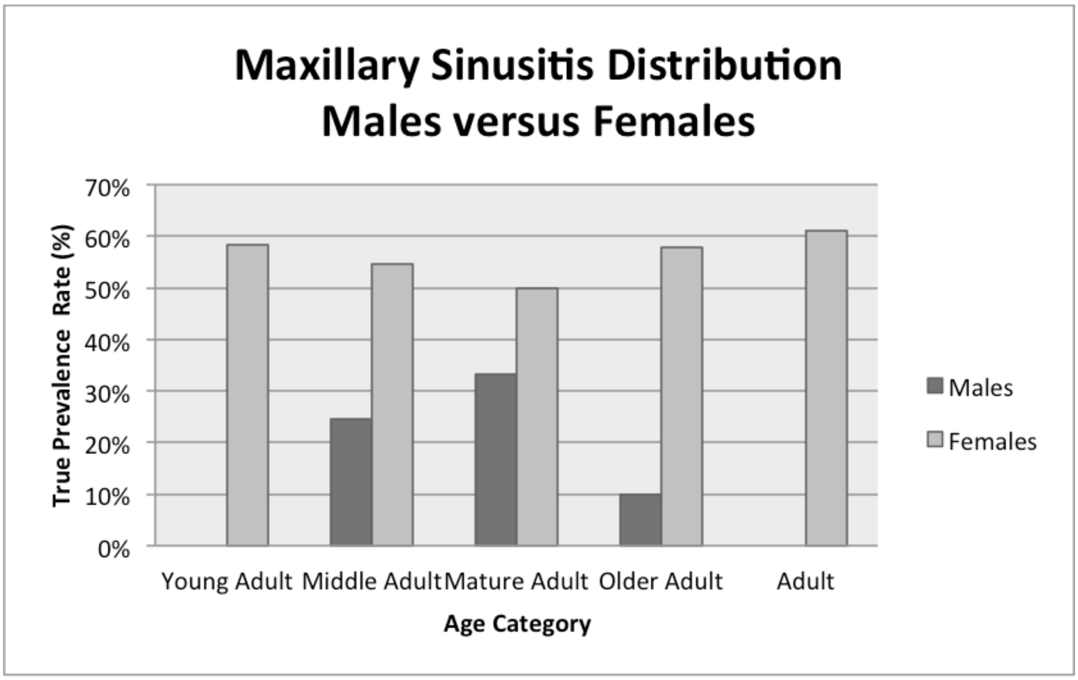


Figure 5.10: True prevalence rates in percentages for distribution of maxillary sinusitis between males and females with recordable maxillary sinuses for each age category within St Hilda's.

The osteological data revealed that both sides (bilateral maxillary sinusitis) were involved in 82.2% (*37/45*) of the affected individuals, although no significant difference was found in prevalence of maxillary sinusitis according to side. Additionally, in some cases of intact sinuses, indirect evidence of chronic sinusitis or exposure to environmental irritants was noted with the presence of enlarged or hypertrophic middle turbinates (concha bullosa), where the turbinates were filled with air. In total, there were three individuals with concha bullosa per se and ten individuals who exhibited inflamed mid concha or bone built on the mid concha. The majority of the affected individuals, 76.9% (*10/13*), were again females. Evidence of direct association between dental disease and maxillary sinusitis was rarely seen although widespread dental disease was noted in the sample. It would appear that dental disease was not a significant predisposing factor to developing maxillary sinusitis; this finding was in accordance with the findings of Merrett and Pfeiffer (2000) and Roberts (2007). Since no endoscope was utilised for endocranial examination, lesions within the maxillary sinuses were only observed where exposure of the cavities occurred due to post-mortem fracturing. Given the overall good preservation of St Hilda's skeletal assemblage, a large proportion of the crania were intact and hence, their sinuses remained unexamined. It is therefore highly probable that the true prevalence of the disorder was very much higher but could not be observed in skulls where the facial bones remained intact.

b. Rib Lesions associated with Pleurisy

Within the St Hilda's skeletal assemblage, a total of 157 individuals possessed at least one rib suitable for analysis, of these 90 were adults and 67 were non-adults. A total of 12 individuals displayed new bone formation on the visceral surface of their ribs from the total number of individuals who had at least one rib available, giving a CPR at 7.6% (*12/157).* The TPR was calculated at 1.93% (*49/2537*) for the total number of recordable ribs. The TPRs for adults and non-adults were 2.94% *(44/1495)* and 0.48% (*5/1042*) respectively, which corresponds to 11 affected adults and 1 affected non-adult. The application of a chi-square (χ^2) test revealed that the prevalence of rib lesions associated with pleurisy was statistically higher in adults than non-adults ($p = 0.013$).

The application of a chi-square (χ^2) test revealed that there was no statistically significant difference in the prevalence of the indicator between different adult age categories (Figure 5.11). No differences were also observed between biological sexes, the TPR's for rib lesions associated with pleurisy seen in males and females were 3.13% (*25/800)* and 2.40% (*15/626)* respectively, this corresponds to 6 affected males and 4 affected females. Consequently, the prevalence rates of rib lesions associated with pleurisy were independent of age-at-death and biological sex, reflecting that the condition was possibly attributable to the surrounding environment and equal exposure to it. No differences were also observed for age groups split by sex when a chi-square (χ^2) test was applied (Figure 5.12). Over half of the individuals (*8/12*) exhibited active lesions indicating constant exposure to pollution. Interestingly among the affected individuals, there was a young child with active lesions at time of death on the pleural surface of five out of seven ribs, indicating a possible cause of death although that is only an assumption as it is really difficult to say with certainty.

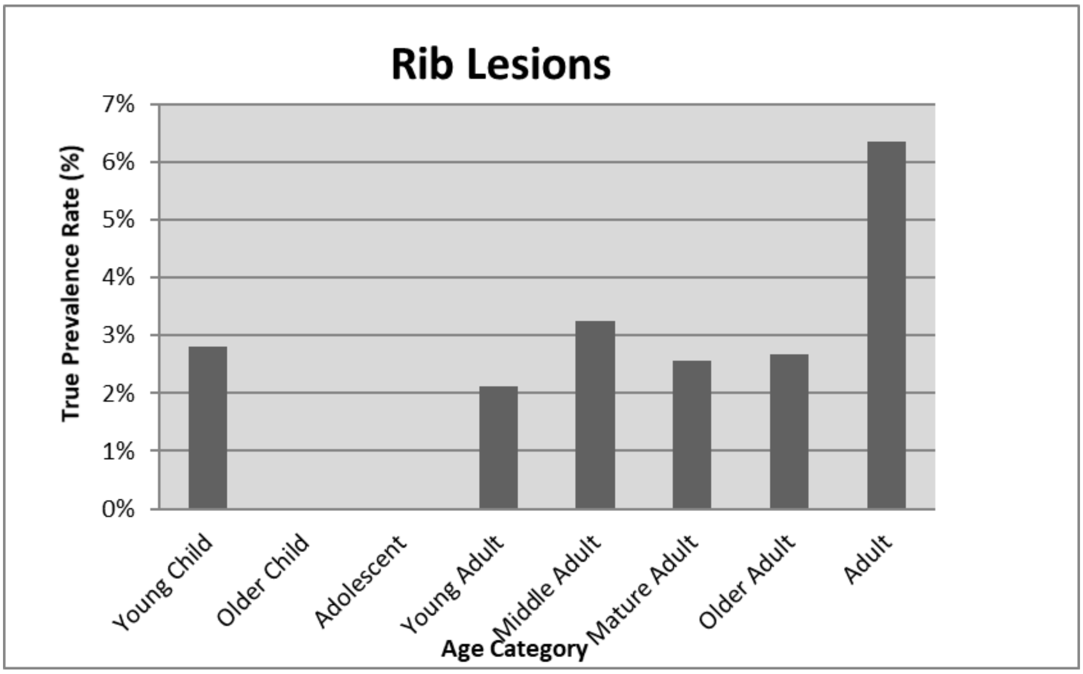


Figure 5.11: True prevalence rates in percentages for distribution of rib lesions associated with pleurisy for each age category within St Hilda's (n= 157) individuals with recordable ribs.

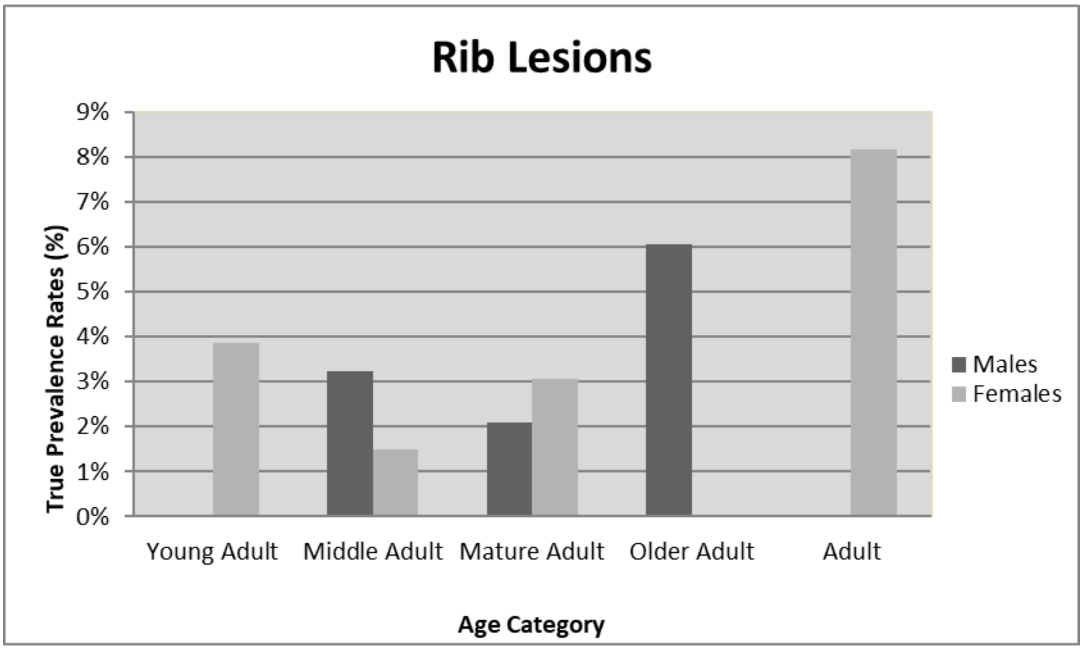


Figure 5.12: True prevalence rates in percentages for distribution of rib lesions associated with pleurisy between males and females for each age category within St Hilda's.

c. Tibial Periosteal New Bone Formation

Within the studied assemblage a total of 154 individuals possessed at least one tibia suitable for analysis, of these 90 were adults and 64 were non-adults. A total of 13 individuals displayed new bone formation on their tibial shafts from the total number of individuals who exhibited tibiae suitable for examination, giving a CPR at 8.4% *(13/154*). The TPR of TPNB for the total number of recordable tibiae was 6.51% (*19/292*). The TPRs for adults was 11.05% *(19/172),* whereas non-adults showed no evidence of the lesions. From all the affected age groups, older adults exhibited the highest prevalence of TPNB with a TPR of 26.5% (*9/34*), this corresponds to 7 older adults from the total number of affected individuals (Figure 5.13). After the application of a standardised residual test between the different age categories, it was ascertained that the higher prevalence in older adults (*p = 0.000)* was statistically significant. This statistically significant prevalence of the condition in older adults possibly reflects the susceptibility with increasing age to specific conditions such as varicose veins due to accumulative wear and tear of the valve veins in elderly.

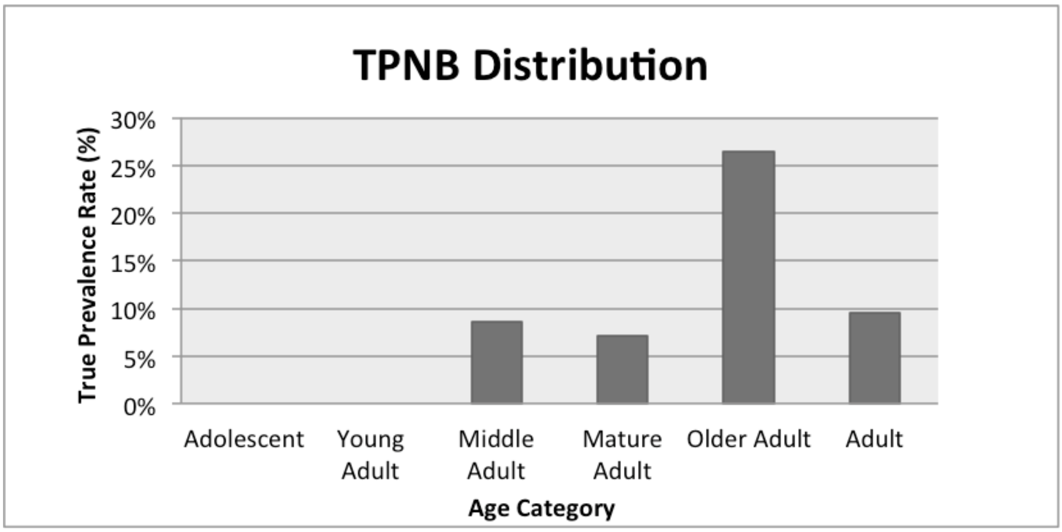


Figure 4.13: True prevalence rates in percentages for distribution of TPNB for each age category within St Hilda's (n= 154) individuals with recordable tibia.

The prevalence of *TPNB* between males and females was virtually the same, the TPRs for females and males were 12.8% (*10/78*) and 10.8% (*9/83*) respectively. This corresponds to 6 affected females and 7 affected males with no statistically significant differences being observed between biological sexes after the application of a chi-square (χ^2) test. A statistically significant higher prevalence of TPNB for older adult males, however, was revealed for age groups split by sex ($p = 0.000$) when a standardised residual test was applied (Figure 5.14). This higher prevalence reported in older male adults possibly reflects the effects of vigorous living that males experienced and the accumulative effects it on their health with increasing age. Reflecting this way discrepancies among sexes with increasing age due to exposure to physically demanding lifestyle.

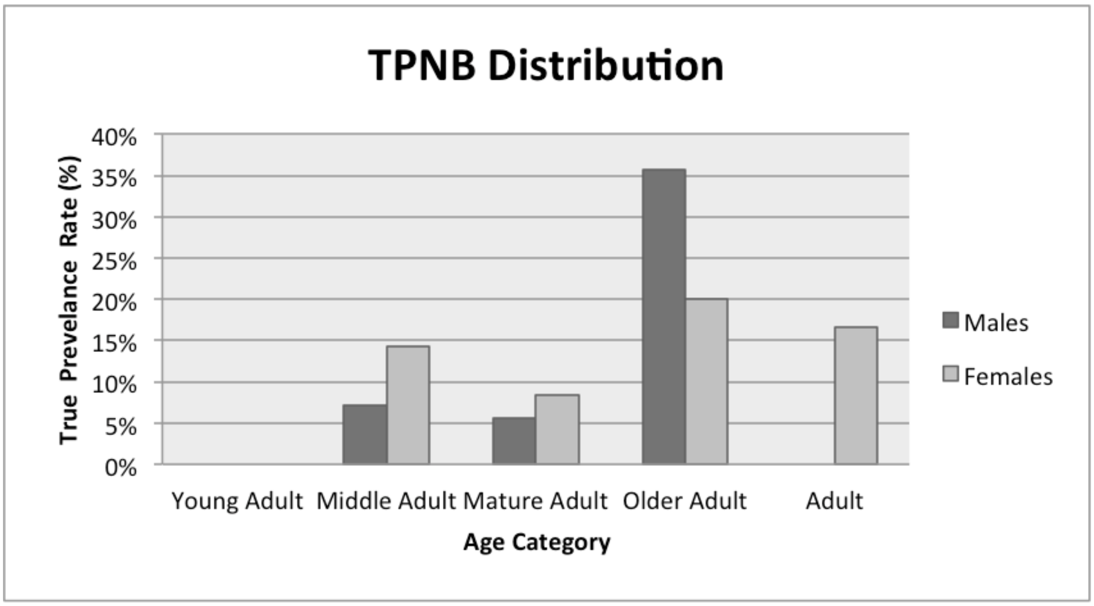


Figure 5.14: True prevalence rates in percentages for distribution of TPNB between males and females for each age category within St Hilda's.

d. Endocranial Lesions

Within the total assemblage 168 individuals possessed crania available for the recording of endocranial lesions, of these 68 were non-adults and 100 were adults. Observations, however, were limited by the complete nature of most of the surviving crania, leading possibly to the underrepresentation of the condition. In the case of intact crania, all observations were made without the use of an endoscope, through the foramen magnum on the base of the skull. Within St Hilda's seven non-adults exhibited evidence of reactive new bone formation on the endocranial surface, manifested as layers of new bone on the original cortical surface, expanding around meningeal vessels, as isolated plaques of 'hair on end' extensions of the diploe or as capillary impressions extending into the lamina of the cranium. The TPR (and CPR) of endocranial lesions within the total assemblage was 4.16% *(7/168).* The TPR (and CPR) for non-adults was 10.3% *(7/68),* whereas adults exhibited no evidence of endocranial lesions. Most of the lesions were active or healing at time of death and all the affected individuals were below the age of one and a half, ranging from preterm to early young child (Table 5.3). The lesions in non-adults are usually recognised as the result of haemorrhage or inflammation of the meninges; however, one-to-one correlations in terms of aetiology are difficult. No comparative data were available, limiting this way comparisons across various sites.

Age Category	(TPR %)
Preterm	2 (10.5%)
Neonate	0 (0.00%)
Infant	3 (37.5%)
Young Child	2 (15.4%)
Older Child	0 (0.00%)

Table 5.3: Number of non-adult individuals with endocranial lesions for each sub-adult age category within St Hilda's.

5.4.3 Skeletal Biomechanical Stress: Trauma

Lesions of traumatic origin were relatively commonplace in the adult assemblage. Within the total assemblage 42 individuals exhibited evidence of one or more traumatic lesions on their skeletons. The CPR of trauma for the total assemblage was 20.6% (*42/204*), while the CPRs for non-adults and adults were 1.15% (*1/87*) and 35.04% (*41/117*) respectively. There was a significantly higher frequency of traumatic lesions amongst the adults compared to the non-adults.

Males were by far more prone to injury than females accounting for two-thirds of all cases of trauma. The CPRs for males and females were 56.9% *(29/51)* and 18.9% *(10/53)* respectively, this corresponds to 29 affected males and ten affected females from the total number of affected individuals. The application of a chi-square test revealed the observed difference between males and females was statistically significant (*p= 0.000*). It is possible that the peak in trauma observed in males represents occupational and/or behavioural differences between biological sexes.

After the application of a standardised residual test as a follow up to a chi-square test, it was found that rates of trauma were found to increase exponentially with age with the prevalence of trauma being statistically higher in mature adults (*p = 0.000)*. The CPR of trauma was 48% (*12/25*) for the total number of mature adults which corresponds to 12 individuals. The difference in the prevalence of the indicator between different adult age groups was statistically significant. The observed increase with age may be connected to underlying pathological conditions that make the bones of the affected individuals more susceptible to fractures after a specific age. When age groups were split by sex the results of a standardised residual test yielded statistical significance (*p = 0.000*) with the older adult males being affected the most with a CPR at 100% (*7/7*). It is possible that the combination of sex and age reflects the work-related accidents that the males were exposed to during their life as well as the underlying pathological conditions arising from senescence (i.e. osteoporosis) which made their bones more prone to fractures.

a. Fractures: Ribs, Vertebrae and Upper and Lower Extremities

Fractures were the most frequently observed type of traumatic lesion, 41 individuals exhibited 76 fractures in total with males being by far more frequently affected than their female counterparts. Due to the high prevalence of fractures which had affected different bones (Appendix 3-4), after the calculation of TPR for each one individually the fractures were divided in four main categories for the easier statistical manipulation of the data. These four categories were ribs, vertebrae and upper and lower extremities (Figure 5.15-5.16). The category of upper extremities included the bones of pectoral girdle, arm, forearm and bones of the hand while lower extremities included the leg and foot bones. This step was necessary as it was observed that when the affected bones were analysed individually, most of the run tests (i.e. chi-square) yielded no statistical significance.

Most of the fractures recorded in St Hilda's were simple, closed fractures. The majority of these fractures were well healed with minimal misalignment and shortening indicating medical intervention to some degree and possibly after care. A few individuals suffered complications including secondary infection and deformity such as the case of a young female, who had suffered a possible compound fracture of the right femur, resulting in severe deformity and shortening of the affected limb by 86 mm, secondary infection (osteomyelitis) and severe joint contour deformity. The injury had also implications for the left limb, which appeared atrophic due to prolonged disuse. It is possible that some more injuries of serious nature existed among St Hilda's individuals, but were not recognised as the individual died shortly after the accident due to infection or other complications.

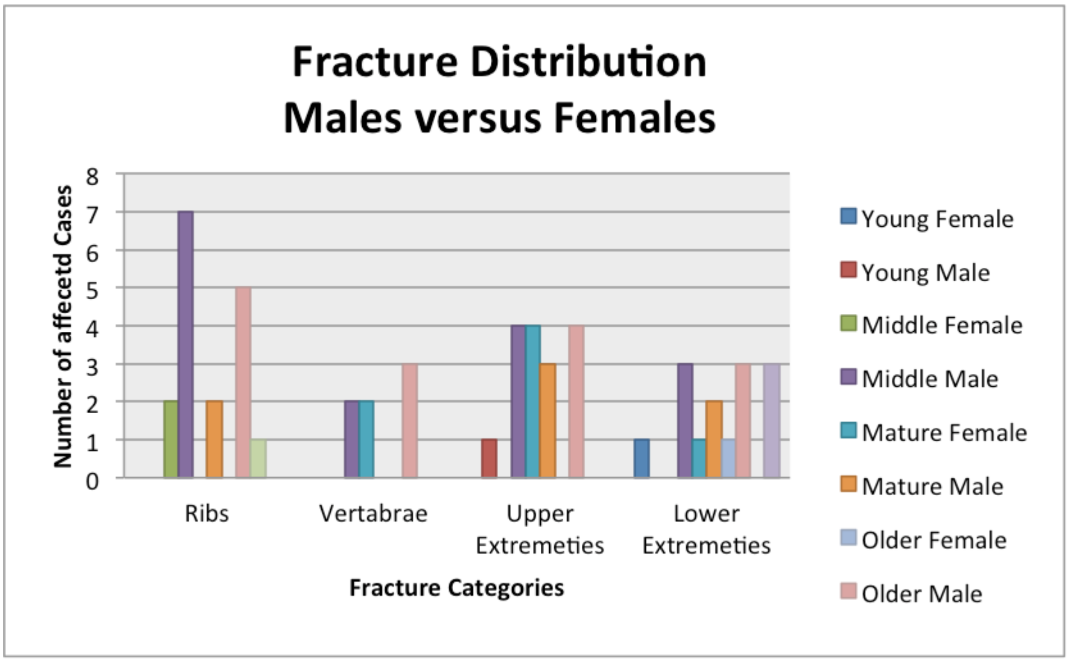


Figure 5.15: Distribution of different types of fractures between different adult age categories within St Hilda's.

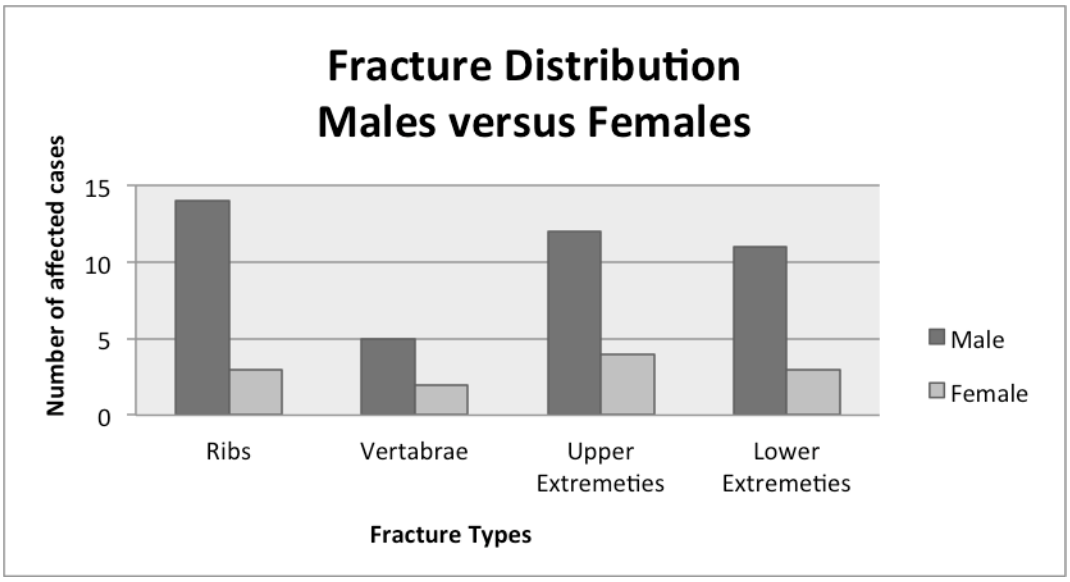


Figure 5.16: Distribution of different types of fractures between males and females within St Hilda's.

The TPR of rib fractures for the total assemblage was 1.85% (*47/2537*). The TPRs for adults and non-adults were 3.08% *(46/1495)* and 0.10% (*1/1042*) respectively. This corresponds to 17 affected adults and one affected non-adult. The application of a standardised residual test as a follow up to a chi-square test revealed that the prevalence of rib fractures was statistically higher in middle adults (*p = 0.000)* with a TPR at 2.94% (*20/680*). This corresponds to nine middle adults from the total number of affected individuals. The application of a chi-square test revealed that the prevalence of rib fractures was statistically higher in males than females (*p= 0.000*), the TPRs for males and females were 5.0% *(40/800)* and 0.96% *(6/626)* respectively. This corresponds to 14 affected males and 3 affected females. When age groups were split by sex the residual test results yielded statistical significance for older adult males (*p = 0.000*). Older adult males were affected the most showing that the lesions were increasing with age, the TPR of rib fractures was 18.18% (*18/99*), this corresponds to five affected individuals.

Within St Hilda's the majority of the rib fractures were healed with a rate at 66.6% (*12/18*), indicating that these fractures were not the cause of death due to complications (Holcomb *et al.* 2003, 553). Most of the affected individuals, 72.2% (*13/18*), exhibited multiple fractures; however, it was unclear whether they represented different episodes of injury or they were all acquired at the same time. Interesting, was the observation of possible green stick rib fracture noted in a young child, where some healing was noted.

The TPR of vertebral fractures (compression fractures) for the total assemblage was 0.31% (*8/2604*). The TPRs for adults was 0.44% *(8/1801)* this corresponds to seven affected adults, whereas no evidence of the lesions was recorded in non-adults. No statistically significant differences were observed between different age categories and biological sexes. The results, however, were significant for older male adults and a standardised residual test was applied. The TPR of vertebral fractures for older males was 2.54% (*3/118*) which corresponds to three individuals.

The TPR of upper extremity fractures for the total assemblage was 0.90% (*24/2666*). The TPR for adults was 1.20% *(24/1998)* which corresponds to 16 affected adults. Whereas no evidence of upper extremity fractures was recorded in non-adults. The application of a standardised residual test as a follow up to a chi-square test, revealed that the prevalence of upper extremity fractures was statistically higher in mature adults (*p = 0.001)* with a TPR at 1.89% (10/527), this corresponds to seven affected mature adults.

The application of a chi-square test, revealed that the prevalence of upper extremity fractures was statistically higher in males than females (*p= 0.024*). The TPRs for males and females were 1.86% *(20/1075)* and 0.48% *(4/828)* respectively, this corresponds to 12 affected males and 4 affected females. When age groups were split by sex, the application of a residual test yielded statistical significance for older adult males (*p = 0.000*) with a CPR at 57.14% (*4/7*), which corresponds to four affected individuals.

The TPR of lower extremity fractures for the total assemblage was 1.35% (*23/1697*). The TPR of lower extremities fractures for adults was 1.80% *(23/1277),* this corresponds to 15 affected adults. No evidence of the lesions was recorded in non-adults. No statistically significant differences were observed between different age categories; however, differences were noted between biological sexes. The application of a chi-square test revealed that the prevalence of lower extremity fractures was statistically higher in males than females (*p= 0.024*), the TPRs for males and females were 3.15% *(19/603)* and 0.51% *(3/583)* respectively, this corresponds to 11 affected males and 3 affected females. When age groups were split by sex the chi-square test results yielded no significance.

Within St Hilda's, males appeared to be more prone to fractures of metacarpal and metatarsal bones. In particular, males exhibited higher prevalence of metacarpal fractures (*p = 0.024)* with a TPR at 3.16% (*7/221*). The same pattern was noted for metatarsals (*p = 0.038)* with a TPR at 3.14% (*6/191*). No differences were observed between different age categories, but the prevalence of metacarpal and metatarsal fractures was statistically higher in older males (*p = 0.000)*, the TPR of metacarpal and metatarsal fractures was 9.09% (*3/33*) and 10.25% (*4/39*) respectively.

b. Other Fractures, Joint Disruptions (Dislocation and Subluxation) and Evidence of Micro-Trauma (Spondylolysis, Osteochondritis Dissecans (OD), Os Acromiale)

It is difficult to be certain, as accidents can produce similar features to those that would be sustained in interpersonal violence but there were a number of cases of individuals with facial fractures recorded in St Hilda's. Facial injuries were recorded in three adults, two males and one female; the CPR for the adult population was 2.56% (*3/117*).

Four examples of joint disruption were identified in St Hilda's skeletal assemblage, two dislocations and two subluxations; a shoulder dislocation, a dislocation of the sternoclavicular joint, a thumb subluxation, and a subluxation of the proximal tibiofibular joint. These few individuals were affected at different joints; consequently, allowing only calculation of CPR otherwise the rates per joint would be too low. The CPR for the adult population was 3.42% (*4/117*) while most of the affected cases were males with CPR at 5.88% (*3/51*). In both cases of dislocation severe joint contour had occurred following the dislocation with further complications such as the formation of a pseudo-arthrosis and ossification of ligamentous attachments (myositis ossificans traumatica).

Within the St Hilda's skeletal assemblage, a total of 133 individuals possessed at least one lumbar vertebra suitable for the recording of separation or partial separation of the vertebral body from the neural arch known as spondylolysis. Of these, 84 were adults and 49 were non-adults. A total of eight individuals displayed defects in the neural arch of the vertebrae, whereby the neural arch was partially or completely separated from the rest of the vertebral body. The TPR of spondylolysis for the total assemblage was 1.44% (*8/557)*. The TPR for adults alone was 2.06% (*8/389*), while non-adults exhibited no evidence of spondylolysis. Six individuals were observed with spondylolysis of the fifth lumbar vertebrae; whereas in two individuals the exact number of lumbar vertebrae affected was unknown with one of them exhibiting bilateral spondylolysis. The predisposition of the fifth lumbar vertebra is consistent with reports from modern living populations. No statistically significant differences were observed between different age groups, biological sexes as well as when age groups were split by biological sex.

Another condition that is frequently associated with a repetitive micro-trauma is osteochondrosis dissecans (OD), which is a localised injury involving separation of a cartilage segment and subchondral bone in an articular surface. Within the St Hilda's assemblage three adults exhibited evidence of this minor injury, the TPR for the adult population was 1.71% (*3/175)*. Two of the affected individuals were middle adult males and one was adolescent; all were affected on the medial or lateral femoral condyle. The application of a standardised residual test after a chi-square test, revealed that the prevalence of OD was statistically higher in adolescents ($p = 0.00$) with a TPR at 25.0% (*1/4*) matching this way the clinical predisposition reported for modern living populations.

Another indicator of micro-trauma observed within the studied assemblage was os acromiale, an accessory bone resulting from union failure of the acromial epiphysis in the scapula. Os acromiale was observed in five adults; of these only one had bilateral involvement. The TPR of os acromiale for adults was 3.51% (*6/171*).

5.4.4 Joint Disease: Extra-spinal and Spinal Joint Disease

Within the assemblage 71 individuals exhibited evidence of joint disease. The CPR of joint disease for the adult assemblage was 60.7% (*71/117*), while non-adults exhibited no evidence of any diseases of the joints. The application of a standardised residual test revealed that the rates of joint disease were found to increase with age with the prevalence of the lesions being statistically higher for older adults (*p = 0.000)*. The CPR of joint disease for this group was 100.0% (*17/17*), indicating that all the older adults of St Hilda's were affected by some joint disease due to degeneration of the joints with increasing age. The difference in the prevalence of the indicator between different adult age groups was statistically significant for both the total and the adult population alone. Males and females were equally affected by joint disease. The CPR for males and females was 68.6% (*35/51*) and 64.1% (*34/53*) respectively, corresponding to 35 affected males and 34 affected females. As a result, there were no statistically significant differences between biological sexes, showing that both sexes were equally exposed to degeneration of the joints. When age groups were split by sex the results yielded no statistical significance.

a. Extra-spinal Joint Disease: Osteoarthritis (OA)

The most commonly observed joint disease within St Hilda's was OA. Lesions characteristic of primary OA were present in 61 adults, affecting adults from all age groups although with a predilection for the older age categories. The CPR of primary OA for the adult population was 52.1% (*61/117*), whilst 17.9% (*21/117*) exhibited generalised OA (more than three joints affected) which corresponds to 21 affected individuals. Over half the group of the individuals with generalised OA, in particular 52.4% (*11/21*) were older adults. Cases of secondary OA were also noted in the St Hilda's individuals. The CPR of secondary OA for the adult population was 16.2% (*19/117*) which corresponds to 19 affected individuals, from these affected individuals 13 exhibited both primary and secondary OA of different joints which corresponds to 68.4% (*13/19*). The total CPR of OA whether primary or secondary was 57.3% (*67/117*) for the adult population which corresponds to 67 affected adults. Rates of OA were found to increase with age with the prevalence of the lesions being statistically higher in older adults (*p = 0.000)*. The CPR of OA for older adults was 100.0% (*17/17*) indicating that all the older adults of St Hilda's were affected by OA due to degeneration of the joints with increasing age.

Of these older adults affected by OA, 11 exhibited generalised OA with 64.7% (*11/17*). The difference in the prevalence of the indicator between different adult age groups was statistically significant for both the total and the adult population alone. No biological sex differences were observed in the prevalence of OA. Males and females of St Hilda's population sample were equally affected by OA with CPRs at 64.7% (*33/51*) and 62.3% (*33/53*) respectively, which corresponds to 33 affected males and females. Consequently, both sexes were probably exposed to degeneration of the joints due to ageing, in combination with repeated stress imposed by strenuous exercise which started earlier in life. When age groups were split by sex the results yielded no statistical significance.

Within the St Hilda's population 40.2% (*47/117*) adults exhibited changes for the diagnosis of extra-spinal OA. In the upper body, the hands were most affected by OA, followed by the shoulder, wrist, elbow and the temporomandibular joints of the skull. Whereas, in the lower body the feet were most affected by OA, followed by the knee and hip joints (Table 5.4; Figure 5.17).

Joint affected	**No Individuals**	**Count Affected**	**Count Present**	**TPR (%)**
Temporomandibular	9	11	200	5.50%
Shoulder	10	15	164	9.15%
Strernoclavicular	8	11	162	6.79%
Costovertebral	4	44	1495	2.94%
Elbow	9	11	182	6.04%
wrist	10	12	143	8.39%
Hand	15	19	153	12.42%
Hip	11	18	175	10.29%
Knee	13	17	114	14.91%
Foot	21	30	153	19.61%

Table 5.4: True prevalence rates in percentages for distribution of extra-spinal OA by joint in St Hilda's adults.

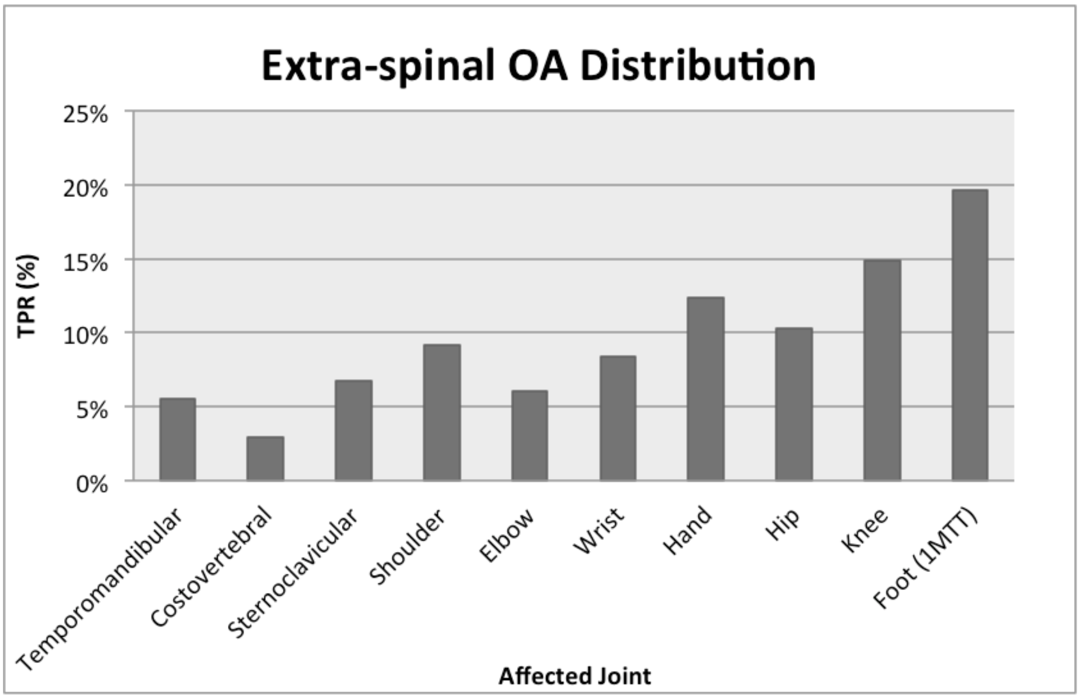


Figure 5.17: True prevalence rates in percentages for distribution of extra-spinal OA by joint in St Hilda's adults.

In terms of TPR per age category, after the application of standardised residual tests it was revealed that older adults exhibited higher predilection of OA, with most of their joints being affected (Figure 5.18). The most frequently affected upper body joints in older adults, where the differences were statistically significant, were those of the hands, followed by the wrists and elbows while from the lower body were the two major weight-bearing joints of the hips and knees (Appendix 5). The TPR of OA of the hands was 12.4% (*19/153)* for adults which corresponds to 15 affected individuals. The prevalence of OA was statistically higher in older adults (*p = 0.00)*, the TPR of hand OA for older adults was 25.8% (*8/31*) which corresponds to six older adults. The difference in the prevalence of the indicator between different adult age groups was statistically significant for both the total and the adult population alone. The TPR of OA of the wrist was 8.4% (*12/143)* for adults which corresponds to ten affected individuals. The prevalence of wrist OA was statistically higher in older adults (*p = 0.00)*, the TPR of OA for older adults was 30.8% (*8/26*) which corresponds to six older adults. The difference in the prevalence of the indicator between different adult age groups was statistically significant for both the total and the adult population alone. The TPR of OA of the elbow was 6.04% (*11/182)* which corresponds to nine affected adults. The prevalence of elbow OA was statistically higher in older adults (*p = 0.00)*, the TPR of OA for older adults was 16.7% (*5/30*) which corresponds to four older adults. The difference in the prevalence of the indicator between different adult age groups was statistically significant for both the total and the adult population alone. Older adults of St Hilda's exhibited also higher prevalence rates in the two major weight-bearing joints of hips and knees. The TPR of OA of the knees was 14.9% (*17/114),* this corresponds to 13 affected adults. The prevalence of knee OA was statistically higher in older adults (*p = 0.000)*, the TPR of OA for older adults was 34.8% (*8/23*), this corresponds to five older adults. The difference in the prevalence of the indicator between different adult age groups was statistically significant for both the total and the adult population alone. The TPR of OA of the hips was 10.3% (*18/175)* for adults*,* this corresponds to 11 affected adults. The prevalence of hip OA was statistically higher in older adults (*p = 0.000)*, the TPR of OA for older adults was 17.7% (*6/34*), this corresponds to four older adults. The difference in the prevalence of the indicator between different adult age groups was statistically significant for both the total and the adult population alone.

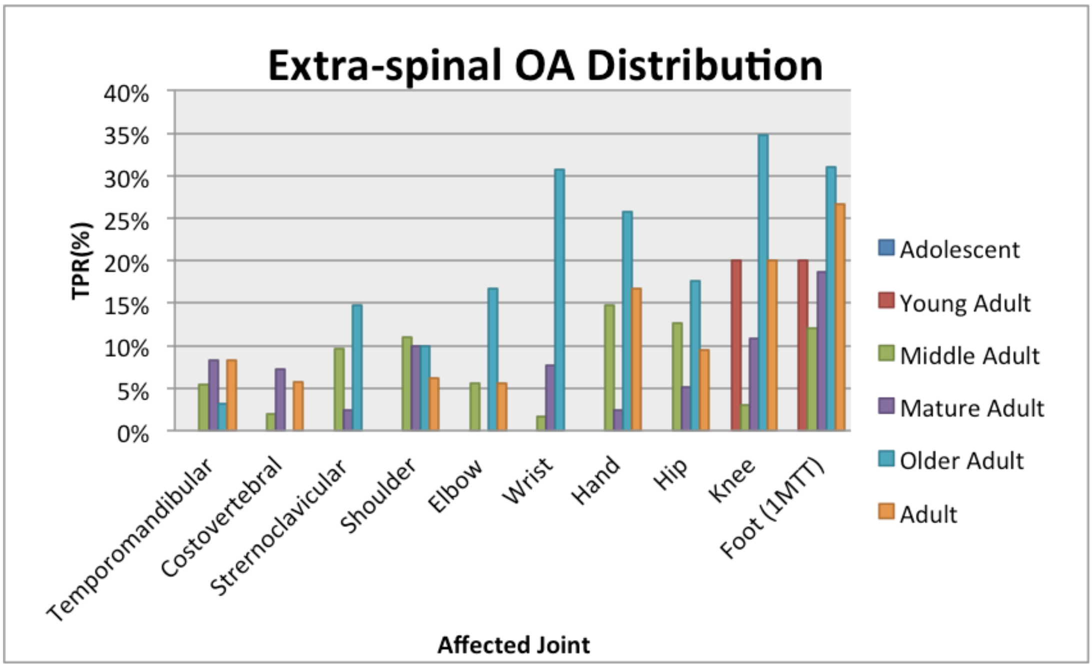


Figure 5.18: True prevalence rates in percentages for distribution of extra-spinal OA by joint in St Hilda's different adult age categories.

The application of chi-square tests revealed that there were no observed statistical differences between males and females, both males and females were equally exposed to most extra-spinal OA and to its complex aetiology (Figure 5.19). However, only in the case of hand and hip joints St Hilda's males exhibited some significant differences compared to females. In particular males seem to have suffered higher rates of OA of the hands and hip compared to females (Table 5.5). The difference between males and females was statistically significant (*p= 0.002*) for OA of the hands, the TPRs for males and females were 20.7% *(17/82)* and 3.13% *(2/64)* respectively. This corresponds to 13 affected males and two affected females. When age groups were split by sex older male adults exhibited statistically higher prevalence (*p= 0.00*), the TPR of hand OA for older male adults was 50.0% (*7/14*). This corresponds to five affected older male adults from the total number of affected individuals. In the case of hip, the difference between males and females was again statistically significant (*p= 0.021*). The TPRs for males and females were 18.0% *(15/83)* and 3.70% *(3/81)* respectively, corresponding to nine affected males and two affected females from the total number of affected individuals. No differences were observed forage groups split by sex.

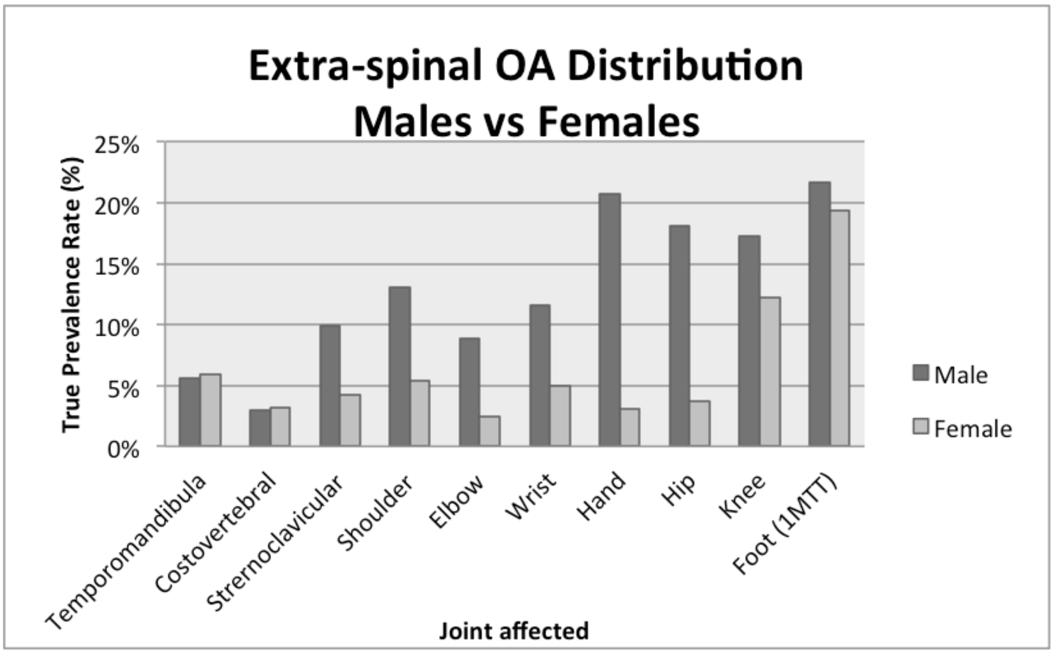


Figure 5.19: True prevalence rates in percentages for distribution of extra-spinal OA by joint between males and females (n= 104).

Males versus Females

Joint affected	No Individuals	Count Affected	Count Present	TPR (%)	No Individuals	Count Affected	Count Present	TPR (%)
Temporo-mandibular	4	5	90	5.6%	5	6	102	5.9%
Shoulder	8	11	84	13.1%	2	4	74	5.4%
Strerno-clavicular	6	8	81	9.9%	2	3	70	4.3%
Costo-vertebral	3	24	800	3.00%	1	20	626	3.2%
Elbow	6	8	90	8.9%	2	2	80	2.5%
Wrist	7	9	78	11.5%	3	3	60	5.0%
Hand	13	17	82	20.7%	2	2	64	3.1%
Hip	9	15	83	18.0%	2	3	81	3.7%
Knee	7	10	58	17.2%	5	6	49	12.2%
Foot	11	16	74	21.6%	9	13	67	19.4%

Table 5.5: True prevalence rates in percentages for distribution of extra-spinal OA by joint between males and females (n= 104).

b. Spinal Degenerative Joint Disease: Spinal Osteoarthritis (OA), Spondylosis Deformans (SD), Schmorl's Nodes and Vertebral Osteophytes

The most frequently affected part of the body with joint disease was the spine, in total 47 adults exhibited spinal joint disease. The CPR of spinal joint disease for the adult population was 40.2% (*47/117*). Due to the greater aetiological complexity of spinal joint disease and the different types of joints in this region, for the calculation of TPR the various spinal anatomical regions were assessed separately. In total 103 adults had one or more vertebrae suitable for the recording of spinal joint disease. These adults exhibited 1801 vertebra in total, these vertebrae were systematically assessed for lesions related to osteoarthritis of the zygapophyseal joints, spondylosis deformans, Schmorl's nodes and marginal osteophytes (Appendix 6).

Degenerative changes and involvement of the zygapophyseal joints (facets) of the spine, is known as spinal OA. In total 42 adults exhibited features on their facets pathognomonic for the diagnosis of spinal OA, the TPR of spinal OA for adults was 23.5% (*424/1801).* The application of a standardised residual test revealed the prevalence of spinal OA was statistically higher in older adults (*p = 0.00)* with a TPR for this age category at 55.0% (*161/293*), this corresponds to 15 older adults (Figure 5.20). The difference in the prevalence of the indicator between different adult age groups was statistically significant for both the total and the adult population alone.

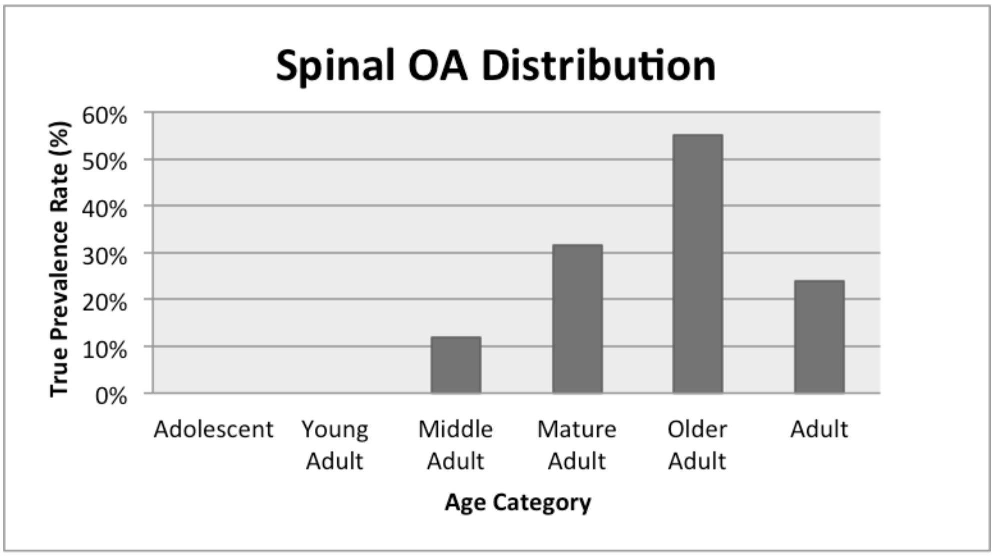


Figure 5.20: True prevalence rates in percentages for distribution of spinal OA (zyg) for each adult age category within St Hilda's (n= 103) adults with recordable vertebrae.

The TPRs for males and females were 19.0% *(172/903)* and 29.4% *(236/802)* respectively. This corresponds to 19 affected males and 22 affected females from the total number of affected individuals. The application of a chi-square test revealed that there were no statistical differences between males and females with both males and females being equally exposed, although females had more vertebrae affected. When age groups were split by sex, older male adults exhibited statistically higher prevalence (*p= 0.00*) with a TPR at 53.4% (*63/118).* This corresponds to five affected older male adults from the total number of affected individuals (Figure 5.21). The lesions showed predominance in the cervical region.

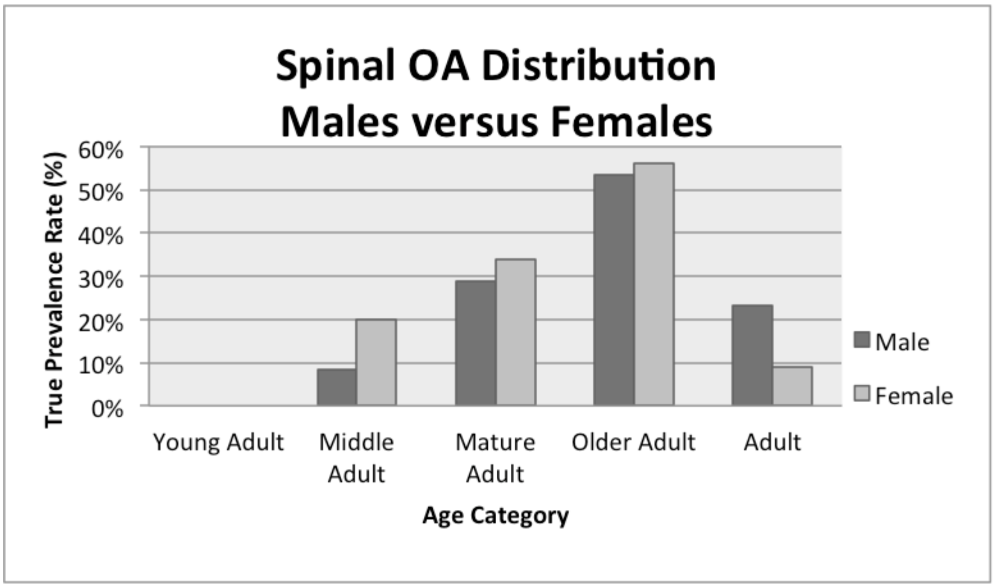


Figure 5.21: True prevalence rates in percentages for distribution of spinal OA (zyg) between males and females for each adult age category within St Hilda's.

Lesions characteristic for the diagnosis of SD of the vertebral bodies were noted in 24 adults with a TPR of SD at 12.9% (*232/1801).* The application of a standardised residual test revealed the prevalence of SD was statistically higher in older adults (*p = 0.00)* with a TPR for this age category at 35.8% (*105/293*), this corresponds to 11 older adults (Figure 5.22). The difference in the prevalence of the indicator between different adult age groups was statistically significant for both the total and the adult population alone.

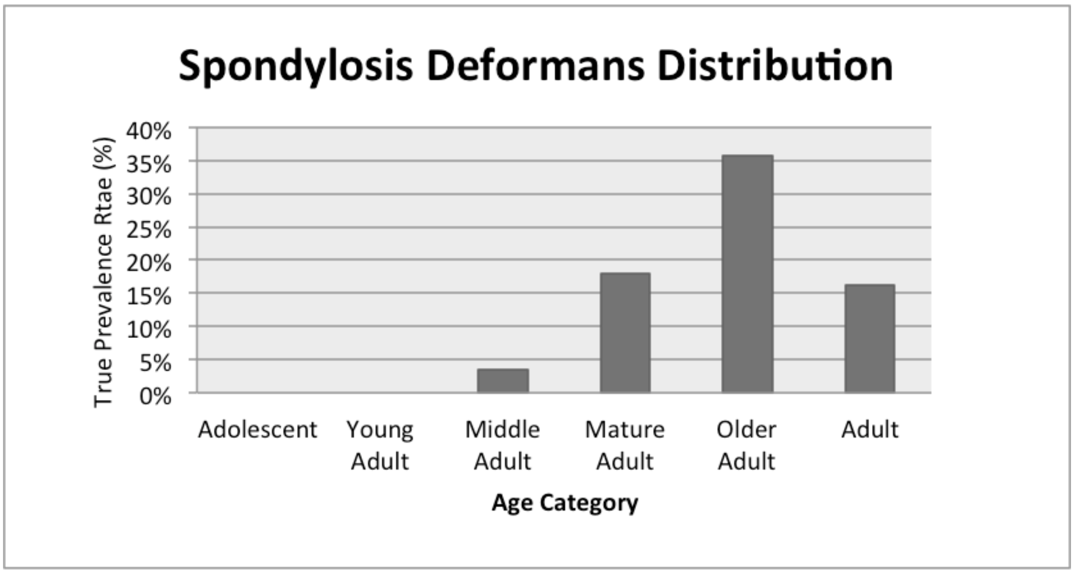


Figure 5.22 True prevalence rates in percentages for distribution of SD for each adult age category within St Hilda's (n= 103) adults with recordable vertebrae.

SD was most pronounced in male individuals the TPRs for males and females were 16.9% *(152/903)* and 9.2% *(74/802)* respectively, this corresponds to 13 affected males and 10 affected females from the total number of affected individuals. The observed difference between males and females was statistically significant (*p= 0.00*). When age groups were split by sex, older male adults exhibited statistically higher prevalence (*p= 0.00*) with a TPR at 45.8% (*54/118).* This corresponds to five affected older male adults from the total number of affected individuals (Figure 5.23). The lesions showed predominance in the cervical region.

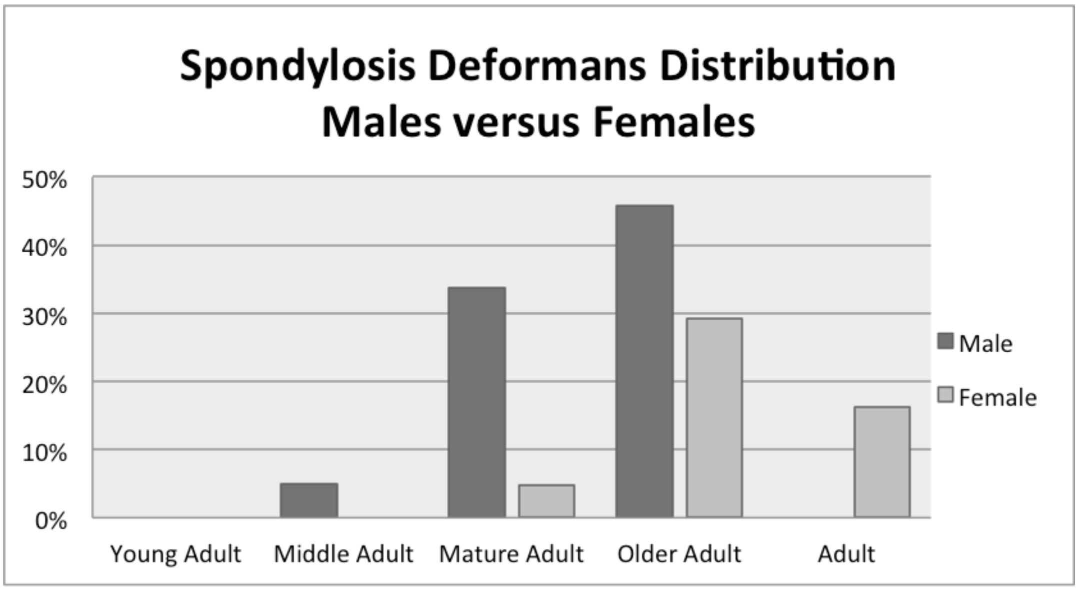


Figure 5.23: True prevalence rates in percentages for distribution of SD between males and females for each adult age category within St Hilda's.

Schmorl's nodes were identified on the superior and inferior surfaces of the vertebral bodies of 47 adults with a TPR for adults at 29.3% *(527/1801)*. The application of a standardised residual test revealed the prevalence of Schmorl's nodes was statistically higher in middle adults (*p = 0.00)* with a TPR for this age category at 32.2% (*247/768*). This corresponds to 20 middle adults from the total number of affected individuals (Figure 4.24).

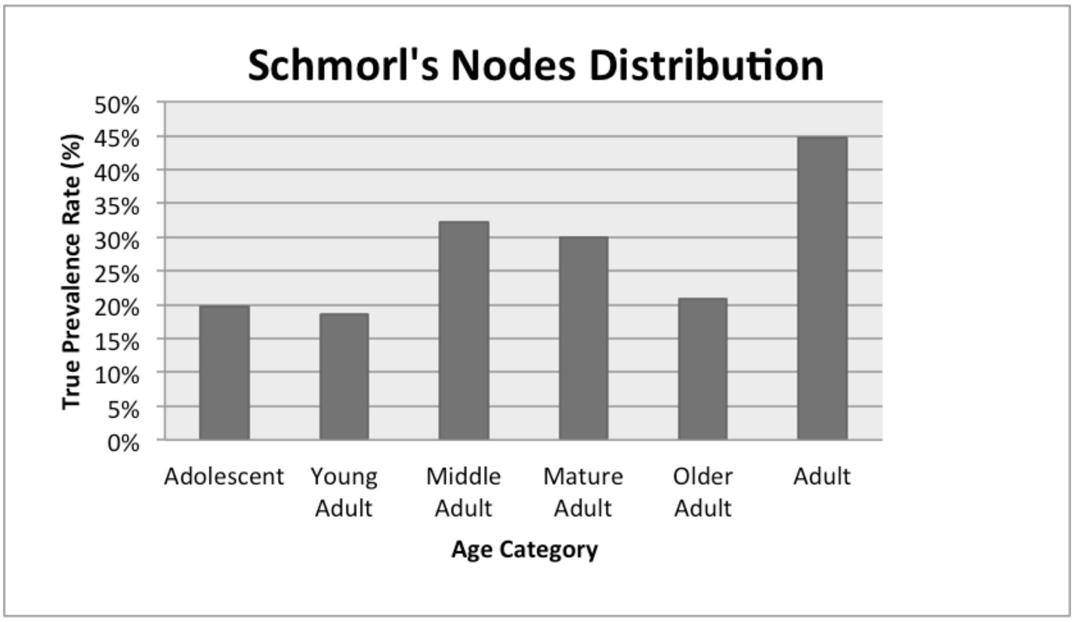


Figure 5.24: True prevalence rates in percentages for distribution of Schmorl's nodes for each adult age category within St Hilda's (n= 103) adults with recordable vertebrae.

The TPRs for males and females were 40.0% *(361/903)* and 18.0% *(144/802)* respectively. This corresponds to 32 affected males and 13 affected females from the total number of affected individuals. The application of a chi-square test revealed the prevalence of Schmorl's nodes was statistically higher in males than females (*p= 0.00*). No statistical difference was observed for age groups were split by sex (Figure 5.25). In the vast majority of cases the lesions occurred in the thoracic and lumbar region.

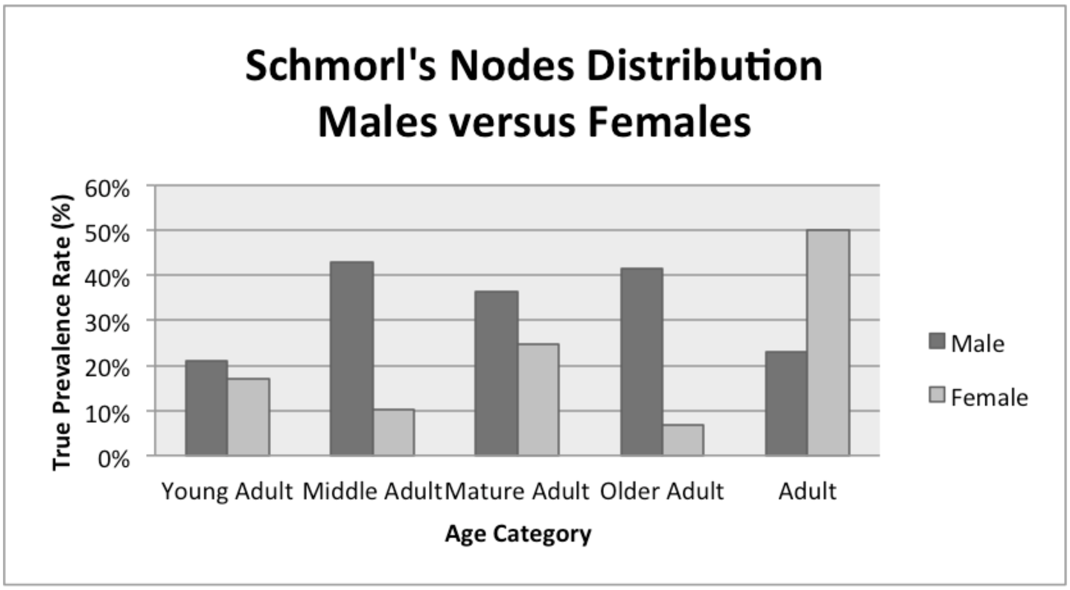


Figure 4.25: True prevalence rates in percentages for distribution of Schmorl's nodes between males and females for each adult age category within St Hilda's.

New bone formation around the margins of the joints, known as osteophytes, was found in a total of 57 adults. This condition varied within the assemblage between individuals with only slight bony spicules on the margins of a couple of vertebral bodies and severe new bone formation wherein most of the extant elements on the vertebral column were severely affected. The TPR of osteophytosis for adults was 48.1% (*867/1801).* The application of a standardised residual test revealed the prevalence of spinal osteophytes was statistically higher in older adults (*p = 0.00)* with a TPR for this age category at 80.2% (*235/293*) for the total population, which corresponds to 13 older adults (Figure 5.26).

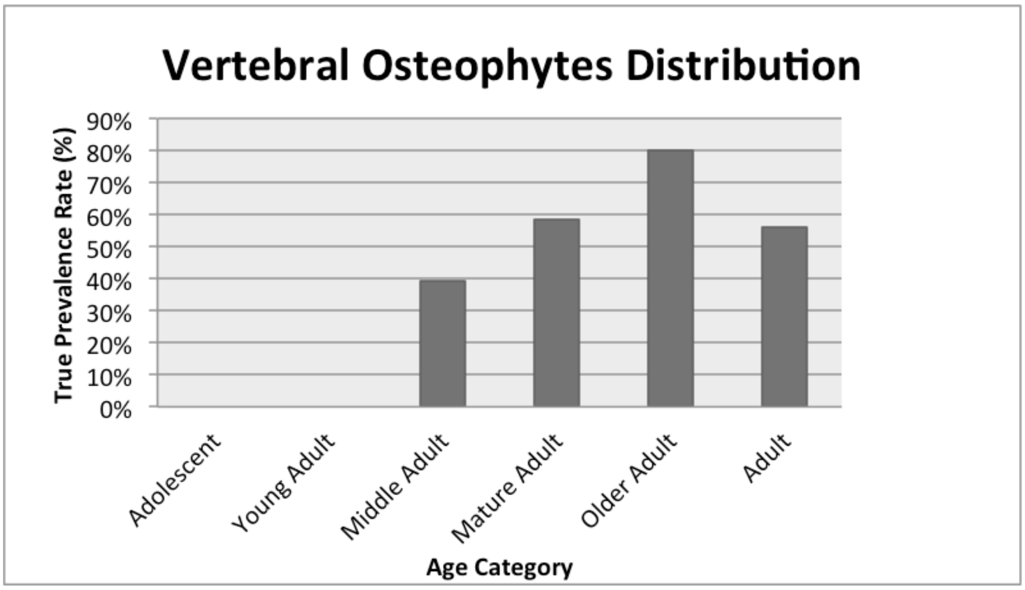


Figure 5.26: True prevalence rates in percentages for distribution of vertebral osteophytes for each adult age category within St Hilda's (n= 103) adults with recordable vertebrae.

Vertebral osteophytosis was most pronounced in male individuals, the TPRs for males and females were 57.1% *(516/903)* and 41.1% *(330/802)* respectively. This corresponds to 34 affected males and 22 affected females from the total number of affected individuals. The application of a chi-square test revealed the observed difference between males and females was statistically significant (*p= 0.01*). When age groups were split by sex the results yielded no statistical significance (Figure 5.27). In the vast majority of cases the lesions occurred in the thoracic and lumbar region.

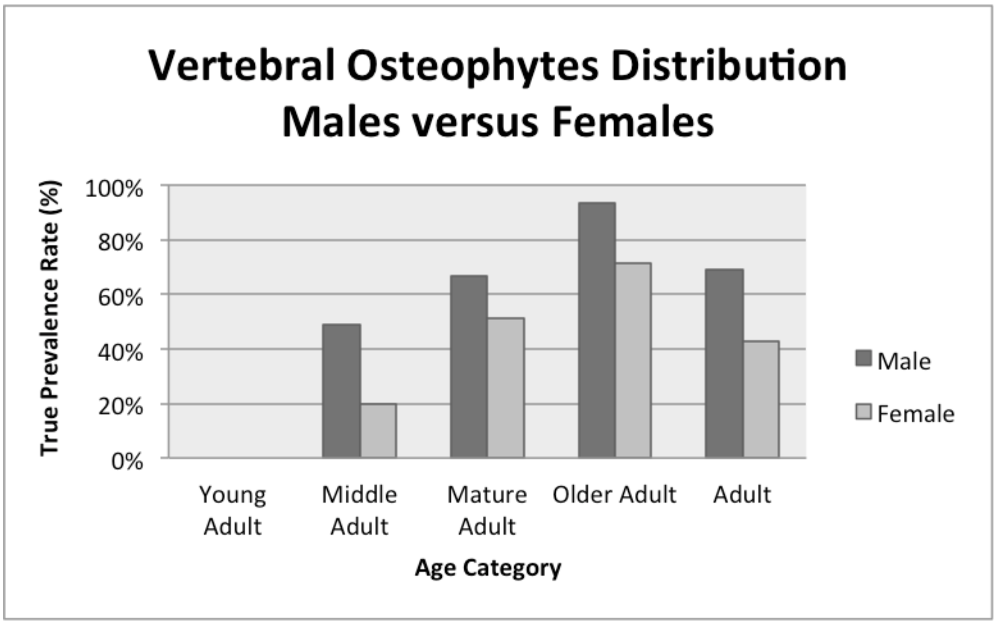


Figure 5.27: True prevalence rates in percentages for distribution of vertebral osteophytes between males and females for each adult age category within St Hilda's.

c. Other Joint Disease: Diffuse Idiopathic Skeletal Hyperostosis (DISH), Ankylosing Spondylitis (AS), Rheumatoid Arthritis (RA), Septic Arthritis (SA) and Gouty Arthritis (GA)

Within the adult assemblage, three probable cases of DISH were diagnosed. All the affected individuals were males, two of them were older adults whilst the third one was classified as adult due to poor preservation. Due to the nature of the condition that requires the involvement of multiple skeletal elements for its diagnosis, it was possible only to estimate the CPR of DISH. The CPR for adults was 2.56% (*3/117*) and for males only was 5.88% (*3/51*). When Fisher's exact test was applied, there were no statistically significant differences in the prevalence of the lesions between males and females or different adult age groups for either the total or the adult population alone. However, when age groups were split by sex, the CPR for older males was statistically significant ($p = 0.00$) with a CPR for older males at 28.57% (*2/7*).

AS characterised by symmetrical sacroilitis and spinal fusion in the form of bamboo spine due to formation of syndesmophytes was noted in three individuals. Again, due to the nature of the condition that requires the involvement of more than one skeletal joint, it was only possible to estimate the CPR. The CPR for the adult assemblage was 2.56% (*3/117*) and the affected individuals were two older adult females and one older adult male, the CPRs for females and males was 3.77% (*2/53*) and 1.96% (1/*51*) respectively.

Erosive inflammatory lesions of the small joints of hands and feet pathognomonic for the diagnosis of RA were identified in an older male adult. Due to the nature of the condition that requires the involvement of multiple joints for its diagnosis, it was possible only to estimate the CPR of RA. The CPR of RA for the adult assemblage was 0.85% (*1/117*).

One case of SA was observed in a mature female with her left first metatarsophalangeal joint being affected, the CPR for the adult population was 0.85% (*1/117*).

Within the adult assemblage, seven individuals had inflammatory skeletal changes on the first metatarsophalangeal joints (great toe) consistent with a diagnosis of GA, giving a CPR at 5.98% (*7/117*). The TPR of GA for the adult assemblage was 5.23% *(8/153)* (Table 5.6-5.7).

Males vs Females	1st MTT Count	TPR (%)	No individuals
Male	5	7.46%	4
Female	2	2.70%	2

Table 5.6: True prevalence rates in percentages for distribution of gout between males and females within the St Hilda's skeletal assemblage.

Age Category	1st MTT Count	TPR (%)	No individuals
Adolescent	1	25.00%	1
Young Adult	1	10.00%	1
Middle Adult	2	4.00%	2
Mature Adult	3	6.97%	2
Older Adult	0	0.00%	0
Adult	1	5.88%	1

Table 5.7: True prevalence rates in percentages for distribution of gout for each adult age category within the St Hilda's skeletal assemblage.

5.4.5 Indicators of Environmental Stress: Dental Health

Dental pathologies were commonly encountered within the adults and sub-adults of St Hilda's revealing valuable information on diet, oral health and hygiene and general health. Various biological factors such as different enamel susceptibility as well as lifestyle factors such as differential consumption of foods, and habitual and occupational use of the teeth are probably to blame for the extent to which teeth were affected by stress (Hillson 2002; DeWitte and Bekvalac 2010).

Within the St Hilda's skeletal assemblage, a total of 115 individuals possessed one or more teeth suitable for analysis. Of these, 29 were non-adult and 86 were adults and from these counted adults, 42 were males and 39 were females. This corresponds to 1,788 teeth in total and from these 393 belonged to non-adults and 1,395 belonged to adults; from the adult dentition 756 belonged to males and 530 belonged to females. While at the same time, 155 individuals possessed one or more tooth sockets suitable for identification of diseases of the alveolar bone. Of these, 58 were non-adults and 97 were adults and from these adults 45 were males and 48 females. This corresponds to 3,838 tooth sockets in total and from these, 982 belonged to non-adults and 2,856 belonged to adults; from these tooth sockets 1,352 were from males and 1,377 were from females.

a. Carious Lesions

A total of 81 individuals displayed destruction of enamel, dentine (internal part of the tooth) and cement (outer layer of the roots) resulting from acid production by bacteria in dental plaque. The TPR of carious lesions for the total assemblage was 26.2% *(468/1788).* The prevalence of carious lesions was higher in adults than non-adults with the TPRs for adults and non-adults being 31.8% (*444/1395*) and 6.11% (*24/393*) respectively, this corresponds to 75 adults and 6 non-adults. The lower prevalence of carious lesions in non-adults, however, could be accorded to the smaller size of deciduous teeth which might affect their retrieval during excavation and their short-use life of deciduous teeth which limits automatically the exposure time of teeth to cariogenic factors. The prevalence of carious lesions increased with age for the adult assemblage. After the application of a standardised residual test as a follow up to a chi-square test, it was revealed that the prevalence of carious lesions was statistically higher in middle adults (*p = 0.00)* with a TPR at 32.4% *(220/680)*, this corresponds to 33 individuals (Figure 5.28).

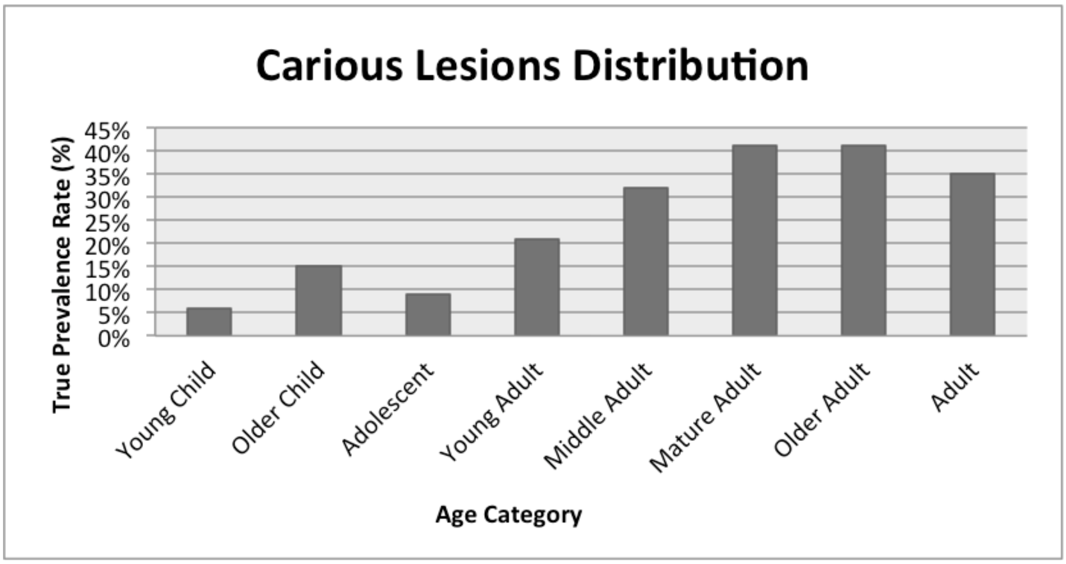


Figure 5.28: True prevalence rates in percentages for distribution of carious lesions for each age category within St Hilda's skeletal assemblage in individuals with recordable teeth (n= 115).

Males and females seemed to have suffered similar rates of carious lesions, the TPRs for males and females were 32.3% (*244/756*) and 34.5% (*183/530*) respectively (Figure 5.29). This corresponds to 38 males and 32 females. The difference observed between males and females was not statistically significant and also was not significant when age groups were split by sex.

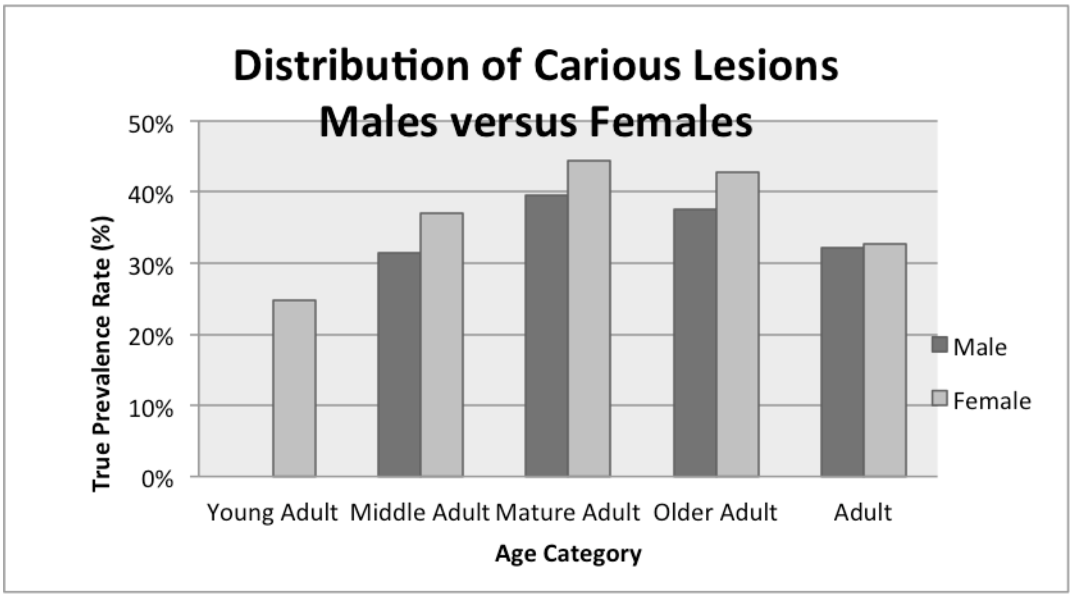


Figure 5.29: True prevalence rates in percentages for distribution of carious lesions between males (n=42) and females (n=39) for each age category within St Hilda's.

b. Dental Calculus

A total of 78 individuals displayed mineralised plaque accumulated in the mouth. The TPR of calculus for the total assemblage was 55.5% *(993/1788).* The prevalence of calculus was higher in adults than non-adults with the TPRs for adults and non-adults being 69.4% *(968/1395)* and *6.4% (25/393)* respectively, this corresponds to 75 adults and 3 non-adults. The lower prevalence of calculus in non-adults could be accorded to a combination of factors such as taphonomy, the smaller size of deciduous teeth which causes difficulties in retrieving them, the short-use life of deciduous teeth and their limited exposure time to plaque-forming factors as well as the nature of the calculus deposits which are frequently loosely attached to teeth leading to easy detachment during excavation and post-excavation processes. The prevalence of calculus increased with age for the adult assemblage. After the application of a standardised residual test as a follow up to a chi-square test, it was revealed that the prevalence of calculus was statistically higher in middle adults ($p = 0.000$) with a TPR at 77.8% *(529/680)*, this corresponds to 34 individuals (Figure 5.30).

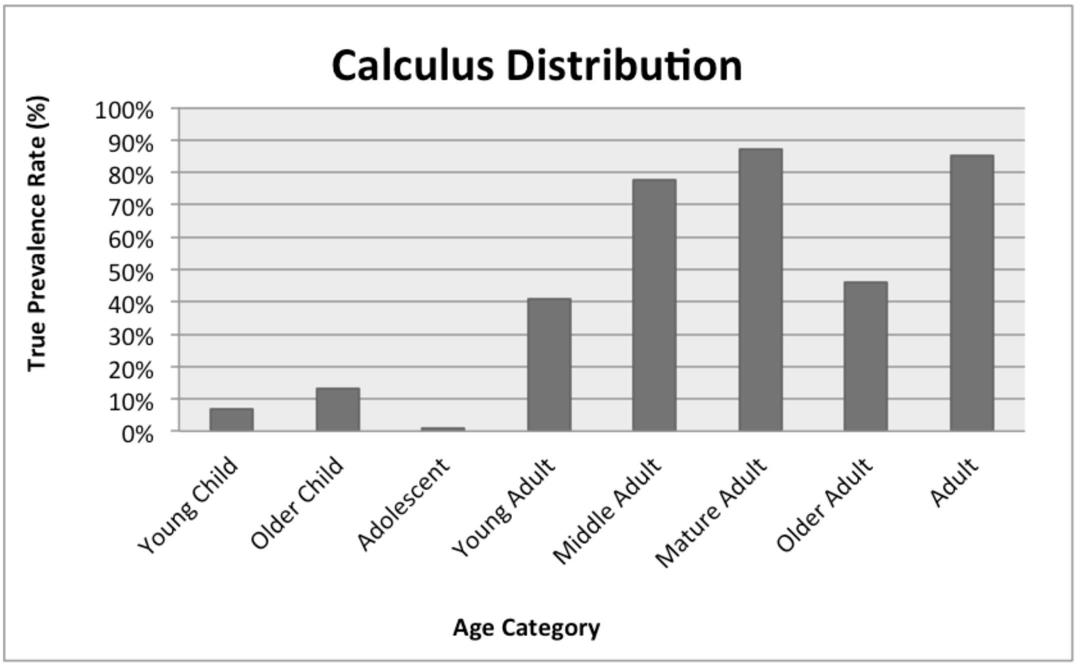


Figure 5.30: True prevalence rates in percentages for distribution of calculus for each age category within St Hilda's individuals with recordable teeth (n= 115).

The prevalence of calculus was statistically higher in males than females (*p= 0.016*), the TPRs for males and females were 79.0% *(597/756)* and 64.7% *(343/530)* respectively (Figure 5.31). This corresponds to 41 affected males and 31 affected females from a total number of 75 adults who exhibited skeletal evidence of calculus. No statistical difference was observed when age groups- were split by sex.

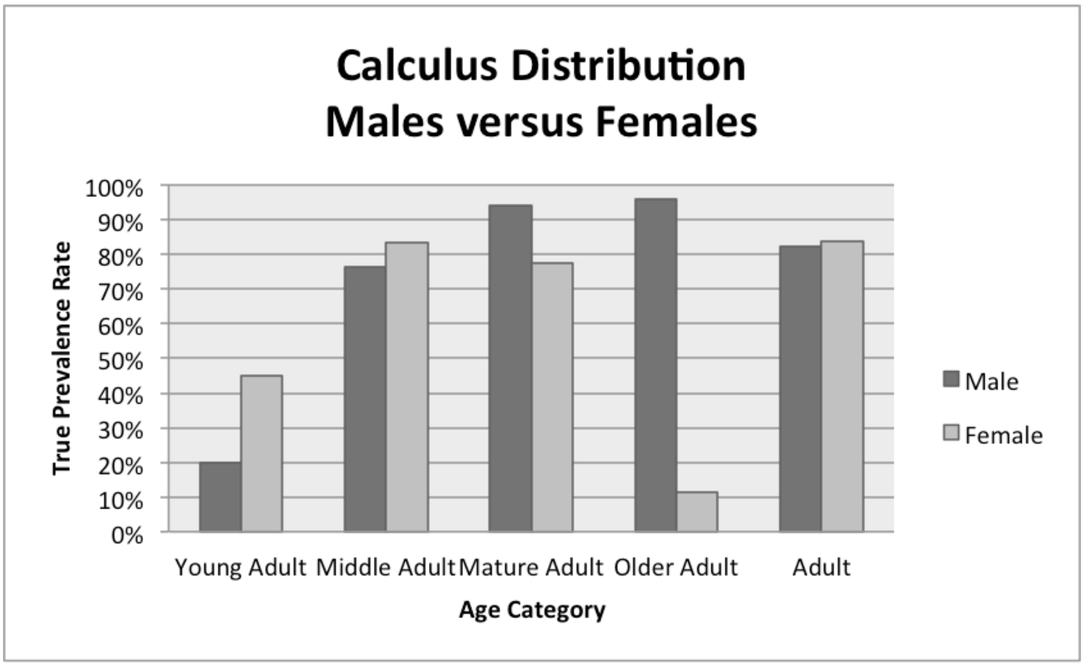


Figure 5.31: True prevalence rates in percentages for distribution of calculus between males (n=42) and females (n=39) for each age category within St Hilda's.

c. Dental Wear (DW)

A total of 60 individuals displayed dental wear due to attrition or abrasion or a combination of both. The TPR of dental wear for the total assemblage was 37.7% (*674/1788*). The TPRs for adults was 48.3% (*674/1395*) while non-adults showed no evidence of the lesions. The prevalence of DW increased with age for the adult assemblage of St Hilda's. After the application of a standardised residual test as a follow up to a chi-square test, it was revealed that the prevalence of DW was statistically higher in middle adults ($p = 0.00$) with a TPR at 55.4% (*377/680*) for this group, which corresponds to 28 middle adults from the total number of affected individuals (Figure 5.32).

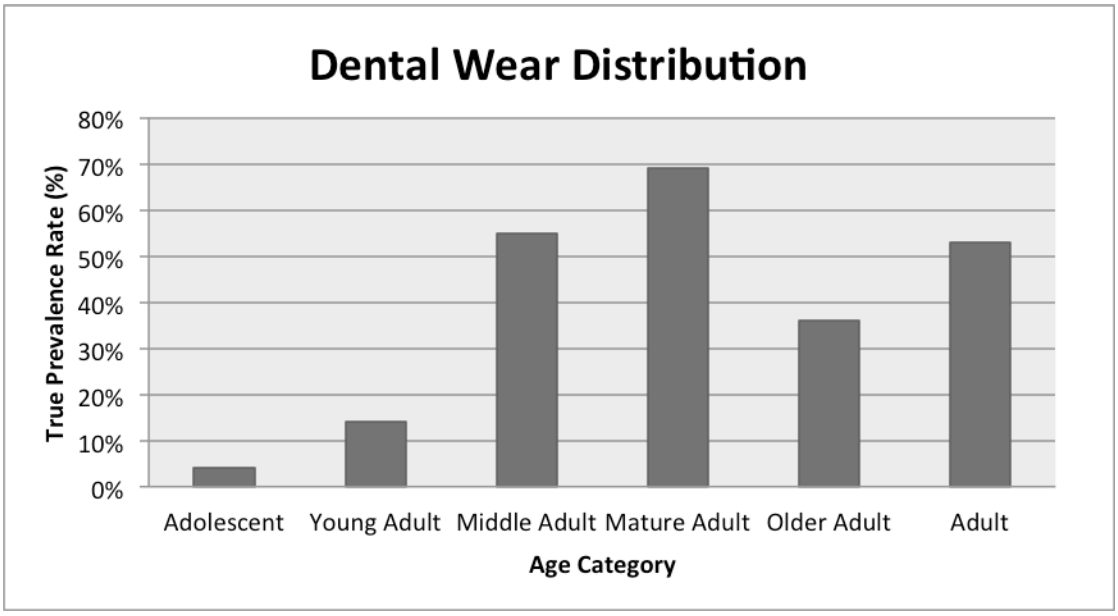


Figure 5.32: True prevalence rates in percentages for distribution of dental wear for each age category within St Hilda's individuals with recordable teeth (n= 115).

The prevalence of dental wear was statistically higher in males than females ($p = 0.017$), the TPRs for males and females were 62.8% *(475/756)* and 33.4% *(177/530)* respectively (Figure 5.33). This corresponds to 34 affected males and 23 affected females. No statistical difference was observed when age groups were split by sex. Pipe facets were also seen in four male middle adults, indicating that the dental wear observed in males might be also the result of abrasion due to contact with an external object such as a pipe. The CPR of pipe facets for the adult assemblage was 3.42% *(4/117)* with no statistical differences being observed between different age and sex groups for either the total population or the adult population alone. No differences were also observed when age groups were split by sex.

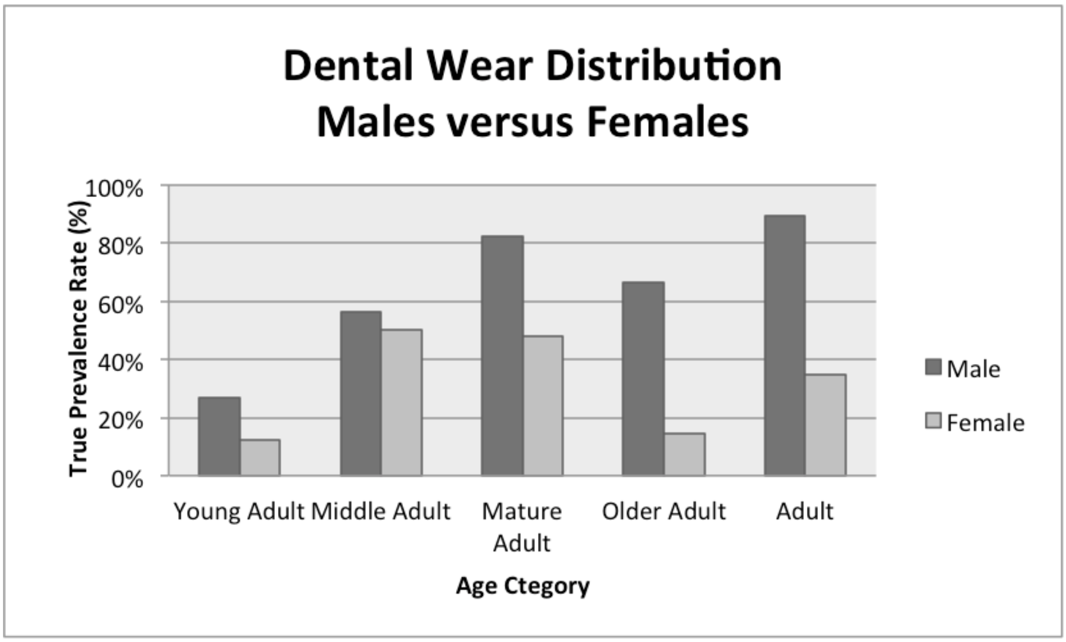


Figure 5.33: True prevalence rates in percentages for distribution of dental wear between males (n=42) and females (n=39) for each age category within St Hilda's.

d. Periodontal Disease (PD)

A total of 83 individuals exhibited inflammation of the alveolar bone, resulting in horizontal or vertical recession. The TPR of PD for the total assemblage was 57.4% (*2204/3838*). The TPR for adults was 77.2% (*2204/2856*), whereas non-adults showed no evidence of the lesions.

The prevalence of PD increased with age for the adult assemblage of St Hilda's. After the application of a residual test in order to determine which age category attributed to the statistical significance of the applied chi-square test, it was revealed that the prevalence of PD was statistically higher in older adults ($p = 0.01$) for the adult population. The TPR of PD was 98.2% (*427/435*) for older adults, this corresponds to 16 older adults from the total number of affected individuals (Figure 5.34). Whilst for the total population the prevalence of PD was statistically higher in mature adults ($p = 0.00$), the TPR was 89.2% (*610/684*); this corresponds to 23 mature adults.

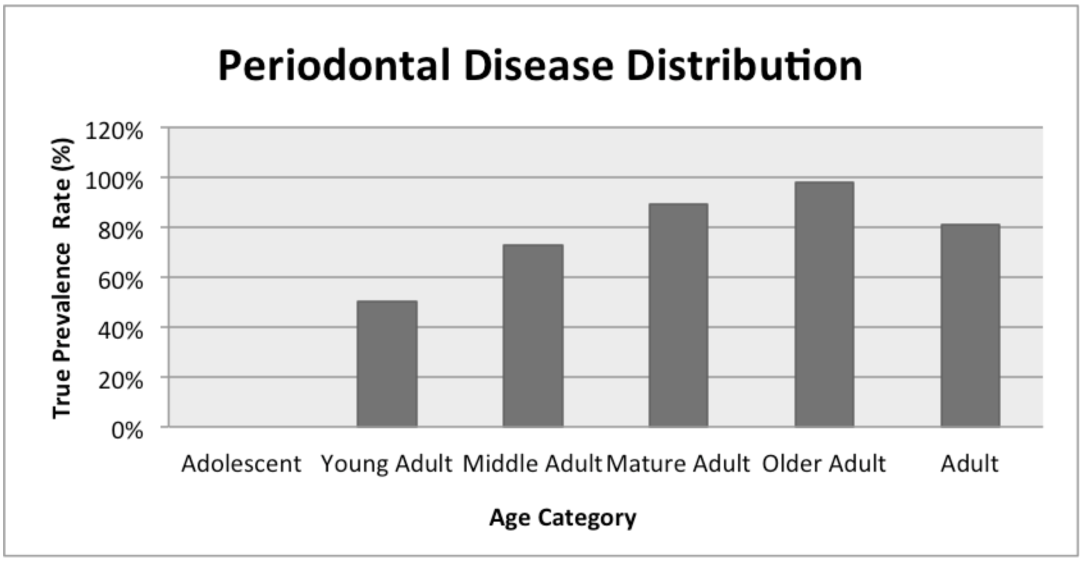


Figure 5.34: True prevalence rates in percentages for distribution of PD for each age category within St Hilda's individuals with recordable alveolar bone (n= 155).

There was no statistically significant difference in the prevalence of PD expressed by females and males. The prevalence of PD between females and males were 82.2% (*1132/1377*) and 77.0% (*1041/1352*) respectively (Figure 5.35). This corresponds to 42 affected females and 40 affected males. Consequently, the number of affected individuals was virtually the same with the females being slightly more affected than their male counterparts. No statistically significant difference was observed for age groups split by sex.

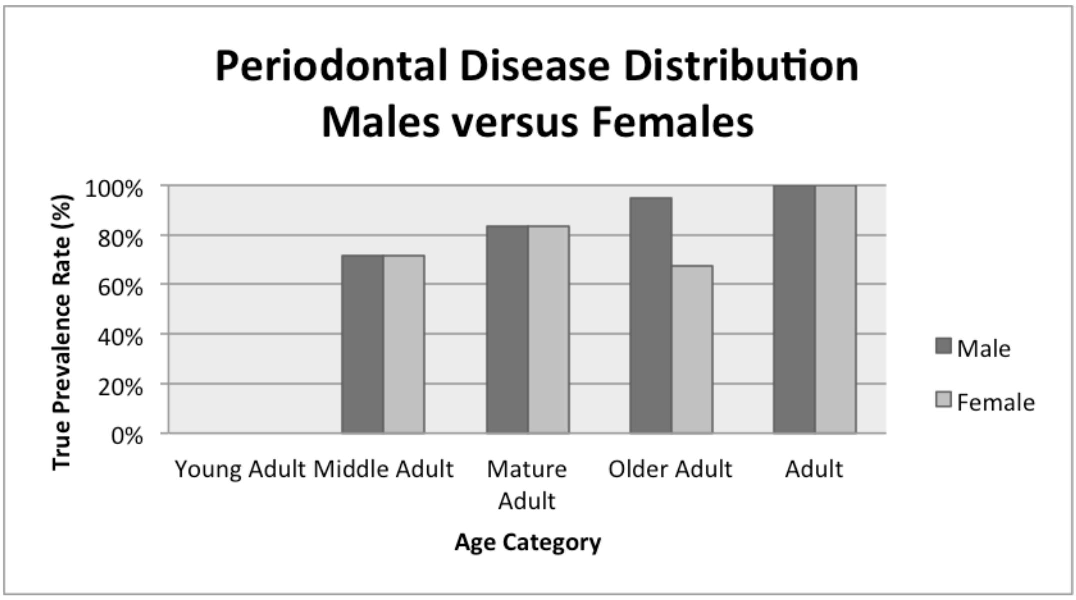


Figure 5.35: True prevalence rates in percentages for distribution of periodontal disease between males (n=42) and females (n=39) for each age category within St Hilda's.

e. Ante-Mortem Tooth Loss (AMTL)

A total of 82 individuals exhibited loss of permanent dentition. The TPR of AMTL for the total assemblage was 29.2% (*1119/3838*). The TPRs for adults was 39.2% (*1119/2856*), whereas no evidence of the lesions was observed in non-adults. The application of a residual test revealed that the prevalence of AMTL was statistically higher in mature adults (*p = 0.00)*, the TPR of AMTL was 50.0% (*343/684*), which corresponds to 23 individuals (Figure 5.36).

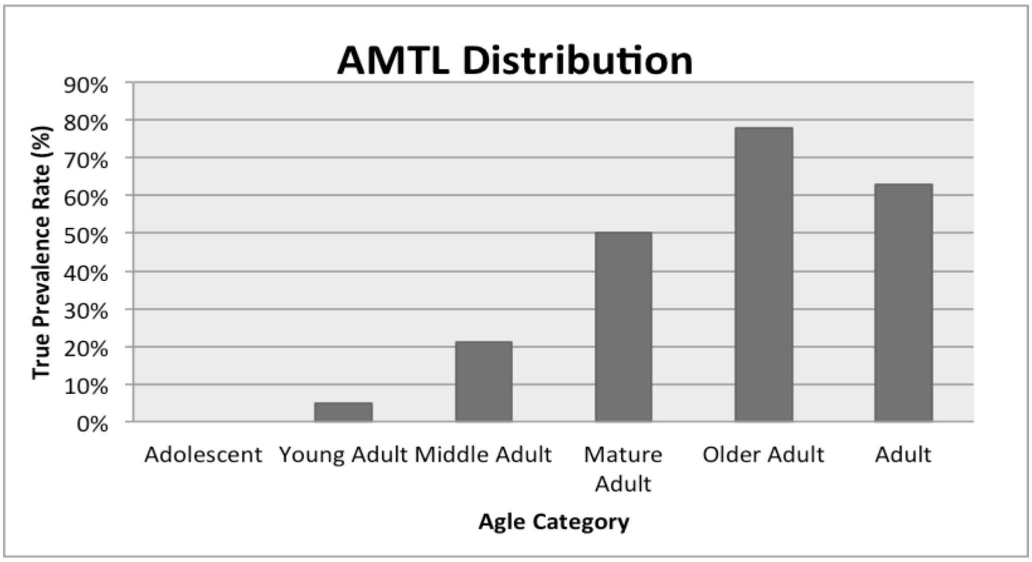


Figure 5.36: True prevalence rates in percentages for distribution of AMTL for each age category within St Hilda's individuals with recordable alveolar bone (n= 155).

There was no statistically significant difference in the prevalence of AMTL expressed by females and males. The prevalence of AMTL between females and males were 50.7% (*698/1377*) and 30.8% (*416/1352*) respectively (Figure 5.37). This corresponds to 41 affected females and 40 affected males. Consequently, the number of affected individuals was virtually the same although males seem to have lost more teeth than their female counterparts. No statistically significant difference was observed for age groups split by sex.

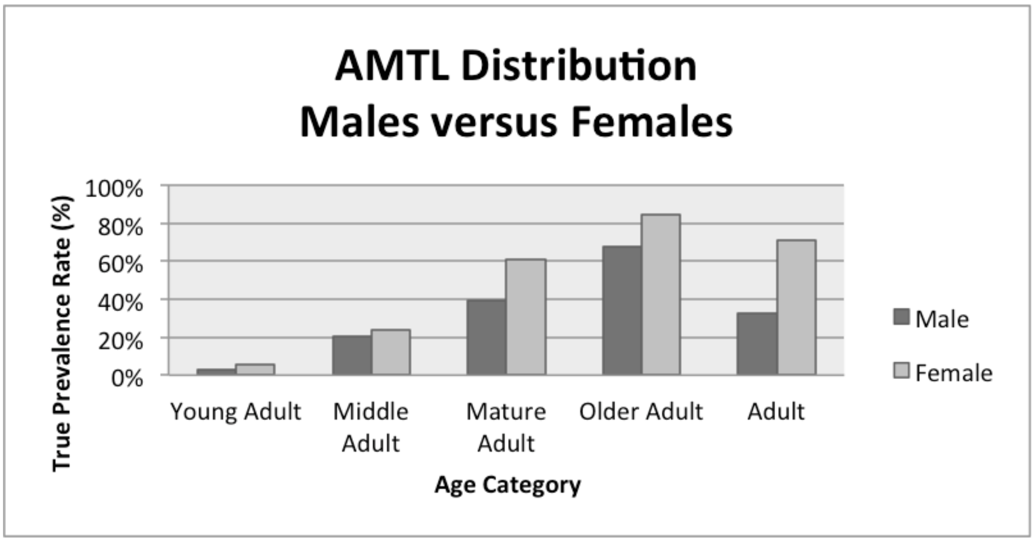


Figure 5.37: True prevalence rates in percentages for distribution of AMTL between males (n=42) and females (n=39) for each age category within St Hilda's.

Only a small portion of the affected individuals 6.09% (*5/82*) was missing only one tooth. The majority of affected individuals 93.9% (*77/82*) were missing two or more teeth with seven individuals being edentulous and six out of seven edentulous individuals being older females. The loss of seven or more teeth was mostly observed in mature and older adults, indicating AMTL severity to be correlated with advancing age.

f. Periapical Cavities: Abscess and Cyst

In terms of the visible pathology, a total of 31 individuals were affected by periapical lesions, of these 23 displayed abscesses and 8 displayed cysts. The TPR of abscess and cyst for the total assemblage was 0.96% (*37/3838*) and 0.34% (*13/3838*) respectively. The TPRs for adults exhibiting abscess and cysts were 1.30% (*37/2856*) and 0.46% (*13/2856*) respectively, whilst non-adults showed no evidence of the lesions. The difference in the prevalence of the indicator between different adult age groups for the total population was statistically significant for abscesses and cysts. The application of residual tests, revealed that the prevalence of abscess was statistically higher in middle adults (*p = 0.00)* for the total population. The TPR of abscess was 1.37% (*15/1097*) for middle adults, this corresponds to ten middle adults from the total number of affected individuals (Figure 5.38a). While the prevalence of cysts was statistically higher in mature adults (*p = 0.00)* for the total population. The TPR of cyst was 0.88% (*6/684*) for mature adults, which corresponds to four mature adults from the total number of affected individuals (Figure 5.38b).

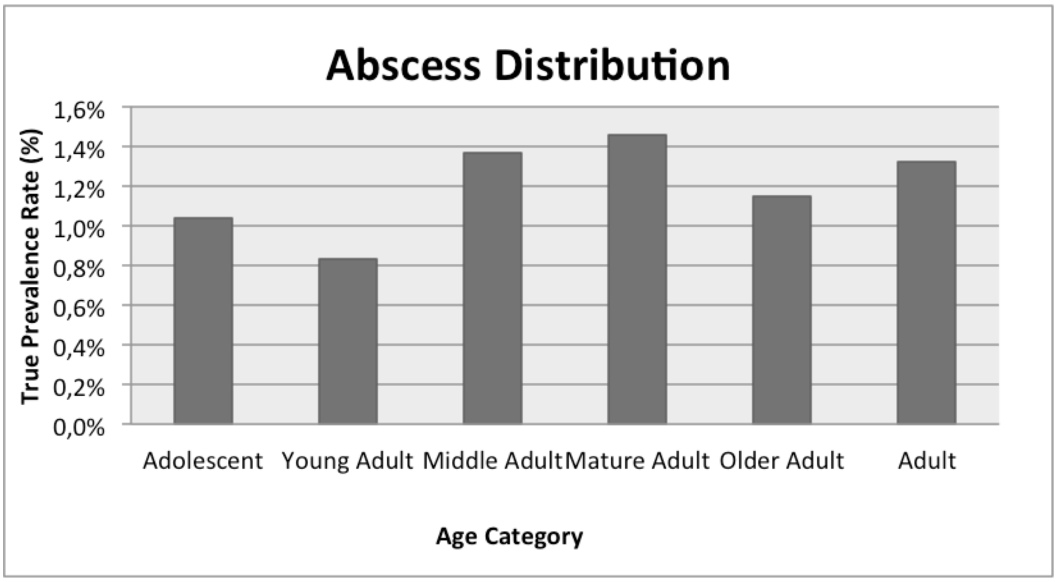


Figure 5.38a: True prevalence rates in percentages for distribution of abscesses for each age category within St Hilda's individuals with recordable alveolar bone (n= 155).

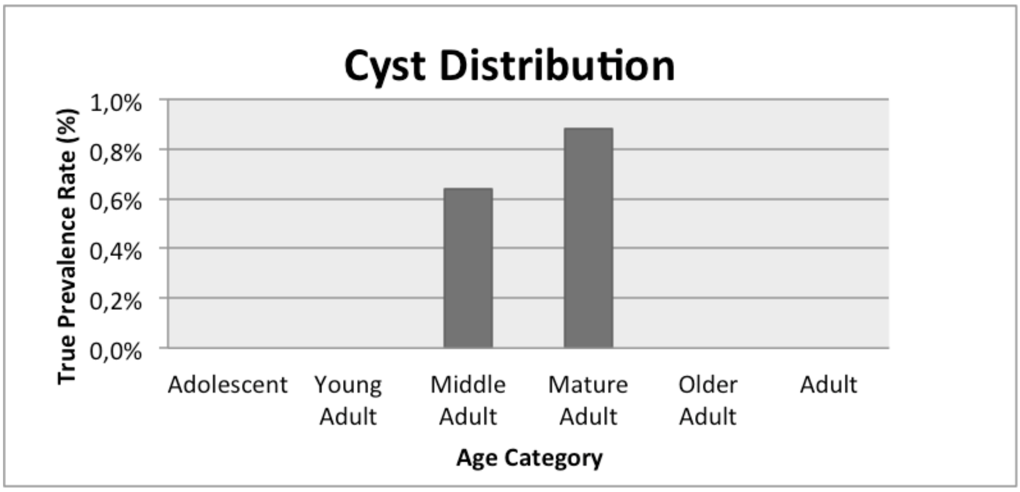


Figure 5.38b: True prevalence rates in percentages for distribution of cysts for each age category within St Hilda's individuals with recordable alveolar bone (n= 155).

There was no statistically significant difference in the prevalence of abscesses and cysts expressed by females and males. The prevalence of abscess between females and males were 1.31% (*18/1377*) and 1.33% (*18/1352*) respectively (Figure 5.39a). This corresponds to 11 affected females and 11 affected males; consequently, both sexes were equally affected. The prevalence of cysts between females and males were 0.65% (*9/1377*) and 0.22% (*3/1352*) respectively (Figure 4.39b). This corresponds to five affected females and two affected males; consequently, females were twice affected compared to their male counterparts. No statistically significant difference was observed when age groups were split by sex.

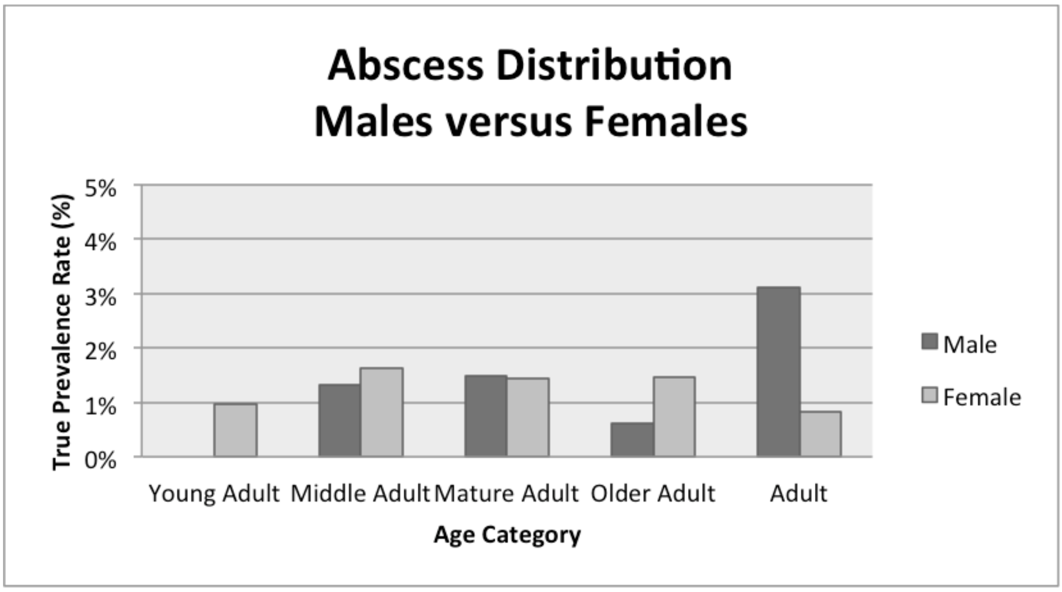


Figure 5.39a: True prevalence rates in percentages for distribution of Abscesses and Cysts between males (n=42) and females (n=39) for each age category within St Hilda's.

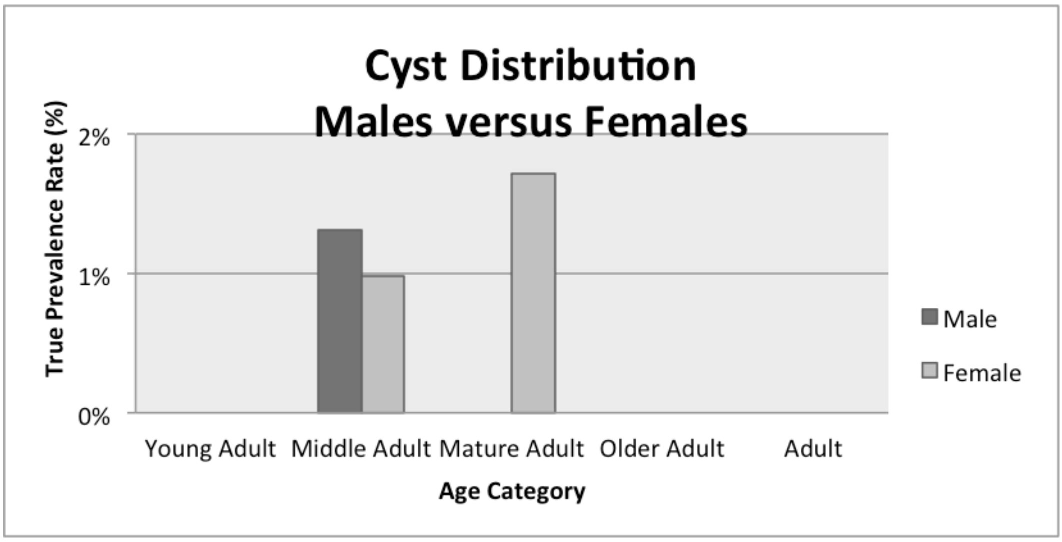


Figure 5.39b: True prevalence rates in percentages for distribution of Abscesses and Cysts between males (n=42) and females (n=39) for each age category within St Hilda's.

g. Dental Enamel Hypoplasia (DEH)

From the 115 individuals who possessed one or more teeth suitable for analysis, a total of 35 individuals exhibited dental enamel defects. The TPR of DEH for the total assemblage was 10.4% (*186/1788*). The prevalence of DEH was statistically higher in adults than non-adults ($p = 0.000$), the TPRs for adults and non-adults was 12.2% (*170/1395*) and 4.07% (*16/393*) respectively. This corresponds to 32 adults and 3 non-adults. After the application of a standardised residual test between the different age categories it was ascertained that middle adults ($p = 0.00$) was the group that contributed to the statistical significance of DEH which was initially identified by a chi-square test applied in a table greater than two-by-two. The TPR of DEH was 14.4% (*98/680*) for the total population; this corresponds to 23 individuals (Figure 5.40).

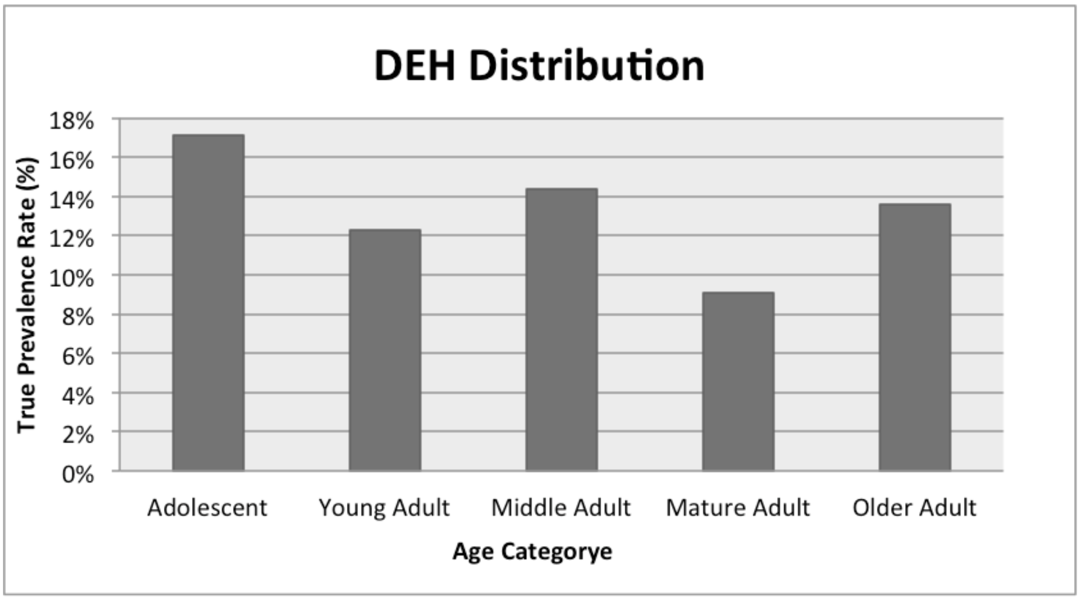


Figure 5.40: True prevalence rates in percentages for distribution of DEH for each age category within the St Hilda's individuals with recordable teeth (n= 115).

Males and females seemed to have suffered similar rates of DEH, the TPRs for males and females were 11.0% (*83/756*) and 12.5% (*66/530*) respectively (Figure 5.41). This corresponds to 15 males and 14 females. The difference observed between males and females was not statistically significant and age groups split by sex.

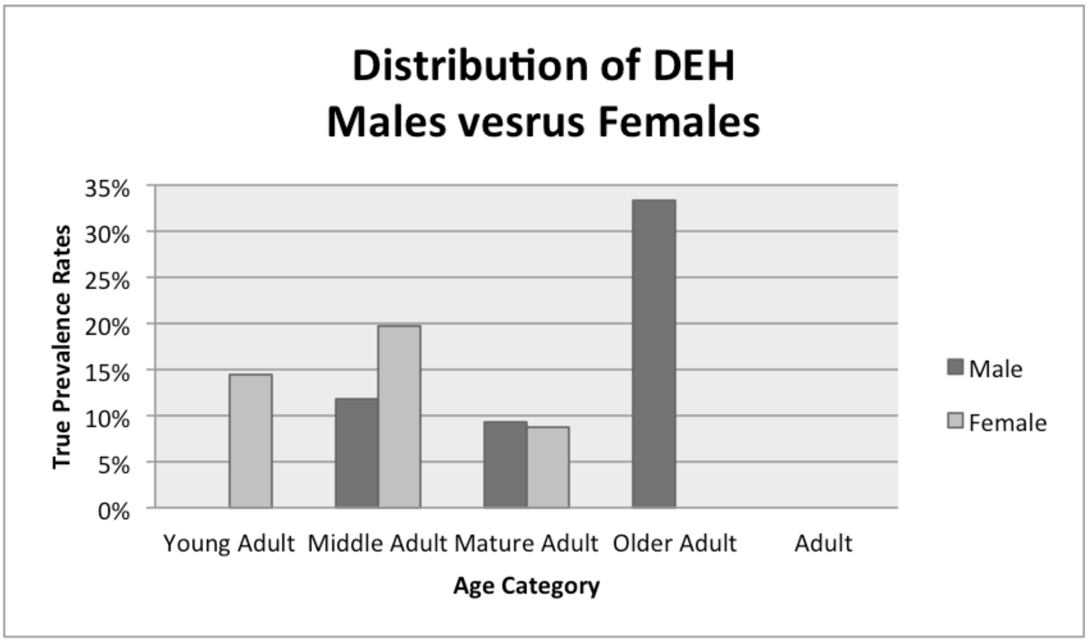


Figure 5.41: *True prevalence rates in percentages for distribution of DEH between males and females for each age category within St Hilda's.*

5.4.6 Indicators of Environmental Stress: Hematopoietic and Metabolic Disorders

Conditions caused by a disruption of bone formation, mineralisation or remodelling, or a combination of these processes was commonly encountered within the adults and sub-adults of St Hilda's, revealing valuable information on socio-economic aspects of their life.

a Cribra Orbitalia (CO)

Within the total assemblage, 151 individuals possessed at least one orbit available for analysis of CO. Of these, 55 were non-adults and 96 were adults. Within the studied population 44 individuals exhibited porosity of the orbit roof, resulting from thinning of the outer table of the bone and diploic expansion, giving a CPR at *29.1%* (*n = 44/151*). The TPR of CO for the total assemblage was 27.6% *(81/293)* while 13.6% (*6/44*) of those individuals who had orbital lesions also had porotic hyperostosis. In 84.0% (*37/44*) of individuals where both orbits could be observed, the changes were bilateral while 59.0% (*26/44*) of the affected individuals exhibited healed lesions. The TPRs for non-adults and adults were 11.8% *(12/102)* and 36.1% *(69/191)* respectively. This corresponds to 7 non-adults and 37 adults. The lower prevalence of CO amongst the non-adults could be due to both taphonomy and a weak immune response which did not allow the condition to manifest upon the skeletons of the non-adults who died swiftly. There were no significant differences in the prevalence of orbital lesions between males and females or different age categories for either the total population or the adult population alone (Table 5.8-5.10). No differences were also observed for age groups split by sex. The severity of the lesions was mild (type 2) for the majority of the affected individuals. The fact that the prevalence rates were independent of biological sex and age category makes it more likely that everybody was equally exposed to dietary deficiencies and pathological factors (e.g. iron deficiency anaemia, genetic anaemias, maternal depleted B12 reserves and parasitic infections) which can cause the formation of the lesions (Mays 1998).

Males vs Females	Orbit Affected	Orbit Count	TPR (%)	No individuals
Male	**34**	**90**	**37.78%**	**18**
Female	**35**	**91**	**38.46%**	**19**

Table 5.8: True prevalence rates in percentages for distribution of CO between males and females within St Hilda's.

Age Category	Orbit Affected	Orbit Count	TPR (%)	No individuals
Preterm	**0**	**30**	**0.00%**	**0**
Neonate	**0**	**42**	**0.00%**	**0**
Infant	**0**	**10**	**0.00%**	**0**
Young Child	**9**	**12**	**75.00%**	**5**
Older Child	**3**	**8**	**37.50%**	**2**

Table 5.9: True prevalence rates in percentages for distribution of CO for each sub-adult age category within St Hilda's.

Age Category	Orbit Affected	Orbit Count	TPR (%)	No individuals
Adolescent	**0**	**6**	**0.00%**	**0**
Young Adult	**9**	**14**	**64.29%**	**5**
Middle Adult	**25**	**73**	**34.25%**	**13**
Mature Adult	**14**	**44**	**31.82%**	**7**
Older Adult	**15**	**28**	**53.57%**	**8**
Adult	**6**	**26**	**23.08%**	**4**

Table 5.10: True prevalence rates in percentages for distribution of CO for each adult age category within St Hilda's.

b. Porotic Hyperostosis (PH)

Within the total assemblage, 168 individuals had cranial vault bones available for analysis of PH, of these 68 were non-adults and 100 were adults. The prevalence of PH within the total assemblage was 4.76% *(8/168)* (Table 5.11-5.12). The TPR (and CPR) for adults was 8.0% (*8/100)* while non-adults exhibited no evidence of the condition. There were no statistically significant differences in the prevalence of PH between different adult age categories or biological sexes. No differences were also observed for age groups split by sex. The severity of the lesions was mild (type 2) for the majority of the individuals (Steckel *et al.* 2006, 13).

Males vs Females	Skull Affected	Skull Count	TPR (%)
Male	**3**	**45**	**6.66%**
Female	**5**	**50**	**10.00%**

Table 5.11: True prevalence rates in percentages for distribution of PH between males and females within St Hilda's.

Age Category	Skull Affected	Skull Count	TPR (%)
Adolescent	**0**	**3**	**0.00%**
Young Adult	**1**	**8**	**12.5%**
Middle Adult	**3**	**37**	**8.10%**
Mature Adult	**0**	**23**	**0.00%**
Older Adult	**3**	**16**	**18.75%**
Adult	**1**	**13**	**7.69%**

Table 5.12: True prevalence rates in percentages for distribution of PH for each adult age category within St Hilda's.

c. Osteoporosis

Within the adult population, ten individuals from the senior age categories exhibited evidence of osteoporosis. Due to the pattern of distribution of the disorder which involves multiple bones, only the CPR was calculated. The CPR of osteoporosis for adults was 8.55% (*10/117*). The prevalence of osteoporosis was statistically higher in older adults with a CPR at 29.41% (*5/17*; $p = 0.00$) for both the total population and adult population alone. Males and females seemed to have similar rates of osteoporosis, the CPRs for males and females were 7.84% (*4/51*) and 11.32% (*6/52*) respectively (Table 5.13). The difference observed between males and females was not statistically significant, however when age groups were split by sex, older males exhibited statistically higher prevalence with a CPR at 42.86% (*3/7*; $p = 0.00$). The majority of the affected individuals, 80% *(8/10),* exhibited one or more fractures with fractures of the ribs and vertebra being most commonly encountered. The presence of fractures in these individuals, especially compressed vertebral fractures, indicates that the underlying aetiology behind those fractures could be osteoporosis.

Age Category	Osteoporosis Count – Males	CPR (%)	Osteoporosis Count – Females	CPR (%)
Young Adult	0	0.00%	0	0.00%
Middle Adult	0	0.00%	0	0.00%
Mature Adult	1	9.09%	4	28.57%
Older Adult	3	42.86%	2	20.00%
Adult	0	0.00%	0	0.00%

Table 5.13: Crude prevalence rates in percentages for distribution of osteoporosis between males and females for each adult age category within St Hilda's.

Where only diminished bone mass was observed without any other features, the cases were described as osteopenic. Within the studied population six individuals were diagnosed with osteopenia, the CPR for the adult population was 5.13% (*6/117*). There were no significant differences in the prevalence of the lesions between males and females or different age categories for either the total population or the adult population alone (Table 5.14). No differences were also observed for age groups split by sex.

Age Category	Osteopenia Count - Males	CPR (%)	Osteopenia Count - Females	CPR (%)
Adolescent	0	0.00%	0	0.00%
Young Adult	0	0.00%	0	0.00%
Middle Adult	1	3.57%	0	0.00%
Mature Adult	0	0.00%	2	14.29%
Older Adult	0	0.00%	1	10.00%
Adult	0	0.00%	1	10.00%

Table 5.14: Crude prevalence rates in percentages for distribution of osteopenia between males and females for each adult age category within St Hilda's.

d. Rickets

Within the total St Hilda's skeletal assemblage, 16 individuals had skeletal changes consistent with a diagnosis of rachitis, the CPR of rickets for the total assemblage was 7.84% *(n = 16/204)*. The CPR rickets for non-adults was 5.75% (*n = 5/87*) while the CPR of residual rickets for adults was 9.40% *(n = 11/117).* In these five sub-adults the condition was active at the time of death whereas in adults the changes were resolved, but left distortion of femora or tibiae or both.

There were no statistically significant differences in the prevalence of the lesions between males and females or any of the different age categories (Table 5.15-5.17). No differences were also observed for age groups split by sex.

Male vs Females	**Residual Rickets Count**	**CPR (%)**
Male	**6**	**11.76%**
Female	**5**	**9.43%**

Table 5.15: True prevalence rates in percentages for distribution of residual rickets between males and females within St Hilda's.

Age Category	**Rickets Count**	**CPR (%)**
Preterm	**1**	**4.35%**
Neonate	**0**	**0.00%**
Infant	**0**	**0.00%**
Young Child	**3**	**18.75%**
Older Child	**1**	**16.67%**

Table 5.16: True prevalence rates in percentages for distribution of rickets for each sub-adult age category within St Hilda's.

Age Category	**Residual Rickets Count**	**CPR (%)**
Adolescent	**0**	**0.00%**
Young Adult	**0**	**0.00%**
Middle Adult	**5**	**12.20%**
Mature Adult	**3**	**12.00%**
Older Adult	**3**	**17.65%**
Adult	**0**	**0.00%**

Table 5.17: Crude prevalence rates in percentages for distribution of residual rickets for each adult age category within St Hilda's.

Osteomalacia, the adult form of active vitamin D deficiency, was also observed among the St Hilda's individuals. The total CPR of St Hilda's was 1.96% (*n = 4/204*) while for adults only was higher at 3.42% (*n = 4/117*). The statistical analysis revealed, as in the case of rickets, no statistically significant differences between sexes or different age categories, indicating that everybody was equally exposed to the 'dangers' of industrial life that could result in Vitamin D deficiency whether adult or sub-adult.

e. Scurvy

Within the total assemblage, 23 individuals exhibited lesions indicative of vitamin C deficiency, scurvy. The CPR of scurvy for the total assemblage was 11.27% *(n = 23/204)*. The CPRs for non-adults and adults were almost equal with 12.64% (*n = 11/87*) and 10.26% *(n = 12/117)* respectively. There were no statistically significant differences in the prevalence of the lesions between males and females; however, the application of a residual tests revealed that the prevalence of scurvy was statistically higher in young children (*p = 0.00*), adolescents (*p = 0.00*) and young adults (*p = 0.00*) (Table 5.18.-5.20). The TPRs of scurvy for young children were 37.5% (*n = 6/16*) and 50% (*n = 2/4*) and 44.4% (*n = 4/9*) for adolescents and young adults respectively. No differences were also observed when age groups were split by sex. The fact that the prevalence rates were independent of biological sex but also major age groups (adults versus non-adults) is indicative that everybody from St Hilda's was to some extent equally exposed to a diet inadequate in vitamin C and other nutrients. However, it would appear that some age categories such as young children, adolescents and young adults were more exposed to an inadequate diet.

Males vs Females	**Scurvy Count**	**CPR (%)**
Male	**5**	**9.80%**
Female	**5**	**9.43%**

Table 5.18: True prevalence rates in percentages for distribution of scurvy between males and females within St Hilda's.

Age Category	Scurvy Count	CPR (%)
Preterm	2	8.70%
Neonate	1	3.03%
Infant	1	11.11%
Young Child	6	37.50%
Older Child	1	16.67%

Table 5.19: True prevalence rates in percentages for distribution of scurvy for each sub-adult age category within St Hilda's.

Age Category	Scurvy Count	CPR (%)
Adolescent	2	50.00%
Young Adult	4	44.44%
Middle Adult	4	9.76%
Mature Adult	1	4.00%
Older Adult	0	0.00%
Adult	1	4.76%

Table 5.20: True prevalence rates in percentages for distribution of scurvy for each adult age category within St Hilda's.

5.4.7 Indicators of Genetic Stress: Congenital Disorders

Developmental defects of the vertebral column, ribs and associated areas of the skull are relatively common and a range of such conditions were recorded in St Hilda's material with defects of the vertebral column being by far the most commonly observed. For the recording of the conditions, the photographic standards of Barnes (1994) were utilised. Within the total assemblage 39 individuals exhibited defects present at birth, of these 35 were adults while the rest were non-adults. In most of the cases the defects were minor asymptomatic developmental variations and likely to have had little or no clinical impact on individuals lives.

a. Congenital Conditions of the Spine and Ribs

A variety of vertebral column defects was recorded in 32 individuals, including sacralisation, lumbarisation, sacrococcygeal shift, bifurcated neural arch, spina bifida occulta, hemi-vertebra, fused vertebrae and supernumerary vertebrae. It was common for more than one congenital defect to occur in the spine of a single individual.

Developmental defects occurring at the lumbosacral junction can result in transitional vertebrae that have a mixture of lumbar and sacral characteristics. Within the St Hilda's skeletal assemblage, a total of 96 individuals possessed sacra suitable for the recording of sacralisation and lumbarisation. Of these, 25 were non-adults and 71 were adults. A total of 17 individuals displayed partial or complete incorporation of the fifth lumbar vertebra into the sacrum. The TPR (and CPR) of sacralisation for the total assemblage was 17.7% (*17/96*), the TPR (and CPR) for adults only was 23.9% *(17/71)* while non-adults showed no evidence of sacralisation. The application of a standardised residual test as a follow up to a chi-square test, revealed that the prevalence of sacralisation was statistically higher in middle adults ($p = 0.00$), the TPR (and CPR) for middle adults was 36.4% (*12/33*) which corresponds to 12 affected individuals in this category. Males and females seemed to have suffered similar rates of sacralisation. The TPR (and CPR) for males and females were 29.7% (*11/37*) and 20.0% (6/30) respectively which corresponds to 11 affected males and six affected females. There was no statistically significant difference in the prevalence of sacralisation expressed by females and males. No statistically significant difference was observed either for age groups split by sex.

A total of six individuals displayed partial or complete separation of the first sacral vertebra from the rest of the sacrum. The TPR (and CPR) of lumbarisation for the total assemblage was 6.25% (*6/96*), the TPR (and CPR) for adults only was 8.45% *(6/71)* while non-adults showed no evidence of lumbarisation. The prevalence of the defect was not statistically significant for any of the population age categories. There was also no statistically significant difference observed between males and females and for age groups split by sex.

Boundary shifts can also occur at the sacral-caudal border. Cranial shifting of the sacral-caudal border affected the last sacral segment of a middle male adult. The last segment of this individual was completely disengaged from the rest of the sacrum and exhibited accessory facets for articulation with the rest. The TPR (and CPR) for the total population was 1.04% (*1/96),* the TPR (and CPR) for adults only was 1.40% (*1/71*) while non-adults had no evidence of the defect.

Cranial shifting at the thoracolumbar border can sometimes lead to numerical errors in segmentation expressed as an extra, transitional vertebral segment that takes the appearance of the last thoracic vertebrae. Supernumerary vertebrae were observed in two mature females. In particular both females exhibited six lumbar vertebrae as well as an extra pair of ribs each. Indeed, one of the females had an extra pair of thoracic-shaped ribs, due to cranial shifting of the thoracolumbar border in order to accompany the extra lumbar vertebrae. The second female exhibited a pair of cervical ribs resulting from cranial shifting of the cervicothoracic border (Barnes 1994, 100). The cervical rib is a product of elongation of the transverse process of the last cervical vertebra (Aufderheide and Rodrigues-Martin 2006). The TPR for the supernumerary lumbar vertebra for the total population was 0.35% (*2/557*), the TPR for adults only was 0.51% (*2/389*) while non-adults exhibited no evidence of the condition. The TPR of supernumerary ribs for the total population was 0.15% (*4/2537*), the TPR for adults only was 0.26% (*4/1495*) while non-adults exhibited no evidence of the condition. The prevalence of the defect was not statistically significant for any of the population age categories. There was also no statistically significant difference between males and females and age groups split by sex.

Another observed condition of the sacrum due to developmental disruptions was spina bifida occulta, a hiatus of the neural arch. A case of spina bifida occulta was identified on the sacrum of an adolescent, the neural arch hiatus was extending from the second to fifth sacral segment. The TPR (and CPR) for the total population was 1.04% (*1/96).*

Four individuals had bifurcated neural arches of the vertebrae and first or second sacral segment. This is the most common defect of the vertebral column and generally occurs in the border regions. Within St Hilda's three out of four affected individuals seem to follow this pattern of lumbosacral border. The prevalence of bifurcated neural arch was 2.45% (*4/163)* for the total population with present spines, the prevalence for adults with present spines was 3.88% (*4/103)* while non-adults exhibited no evidence of the condition.

Segmental disarrangement of the vertebral ossification centres may result in congenital fusion of vertebral segments. Within St Hilda's block vertebrae with failure to segment between the neural arches only was noted in two individuals. The TPR of block vertebrae for the total population was 0.15% (4*/2604),* the TPR for non-adults was 0.49% (*4/803)* while adults presented no evidence of the condition.

Hemi-vertebra is the result of a failure in normal segmentation and is expressed as aplasia of the vertebral body. The TPR of hemi-vertebrae for the lumbar region of the total population was 0.17% (1*/557),* the TPR of hemi-vertebrae for the lumbar region of adults only was 0.25% (*1/389)* while non-adults exhibited no evidence of the condition.

From the whole population, middle adults seemed to be more frequently affected by spinal congenital disorders. The prevalence of spinal congenital disorders was statistically higher in middle adults (*p = 0.00)*, the CPR of the conditions when merged into one category was 46.3% (*19/41*) which corresponds to 19 individuals. The difference in the CPR of the indicators in middle adults was statistically significant for both the total population and the adult population alone. This perhaps is due to the higher number of deaths which occurred in this age category.

b. Congenital Conditions of the Cranium

Cranial abnormalities such as metopism, craniosynostoses and brachycephaly were present in eight individuals of the 168 with suitable crania for analysis. The most commonly encountered cranial anomaly was metopism, which is described as persistent metopic suture in the adult human skull. The TPR (and CPR) of metopism for the total assemblage was 4.16% *(7/168),* the TPR (and CPR) for adults alone was 7% *(7/100)* while non-adults showed no evidence of metopism. There was no statistically significant difference between different age categories and biological sexes as well as when age groups were split by sex. In addition to metopism, one of the affected middle male adults exhibited features of brachycephaly. The TPR (and CPR) of brachycephaly within the total assemblage was 0.59% *(1/168)*, the TPR (and CPR) for adults alone was 1% *(1/100).* The prevalence of the defect was not statistically significant for any of the population age categories. There was also no statistically significant difference between males and females and for age groups split by sex.

Another cranial anomaly characterised by failure of fusion at one suture was craniosynostosis, which is described as a premature closure of the cranial sutures. The TPR (and CPR) of craniosynostosis within the total assemblage was 0.59% *(1/168)*, the TPR (and CPR) for non-adults alone was 1.47% *(1/68)* with one infant being affected.

c. Other Congenital Disorders

A possible case of congenital dysplasia, known as thanatomorphic dysplasia, likely incompatible with life was noted in a preterm individual. The CPR of the condition for the total population was 0.49% (*1/204*), the CPR for non-adults alone was 1.14% *(1/87)*. The skeletal changes included shortening and widening of the long bones with the bones appearing flatter than tubular, premature fusion as indicated by the presence of some epiphyses, premature fusion of some vertebral bodies to their neural arches and premature fusion of squamous temporal to the pars petrosa. Differential diagnoses included type I and II achondrogenesis and campomelic dysplasia.

A fairly unusual congenital defect observed within the studied population was symphalagism, a congenital fusion of one or more proximal, intermediate or distal foot phalanges of the same digit. Symphalagism is recognised as a highly hereditary development defect, although based on the burial evidence these individuals did not seem to be related as they did not share the same burial plot, nor were they in close proximity. The TPR of symphalagism within the total assemblage was 1.11% *(2/179),* the TPR for adults only was 1.28% *(2/156)* while non-adults exhibited no evidence of symphalagism. No statistical differences were also observed between different age and sex groups.

5.4.8 Miscellaneous Pathology

During analysis, lesions uncharacteristic of the disease categories outlined above were recorded and presented at this section as miscellaneous cases of pathology.

a. Hallux Valgus

Within the studied assemblage, a total of 163 individuals possessed at least one first metatarsophalangeal joint suitable for assessment of hallux valgus, of these 153 were adults and 10 were non-adults. The condition was diagnosed based on the recording standards of Mays (2005, 139-149) and Trujillo-Mederos *et al.* (2012). A total of 15 individuals exhibited hallux valgus, from these affected individuals none were below the age range of 36-45, reflecting a process that requires time to manifest on the skeleton (Miles *et al.* 2008, 122). Alternatively, this might be also due to difficulties recognising the subtle bone changes encountered in the primary stages of the condition. The TPR of hallux valgus for the total assemblage was 12.8% *(21/163),* the TPR for adults was 13.7% *(21/153)* while non-adults exhibited no evidence of the deformity. The application of a standardised residual test revealed that the prevalence of the deformity was statistically higher in older adults (*p = 0.00)*, the TPR of hallux valgus was 24.1% (*7/29*) for older adults which corresponds to five individuals. There was no statistically significant difference in the prevalence of hallux valgus expressed by females and males. The TPR of the deformity between females and males were 14.9% (*10/67*) and 12.1% (*9/74*) respectively (Figure 4.42). This corresponds to seven affected individuals for each sex group. Consequently, the number of affected individuals was virtually the same. No statistically significant difference was observed when age groups were split by sex. At St Hilda's, 40% (*6/15*) of the affected cases were bilateral while the rest were unilateral. An alternative diagnosis here would be gouty arthritis.

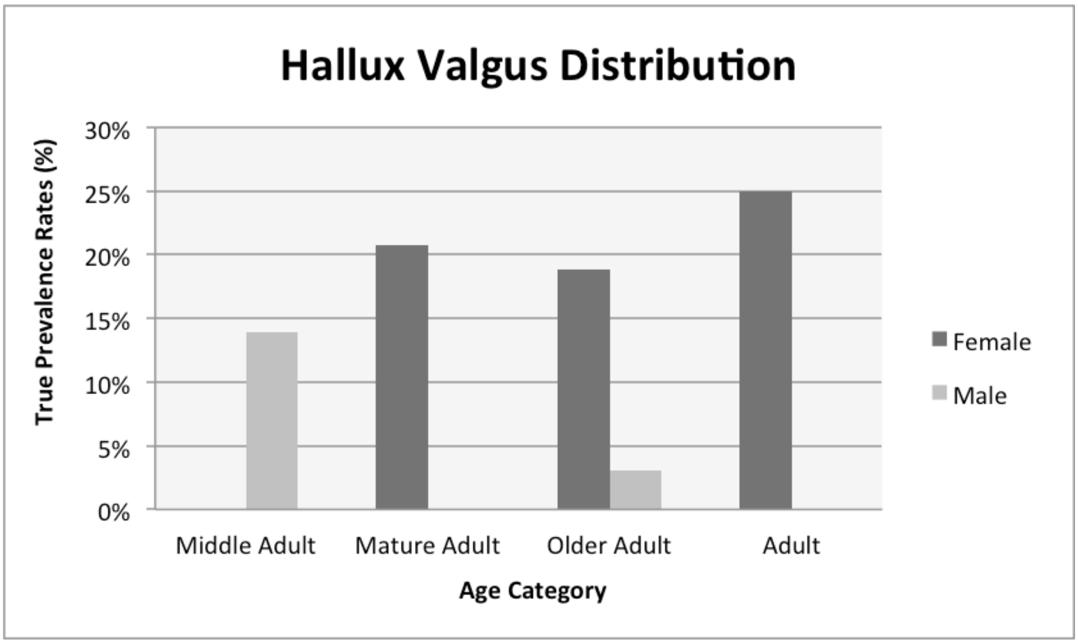


Figure 4.42: True prevalence rates in percentages for distribution of hallux valgus between males and females for each age category within St Hilda's.

b. Corset-Wearing

Flattening of the angle of the lower ribs from the fourth rib downwards was recorded in an older female. These types of changes have been recorded previously in post-medieval assemblages and are attributed to tight fitting corsets worn over a long period of time (Miles *et al.* 2008). In this particular female, the rib deformation due to corset-wearing was exacerbated by osteopenia which had affected the ribs along with the long bones. The ribs of the female appeared gracile, with a flattened angle and anteriorly projecting sternal ends.

The age of this female is indicative that she wore restrictive undergarments for many decades. The TPR of the condition for the females of St Hilda's was 2.87% (*18/626*).

c. Spinal Deformity

Within the studied population three older individuals exhibited abnormally excessive convex curvature of the spine pathognomonic for the diagnosis of kyphosis. One out of three individuals exhibiting secondary kyphosis to senile osteoporosis, whilst the other two exhibited senile kyphosis due to degeneration of intervertebral discs with age, especially at their anterior portions, in the physiologically kyphotic thoracic segments (Ortner 2003, 465). The TPR (and CPR) of kyphosis was 1.84% (3*/163)* for the total population with present spines. The TPR (and CPR) for adults with present spines was 2.91% (*3/103)* while non-adults exhibited no evidence of the condition. The application of a standardised residual test as a follow up to a chi-square test, revealed that the prevalence of the spinal deformity was statistically higher in older adults (*p = 0.00)*, the TPR (and CPR) of kyphosis for older adults was 17.6% (*3/17*). There was no statistically significant difference between males and females and for age groups split by sex.

A possible case of Scheuermann's disease, a form of idiopathic kyphosis which develops during adolescent years, was recorded in a middle male adult who also exhibited cranial shifting of the sacral-caudal border (Üstündağ and Deveci 2011). The deformity was greater than 60 degrees extending from the seventh to the eleventh thoracic vertebrae of the individual, accompanied by wedged vertebrae, Schmorl's nodes at the ends of the wedged vertebrae due to protrusion of the vertebral disc, marginal osteophytes-lipping arising from the vertebral end plate and anterior extension of the vertebral bodies outside the annular rings (Strati 2012, 23). The TPR (and CPR) of Scheuermann's disease for the total population was 0.61% (*1/163*). The TPR (and CPR) for adults was 0.97% (*1/103*) while non-adults exhibited no evidence of the condition. The application of a chi-square test revealed that the prevalence of the defect was not statistically significant for any of the population age groups. There was also no statistically significant difference between males and females and for age groups split by sex. The presence of Scheuermann's disease in an archaeological population is rare, this is perhaps due to the difficulties in identifying the condition that requires multiple diagnostic criteria (Üstündağ and Deveci 2011).

Evidence of dextroscoliosis of the thoracic spine combined with levoscoliosis of the lumbar spine was noted in a mature female adult. The curvature had affected the right side of thoracic spine, extending from the first to sixth thoracic vertebra but also had affected the left side of lumbar spine, forming an 'S' shape. The TPR (and CPR) of scoliosis was 0.61% (1*/163)* for the total population. The TPR (and CPR) for adults with present spines was 0.97% (*1/103)* while non-adults exhibited no evidence of the condition. The application of a chi-square test revealed that the prevalence of the spinal defect was not statistically significant for any of the population age groups. There was also no statistically significant difference between males and females and age groups split by sex. One other female adult exhibited kyphoscoliosis secondary to Pott's disease (spinal TB or TB Spondylitis). The TPR (and CPR) of kyphoscoliosis was 0.61% (1*/163)* for the total population with present spines. The TPR (and CPR) for adults with present spines was 0.97% (*1/103)* whilst non-adults exhibited no evidence of the condition.

d. Occupational Disease: Phosphorus Necrosis

Severe osteomyelitis resulting in bone loss on the left mandible adjacent to gonial angle was noted in a mature male. The features were compatible with the standards of Roberts *et al.* (2016, 39-48) for the diagnosis of phosphorus necrosis due to prolonged exposure to the vapour of white phosphorus. A differential diagnosis could be a bad case of tooth abscess or a specific infection such as syphilis; however, in phosphorus necrosis the lower jaw is more affected than the upper, as in this individual. The TPR (and CPR) for the total number of individuals with present mandibles was 0.59% (*1/168*) while for adults only was 1% (*1/100*).

e. Benign Neoplasms: Button Osteoma

Within the studied collection only benign neoplasms were noted. Button or ivory osteomas were identified on the cranial vaults of six adults. The TPR (and CPR) of button osteomas within the total assemblage with present crania was 3.57% *(6/168).* The TPR (and CPR) for adults was 6% *(6/100)* while non-adults exhibited no evidence of the condition. The application of a chi-square test revealed that the prevalence of button osteomas was not statistically significant for any of the population age groups. Although five out of six affected individuals were females, there was no statistically significant difference between males and females. The TPR (and CPR) of button osteoma for females was 11.1% (*5/45*). The same observation was noted for age groups split by sex.

f. Trephination

Evidence of trephination was noted in a possible female. The individual exhibited a well healed circular lesion indicative of a successful procedure on the left parietal bone. There was no indication, however, why this procedure was undertaken. The procedure is often used following injury to release pressured blood build-up by exposure of the dura mater, however, no such injury noted in this particular individual (Roberts and Manchester 1997). That the bone was healed demonstrates that the patient lived for some time after the surgery. The TPR (and CPR) of trephination for the total population with present crania was 0.59% (*1/168*).

g. Post-Mortem Craniotomy

Evidence of autopsy was noted in an adult male, the individual had circumferential post-mortem cuts on the cranial vault indicating that a craniotomy was performed after death. The TPR (and CPR) of craniotomy for the total population was 0.59% (*1/168*).

5.5 Charnel and Disarticulated Material

5.5.1 Charnel: Minimum Number of Individuals (MNI)

The entire collection of charnel bone material represented a minimum number of 120 individuals. Of these, 13 (*10.8%*) were non-adults and 107 (*89.2%*) were adults (Figure 5.43). Almost every element of the skeleton was accounted for, in various stages of preservation, varying from poor to good.

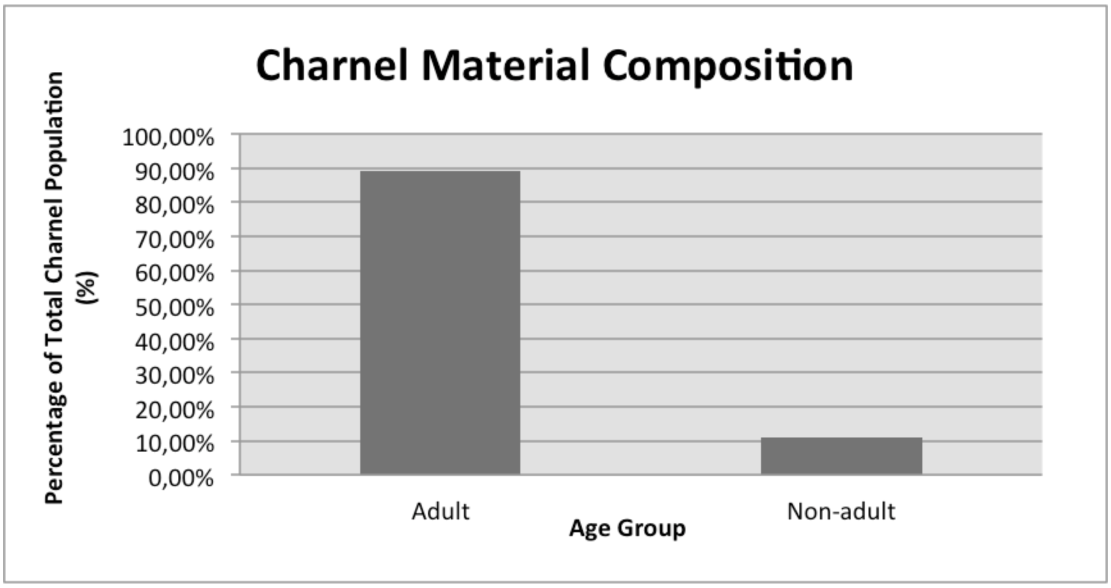


Figure 5.43: Summary of charnel material composition in St Hilda's assemblage, represented by percentage of the total population (n =120).

Within the adult population 26.2% (*28/107*) were assigned a definite biological sex. To maximise the numbers of known sex individuals available for analysis and make the analysis more consistent, the probable males and females were incorporated to the definite male and female categories. From this adult population 68.2% (*73/107*) could not be osteollogically sexed, due to lack of diagnostic elements necessary for sex determination. No attempt was made to sex the non-adults and adolescents (15.8%). The proportion of males (*12.1%; 13/107)* and females (*14%; 15/107)* constituting the total adult population was virtually the same with a slight female predominance following the pattern of the articulated sample, with a male to female ratio 1:1.15 (Figure 5.44). In order to determine the probability that the male to female ratio of the charnel material was equivalent to the articulated material, z-tests for proportions were applied to confirm the observation. There were no statistical differences in the proportions of male and female ratios between St Hilda's charnel and articulated material, revealing that the charnel material came from the same general osteological population of St Hilda's.

With 73 out of 120 individuals being classified as unspecified adults, due to lack of osteological evidence on age, it was impossible to accurately determine how different age categories experienced mortality; however, some basic conclusions were drawn. The mortality profile for adults (Table 5.21) showed that young and middle adults had suffered higher mortality rates with nine deaths in each age group; while young children seemed to have suffered higher death rates with seven deaths in this group. Consequently, it would appear that a similar mortality profile existed between articulated and charnel material.

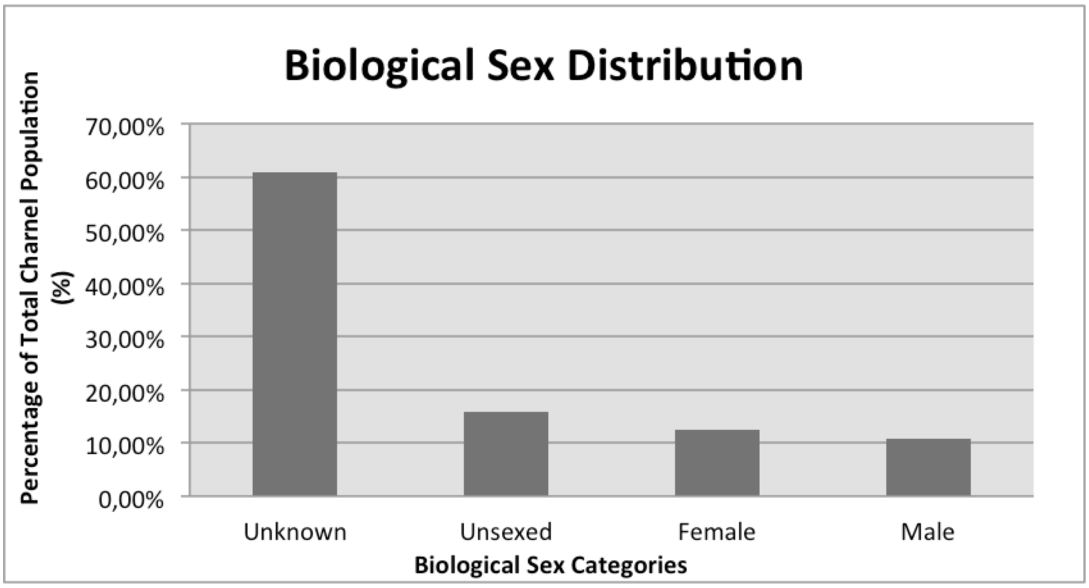


Figure 5.44: Summary of biological sex distribution in charnel deposit, represented by percentage of the total population (120).

Age Group	Count	Percentage
Neonate	2	1.67%
Young Child	7	5.83%
Older Child	1	0.83%
Adolescent	6	5.00%
Young Adult	9	7.50%
Middle Adult	9	7.50%
Mature Adult	6	5.00%
Older Adult	4	3.33%
Unspecified Adult	73	60.83%
Unsp, Non-adult	3	2.50%

Table 5.21: Distribution of deaths between age groups.

5.5.2 Charnel: Health and Disease

It was impossible to accurately calculate stature, however, from a small number of femoral bones (*n =11*) the dimensions were measured and the femur stature ratio was applied, which determined the mean adult stature was 169cm with a range of 149-187cm. This stature was fairly close to the calculated stature from the articulated material, consistent with individuals were derived from the same general osteological population. This observation was also confirmed statistically by applying z-tests for means between St Hilda's charnel and articulated sample. There were no statistical differences in the stature means of males and females, between St Hilda's charnel and articulated material, revealing that the mean stature of the charnel sample was similar to that of the articulated sample.

Some pathological conditions were noted, however, due to the incomplete nature of the material it was not within the scope of the thesis to record CPR and TPR and identify how different groups were affected by specific conditions. Instead, a more qualitative approach was taken to determine whether the charnel material was following the same pathological trends observed in the articulated material. The recorded pathological conditions were spinal joint disease such as Schmorl's nodes and vertebral osteophytes, SD, spinal and extra spinal OA; other joint diseases such as GA; trauma such as a subluxation and some fractures of ribs, vertebrae and long bones; surgical interventions such as a case of a very well healed femoral amputation with no infection as a postoperative complication; some cases of non-specific infection such as maxillary sinusitis, rib lesions associated with pleurisy and tibial periosteal new bone formation; a possible case of TB with tuberculous septic arthritis of the elbow; hematopoietic disorders such as PH and CO; some cases of congenital disorders such as sacralisation, metopism and brachycephaly; benign neoplasms such as button osteomas; and the same range of dental diseases observed in the articulated sample (Table 5.24). From this qualitative assessment it was determined that St Hilda's charnel material was following exactly the same pathological pattern as the articulated material, indicating that this osteological sub-set was coming from the same general population.

Condition	Case Count
Specific Infection	1
Non-Specific Infection	5
Trauma	4
Joint Disease	9
Metabolic Disease	6
Hematopoietic Disorder	6
Dental Disease	12
Congenital Disease	6

Table 5.23: Distribution of pathological conditions in charnel material (n= 120).

5.5.3 Disarticulated Material

Disarticulated human bone was present in various contexts, and several fragments were also removed from unstratified deposits. The entire collection of disarticulated bones represented a minimum number of 29 individuals. Most of the accounted skeletal elements were in very poor and fragmentary condition with few exceptions, exhibiting complete and excellent condition. From these 29 people, three males and females were noted, one older child, two adolescents, and three mature adults, while the rest were unspecified due to lack of diagnostic elements.

Some pathological conditions were noted, joint disease such as Schmorl's nodes, spinal and extra-spinal OA, AS and GA; non-specific infections such as tibial periosteal new bone formation and osteomyelitis; metabolic conditions such as scurvy; hematopoietic disorders such as PH and CO; trauma such as spondylolysis and compressed vertebrae; some cases of congenital disorders such as lumbarisation; and benign neoplasms such as button osteomas. From this qualitative assessment it was determined that the disarticulated material was following exactly the same pathological pattern as the articulated and charnel sample.

CHAPTER 6

RESULTS OF QUANTITATIVE COMPARATIVE ANALYSIS

This chapter presents the results of St Hilda's demographic, health and disease profile comparison with fifteen sites of known context. The St Hilda's population sample is placed in perspective by comparing with both richer and poorer post-medieval populations from different regions in England (North and South) (Table 6.1). The comparative sites from the North of England include Coach Lane, North Shields (Proctor *et al.* 2016), Infirmary Newcastle (Boutler *et al.* 1998), Carver Street Methodist Chapel, Sheffield (data collected by the author) and St Martin's-in-the-Bull Ring, Birmingham (Brickley *et al.* 2001). The sites mentioned above were primarily of working-class status. The comparative sites of different socio-economic status from the South of England include Littlemore Baptist Church, Oxford (McCarty *et al.* 2012), St Benet Sherehog, London (Miles *et al.* 2008), St Marylebone, London (Miles *et al.* 2008), St Luke's Church Islington, London (named and unnamed assemblage) (Boyle *et al.* 2005), St George's Bloomsbury Camden, London (named and unnamed assemblage) (Boston *et al.* 2006), Christ Church Spitalfields, London (Molleson and Cox 1993), All Saints, Chelsea Old Church, London (Cowie *et al.* 2008), St Bride's Lower Churchyard, Farringdon Street, London (Conheeney and Miles 2000), St Pancras, London (Emery and Wooldridge 2011), Cross Bones burial ground Southwark, London (Brickley and Miles 1999) and the Royal Hospital Greenwich Tier, London (Boston *et al.* 2008). The above-mentioned sites ranged from lower to upper-class. The intention of this chapter is to report whether there were observable differences in the demographic and health and disease profile of urban populations from different geographical regions of industrial England (North and South) and different socio-economic status. Comparative analysis of the demographic and health status between different sites can help place the St Hilda's health profile in context, and enable us to establish whether the people of this population sample experienced stress in an analogous way with the other populations of industrial England. This subsequently will also determine if any demographic and health and disease differences existed between the population samples, derived from different socio-economic or geographic divisions. In the first part of the chapter, the results of the biological sex, age-at-death and stature comparisons are presented in order to compare the demographic profiles. In the second part of the chapter the results of the prevalence rates comparisons (CPR to CPR and/or TPR to TPR) of each stress related palaeopathological condition are presented in order to compare the pathological profiles. Each health and disease indicator available between St Hilda's and the comparative site were compared independently to identify where similarities and differences between the sites arise. For the needs of the quantitative comparative analysis the run statistical tests used were z-tests for proportions and means, as opposed to t-test (*n* <*30*) that was used for the primary analysis of St Hilda's results such as in the case of stature means between males and females. Z-test was used for the comparative analysis of the case study with the sites of known context. Z-test is used to determine whether two population means are different when the variances are known and the sample size is greater than 30 (Harvey 2016).

Assemblage	Status
St Hilda's, South Shields	Primarily working class with a few middle-class exceptions, 1763-1855
Coach Lane, North Shields	Mostly mixed, with primarily working-class individuals, but also some middle-class, 1711-1829
Infirmary Newcastle	Mostly lower and working class with some portion of merchant sailors, 1753-1845
Carver Street Methodist Chapel, Sheffield	Primarily working class, 1763-1855
St Martin's-in-the Bull Ring, Birmingham	Primarily working class with some middle-class individuals, 1720-1863
Littlemore Baptist, Oxford	Middle class and some skilled working class, 1861-1881
Cross Bones, London	Lower class: Paupers cemetery, 1800-1853
All Saints, Chelsea Old Church	Upper class mostly, but also some better off working-class individuals, 1712-1842
St Benet Sherehog, London	Primarily middle class, but also some poor. Post London Great Fire (1666) with few late 17th-century individuals
St Marylebone, London	Primarily upper and middle class, 1817-1854
Christ Church Spitalfields, London	Middle class, 1729-1852
St Luke's-Islington-named, London	Primarily middle class, crypt 1760-1850
St Luke's-Islington -unnamed, London	Primarily working class, northern churchyard 1778-1848 and southern churchyard 1755-1844

St George's Bloomsbury-named	Primarily middle class, 1804-1856
St George's Bloomsbury-unnamed, London	Middle class, but the identities of the individuals were unknown although they were from the same period
St Bride's Lower Churchyard, London	Primarily lower class, 1770-1849
St Pancras, London	London's population cross-section with many people from outside the metropolis and immigrants, 1792-1854
Greenwich Tier, London	Retired sailors and marines of working-class origin, 1749-1856

Table 6.1: List of used comparative sites along with the social status of each.

6.1 The Palaeodemographic Profile

6.1.1. Biological Sex

The use of biological sex within this study was twofold; it was used to assess the demographic structure of the population sample, but also to determine if this sample was following the general demographic profile of the period, where males had suffered higher mortality rates at younger ages (General Registrar Office 1839; General Registrar Office 1842). The site of St Hilda's appeared to exhibit a slight female predominance with a male to female ratio 1:1.04, achieving almost precise parity of the sexes. This observed slight female predominance was also confirmed with the study of the St Hilda's burial registers.

As only the southern section of St Hilda's cemetery was excavated and analysed, a further step was taken in order to assess if this osteological female predominance was statistically meaningful in relation to other sites or was an excavation bias artefact. In order to determine the probability that the male to female proportion from St Hilda's burial ground was still near the norm of the period, z-tests for proportions were applied to confirm the observation. There were no statistically significant differences in the proportion of males to females between St Hilda's and most of the comparative sites (Figure 6.1; Table 6.2). Z-tests of proportions revealed that despite St Hilda's slight female predominance the population sample followed the general profile of the period with most of the comparative sites; only a few sites such as the Royal Hospital Greenwich Tier, Infirmary Newcastle, St Bride's Lower and Cross Bones, exhibited different male to female proportions. The Greenwich Tier ($z = -7.04$; $p = 0.00$), Infirmary Newcastle ($z = -2.90$; $p = 0.00$), and St Bride's Lower ($z = -2.11$;

$p = 0.03$) exhibited statistically higher male proportion than St Hilda's while Cross Bones (*$z = 1.95$*; *$p = 0.05$*) exhibited statistically lower. Hence, the difference was statistically meaningful and not an excavation artefact, but instead a product of the purpose of the use of the cemeteries. For example, a higher male predominance was observed in Greenwich Tier Hospital and Infirmary Newcastle with a male to female ratio 14:1 and 2.06:1 respectively. Both sites were used by seamen, in the case of the former the place was used exclusively by retired sailors and mariners while the latter was partially used by merchant sailors; hence a male predominance in these two sites was perhaps expected beforehand, although there were also some female exceptions (Boston *et al.* 2008). In the case of St Bride's Lower, a male predominance was also revealed with a ratio 1.6:1, showing the nature of the cemetery that possibly contained individuals from Bridewell workhouse and Fleet prison (mainly debtors' prison), which were located nearby (Kausmally 2008, for MOLA). Whereas, in the case of Cross Bones a female predominance was noted, with a ratio 0.4:1; this ratio, once more reflects the nature of the cemetery which was initially used as a burial ground for single women (prostitutes') and later became a pauper's cemetery, including criminals. In the same cemetery a high concentration of infant burials was also revealed. In particular 70% of the found skeletons were aged five years or younger, indicating a very high infant mortality rate or alternatively the selective burial of infants or both. The sampling strategy used may have also affected the frequency this age group appeared and subsequently may have had some impact on the male to female ratio (Mikulski 2007).

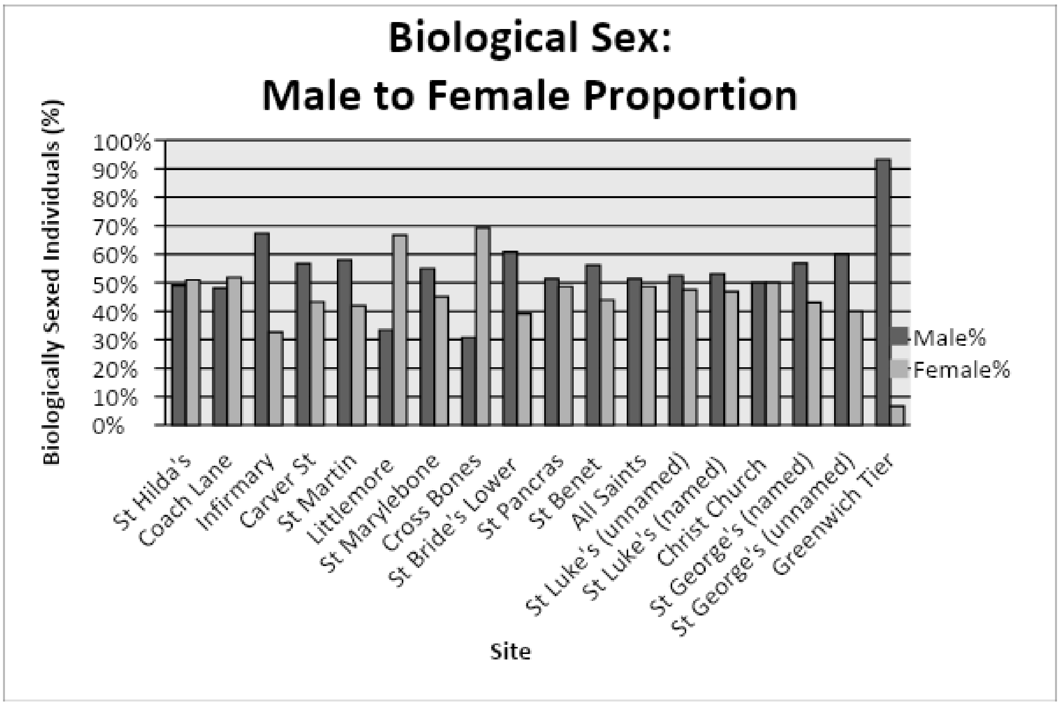


Figure 6.1: Summary of biological sex distribution in St Hilda's in comparison with the comparative sites.

Assemblage	M	M %	F	F %	M:	F Ratio	z-value	p-value
St Hilda's, South Shields	51	49.0%	53	51.0%	1.00	1.04		
Coach Lane, North Shields	50	48.1%	54	51.9%	0.93	1.08	0.13	0.88
Infirmary Newcastle	97	67.4%	47	32.6%	2.06	1	-2.90	0.00
Carver Street, Sheffield	38	56.7%	29	43.3%	1.31	1	-0.98	0.32
St Martin, Birmingham	180	58.1%	130	41.9%	1.38	1	-1.60	0.10
Littlemore Baptist, Oxford	5	33.3%	10	66.7%	0.50	1	1.13	0.25
St Marylebone, London	105	55.0%	86	45.0%	1.22	1	-0.97	0.32
Cross Bones, London	12	30.8%	27	69.2%	0.40	1	1.95	0.05
St Bride's Lower Churchyard, London	194	60.8%	125	39.2%	1.60	1	-2.11	0.03
St Pancras, London	231	51.3%	219	48.7%	1.05	1	-0.42	0.67
St Benet Sherehog, London	82	56.2%	64	43.8%	1.28	1	-1.11	0.26
All Saints, Chelsea Old Church	78	51.3%	74	48.7%	1.05	1	-0.35	0.72
St Luke's Islington-unnamed, London	270	52.5%	244	47.5%	1.11	1	-0.64	0.51
St Luke's Islington-named, London	128	53.1%	113	46.9%	1.13	1	-0.69	0.48

Christ Church Spitalfields, London	345	50.0%	345	50.0%	1.00	1	-0.18	0.85
St George's Bloomsbury-named London	41	56.9%	31	43.1%	1.32	1	-1.03	0.30
St George's Bloomsbury-unnamed, London	21	60.0%	14	40.0%	1.50	1	-1.12	0.26
Greenwich Tier, London	97	93.3%	7	6.7%	14	1	-7.04	0.00

Table 6.2: Male to Female ratio along with z- and p-values of significance in St Hilda's in comparison with the comparative sites.

6.1.2 Age-at-Death

Age-at-death was used to assess the longevity of the population sample and describe the overall health status. It was observed that the site followed the general mortality profile of the period, where highest rates of mortality were observed among middle adults. More than half of the comparative sites exhibited a high proportion of deaths in the category of middle adults. Within the population in study, it was observed that 35.04% (*41/117*) of all deaths were middle adults (Figure 6.2). In order to assess whether the proportions were equivalent and hence this observation was statistically meaningful, the proportion of middle adult deaths from St Hilda's was compared to the proportions of the other unrelated sites. In order to determine the probability that the new data were near a point for which a score was calculated, z-tests for proportions were applied to confirm that St Hilda's adults followed the general mortality profile of the period.

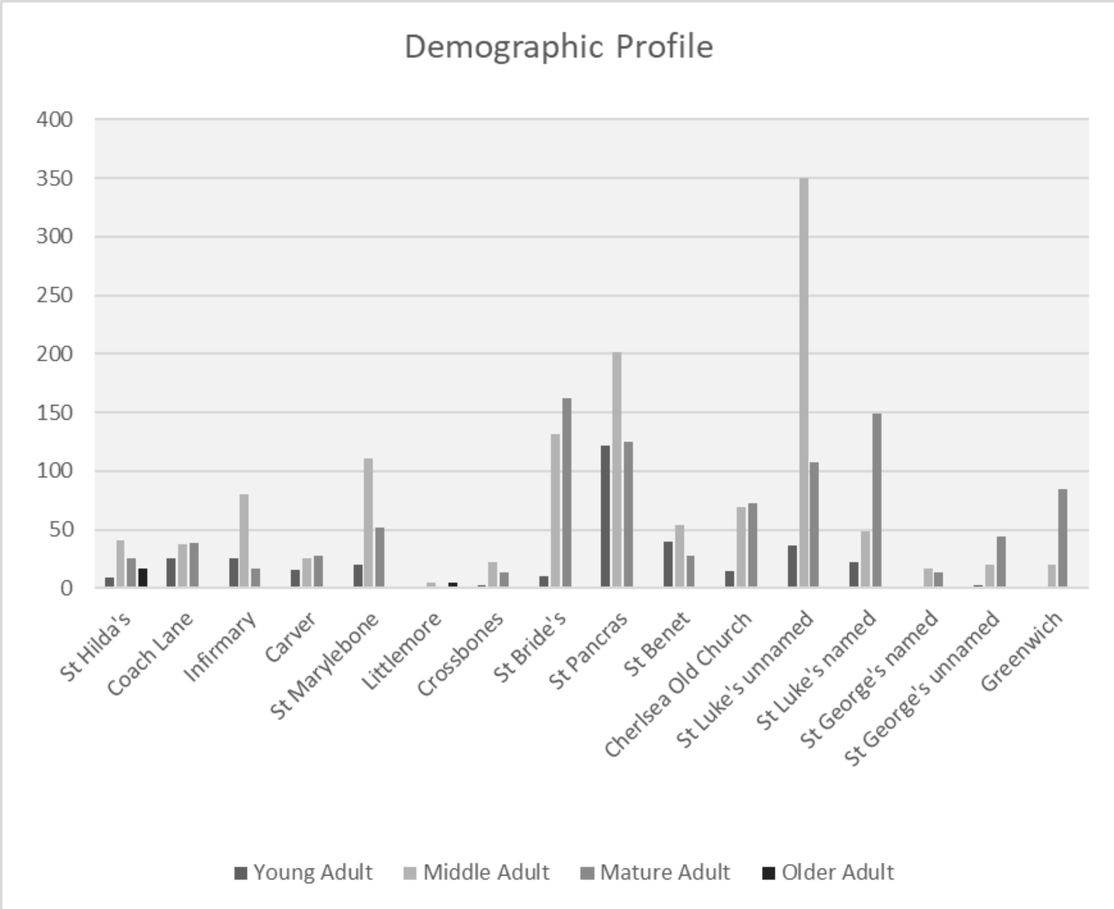


Figure 6.2: Adult demographic profiles across different sites.

The results revealed that there were no major significant differences in the demographic profiles across sites with middle adults being more frequently affected by increased mortality (Table 6.3). Z-tests of proportions revealed that only a few sites such as the Greenwich Tier (*z = -6.89*; *p = 0.00*), St Marylebone (*z = -2.59*; *p = 0.00*), St Luke's Islington-named (*z = -5.81*; *p = 0.00*), St Luke's Islington-unnamed (*z = -5.63*; *p = 0.00*) and St George's Bloomsbury-named (*z = -4.01*; *p = 0.00*) exhibited different mortality patterns such as for instance in older age categories than middle adulthood. The differences in deaths observed were all statistically significant. In particular, the Greenwich Tier and St Luke's Islington-named exhibited a higher number of deaths in the category of mature adults with 81.00% (*85/105*) and 68.00% (*149/219*) respectively, while St George's Bloomsbury-named exhibited a higher number of deaths in the category of late middle adults, above 40 years with 66.00% (*44/67*). The same pattern was observed in St Luke's Islington-unnamed with middle adults above 40 counting for 63.00% (*350/553*). These disparities could primarily be due to differences in socio-economic status, but in the case of Greenwich Tier Hospital these differences could also be related to lifestyle as the interred individuals were retired sailors and mariners. However, this socio-economic explanatory model is contradicted by the fact that St Marylebone, despite not being a working-class site, exhibited a statistically higher number of middle adult deaths when compared to St Hilda's, which was a working-class site. In particular 50.00% (*111/223*) of St Marylebone deaths were middle adults, while from St Hilda's only 35.04% (*41/117*) of deaths were from this group, the difference was statistically significant for St Marylebone. The same observation was made for St George's Bloomsbury-named, which exhibited higher mortality among middle adults compared to St Hilda's. In some other cases it was noted that St Hilda's followed the mortality profile of the period, but exhibited a higher proportion of middle adult deaths than some comparative sites of the same status. For example, Coach Lane although exhibited a high proportion of middle adult deaths the proportions of deaths were statistically lower when compared to St Hilda's. This difference could be linked to observed methodological issues chosen, combined with intra- and inter-observer errors; however, these limitations could have also affected the rest of the sites.

Assemblage	Adult Age Group	Highest Adult Category	Adult	Adult %	z-value	p-value
Hilda's, South Shields	Middle Adult (26-45)	41	117	35.0%		
Coach Lane, North Shields	Middle Adult (30-49)	29	156	18.6%	3.08	0
Infirmary Newcastle	Middle Adult (26-45)	80	191	41.9%	-1.19	0.2
Carver Street, Sheffield	Middle Adult (26-45)	26	93	28.0%	1.09	0.27
St Martin, Birmingham	Middle Adult (35-50)	135	352	38.4%	-0.64	0.52
Littlemore Baptist, Oxford	Mature 50+-Older	8	15	53.3%	-1.38	0.17
St Marylebone, London	Middle Adult (26-45)	111	223	49.8%	-2.6	0.01
Cross Bones, London	Middle Adult (36-45)	22	44	50.0%	-1.73	0.08
St Bride's Lower Churchyard, London	Mature 45+	162	369	43.9%	-1.69	0.09
St Pancras, London	Middle Adult (26-45)	201	448	44.9%	-1.91	0.06
St Benet Sherehog, London	Middle Adult (26-45)	54	165	32.7%	0.41	0.69
All Saints, Chelsea Old Church	Mature Adult	72	165	43.6%	-1.45	0.15
St Luke's Islington-unnamed, London	Late Middle (40+)	350	553	63.3%	-5.63	00
St Luke's Islington-named, London	Mature 50+	149	219	68.0%	-5.81	0
St George's Bloomsbury-named, London	Late Middle (40+)	44	67	65.7%	-4.01	0
St George's Bloomsbury-unnamed, London	Mature Adult 50+	13	35	37.1%	-0.23	0.82
Greenwich Tier	Mature 45+	85	105	81.0%	-6.89	0

Table 6.3: Proportion of deaths in the most affected by mortality adult category along with z- and p-values of significance in St Hilda's in comparison with the comparative sites.

That there was a lack of statistical significance between the highest category of deaths in St Hilda's and over half of the comparative sites was not a chance finding, but instead indicated the site followed the general mortality profile of the period. Despite the existence of some exceptions that were affected by mortality at an older stage, overall it would appear that the status or geographical location did not work as a 'buffer' for adults.

In the case of sub-adults, the comparison was unfortunately not as straightforward as in the case of adults due to inconsistencies observed in the used age category systems between different sites. A frequently observed classification mistake was the merging of three age categories into one, in particular it was noted that the time of birth, first month of life and first year (s) of life were included under the same age category leading to skewing of the results. Despite this methodological issue it was clear in all sites that after passing young childhood there was a decline in deaths.

Assessment of sub-adult deaths can be used as an indirect indicator to reflect unsanitary conditions (Wohl 1983). Within the population in study a high number of sub-adult deaths were observed during the first months of life, in particular 38.00% (*33/87*) of all sub-adult deaths were neonates (Figure 6.3). The results revealed that there were no significant differences in the proportion of deaths in the highest sub-adult category at St Hilda's (neonates) and the highest category of most of the comparative sites (Table 6.4). The lack of statistical differences revealed when z-tests applied, indicated that everybody was at high risk of mortality during early life, regardless of geographic or socio-economic background. Statistically significant differences for the highest category of sub-adult deaths were only observed between St Hilda's and St Marylebone ($z = 2.25$; $p = 0.02$) and Christ Church ($z = 3.86$; $p = 0.00$) for early life and St George's Bloomsbury-unnamed ($z = -2.47$; $p = 0.01$) for adolescence. When the sites were compared to St Hilda's, it was noted that the case study exhibited a higher proportion of deaths in the highest category of sub-adult deaths in relation to these first two sites. The proportions for St Marylebone and Christ Church were 22.00% (*17/78*) and 17.00% (*37/215*) respectively. The few differences perhaps reflect socio-economic status differences that worked as a 'buffer' to protect the immature individuals. That is also something that was further confirmed by the fact that the affected categories for St Marylebone and St George's were not neonates as in the case of St Hilda's and Christ Church, but older sub-adult categories (i.e. infant and adolescent) reflecting perhaps that they managed to live slightly longer than the other sites due to their status. However, in the case of St George's Bloomsbury the conclusions were a bit problematic because there were, in general, very few sub-adults interred in the crypt and these few were only adolescents 100.00% (*4/4*) the difference was statistically significant. This last case could, therefore, reflect burial customs and practices differences instead of socio-economic factors.

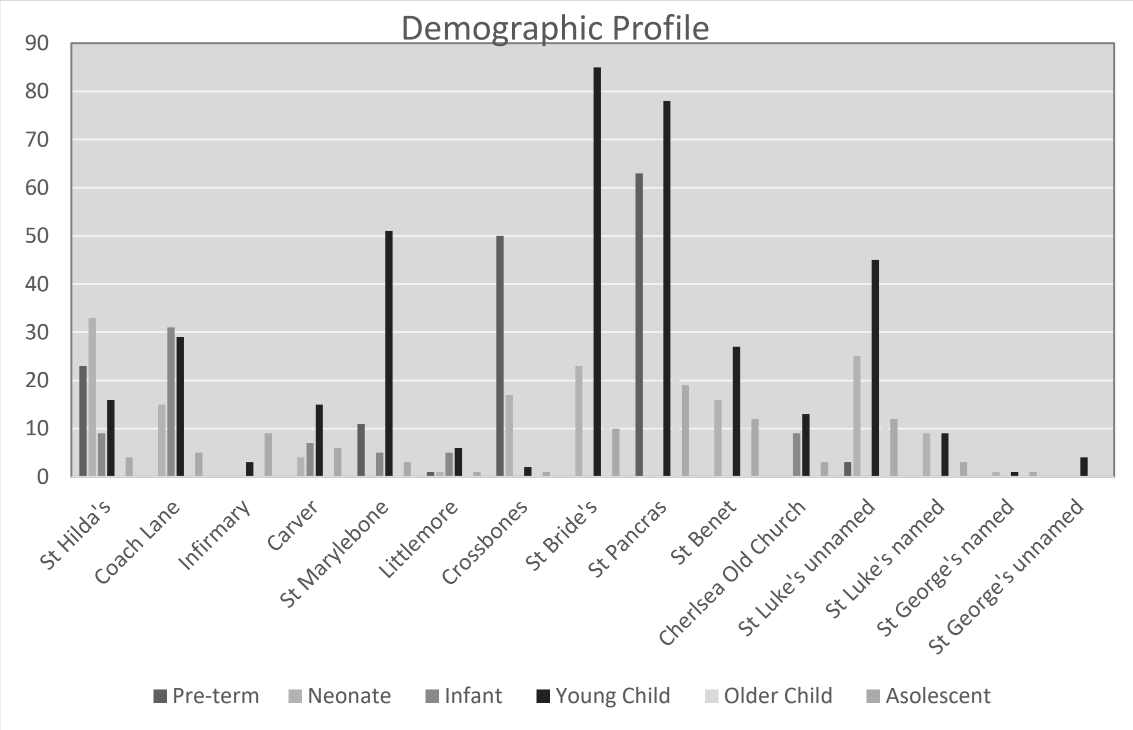


Figure 6.3: Sub-adult demographic profiles across different sites.

Assemblage	Sub-adult Age Group	Highest Sub-adult Category	Sub-adults	Sub-adult %	z-value	p-value
St Hilda's, South Shields	Neonate (birth-1mth)	33	87	38%		
Coach Lane, North Shields	Infant (birth-1 year)	31	80	39%	-0.11	0.91
Infirmary Newcastle	Older Child and Adolescent	7	19	37%	0.09	0.93
Carver Street, Sheffield	Infant and adolescent	10	37	27%	1.17	0.24
St Martin, Birmingham	Infant (birth-3years)	73	153	48%	-1.47	0.14
Littlemore Baptist, Oxford	Infant	5	14	36%	0.16	0.87

St Marylebone, London	Infant (around one year)	17	78	22%	2.25	0.02
Cross Bones, London	Perinatal	50	104	48%	-1.41	0.16
St Bride's Lower Churchyard, London	Young Child (1-5)	85	175	49%	-1.63	0.10
St Pancras, London	Early Childhood (0-5)	78	183	43%	-0.73	0.46
St Benet Sherehog, London	Young Child (1-5)	27	65	42%	-0.45	0.65
All Saints, Chelsea Old Church	Young Child (1-5)	13	33	39%	-0.15	0.88
St Luke's Islington-unnamed, London	Young Child (1-5)	45	102	44%	-0.86	0.39
St Luke's Islington-named, London	Neonate-Infant and Young Child	9	22	41%	-0.26	0.80
Christ Church, Spitalfields	Neonate (birth-1mth)	37	215	17%	3.86	0.00
St George's Bloomsbury-named, London	Older Child	2	5	40%	-0.09	0.93
St George's Bloomsbury-unnamed, London	Adolescent	4	4	100%	-2.47	0.01
Greenwich Tier	Adolescent	2	2	100%	1.10	0.27

Table 6.4: Proportion of deaths in the most affected by mortality sub-adult category along with z- and p-values of significance in St Hilda's in comparison with the comparative sites.

6.1.3 Stature

Stature was another method through which the overall population health was assessed within the population in study. It was observed that the mean height and the level of sexual dimorphism were similar to those found at other sites, with the males and females of St Hilda's exhibiting a mean height of 170cm and 158cm respectively, following the general stature profile of the period. This observation was also confirmed statistically by the comparison of mean statures in the unrelated groups of St Hilda's and the comparative sites, males and females from each site were compared separately.

In order to determine the probability that the new data were near a point for which a score was calculated, z-tests for means were applied to confirm the observation. There were no statistical differences in the means of statures of males and females, between St Hilda's and most of the comparative sites (Table 6.5). Only two sites, St George's Bloomsbury-unnamed and St Benet Sherehog exhibited statistically higher stature than St Hilda's. In the cases of St George's Bloomsbury ($z = -3.84$; $p = 0.00$) only the females exhibited higher mean stature than St Hilda's with a stature 166cm, while in the case of St Benet Sherehog ($z = -2.13$; $p = 0.03$) only the males exhibited higher stature with 174cm. Given the socio-economic status of these two sites, these differences could be attributed or partially attributed to the status of the samples that worked as a 'buffer'. However, these two sites were not the only ones derived from wealthier strata; therefore, the aetiology behind these differences is unclear.

Assemblage	Mean Stature Male	z-value	p-value	Mean Stature Female	z-value	p-value
St Hilda's, South Shields	170 cm			158 cm		
Coach Lane, North Shields	171 cm	-0.56	0.57	160 cm	-0.85	0.39
Infirmary Newcastle	171 cm			160 cm		
Carver Street, Sheffield	168 cm	1.04	0.29			
St Martin, Birmingham	172 cm	-1.19	0.23	159 cm	-0.33	0.73
Littlemore Baptist, Oxford	166 cm	1.95	0.05	158 cm	0.00	1.00
St Marylebone, London	170 cm	0.00	1.00	159 cm	-0.80	0.42
Cross Bones, London	169 cm	0.43	0.66	158 cm	0.00	1.00
St Bride's Lower Churchyard, London	171 cm	-0.59	0.55	157 cm	0.83	0.40
St Pancras, London	171 cm	-0.57	0.56	157 cm	0.82	0.41
St Benet Sherehog, London	174 cm	-2.13	0.03	157 cm	0.74	0.45
All Saints, Chelsea Old Church	170 cm	0.00	1.00	160 cm	-1.64	0.10
St Luke’s Islington-unnamed, London	170 cm	0.00	1.00	158 cm	0.00	1.00
St Luke’s Islington-named, London	170 cm			158 cm		
Christ Church Spitalfields, London	170 cm	0.00	1.00	157 cm	0.79	0.42
St George’s Bloomsbury-named, London	172 cm	-0.75	0.45	160 cm	-1.00	0.31
St George’s Bloomsbury-unnamed, London	171 cm	-0.48	0.62	166 cm	-3.83	0.00
Greenwich Tier, London	168 cm	1.13	0.25	160 cm	-1.68	0.09

*where there are no z and p-values the calculation of the values was impossible due to absence of the number of males and females that their stature was calculated was not provided

Table 6.5: Mean stature for males and females in St Hilda’s in comparison with the comparative sites.

6.2 Specific and Non-specific Infections

6.2.1 Specific Infections

Lesions indicative of specific infections such as tuberculosis (TB) and syphilis were identified in a few individuals from St Hilda’s. St Hilda’s exhibited similar rates of TB with the comparative sites, following the general pathological trend of the period. Hence, no statistical differences were observed between St Hilda’s and the comparative sites for the prevalence of TB when z-tests of proportions were applied (Figure 6.4; Table 6.6). A crude prevalence of 0.5% is reported for archaeological material from the period; St Hilda's was not far from that at 0.98% (*2/204*) (Roberts and Cox 2003, 339).

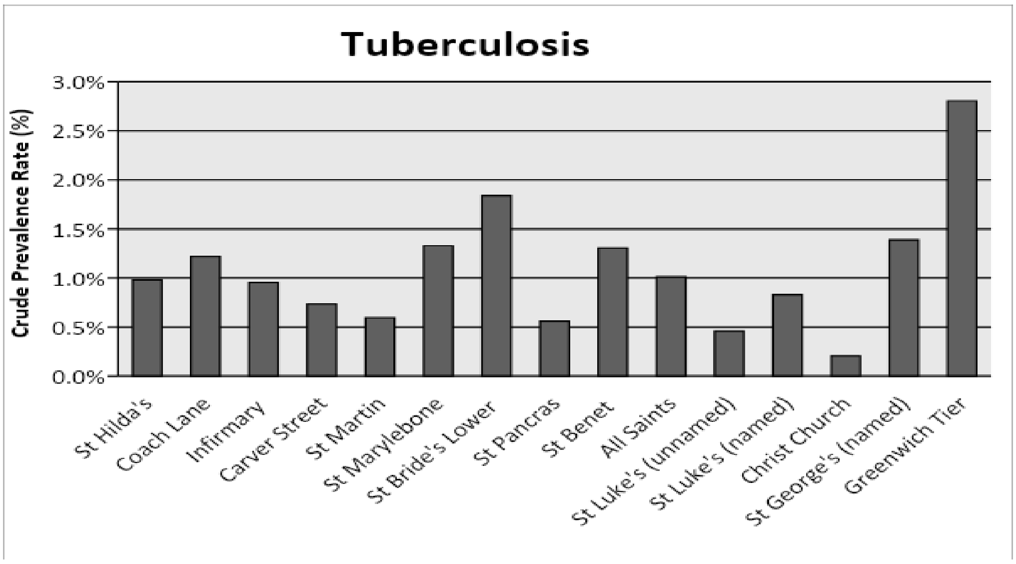


Figure 6.4: Crude prevalence rates in percentages for distribution of TB in St Hilda's in comparison with the comparative sites.

Assemblage	CPR: TB	Population	TB%	z-value	p-value
St Hilda's, South Shields	2	204	0.98%		
Coach Lane, North Shields	1	82	1.22%	-0.17	0.85
Infirmary Newcastle	2	210	0.95%	0.02	0.97
Carver Street, Sheffield	1	136	0.70%	0.23	0.81
St Martin, Birmingham	3	505	0.59%	0.55	0.57
St Marylebone, London	4	301	1.30%	-0.35	0.72
St Bride's Lower Churchyard, London	10	544	1.80%	-0.14	0.88
St Pancras, London	4	715	0.60%	0.65	0.51
St Benet Sherehog, London	3	230	1.30%	-0.98	0.32
All Saints, Chelsea Old Church	2	198	1.01%	-0.03	0.97
St Luke’s Islington-unnamed, London	3	655	0.50%	0.85	0.39
St Luke’s Islington-named, London	2	241	0.80%	0.16	0.86
Christ Church, Spitalfields	2	968	0.20%	1.72	0.08
St George’s Bloomsbury-named, London	1	72	1.40%	-0.28	0.77
Greenwich Tier, London	3	107	2.80%	-1.21	0.22

Table 6.6: Crude prevalence rates of tuberculosis along with z- and p-values of significance in St Hilda’s in comparison the comparative sites.

The same pattern was observed with venereal syphilis; apart from Cross Bones (*z = -2.35; p = 0.02*) and Christ Church (*z = 2.51; p = 0.01*) which exhibited statistically higher and lower prevalence respectively in relation to the case study, reflecting perhaps socio-economic differences and the nature of the cemeteries (Figure 6.5; Table 6.7). As it was earlier mentioned Cross Bones was possibly used during the 17th century as a burial ground for single women (prostitutes’) and later became a cemetery for paupers, therefore a higher prevalence of venereal syphilis was perhaps anticipated. In contrast, Christ Church cemetery was primarily a middle-class cemetery and the status could be perhaps the reason behind a more conservative behaviour and subsequently a lower prevalence (Mikulski 2007). Such a low prevalence of venereal syphilis at 1.47% (*3/204*) was consistent with the overall skeletal rates of the period of 0.8% (Roberts and Cox 2003, 341). Similar were also the rates of congenital syphilis, St Hilda’s CPR at 0.49% (*1/204*) was not far from the comparative sites rates, showing no statistical differences (Figure 6.6; Table 6.8). Consequently, the lack of statistically significant differences for the rates of specific infections between St Hilda's and the comparative sites revealed that everybody was equally affected by the effects of industrialisation and subsequent urbanisation.

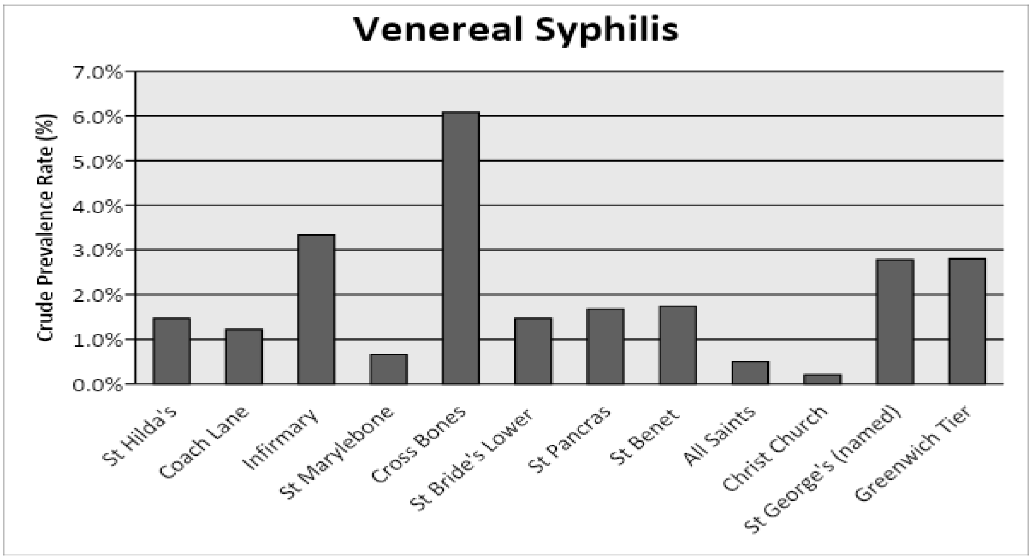


Figure 6.5: Crude prevalence rates in percentages for distribution of venereal syphilis in St Hilda's in comparison with the comparative sites.

Assemblage	CPR: Ven. Syphilis	Population	Ven. Syphilis %	z-value	p-value
St Hilda's, South Shields	3	204	1.47%		
Coach Lane, North Shields	1	82	1.22%	0.16	0.87
Infirmary Newcastle	7	210	3.30%	-1.23	0.21
St Marylebone, London	2	301	0.70%	0.89	0.36
Cross Bones, London	9	148	6.10%	-2.35	0.01
St Bride's Lower Churchyard, London	8	544	1.50%	0	1
St Pancras, London	12	715	1.70%	-0.2	0.83
St Benet Sherehog, London	4	230	1.70%	-1.09	0.27
All Saints, Chelsea Old Church	1	198	0.50%	0.97	0.32
Christ Church, Spitalfields	2	968	0.21%	2.51	0.01
St George's Bloomsbury-named, London	2	72	2.80%	-0.71	0.47
Greenwich Tier, London	3	107	2.80%	-0.81	0.41

Table 6.7: Crude prevalence rates of venereal syphilis along with z- and p-values of significance in St Hilda's in comparison with the comparative sites.

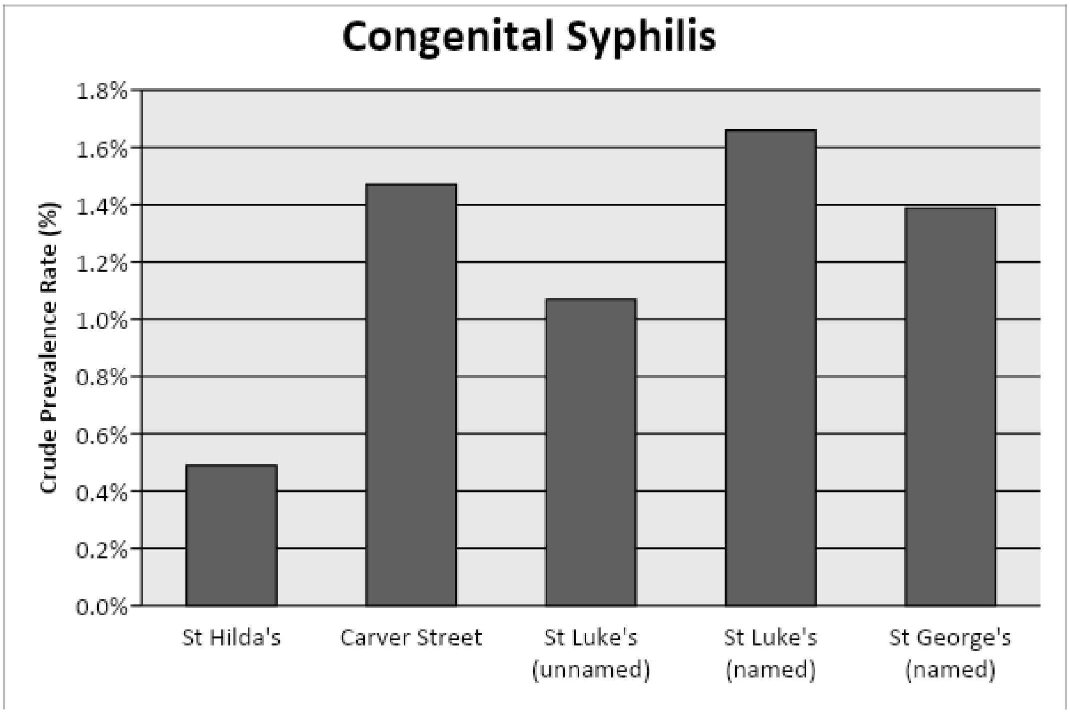


Figure 6.6: Crude prevalence rates in percentages for distribution of congenital syphilis in St Hilda's in comparison with the comparative sites.

Assemblage	CPR: Con. Syphilis	Population	Con. Syphilis %	z-value	p-value
St Hilda's, South Shields	1	204	0.5%		
Carver Street, Sheffield	2	136	1.5%	-0.94	0.34
St Luke's Islington-unnamed, London	7	655	1.1%	-0.75	0.45
St Luke's Islington-named, London	4	241	1.7%	-1.16	0.24
St George's Bloomsbury-named, London	1	72	1.4%	-0.77	0.43

Table 6.8: Crude prevalence rates of congenital syphilis along with z- and p-values of significance in St Hilda's in comparison with the comparative sites.

6.2.2 Non-specific Infections

Among non-specific infections there was little evidence of maxillary sinusitis at most of the sites. It is speculated that the reason behind that was the limited accessibility of maxillary sinus due to the methodological complexity of recording it; which requires either crania that have undergone post-mortem breakage or in the case of intact crania the use of an endoscope or x-rays. From these sites that were giving some prevalence, St Hilda's exhibited statistically significantly higher prevalence (Table 6.9). In some other cases such as St Benet Sherehog, St Bride's Lower Churchyard and the Cross Bones it was noted, that the too little evidence of lesions was recorded by chance and therefore, it was deemed inappropriate to compare these few examples of individuals to St Hilda's where the individuals were properly studied for the purpose of recording the lesions. Consequently, it was impossible to determine with certainty whether or not St Hilda's prevalence was consistent with other skeletal rates of the period. It would appear, however, that few status differences existed; St Hilda's exhibited higher prevalence of maxillary sinusitis than Christ Church, Spitalfields with CPR's at 43.3% (*45/104)* and 18% (*71/394*) respectively. St Hilda's and Christ Church were both systematically studied for the recording of maxillary sinusitis on a non-commercial setting; therefore, that was perhaps the difference between these two sites, which exhibited adequate evidence of the lesions, and the rest of the sites where the lesions were not systematically recorded due to lack of time for a thorough examination.

Assemblage	CPR: Maxillary Sinusitis	Total	Maxillary Sinusitis %	z-value	p-value
St Hilda's, South Shields	45	104	43.27%		
Carver Street, Sheffield	22	136	16.2%	4.63	0.00
St Martin, Birmingham	14	279	5.02%	9.22	0.00
St Marylebone, London	15	301	5.0%	9.47	0.00
St Pancras, London	2				
St Benet Sherehog, London	1				
All Saints, Chelsea Old Church	2				
St Luke's Islington-unnamed, London	6	655	0.9%	16.02	0.00
St Luke's Islington-named, London	4	241	1.7%	10.15	0.00

Christ Church, Spitalfields	71	394	18.0%	5.41	0.00
Greenwich Tier, London	8	93	8.6%	5.47	0.00

Table6.9: Crude prevalence rates of maxillary sinusitis with z- and p-values of significance in St Hilda's in comparison with the comparative sites.

St Hilda's exhibited similar CPR of rib lesions associated with pleurisy 7.6% (*12/157*) and/or TPR 1.93% (*49/2537*) with most of the comparative sites where the information was provided. This equal prevalence was indicative that everybody, regardless of status or geographical region was equally exposed to indoor and outdoor air pollution and (Figure 6.7; Table 6.10). Only Greenwich Tier Hospital ($z = -4.63;\ p = 0.00$), Infirmary Newcastle ($z = -3.49;\ p = 0.00$) and St Luke's-unnamed ($z = 6.00;\ p = 0.00$) exhibited different prevalence. The first two had higher prevalence and the third one lower than St Hilda's. Greenwich Royal Hospital and Infirmary Newcastle were used by seamen while St Luke's-unnamed was a working-class site. In the case of Greenwich Tier and Infirmary Newcastle the higher prevalence reflects perhaps the nature of the burial site and subsequently the nature of the population (Boston *et al.* 2008), but in the case of St Luke's perhaps the difference was methodological due to the increased number of found individuals.

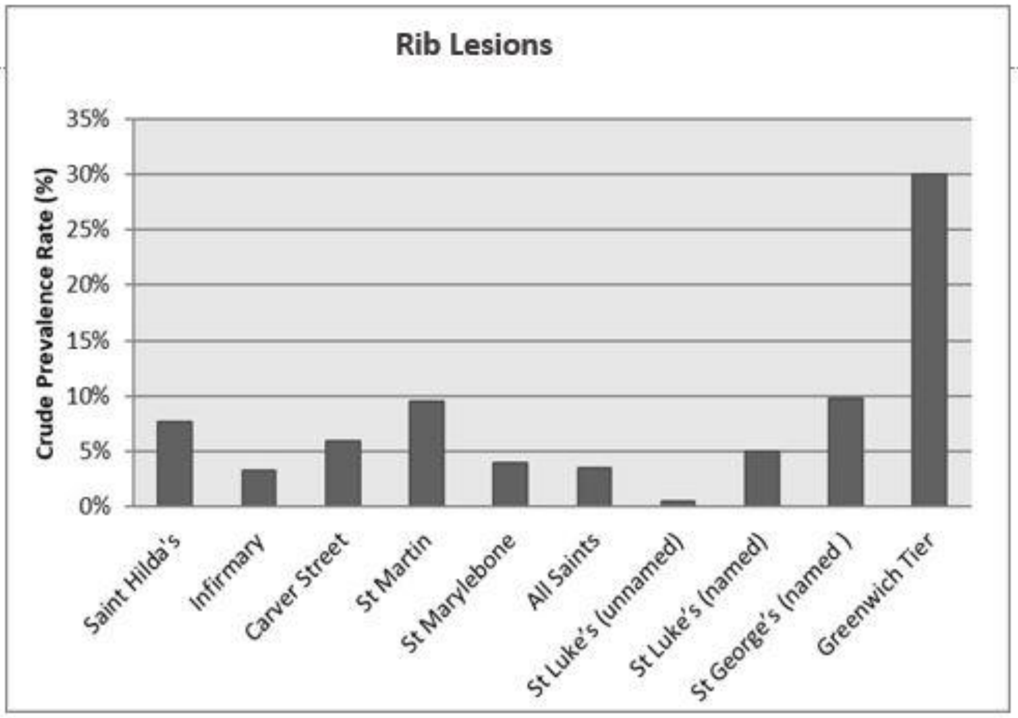


Figure 6.7: Crude prevalence rates in percentages for distribution of rib lesions associated with pleurisy in St Hilda's in comparison with the comparative sites.

Assemblage	CPR: Pleurisy	Total	Pleurisy %	z-value	p-value	TPR: Pleurisy	Total Ribs	Pleurisy %	z-value	p-value
St Hilda's, South Shields	12	157	7.60%			49	2.537	1.93%		
Infirmary Newcastle						75	2.084	3.60%	-3.49	0
Carver Street, Sheffield	8	136	5.90%	0.59	0.55					
St Martin, Birmingham	43	452	9.50%	-0.7	0.48					
St Marylebone, London	12	301	4.00%	1.66	0.09	72	4.059	1.80%	0.46	0.64
All Saints, Chelsea Old Church	7	198	3.50%	1.7	0.08					
St Luke's Islington-unnamed, London	3	655	0.50%	6	0					
St Luke's Islington-named, London	12	241	4.98%	1.09	0.27					
St George's Bloomsbury-named, London	7	72	9.70%	-0.52	0.59					
Greenwich Tier	27	90	30.00%	-4.63	0					

Table 6.10: Crude and true prevalence rates of rib lesions associated with pleurisy along with z- and p-values of significance in St Hilda's in comparison with the comparative sites.

St Hilda's exhibited similar CPR of TPNB 8.4% (*13/154*) and/or TPR 6.51% (*19/292*) to many of the comparative sites where the rates of this non-specific indicator were systematically recorded (Figure 6.8; Table 6.11). The equal or relatively similar prevalence between St Hilda's and these sites of various backgrounds (e.g. Coach Lane, St Martin Birmingham, St Marylebone and St Luke's Islington-named) is indicative that everybody was exposed to at least one of the possible aetiologies of inflammation of the tibial periosteum. Only few cases exhibited a higher prevalence than St Hilda's such as the Greenwich Tier (*z = -7.92; p = 0.00*), Infirmary Newcastle (*z = -3.19; p = 0.00*) and St George's-named assemblage (*z = -2.63; p = 0.00*). While St Benet Sherehog (*z = 2.58; p = 0.00*) and St Luke's Islington-unnamed (*z = 2.12; p = 0.03*) exhibited lower prevalence than St Hilda's. Consequently, it seems that despite the socio-economic status everybody was affected by TPNB; however, it is expected that based on the status the underlying aetiology would differ from site to site.

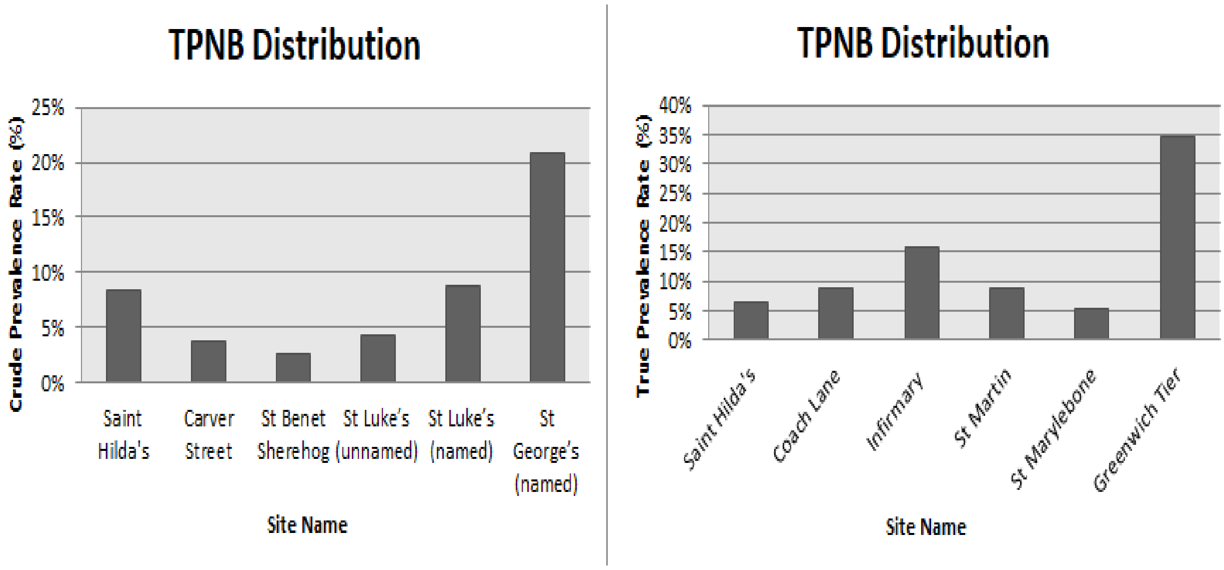


Figure 6.8: Crude and true prevalence rates in percentages for distribution of TPNB in St Hilda's in comparison with the comparative sites.

Assemblage	CPR TPNB	Total	TPNB %	z-value	p-value	TPR TPNB	Tibiae	TPNB%	z-value	p-value
St Hilda's, South Shields	13	154	8.4%			19	292	6.51%		
Coach Lane, North Shields						8	92	8.70%	-0.71	0.47
Infirmary Newcastle						27	172	15.70%	-3.19	0
Carver Street, Sheffield	5	136	3.68%	1.67	0.09					
St Martin, Birmingham						73	825	8.85%	-1.25	0.21
St Marylebone, London						22	399	5.51%	0.54	0.58
St Benet Sherehog, London	6	230	2.6%	2.58	0					
St Luke's Islington-unnamed, London	28	655	4.3%	2.12	0.03					
St Luke's Islington-named, London	21	241	8.7%	-0.09	0.92					
St George's Bloomsbury-named, London	15	72	20.8%	-2.63	0					
Greenwich Tier						67	194	34.54%	-7.92	0

Table 6.11: Crude and true prevalence rates of TPNB along with z- and p-values of significance in St Hilda's in comparison with the comparative site.

6.3 Trauma: Fractures

Fractures were a relatively commonplace in St Hilda's adult assemblage, a pattern reflecting the industrialised environment of South Shields, which predisposed the adult inhabitants and especially the male ones to injury risk. The overall CPR rate at 20.10% (*41/204*) was comparable with other sites from this period reporting high rates of fractures, indicating that the case study followed the general pathological trend of the period (Figure 6.9; Table 6.12). It was observed that many sites of various socio-economic backgrounds such as St Martin, St Marylebone, St Bride's Lower, All Saints Chelsea, St Luke's Islington-named and St George's Bloomsbury-named exhibited similar rates with St Hilda's. Only the sites of Greenwich Tier ($z = -10.12$; $p = 0.00$) and St Benet, Sherehog ($z = -5.27$; $p = 0.00$) exhibited statistically significantly higher prevalence than St Hilda's. It was also observed that some sites of working-class origin exhibited lower prevalence than St Hilda's. For instance, in the case of Cross Bones a higher prevalence of primary or secondary fractures was expected due to the fact that the cemetery was a pauper's ground; however, the observed difference could also be attributed to the low number of interred adults. It is speculated that this statistically significant difference among sites could be the result of bias due to poor preservation and selected methodological criteria due to medium resolution analysis (e.g. Coach Lane, St Luke's -unnamed and St Pancras). It was noted that in these cases the number of the fractures was relatively low in relation to the very high number of preserved skeletons. While there were also cases of higher status (e.g. Christ Church, Spitalfields) that exhibited lower prevalence, possibly due to higher socio-economic status differences.

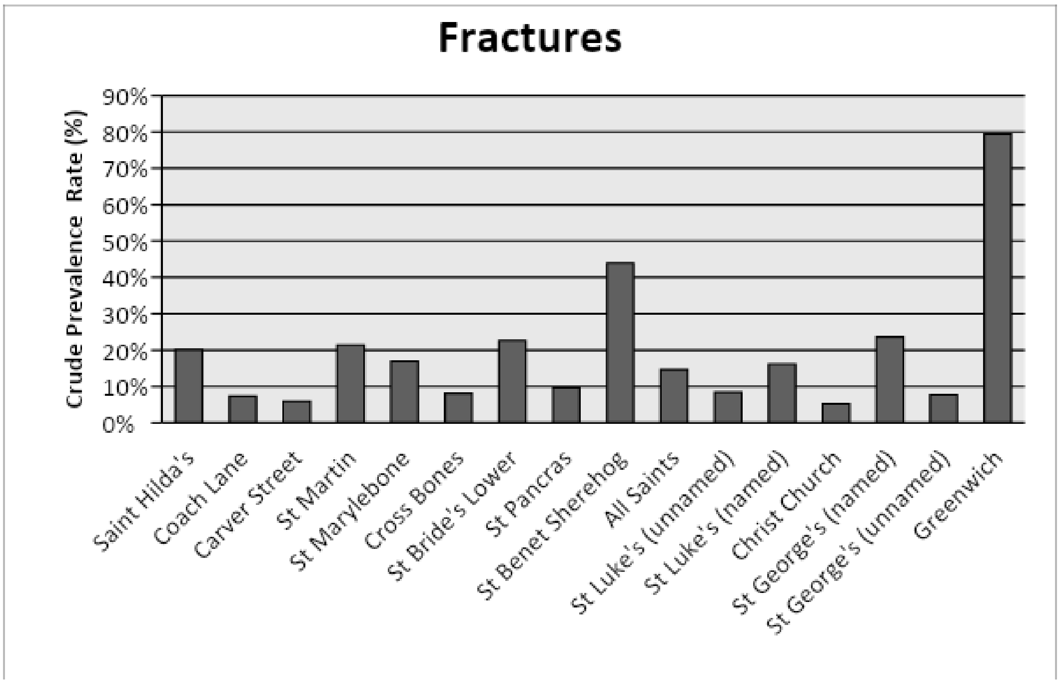


Figure 6.9: Crude prevalence rates in percentages for distribution of fractures in St Hilda's in comparison with the comparative sites.

Assemblage	CPR Total Fractures	Total	Fractures %	z-value	p-value
St Hilda's, South Shields	41	204	20.10%		
Coach Lane, North Shields	6	82	7.32%	2.63	0.00
Carver Street, Sheffield	8	136	5.88%	3.65	0.00
St Martin, Birmingham	108	505	21.39%	-0.38	0.70
St Marylebone, London	51	301	16.94%	0.90	0.36
Cross Bones, London	12	148	8.11%	3.10	0.00
St Bride's Lower Churchyard, London	123	544	22.61%	-0.73	0.45
St Pancras, London	69	715	9.65%	4.05	0.00
St Benet Sherehog, London	101	230	43.91%	-5.27	0.00
All Saints, Chelsea Old Church	29	198	14.65%	1.44	0.14
St Luke's Islington-unnamed, London	55	655	8.40%	4.63	0.00
St Luke's Islington-named, London	39	241	16.18%	1.07	0.28
Christ Church, Spitalfields	51	968	5.27%	7.15	0.00
St George's Bloomsbury-named, London	17	72	23.61%	-0.62	0.52
St George's Bloomsbury-unnamed, London	3	39	7.69%	1.84	0.06
Greenwich Tier	85	107	79.44%	-10.12	0.00

Table 6.12: Crude prevalence rates of fractures along with z- and p-values of significance in St Hilda's in comparison with selected comparative sites.

Interestingly, when these population samples were divided in male and female groups it was noted that St Hilda's males exhibited significantly higher prevalence despite the overall similar prevalence between many sites (Figure 6.10; Table 6.13). The only site that its males were similarly affected by fractures was the site of St Martin, Birmingham; while the males from the sites of St Benet, Sherehog (*z = -2.93; p = 0.01*) and Greenwich Tier (*z = -3.69; p = 0.00*) were more affected than St Hilda's male counterparts. These two last sites also exhibited elevated levels of overall fractures, so it seems that the high predilection of male fractures was the reason behind their overall high levels. Females on the other hand appeared to be almost equally affected despite the status differences with only a couple of exceptions that exhibited statistically lower prevalence than the case study such as the Christ Church (*z = 3.90; p = 0.00*) and St Pancras (*z = 2.03; p = 0.04*) and St Benet, Sherehog (*z = -2.53; p = 0.01*) which exhibited statistically higher prevalence.

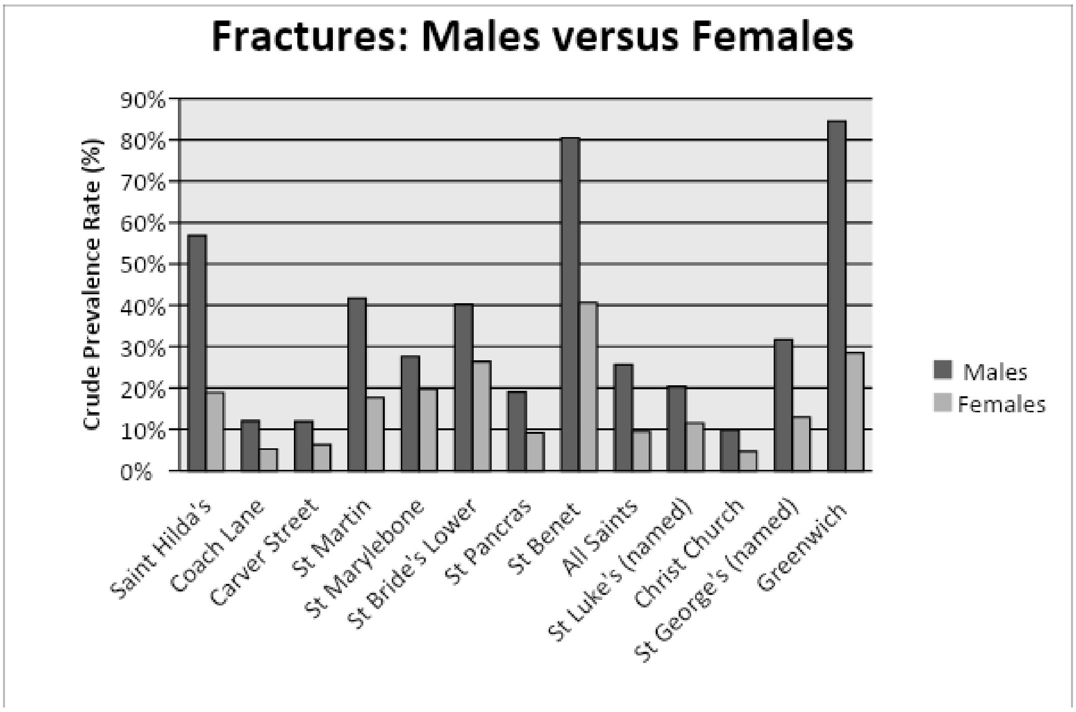


Figure 6.10: Crude prevalence rates in percentages for distribution of fractures between males and females in St Hilda's in comparison with the comparative sites.

Assemblage	CPR Males Fractures	Males	Males Fractures %	z-value	p-value	CPR Females Fractures.	Females	Females Fractures %	z-value	p-value
St Hilda's	29	51	56.86%			10	53	18.90%		
Coach Lane	3	25	12.00%	3.72	0	1	19	5.30%	1.41	0.15
Carver Street	5	42	11.90%	4.48	0	2	32	6.30%	1.61	0.1
St Martin	75	180	41.67%	1.92	0.05	23	130	17.70%	0.18	0.85
St Marylebone	29	105	27.62%	3.54	0	17	86	19.80%	-0.13	0.89
St Bride's Lower	78	194	40.21%	2.13	0.03	33	125	26.40%	-1.07	0.28
St Pancras	44	231	19.05%	5.58	0	20	219	9.10%	2.03	0.04
St Benet	66	82	80.49%	-2.9	0	26	64	40.60%	-2.53	0.01
Chelsea Old Church	20	78	25.64%	3.57	0	7	74	9.50%	1.53	0.12
St Luke's-named	26	128	20.31%	4.78	0	13	113	11.50%	1.28	0.2
Christ Church, Spitalfields	34	345	9.86%	8.56	0	16	345	4.60%	3.9	0
St George's-named	13	41	31.71%	2.4	0.01	4	31	12.90%	0.7	0.47
Greenwich Tier	82	97	84.54%	-3.6	0	2	7	28.60%	-0.6	0.54

Table6.13: Crude prevalence rates of fractures in St Hilda's males and females along with z- and p-values of significance in comparison with the sites.

6.4 Joint Disease

6.4.1 Osteoarthritis: Extra-spinal and Spinal

Evidence of osteoarthritic lesions in one or more joints were recorded in more than half of the St Hilda's adult population (*67/117*) achieving a CPR at 57.3% for both primary and secondary OA together (Figure 6.11). For the needs of the comparative analysis both primary and secondary OA were analysed together as it appeared that most of the sites had this information combined. When z-tests of proportions were applied between the case study and these sites which had this information recorded, it was noted that St Hilda's exhibited higher prevalence than many comparative sites of higher status, showing socio-economic status differences. St Hilda's had higher prevalence than the higher status sites of All Saints Chelsea, St Luke's Islington-named, and Christ Church Spitalfields, but the same prevalence with the lower status sites of Cross Bones and Greenwich Tier indicating social status similarities (Table 6.14-6.15). There were, however, also lower status sites such as Coach Lane, Carver Street and St Bride's that exhibited lower prevalence than St Hilda's.

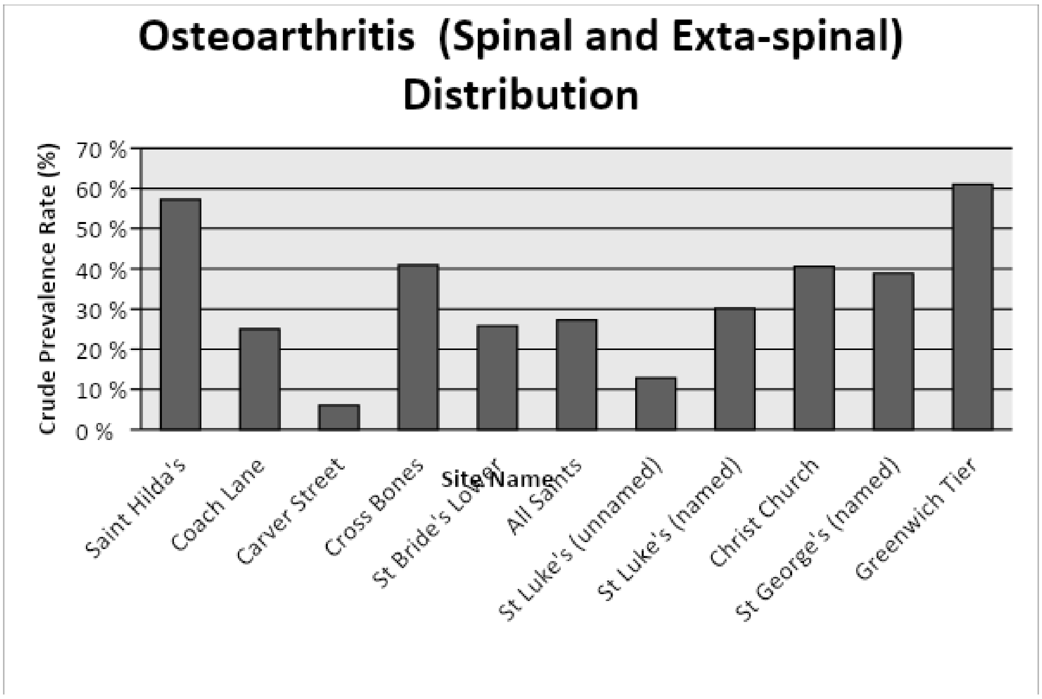


Figure 6.11: Crude prevalence of OA in St Hilda's adults in comparison with the comparative sites.

Assemblage	CPR OA Adult	Adults	OA Adult %	z-value	p-value
St Hilda's. South Shields	67	117	57.26%		
Coach Lane. North Shields	11	44	25.00%	3.65	0.00
Carver Street. Sheffield	6	99	6.06%	7.92	0.00
Cross Bones. London	18	44	40.91%	1.85	0.06
St Bride's Lower Churchyard. London	95	369	25.7%	6.30	0.00
All Saints. Chelsea Old Church	45	165	27.27%	5.07	0.00
St Luke's Islington-unnamed. London	71	553	12.84%	10.79	0.00
St Luke's Islington-named. London	66	219	30.14%	4.84	0.00
Christ Church. Spitalfields	255	628	40.61%	3.33	0.00
St George's Bloomsbury-named	26	67	38.81%	2.40	0.01
Greenwich Tier	64	105	60.95%	-0.55	0.57

Table 6.14: Crude prevalence of spinal and extra-spinal OA in St Hilda's population in comparison with the comparative sites.

Assemblage	CPR Adult Extra-Spinal OA	Adults	Adult Extra-Spinal OA %	z-value	p-value
St Hilda's. South Shields	47	117	40.17%		
Infirmary Newcastle	26	191	13.61%	5.31	0.00
Carver Street. Sheffield	2	99	2.02%	6.67	0.00
St Martin. Birmingham	78	352	22.16%	3.81	0.00
St Marylebone. London	49	223	21.97%	3.54	0.00

Table 6.15: Crude prevalence of extra-spinal OA in St Hilda's population in comparison with the comparative sites.

6.4.2 Spinal Osteoarthritis

Degenerative changes and involvement of the zygapophyseal joints (facets) of the spine were recorded in 42 of St Hilda's adults (Figure 65.12; Table 6.16). When z-tests of proportions were applied, St Hilda's adult CPR at 35.90% was similar to the rates of Infirmary Newcastle, Cross Bones, St Bride's, All Saints and Christ Church showing that everybody was equally affected by spinal OA, despite the status differences. St Hilda's prevalence both CPR and TPR were statistically higher than Coach Lane (*z = 3.05; p = 0.00*), Carver Street (*z = 5.25; p = 0.00*), St Martin (*z = 3.48; p = 0.00*), St Benet (*z = 3.34; p = 0.00*), St Luke's Islington-unnamed (*z = 9.90; p = 0.00*) and St Luke's Islington-named (*z = 3.80; p = 0.00*). St Marylebone (*z = 18.7; p = 0.00*) and St George's Bloomsbury-unnamed (*z = 9.05; p = 0.00*).

St Hilda's CPR for spinal OA is much higher than the 13.49% reported by Roberts and Cox (2003, 352) for other post-medieval sites. It is suspected that in some cases such as Coach Lane, Carver Street, St Marylebone and St George's Bloomsbury, this difference was mainly due to methodology and preservation issues, and it is assumed that these sites had a much higher prevalence than what was reported here.

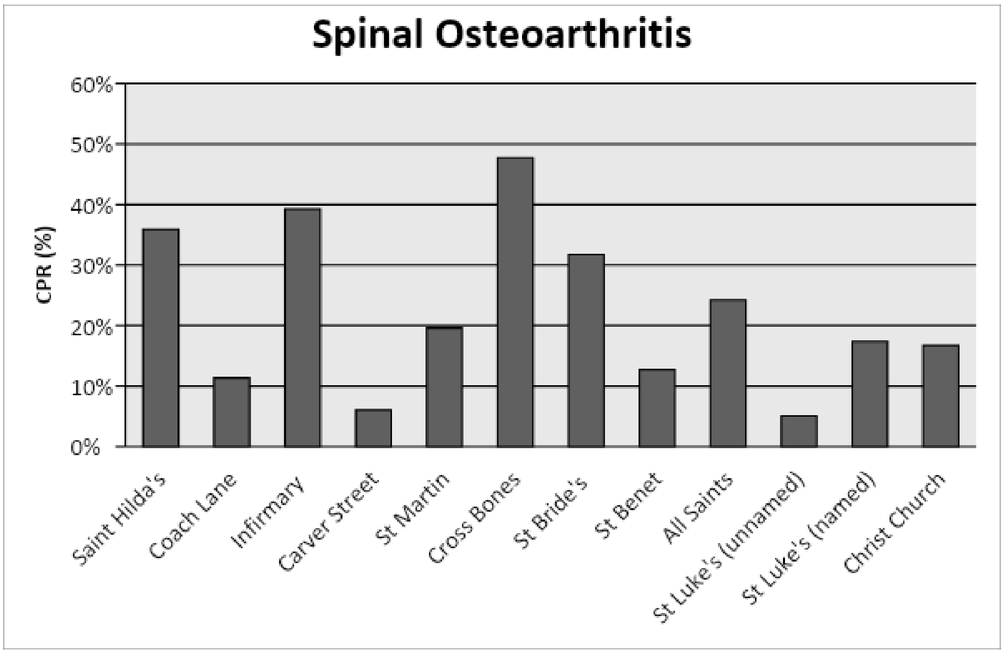


Figure 6.12: Crude prevalence of spinal OA in St Hilda's adults in comparison with the comparative sites.

Assemblage	CPR Adult Spinal OA	Adults	Spinal OA %	z-value	p-value	TPR Adult Spinal OA	Vertebrae	Spinal OA %	z-value	p-value
St Hilda's, South Shields	42	117	35.90%			424	1801	23.50%		
Coach Lane, North Shields	5	44	11.36%	3.05	0					
Infirmary Newcastle	75	191	39.27%	-0.59	0.55					
Carver Street, Sheffield	6	99	6.06%	5.25	0					
St Martin, Birmingham	58	296	19.59%	3.48	0					
St Marylebone, London						272	4162	6.50%	18.77	0
Cross Bones, London	21	44	47.73%	-1.48	0.13					
St Bride's Lower, London	117	369	31.71%	0.84	0.39					
St Pancras, London		448								
St Benet Sherehog, London	21	165	12.73%	3.34	0					
All Saints, Chelsea Old Church	40	165	24.24%	1.21	0.22					
St Luke's Islington-unnamed, London	28	553	5.06%	9.9	0					
St Luke's Islington-named	38	219	17.35%	3.8	0					
Christ Church, Spitalfields	105	628	16.72%	4.78	0					
St George's Bloomsbury-named, London		67				139	1288	11%	9.05	0

Table 6.16: Crude and true prevalence of spinal OA in St Hilda's in comparison with the comparative sites.

6.4.3 Schmorl's Nodes

Schmorl's nodes identified as depressions on the end plates of vertebrae were recorded in almost half of the St Hilda's adult population (*47/117*) affecting almost one third of the vertebrae present (*527/1801*) (Figure 6.13; Table 6.17). When z-tests of proportions were applied, St Hilda's adult CPR at *40.17%* and TPR at 29.3% were statistically higher than Carver Street (*z = 5.80; p = 0.00*), St Martin (*z = 16.6; p = 0.00*), St Marylebone (*z = 16.3; p = 0.00*), Christ Church (*z = 5.16; p = 0.00*), St Luke's Islington-unnamed (*z = 10.2; p = 0.00*) and St Luke's Islington-named (*z = 2.57; p = 0.00*), and statistically lower than the sites of Coach Lane (*z = -3.17; p = 0.00*), Cross Bones (*z = -4.36; p = 0.00*), St Benet's (*z = -3.02; p = 0.00*) and Greenwich Tier (*z = -3.94; p = 0.00*). However, there were also sites that exhibited no statistical differences with St Hilda's such as the sites of Infirmary Newcastle, St Bride's, All Saints Chelsea and St George's Bloomsbury-named, which exhibited similar prevalence with the case study.

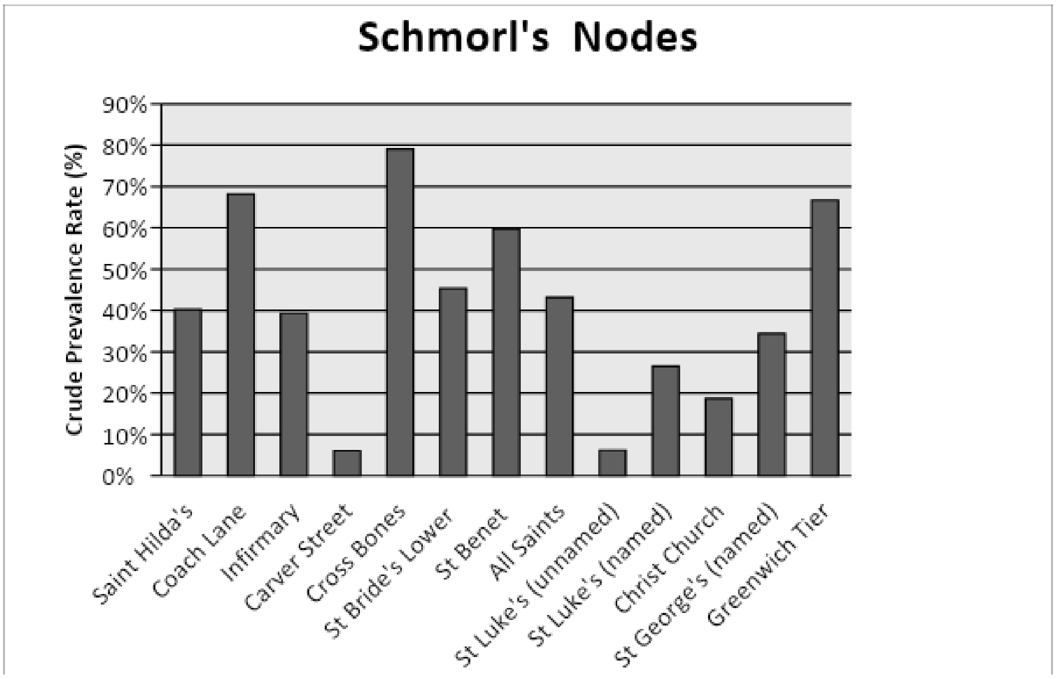


Figure 6.13: Crude prevalence of Schmorl's nodes in St Hilda's adults in comparison with the comparative sites.

Assemblage	CPR Adult Schmorl's	Adults	CPR Schmorl's %	z-value	p-value	TPR Adult Schmorl's	Vertebrae	TPR Schmorl's %	z-value	p-value
St Hilda's, South Shields	47	117	40.17%			527	1801	29.3%		
Coach Lane, North Shields	30	44	68.18%	-3.17	0					
Infirmary Newcastle	75	191	39.27%	0.15	0.87	466	2271	20.5%		
Carver Street, Sheffield	6	99	6.06%	5.8	0					
St Martin, Birmingham		352				877	6767	13.0%	16.6	0
St Marylebone, London						495	4162	11.9%	16.34	0
Cross Bones, London	34	43	79.07%	-4.36	0					
St Bride's Lower Churchyard, London	167	369	45.26%	-0.96	0.33					
St Pancras, London		448								
St Benet Sherehog, London	74	124	59.68%	-3.02	0					
All Saints, Chelsea Old Church	60	139	43.17%	-0.48	0.62					
St Luke's Islington-unnamed, London	34	553	6.15%	10.25	0					
St Luke's Islington-named, London	58	219	26.48%	2.57	0					
Christ Church, Spitalfields	117	628	18.63%	5.16	0					
St George's Bloomsbury-named, London	23	67	34.33%	0.78	0.43					
St George's Bloomsbury-unnamed, London		35								
Greenwich Tier	70	105	66.67%	-3.94	0					

Table 6.17: Crude and true prevalence of Schmorl's nodes in St Hilda's population in comparison with the comparative sites.

As males tend to be more prone to the lesions further analysis was applied in order to see if there were any differences between the two biological sexes (Diehn *et al.* 2016). No substantial differences existed, when the population sample was divided into males and females and z-tests of proportions were applied, no substantial differences were observed between St Hilda's and most of the sites which provided this separate information on male and female population (Figure 6.14; Table 6.18). Apart from the site of Christ Church ($z = 7.77; p = 0.00$) that exhibited much lower prevalence of Schmorl's nodes in males than St Hilda's and the site of Cross Bones ($z = -4.55; p = 0.00$) which exhibited much higher prevalence than St Hilda's females. These few found differences here were possibly due to social status dissimilarities. Christ Church's lower prevalence of the lesions in males and Cross Bone's higher prevalence in females was perhaps due to lifestyle differences, the first one was a site of higher status than St Hilda's, while the second was of a lower status and included many single women. It would appear that no social status differences existed between the separately studied groups; however, no further conclusions should be drawn and this theory should not be generalised further as only the sites of Coach Lane, Cross Bones, St Bride's, St Benet, All Saints, Greenwich Tier and Christ Church provided rates on how males and females were separately affected by the lesions.

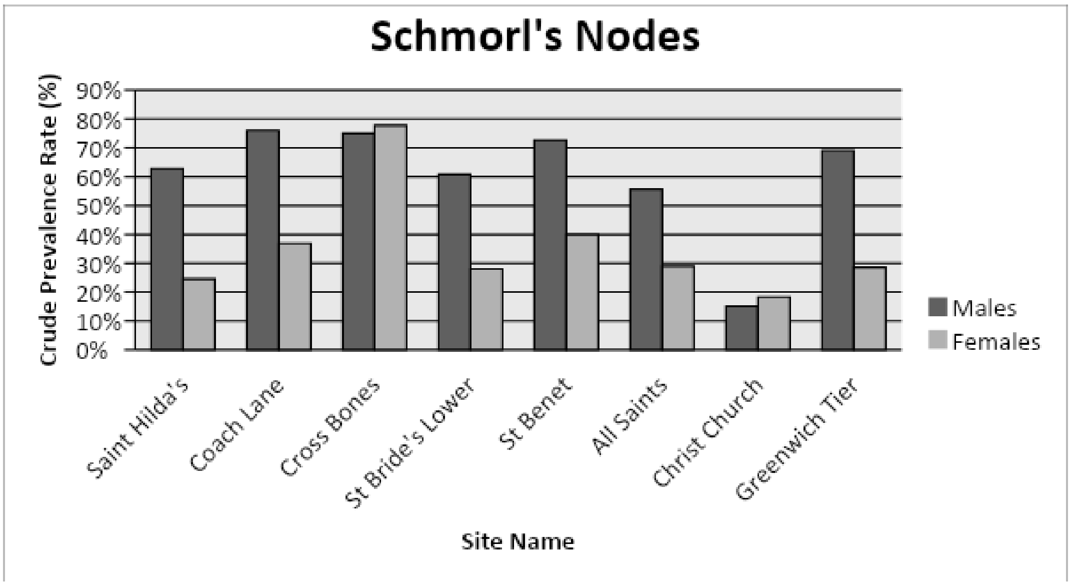


Figure 6.14: Crude prevalence of Schmorl's nodes in St Hilda's males and females in comparison with the comparative sites.

Assemblage	p-value	z-value	CPR Females Schmorls %	Females	CPR Females Schmorls	p-value	z-value	CPR Males Schmorls%	Males	CPR Males Schmorls
St Hilda's, South Shields			24.50%	53	13			62.75%	51	32
Coach Lane, North Shields	0.3	-1.02	36.80%	19	7	0.24	-1.15	76.00%	25	19
Cross Bones, London	0	-4.55	77.80%	27	21	0.42	-0.8	75.00%	12	9
St Bride's Lower Churchyard, London	0.63	-0.47	28.00%	125	35	0.8	0.25	60.82%	194	118
St Benet Sherehog, London	0.1	-1.64	40.00%	45	18	0.24	-1.16	72.60%	73	53
All Saints, Chelsea Old Church	0.58	-0.54	29.00%	62	18	0.43	0.77	55.71%	70	39
Christ Church, Spitalfields	0.27	1.08	18.30%	345	63	0	7.77	15.07%	345	52
Greenwich Tier	0.81	-0.23	28.60%	7	2	0.43	-0.77	69.07%	97	67

Table 6.18: Crude and true prevalence of Schmorl's nodes in St Hilda's population between males and females in comparison with the comparative sites.

6.5 Other Joint Disease: Diffuse Idiopathic Skeletal Hyperostosis (DISH) and Gouty Arthritis (GA)

Lesions indicative of DISH were identified in a few individuals from St Hilda's adult assemblage (*3/117*). St Hilda's adult CPR at *2.56%* was in line with the results of the comparative sites. The application of z-tests of proportions revealed no differences between St Hilda's and the sites (Figure 6.15; Table 6.19). Although the condition has been frequently associated with dietary excess and therefore has been further associated with higher status, St Hilda's statistical analysis revealed no status differences between sites of various backgrounds (Miles *et al.* 2018).

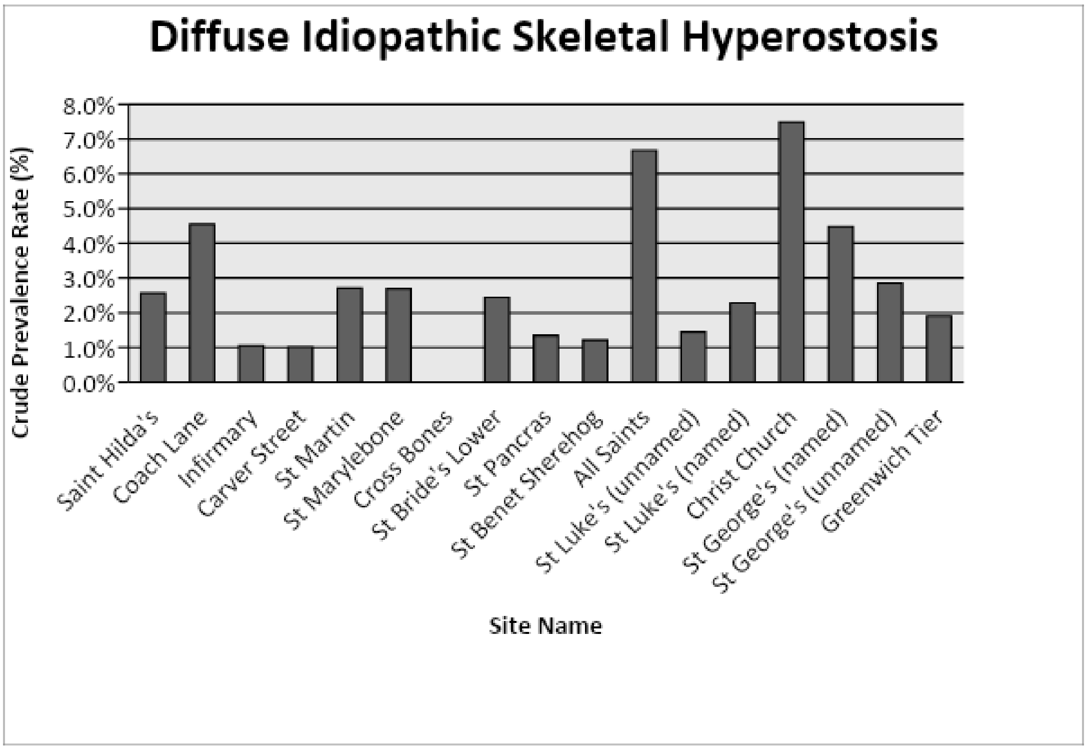


Figure 6.15: Crude prevalence of DISH in St Hilda's adults in comparison with the comparative sites.

Assemblage	CPR Adult DISH	Adults	DISH %	z-value	p-value
St Hilda's, South Shields	3	117	2.56%		
Coach Lane, North Shields	2	44	4.55%	-0.64	0.51
Infirmary Newcastle	2	191	1.05%	1.02	0.30
Carver Street, Sheffield	1	99	1.01%	0.84	0.39
St Martin, Birmingham	8	296	2.70%	-0.07	0.93
St Marylebone, London	6	223	2.69%	-0.06	0.94
St Bride's Lower Churchyard, London	9	369	2.44%	0.07	0.93
St Pancras, London	6	448	1.34%	0.94	0.34
St Benet Sherehog, London	2	165	1.21%	0.84	0.39
All Saints, Chelsea Old Church	11	165	6.67%	-1.56	0.11
St Luke's Islington-unnamed, London	8	553	1.45%	0.86	0.38
St Luke's Islington-named, London	5	219	2.28%	0.16	0.87
Christ Church, Spitalfields	47	628	7.48%	-1.95	0.05
St George's Bloomsbury-named, London	3	67	4.48%	-0.70	0.48
St George's Bloomsbury-unnamed	1	35	2.86%	-0.09	0.92
Greenwich Tier	2	105	1.90%	0.33	0.74

Table 6.19: Crude prevalence of DISH in St Hilda's population in comparison with the comparative sites.

Skeletal changes indicative of GA were observed in some of the St Hilda's individuals (*7/117*). St Hilda's adult CPR at 5.98*%* was statistically higher compared to the sites that had this information recorded. The application of z-tests of proportions revealed statistically significant differences between St Hilda's and the sites, apart from Carver Street and All Saints, Chelsea (Figure 6.16; Table 6.20). As the lesions for both the case study and Carver Street were recorded by the author, it is suspected that the statistical difference was the result of methodological analysis in a non-commercial setting.

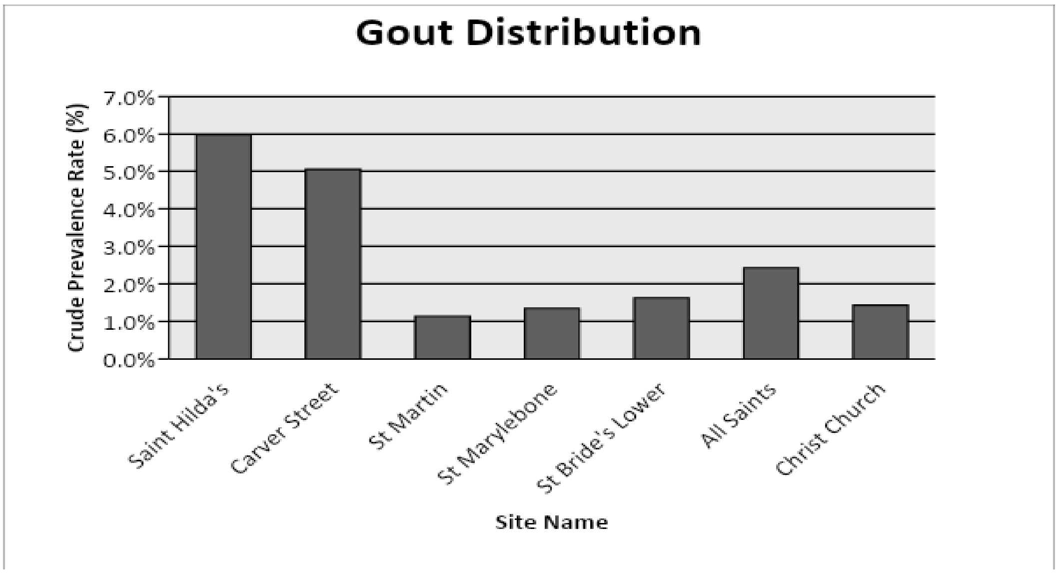


Figure 6.16: Crude prevalence of GA in St Hilda's adults in comparison with the comparative sites.

Assemblage	CPR Adult Gout	Adults	Gout %	z-value	p-value
St Hilda's, South Shields	7	117	5.98%		
Carver Street, Sheffield	5	99	5.05%	0.29	0.76
St Martin, Birmingham	4	352	1.14%	3.00	0.00
St Marylebone, London	3	223	1.35%	2.40	0.01
St Bride's Lower Churchyard, London	6	369	1.63%	2.54	0.01
All Saints, Chelsea Old Church	4	165	2.42%	1.52	0.12
Christ Church, Spitalfields	9	628	1.43%	3.11	0.00

Table 6.20: Crude prevalence of GA lesions in St Hilda's population in comparison with the comparative sites.

Some other joint diseases that were possible to be compared between St Hilda's and other comparative sites included rheumatoid arthritis (RA) and ankylosing spondylitis (AS). From the sites that provided information on RA, no differences were observed. In particular no differences were observed between St Hilda's and St Martin, St Marylebone, Cross Bones, Greenwich Tier, St Bride's Lower, St Luke's Islington-named and St George's Bloomsbury-named. The recorded cases from site to site ranged from one to two. In the case of AS no differences were observed again between St Hilda's and Carver Street, All Saints, St Marylebone and St Luke's Islington-named. While St Hilda's exhibited higher prevalence than the sites of St Martin and St Luke's-unnamed. The number of cases between sites ranged from one to three.

6.6 Dental Disease

It would appear that the TPR of caries (or CPR when TPR was not available) in St Hilda's was higher than many other comparative sites used. Roberts and Cox (2003, 326) calculate that the prevalence of carious lesions for the period was 11.2% of teeth (43.06% of individuals) ranging from 5.4-29.9%. However, St Hilda's exceeded this number, although it still fell within the given range, with caries prevalence at 26% (*468/1788*) which corresponds to 81 (*39.7%*) affected individuals from the total population. Although the TPR's at first sight seemed similar between St Hilda's and the comparative sites, after applying z-tests of proportions, it was revealed that St Hilda's exhibited higher rates of caries than many of the sites that provided this information (Figure 6.17; Table 6.21). There were, however, also sites that exhibited similar rates with St Hilda's such as the sites of Coach Lane, Carver Street, Cross Bones and St Bride's Lower Churchyard. These sites were of working- or lower-class origin, revealing that some lifestyle and diet similarities existed. A factor that may have reduced the formation of caries in the comparative sites was dental attrition and abrasion that results in flattening of the enamel folds of the occlusal surface that reduces the risks of food entrapment and hence, carries (Roberts and Manchester 1997: Boston *et al.* 2008). However, confirming this theory was problematic because only two comparative sites had calculated rates of dental wear (Table 6.22).

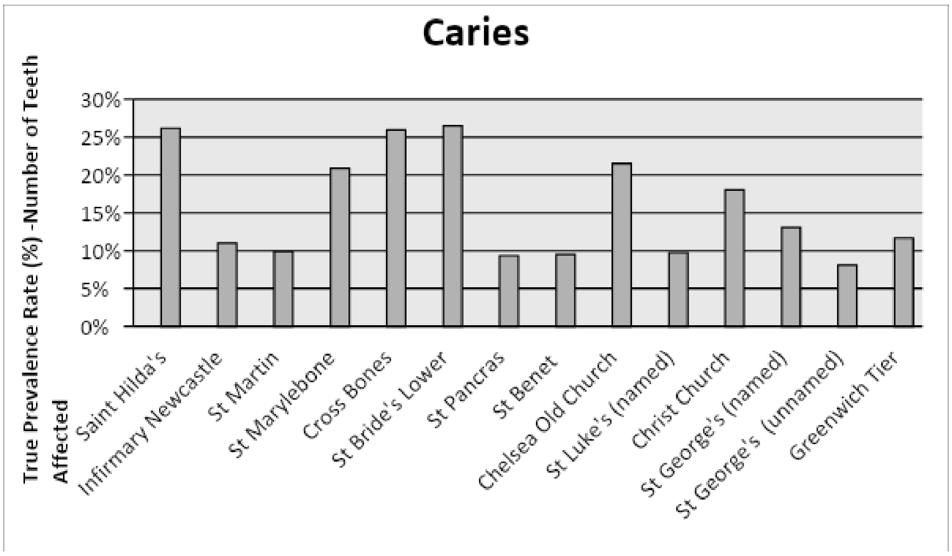


Figure 6.17: True prevalence rates in percentages for distribution of caries in St Hilda's in comparison with the comparative sites.

Assemblage	p-value	z-value	Caries %	Total	CPR Caries	p-value	z-value	Caries %	Teeth No	TPR Caries
St Hilda's, South Shields	468	1788	26%			81	204	39.70%		
Coach Lane, North Shields						35	82	42.70%	0.46	0.64
Infirmary Newcastle	146	1327	11%	10.52	0					
Carver Street, Sheffield						47	136	34.60%	0.95	0.33
St Martin, Birmingham	488	4940	10%	16.91	0					
St Marylebone, London	592	2837	21%	4.18	0					
Cross Bones, London	161	621	26%	0.12	0.9					
St Bride's Lower Churchyard, London	343	1294	27%	-0.2	0.83					
St Pancras, London	585	6289	9%	18.69	0					
St Benet Sherehog, London	190	2003	9%	13.54	0					
All Saints, Chelsea Old Church	471	1172	22%	2.89	0					
St Luke’s Islington-unnamed, London										
St Luke’s Islington-named, London	219	2249	10%	13.8	0					
Christ Church, Spitalfields	385	2140	18%	6.19	0					
St George’s Bloomsbury-named, London	110	844	13%	7.6	0					
St George’s Bloomsbury-unnamed	38	470	8%	8.36	0					
Greenwich Tier	152	1303	12%	9.94	0					

Table 6.21: True and crude prevalence rates of caries in St Hilda’s in comparison with the comparative sites.

Assemblage	CPR DW	Total	DW %	z-value	p-value
St Hilda's, South Shields	60	204	29%		
Infirmary Newcastle	18	136	13%	3.30	0.00
Christ Church, Spitalfields	19	96	20%	1.61	0.10

Table 6.22: True prevalence rates of DW in St Hilda's in comparison with the comparative sites.

Another possible explanation for the low prevalence of carious lesions in the comparative sites could be secondary AMTL. Presumably because of the large tooth decay there were fewer teeth to analyse in the comparative sites' assemblages. It was observed, indeed, that the comparative sites exhibited higher AMTL in relation to a lower prevalence of caries (Figure 6.18; Table 6.23). The TPR of AMTL 29.2% (*1119/3838*) in St Hilda's was statistically higher than the rates of Infirmary Newcastle ($z = 9.43$; $p = 0.00$), St Martin ($z = 2.93$; $p = 0.00$), St Benet ($z = 9.66$; $p = 0.00$), Cross Bones ($z = 8.14$; $p = 0.00$) and Christ Church ($z = 16.14$; $p = 0.00$) and statistically lower than St Bride's Lower Churchyard ($z = -8.21$; $p = 0.00$), Chelsea Old Church ($z = -7.10$; $p = 0.00$), St Luke's Islington-named ($z = -6.12$; $p = 0.00$), St George's Bloomsbury-unnamed ($z = -2.13$; $p = 0.00$), St George's Bloomsbury-named ($z = -8.53$; $p = 0.00$) and Greenwich Tier ($z = -12.79$; $p = 0.00$); while the site shared the same rates with Carver Street, Coach Lane and St Marylebone. This explanatory model was partially confirmed for the sites of Chelsea Old Church, St Luke's-named, St George's Islington-named and St George's Islington-unnamed and Greenwich Tier where their AMTL rates were higher than St Hilda's, while their rates of carious lesions were lower than St Hilda's. However, there were also sites that had both diseases lower than St Hilda's (e.g. Infirmary Newcastle and St Martin). Regardless of the aetiology, the fact that individuals from different strata exhibited both of the conditions is indicative that both poor and rich were exposed to poor dental hygiene and diet to a certain extent.

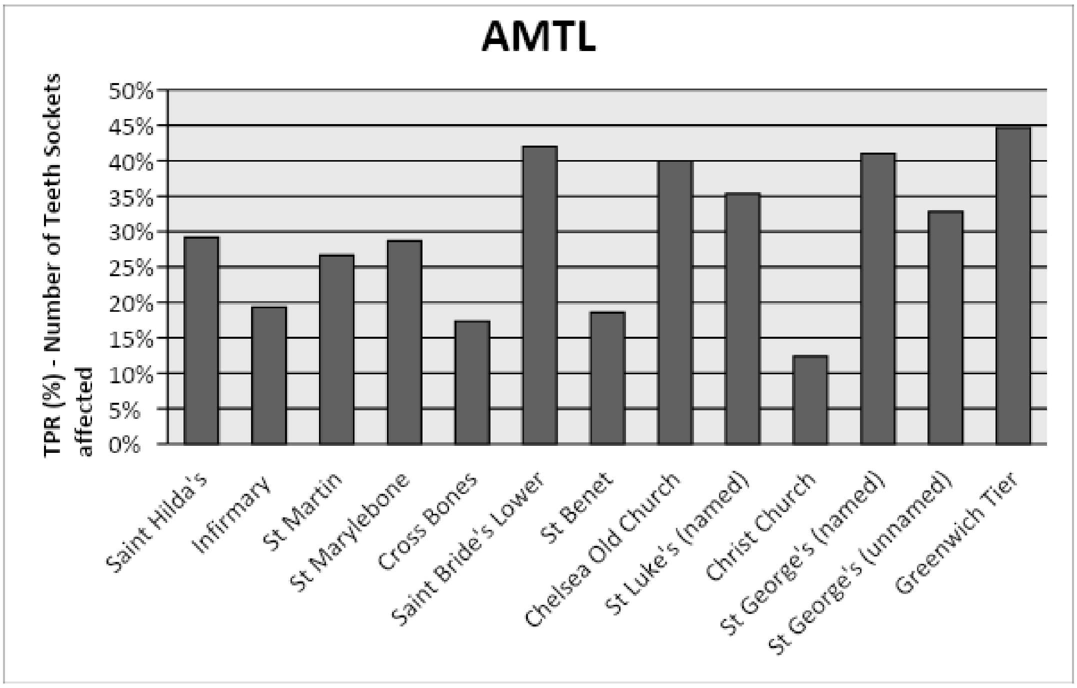


Figure 6.18: True prevalence rates in percentages for distribution of AMTL in St Hilda's in comparison with the comparative sites.

Assemblage	TPR AMTL	Sockets No	AMTL %	z-value	p-value	CPR AMTL	Total	AMTL %	z-value	p-value
St Hilda's, South Shields	1119	3838	29.20%			82	204	40.20%		
Coach Lane, North Shields						25	82	30.50%	1.53	0.12
Infirmary Newcastle	604	3123	19.30%	9.43	0					
Carver Street, Sheffield						35	136	25.70%	2.74	0
St Martin, Birmingham	2488	9337	26.65%	2.93	0					
St Marylebone, London	1518	5298	28.70%	0.52	0.6					
Cross Bones, London	211	1216	17.35%	8.14	0					
St Bride's Lower Churchyard, London	537	1294	41.50%	-8.2	0					
St Benet Sherehog, London	486	2617	18.60%	9.66	0					
All Saints, Chelsea Old Church	471	1172	40.19%	-7.1	0					
St Luke's Islington-named, London	1726	4883	35.30%	-6.12	0					
Christ Church, Spitalfields	341	2750	12.40%	16.14	0					
St George's Bloomsbury-named, London	669	1632	41.00%	-8.53	0					
St George's Bloomsbury-unnamed	284	865	32.80%	-2.13	0.03					
Greenwich Tier	1172	2624	44.70%	-12.79	0					

Table 6.23: True and crude prevalence of AMTL in St Hilda's in comparison with the comparative sites.

AMTL can frequently be the result of calculous deposits that irritate the dental tissues, leading to weakening of the periodontal ligament and resorption of the alveolar bone (periodontal disease) and eventually in many cases to subsequent tooth loss (Roberts and Manchester 1997, 50). In addition, periapical abscesses forming as a result of gross carious lesions and exposure of the underlying pulp cavity or/and excessive attrition can lead to death of the root and loss of the tooth (Hillson 2002, 196).

The TPR of calculus 55.5% (*993/1788*) in St Hilda's falls close to the rates of Infirmary Newcastle, St Marylebone and St George's-unnamed (Figure 6.19; Table 6.24). The rates, however, were statistically higher than Carver street ($z = 4.37; p = 0.00$), St Pancras ($z = 2.33; p = 0.02$), St Luke's Islington-named ($z = 5.81; p = 0.00$) and St Luke's Islington-unnamed ($z = 7.89; p = 0.00$), but statistically lower than St Martin ($z = -5.29; p = 0.00$), Greenwich Tier ($z = -15.27; p = 0.00$) and St George's Bloomsbury -named ($z = -7.14; p = 0.00$).

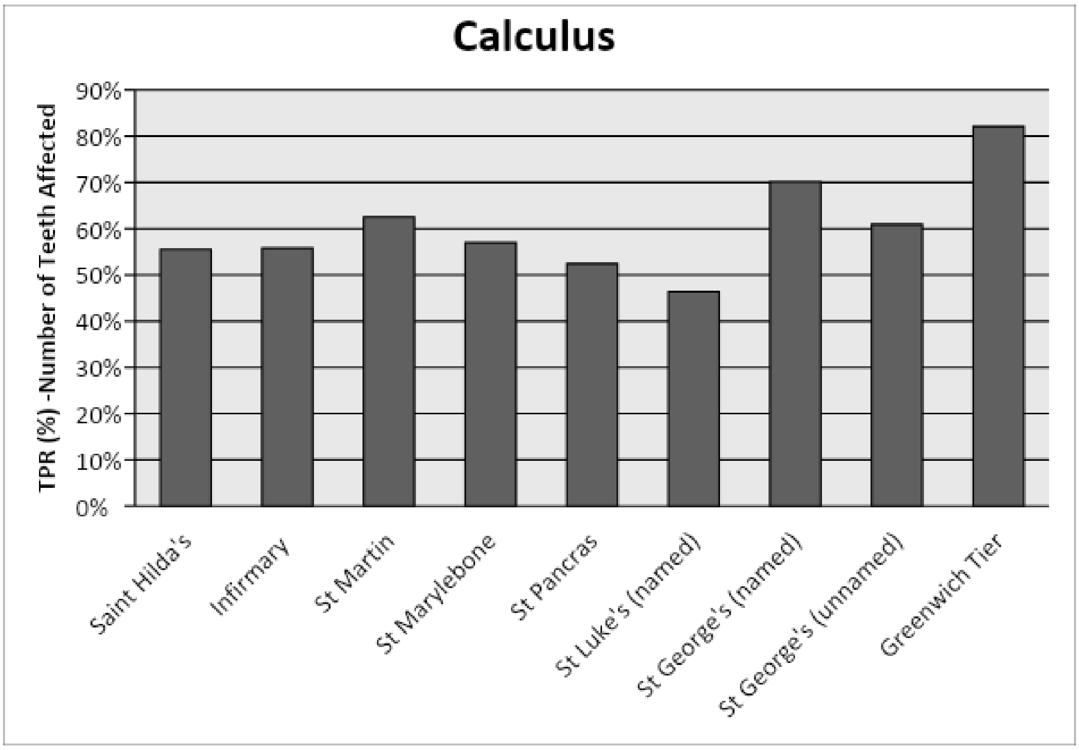


Figure 6.19: True prevalence in percentages for distribution of calculus in St Hilda's in comparison with the comparative sites.

Assemblage	TPR Calculus	Teeth	Calculus %	z-value	p-value	CPR Calculus	Total	Calculus %	z-value	p-value
St Hilda's, South Shields	993	1788	55.50%			78	204	38.20%		
Infirmary Newcastle	718	1287	55.80%	-0.13	0.88					
Carver Street, Sheffield						22	136	16.20%	4.37	0
St Martin, Birmingham	3684	5893	62.50%	-5.29	0					
St Marylebone, London	1616	2837	57.00%	-0.95	0.34					
St Pancras, London	3296	6289	52.40%	2.33	0.01					
St Luke’s Islington-unnamed, London						16	230	6.96%	7.89	0
St Luke’s Islington-named, London	1042	2249	46.33%	5.81	0					
Christ Church, Spitalfields										
St George’s Bloomsbury-named, London	592	844	70.10%	-7.14	0					
St George’s Bloomsbury-unnamed	162	266	60.90%	-1.64	0.09					
Greenwich Tier	1028	1252	82.10%	-15.27	0					

Table 6.24: True and crude prevalence of calculus in St Hilda’s in comparison with the comparative sites.

Within St Hilda's a very high prevalence of PD, probably resulting from chronic inflammation of the mouth due to poor dental hygiene, was noted (Hillson 2002). PD had affected 57% tooth positions from 40.7% affected individuals (*83/204*). The prevalence rates correlate well with the contemporary sites of St Luke's Islington-named, St George's Bloomsbury-named and St George's Bloomsbury-unnamed. While the site exhibited statistically higher prevalence than Carver Street (*z = 7.10; p = 0.00*), St Marylebone (*z = 53.52; p = 0.00*), St Martin (*z = 6.77; p = 0.02*), St Luke's Islington-unnamed (*z = 4.70; p = 0.00*) and Christ Church (*z = 2.46; p = 0.00*) and statistically lower than Greenwich Tier (*z = -4.30; p = 0.00*) (Figure 6.20 and Table 6.25).

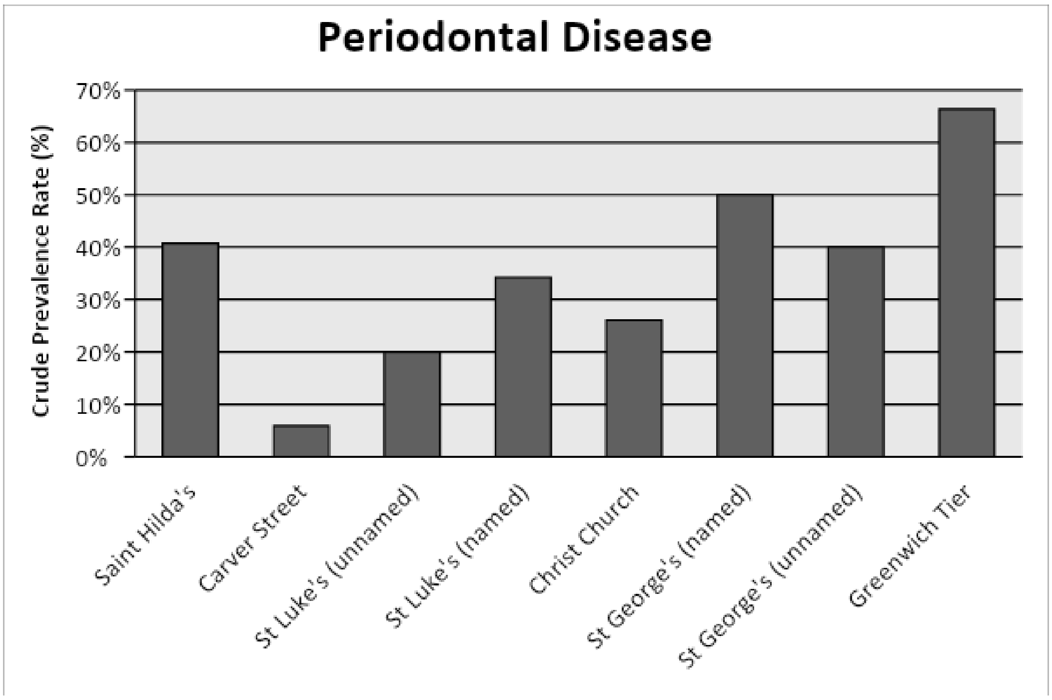


Figure 6.20: Crude prevalence in percentages for distribution of PD in St Hilda's in comparison with the comparative sites.

Assemblage	TPR PD	Sockets	PD%	z-value	p-value	CPR PD	Total	PD %	z-value	p-value
St Hilda's, South Shields	2204	3838	57%			83	204	40.70%		
Carver Street, Sheffield						8	136	5.90%	7.1	0
St Martin, Birmingham	2454	4894	50%	6.77	0					
St Marylebone, London	346	5298	7%	53.52	0					
St Luke’s Islington-unnamed, London						46	230	20.00%	4.7	0
St Luke’s Islington-named, London						75	219	34.20%	1.36	0.17
Christ Church, Spitalfields						25	96	26.00%	2.46	0.01
St George’s Bloomsbury-named, London						31	62	50%	-1.29	0.19
St George’s Bloomsbury-unnamed, London						14	35	40%	0.07	0.93
Greenwich Tier						71	107	66.36%	-4.3	0

Table 6.25: True prevalence of PD in St Hilda’s in comparison with the comparative sites.

PD, caries and calculus are all predisposing factors to the development of dental abscess (Roberts and Manchester 1997, 50). Subsequently, given the presence of the above lesions in St Hilda's population, periapical abscesses were also observed in St Hilda's which exhibited statistically lower true prevalence of abscess (*50/3838*) than many of the comparative sites apart from Coach Lane, Infirmary Newcastle and St Luke's Islington-named which exhibited equal prevalence (Figure 6.21; Table 6.26). The prevalence of St Hilda's at 1.3% falls below the prevalence of St Martin ($z = -4.63$; $p = 0.00$), St Marylebone ($z = -4.78$; $p = 0.00$), Cross Bones ($z = -2.46$; $p = 0.00$), Greenwich ($z = -12.74$; $p = 0.00$) and St George's-named ($z = -3.90$; $p = 0.00$), but above the prevalence of St Benet ($z = 2.71$; $p = 0.00$), St George's-unnamed ($z = 2.09$; $p = 0.03$) and Carver Street ($z = 4.18$; $p = 0.00$). The lower prevalence of the lesions in St Hilda's and the rest of the sites which exhibited similar prevalence, may indicate a stronger immune response due to nutrition and health (Dias and Tyles 1997, 548).

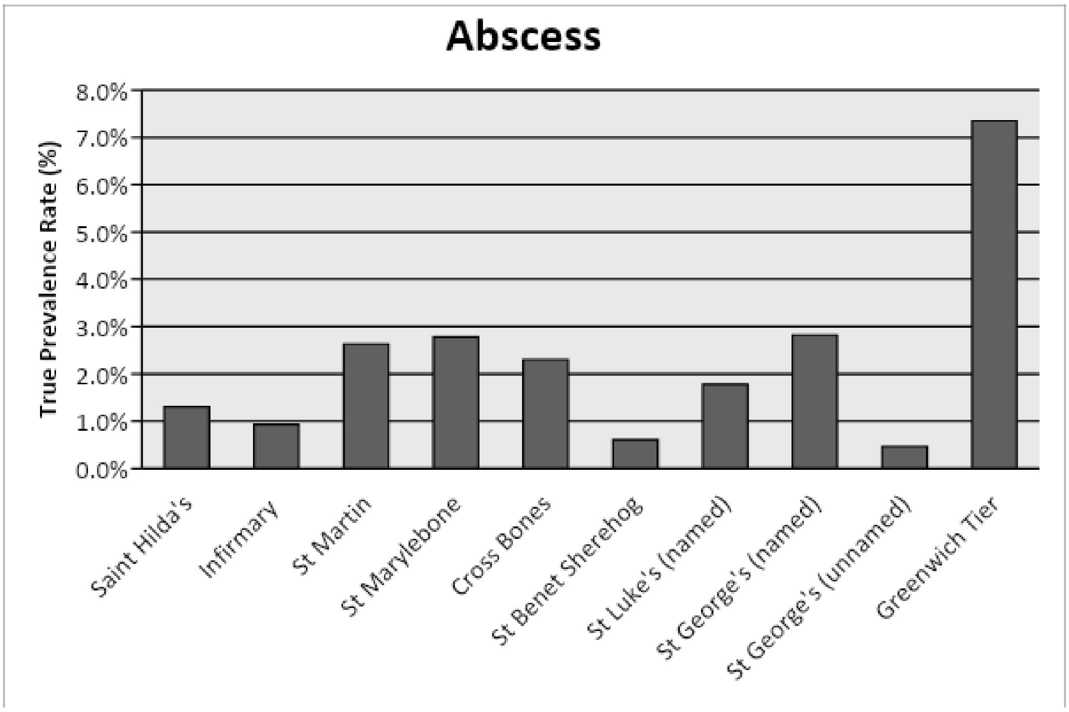


Figure 6.21: True prevalence rates in percentages for distribution of abscess in St Hilda's in comparison with the comparative sites.

Assemblage	TPR Abscess	Sockets	Abscess %	z-value	p-value	CPR Abscess	Skeletons	Abscess %	z-value	p-value
St Hilda's, South Shields	50	3838	1.30%			31	204	15%		
Coach Lane, North Shields						11	81	14%	0.34	0.72
Infirmary Newcastle	29	3123	0.90%	1.46	0.14					
Carver Street, Sheffield						2	136	1%	4.18	0
St Martin, Birmingham	222	8433	2.60%	-4.63	0					
St Marylebone, London	147	5298	2.80%	-4.78	0					
Cross Bones, London	28	1216	2.30%	-2.46	0.01					
St Benet Sherehog, London	16	2617	0.60%	2.71	0					
St Luke’s Islington-named, London	87	4883	1.80%	-1.78	0.07					
St George’s Bloomsbury-named, London	46	1632	2.80%	-3.9	0					
St George ‘s Bloomsbury-unnamed	4	865	0.50%	2.09	0.03					
Greenwich Tier	224	3048	7.30%	-12.74	0					

Table 6.26: True prevalence of abscess at St Hilda’s population in comparison with the comparative sites.

More than one quarter of St Hilda's population was found to have experienced at least one episode of significant illness or malnutrition that lasted more than three weeks in childhood, as evidenced by the presence of lesions retained into adulthood (Aufderheide and Rodriguez-Martin 1998; Hillson 2002). This indicated that the individual's health was compromised physiologically but they recovered. These episodes were manifested as DEH (*186/1778*) on their dentition. St Hilda's TPR at 10.4% was similar to the rates of St Benet and St Luke's Islington-named, statistically higher than Carver Street (*z = 1.97; p = 0.04*) and St Martin Birmingham (*z = 17.44; p = 0.00*), but statistically lower than the rest of the sites of various backgrounds that had recorded the rates of the lesions (Figure 6.22; Table 6.27). It is surprising that the DEH prevalence in St Hilda's was fairly low, given its known working-class origin, and the higher prevalence of other indicators of childhood stress (e.g. CO and rickets). This prevalence, however, was relatively higher than the reported average of 0.6% for British post-medieval assemblages (Roberts and Cox 2003, 327; Boston *et al.* 2008). Such wide variation between sites may reflect inter-observer differences in identifying DEH; frequently the hypoplastic lesions resemble the normal incremental growth lines of tooth enamel, known as perikymata (Hillson 2002). St Hilda's profile, however, was not unique to that phenomenon; the Greenwich Tier exhibited a similar profile with low DEH and high prevalence of childhood diseases (Boston *et al.* 2008, 67).

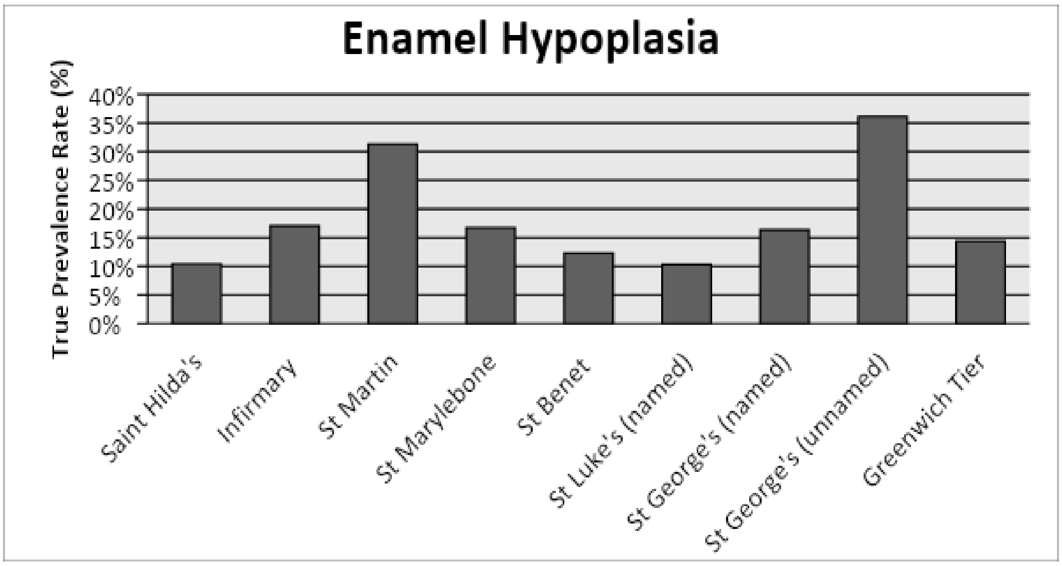


Figure 6.22: True prevalence rates in percentages for distribution of DEH in St Hilda's in comparison with the comparative sites.

Assemblage	TPR EH	Teeth	EH %	z-value	p-value	CPR EH	Total	EH %	z-value	p-value
St Hilda's, South Shields	186	1788	10%			35	204	17.20%		
Coach Lane, North Shields						28	82	34.10%	-3.96	0
Infirmary Newcastle	219	1287	17%	-5.35	0					
Carver Street, Sheffield						13	136	9.60%	1.97	0.04
St Martin, Birmingham	1705	5450	31%	17.44	0					
St Marylebone, London	475	2837	17%	-5.99	0					
St Benet Sherehog, London	246	2003	12%	-1.81	0.06					
St Luke's Islington-named, London	231	2249	10%	0.13	0.89					
St George's Bloomsbury-named, London	138	844	16%	-4.33	0					
St George's Bloomsbury-unnamed	78	216	36%	-10.55	0					
Greenwich Tier	178	1239	14%	-3.29	0					

Table 6.27: True prevalence of DEH in St Hilda's population in comparison with the comparative sites.

6.7 Metabolic and Hematopoietic Disorders

6.7.1 Cribra Orbitalia and Porotic Hyperostosis

Porotic Hyperostosis and its direct expression Cribra Orbitalia were both recorded in St Hilda's, with CO being by far more frequently observed than PH. St Hilda's overall CPR for CO at 29.1% (*44/151*) was higher compared to most of the comparative sites, apart from the sites of Infirmary Newcastle, Greenwich Tier, St Marylebone and St Benet which exhibited similar rates with St Hilda's, while the site of Cross Bones (*z = -4.37; p = 0.00*) exhibited statistically higher rates (Figure 6.23; Table 6.28).

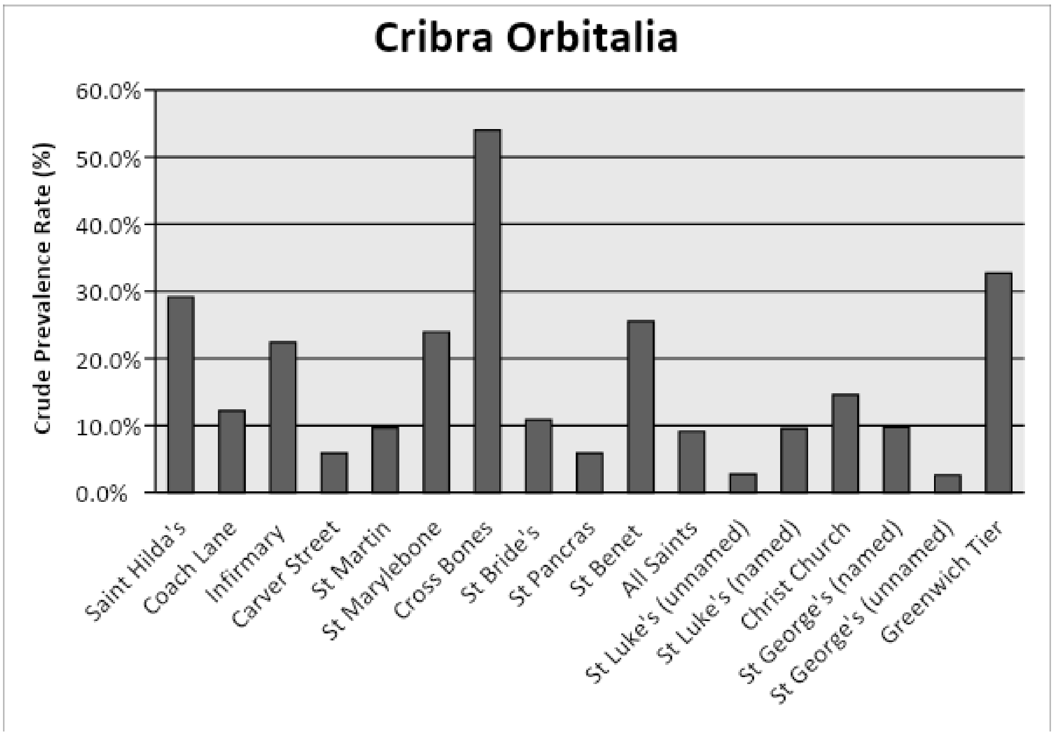


Figure 6.23: Crude prevalence rates in percentages for distribution of CO in St Hilda's in comparison with the comparative sites.

Assemblage	CPR Total CO	Total	CPR Total CO %	z-value	p-value
St Hilda's, South Shields	44	151	29.14%		
Coach Lane, North Shields	10	82	12.20%	2.92	0.00
Infirmary Newcastle	47	210	22.38%	1.45	0.14
Carver Street, Sheffield	8	136	5.88%	5.10	0.00
St Martin, Birmingham	38	394	9.64%	5.69	0.00
St Marylebone, London	72	301	23.92%	1.19	0.23
Cross Bones, London	80	148	54.05%	-4.37	0.00
St Bride's Lower Churchyard, London	59	544	10.85%	5.59	0.00
St Pancras, London	42	715	5.87%	8.68	0.00
St Benet Sherehog, London	25	98	25.51%	0.62	0.53
All Saints, Chelsea Old Church	18	198	9.09%	4.85	0.00
St Luke’s Islington-unnamed, London	18	655	2.75%	10.97	0.00
St Luke’s Islington-named, London	23	241	9.54%	5.01	0.00
Christ Church, Spitalfields	141	968	14.57%	4.48	0.00
St George’s Bloomsbury-named, London	7	72	9.72%	3.22	0.00
St George’s Bloomsbury-unnamed, London	1	39	2.56%	3.48	0.00
Greenwich Tier	35	107	32.71%	-0.61	0.53

Table 6.28: Crude prevalence of CO in St Hilda’s in comparison with the comparative sites.

When the populations were divided into adults and sub-adults, it was observed that the most sensitive part of the population, the sub-adults exhibited similar CPR rates across all sites and therefore, were equally affected by the multiple aetiologies that result in CO (Figure 6.24; Table 6.29). Only the site of Cross Bones ($z = -5.25; p = 0.00$) exhibited higher prevalence than the case study, but that was expected beforehand due to the nature of the cemetery that was characterised by high infant mortality. Consequently, it would appear that CO in the most sensitive part of the population, the sub-adults was independent of socio-economic status or a North and South division.

In the case of adults, the results corresponded with the total population impression formerly stated. Interestingly enough, the Cross Bones adults turned out to be equally affected by CO as St Hilda’s adults, despite the fact that the site exhibited much higher total prevalence than St Hilda’s. It would appear that the total prevalence was elevated due to the high proportion of affected sub-adults at this particular site. Apart from this difference, it was also noted that St Marylebone's adults exhibited lower prevalence (*z = 2.78; p = 0.00*) compared to the case study although their overall population and sub-adults exhibited similar rates with St Hilda's. Perhaps, this difference was related to the status of the site that protected these adults in early life. It is also possible that the living conditions in this area became worse through time, initially these individuals were born and raised in a less unsanitary environment, but progressively with the population expansion, the conditions deteriorated and their offspring were more affected.

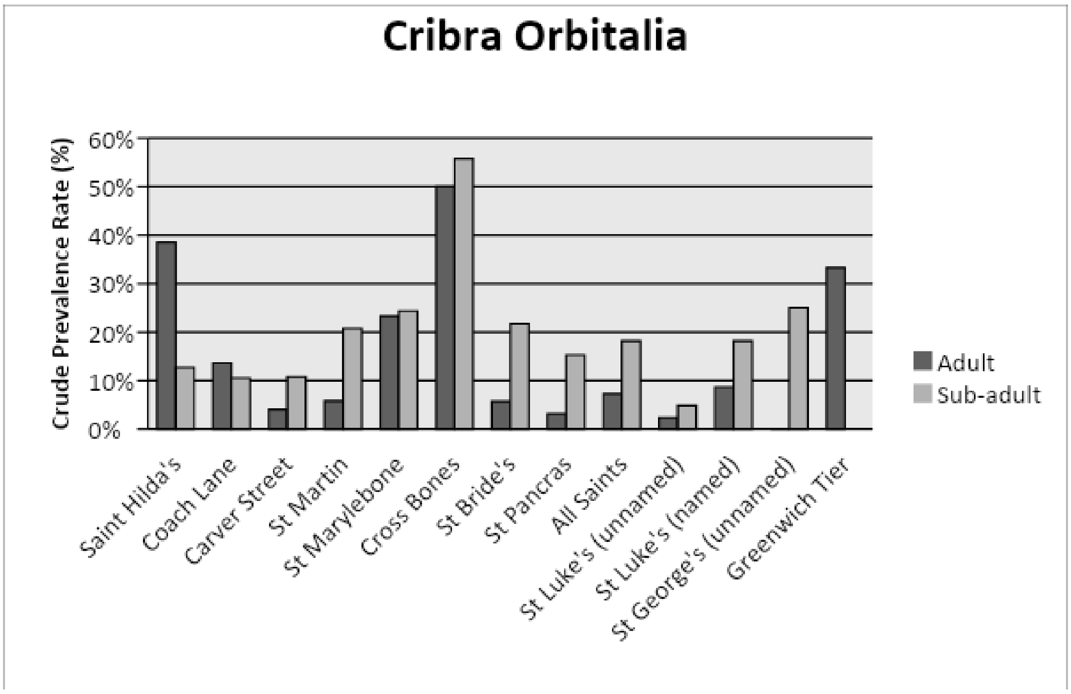


Figure 6.24: Crude prevalence of CO in St Hilda's adults and sub-adults in comparison with the comparative sites.

Assemblage	CPR sub-adult CO	Sub-adults	CO %	z-value	p-value
St Hilda's, South Shields	7	55	12.7%		
Coach Lane, North Shields	4	38	10.5%	0.32	0.74
Carver Street, Sheffield	4	37	10.8%	0.27	0.78
St Martin, Birmingham	21	101	20.8%	-1.25	0.20
St Marylebone, London	20	78	25.6%	-1.66	0.09
Cross Bones, London	58	104	55.8%	-5.25	0.00
St Bride's Lower Churchyard, London	38	175	21.7%	-1.46	0.14
St Pancras, London	28	183	15.3%	-0.47	0.63
All Saints, Chelsea Old Church	6	33	18.2%	-0.69	0.48
St Luke's Islington-unnamed, London	5	102	4.9%	1.76	0.07
St Luke's Islington-named, London	4	22	18.2%	-0.61	0.53
St George's Bloomsbury-unnamed, London	1	4	25.0%	-0.69	0.48

Table 6.29: Crude prevalence of CO in St Hilda's adults and sub-adults in comparison with the comparative sites.

According to Robert and Cox (2003, 307), the overall prevalence of CO of this period was found to be 8.95%, a prevalence much lower than that of St Hilda's at 29.1*%*. Although, it is known that in South Shield's the conditions were unsanitary, during this period, the higher figures produced by this study are almost certainly due to the very detailed approach taken to the recording of CO. The majority of the sites appeared to be focused on the systematic recording of the lesions in sub-adults due to the hypothesis that the lesions occur in childhood; while in this case study both proportions of the population were equally examined. Therefore, this higher prevalence recorded in St Hilda's could be the result of systematic approach in a non-commercial setting. Nonetheless, it would appear that the sites were all affected to some extent by anaemia and its multifactorial aetiologies such as inadequate diet, inadequate sanitation, crowded living conditions and contaminated water that are frequently linked to iron malabsorption due to various infections, indicating that everyone was equally exposed to infectious agents (Kent *et al*. 1994).

PH had affected a smaller proportion of the St Hilda's population (*8/168*) than CO, giving a total CPR at 4.76%; no significant differences were observed between the case study and most of the comparative sites (Figure 6.25; Table 6.30). Overall, it would appear that St Hilda's followed the general pathological trend of the period with a CPR at 8.00%. However, only the sites of St Bride's (*z = 2.51; p = 0.01*), All Saints Chelsea (*z = 2.19; p = 0.02*) and Greenwich Tier (*z = -8.18; p = 0.00*) exhibited statistically different prevalence compared to the case study, the first two exhibited lower and the last one higher. Indicating perhaps status dissimilarities and the nature of the sites affected the prevalence. For example, in the case of Greenwich Tier the higher prevalence could be attributed to life on board, that frequently started in adolescence, where sailors had a deprived diet and infections were rife, especially during long trips (Boston *et al.* 2008).

When the population was divided in adults and sub-adults, in the case of adults the picture was similar to the overall population; differences were observed again between St Hilda's and All Saints Chelsea (*z = 3.22; p = 0.00*), St Bride's (*z = 421; p = 0.00*), and this time St Benet (*z = 2.44; p = 0.01*), and the three sites exhibited statistically lower prevalence than St Hilda's. St Hilda's sub-adults exhibited no prevalence of PH compared to the used sites, perhaps the difference was methodological. No straightforward patterns were observed between wealthy and poor; overall however it would appear that the sites were equally affected by anaemia and its multifactorial aetiologies that are frequently linked to iron malabsorption due to various infections, indicating that everyone was equally exposed to infectious agents.

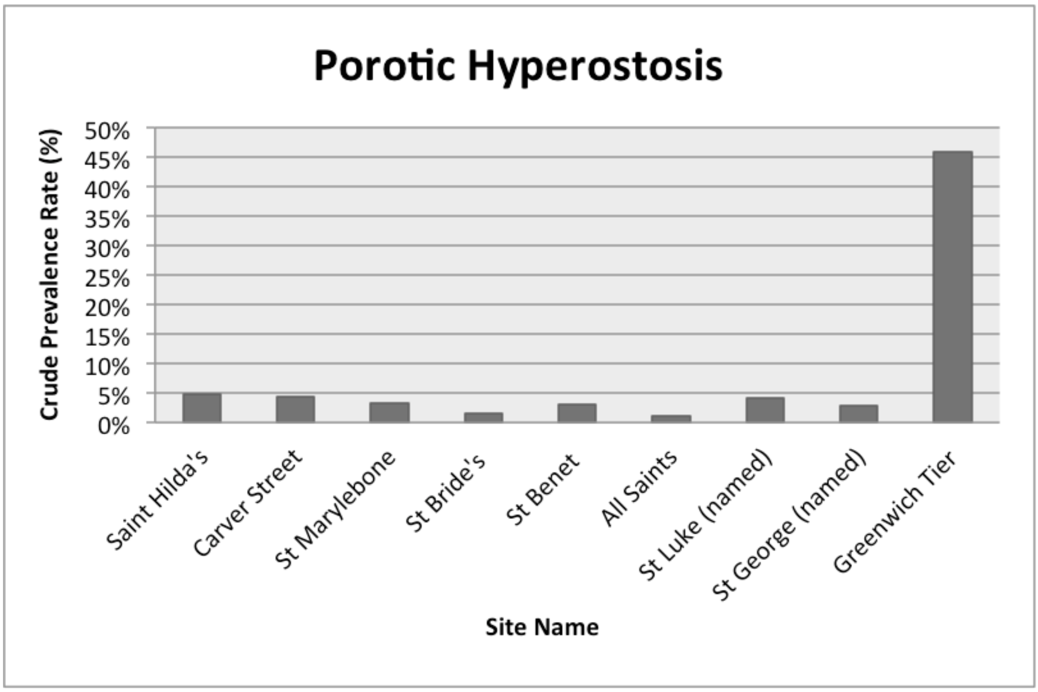


Figure 6.25: Crude prevalence of PH in St Hilda's in comparison with the comparative sites.

Assemblage	CPR Total PH	Total	PH %	z-value	p-value
St Hilda's, South Shields	8	168	4.76%		
Carver Street, Sheffield	6	136	4.41%	0.14	0.88
St Marylebone, London	10	301	3.32%	0.77	0.43
St Bride's Lower Churchyard, London	8	544	1.47%	2.51	0.01
St Benet Sherehog, London	7	230	3.04%	0.88	0.37
All Saints, Chelsea Old Church	2	198	1.01%	2.19	0.02
St Luke's Islington-named, London	10	241	4.15%	0.29	0.76
St George's Bloomsbury-named, London	2	72	2.78%	0.70	0.48
Greenwich Tier	49	107	45.79%	-8.18	0.00

Table 6.30: Crude prevalence of PH in St Hilda's in comparison with the comparative sites.

6.7.2 Osteoporosis

Skeletal changes indicative for the diagnosis of osteoporosis were identified in some of the elderly individuals of St Hilda's (10*/117*). St Hilda's exhibited higher rates of osteoporosis compared to some of the comparative sites used (Figure 6.20; Table 6.24). Hence, St Hilda's higher prevalence was statistically significant. Whilst, there were also some sites of various backgrounds such as that of Cross Bones, St Bride's, St Benet, and All Saints Chelsea which exhibit similar prevalence with St Hilda's. The similar rates can be better observed when the adult CPR is considered rather than the total CPR of osteoporosis. Roberts and Cox (2003, 355) have reported a total prevalence for the period of 1.2% for London sites (mostly of high status), St Hilda's figures at 4.90% for the total population and 8.55% for the adult population were higher than what the authors reported. These differences may reflect the author's research interests, methodological and preservation issues such as in the case of Carver Street and St Pancras, as well as higher versus lower socio-economic status dissimilarities such as in the case of St Marylebone and Christ Church.

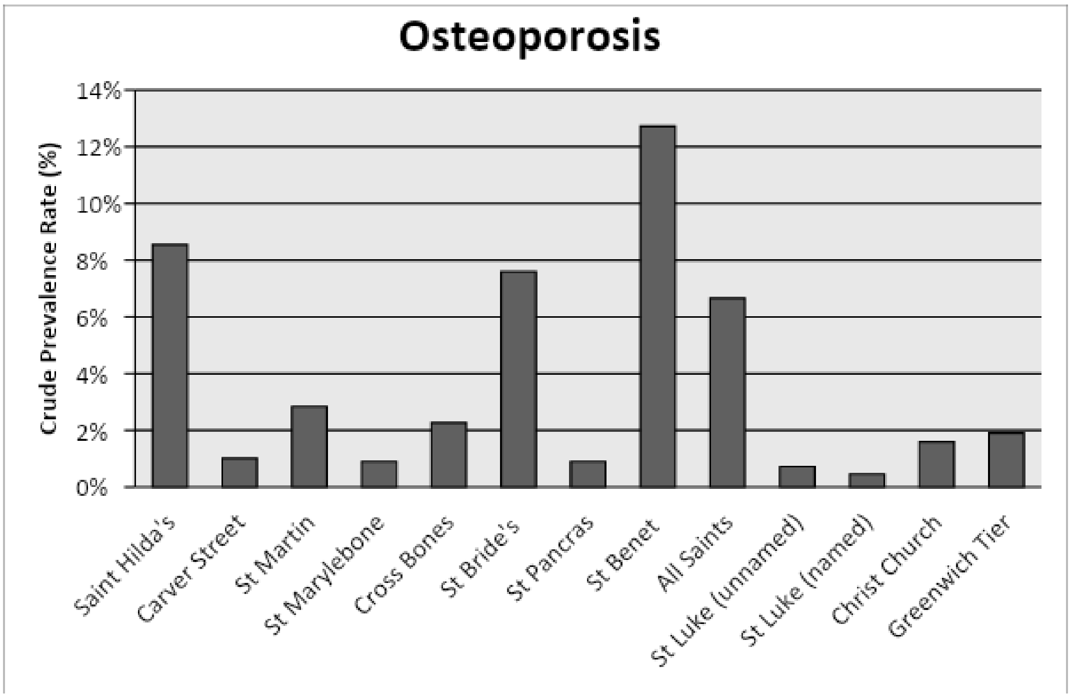


Figure 6.26: Crude prevalence of osteoporosis in St Hilda's adults in comparison with the comparative sites.

Assemblage	CPR Adult Osteoporosis	Adults	Osteoporosis %	z-value	p-value
St Hilda's, South Shields	10	117	8.55%		
Carver Street, Sheffield	1	99	1.01%	2.51	0.01
St Martin, Birmingham	10	352	2.84%	2.64	0.00
St Marylebone, London	2	223	0.90%	3.63	0.00
Cross Bones, London	1	44	2.27%	1.40	0.15
St Bride's Lower Churchyard, London	28	369	7.59%	0.33	0.73
St Pancras, London	4	448	0.89%	4.74	0.00
St Benet Sherehog, London	21	165	12.73%	-1.10	0.26
All Saints, Chelsea Old Church	11	165	6.67%	0.59	0.55
St Luke's Islington-unnamed, London	4	553	0.72%	5.37	0.00
St Luke's Islington-named, London	1	219	0.46%	3.97	0.00
Christ Church, Spitalfields	10	628	1.59%	4.27	0.00
Greenwich Tier	2	105	1.90%	2.18	0.02

Table 6.31: Crude prevalence of osteoporosis in St Hilda's adult population in comparison with the comparative sites.

6.7.3 Rickets and Osteomalacia

Rickets, the childhood form of active vitamin D deficiency and residual rickets, the recovered form of vitamin D deficiency which was experienced by an adult during their childhood, was observed in some cases from St Hilda's giving a total CPR at 7.84% (*16/204*). St Hilda's population as a whole seems to have exhibited similar rates of rickets with most of the comparative sites, apart from the sites of St Pancras ($z = 3.55$; $p = 0.00$), Christ Church ($z = 2.68$; $p = 0.07$) and St Benet ($z = -2.01$; $p = 0.04$). The first two sites exhibited lower prevalence than the case study, while the last one was higher (Figure 6.27; Table 6.32). When the total populations were further divided in adults and sub-adults a few meaningful differences were observed (Figure 6.28; Table 6.33). However, overall it seems that most of the adults and sub-adults from the sites were equally affected by the factors that can result in Vitamin D deficiency. In the case of adults (residual rickets), St Hilda's exhibited similar rates with most of the sites, apart from the sites of Coach Lane ($z = 2.10$; $p = 0.03$), St Bride's ($z = 3.30$; $p = 0.00$), Christ Church ($z = 3.79$; $p = 0.00$) and St George's-named ($z = 2.09$; $p = 0.03$) which exhibited statistically lower prevalence. Interestingly in the case of sub-adults, St Hilda's again exhibited similar prevalence with most of the comparative sites, apart from the sites of St Marylebone ($z = -3.72$; $p = 0.00$), St Benet ($z = -4.66$; $p = 0.00$) and St Bride's ($z = -2.15$; $p = 0.03$) which exhibited higher prevalence than St Hilda's.

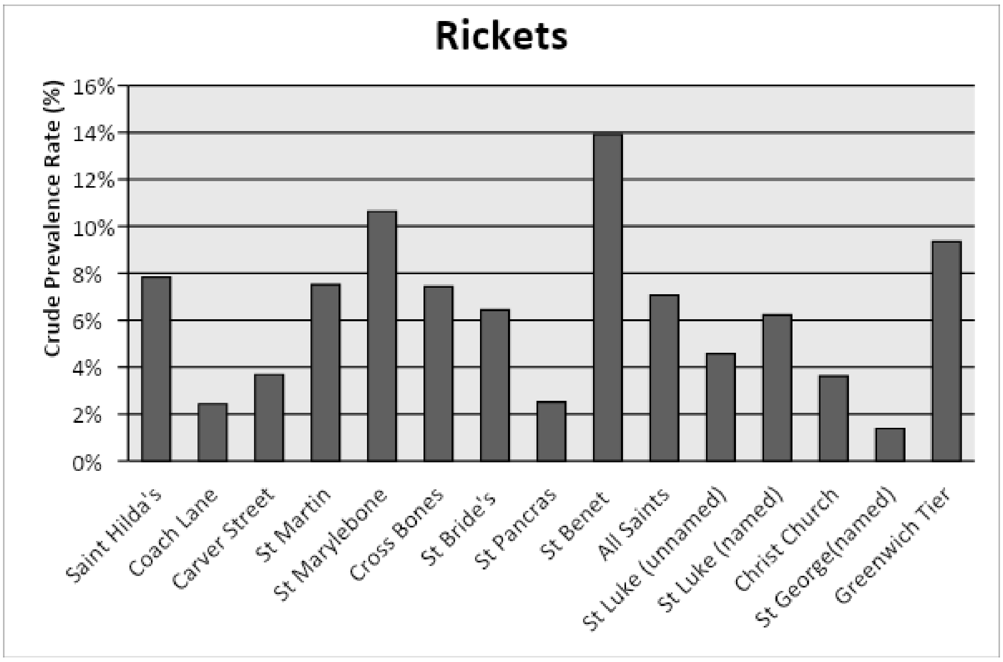


Figure 6.27: Crude prevalence of rickets in St Hilda's total population in comparison with the comparative sites.

Assemblage	CPR Total Rickets	Total	Rickets %	z-value	p-value
St Hilda's, South Shields	16	204	7.84%		
Coach Lane, North Shields	2	82	2.44%	1.70	0.08
Carver Street, Sheffield	5	136	3.68%	1.56	0.11
St Martin, Birmingham	38	505	7.52%	0.14	0.88
St Marylebone, London	32	301	10.63%	-1.04	0.29
Cross Bones, London	11	148	7.43%	0.14	0.88
St Bride's Lower Churchyard, London	35	544	6.43%	0.68	0.49
St Pancras, London	18	715	2.52%	3.55	0.00
St Benet Sherehog, London	32	230	13.91%	-2.01	0.04
All Saints, Chelsea Old Church	14	198	7.07%	0.29	0.76
St Luke's Islington-unnamed, London	30	655	4.58%	1.80	0.07
St Luke's Islington-named, London	15	241	6.22%	0.66	0.50
Christ Church, Spitalfields	35	968	3.62%	2.68	0.00
St George's Bloomsbury-named, London	1	72	1.39%	1.95	0.05
Greenwich Tier	10	107	9.35%	-0.45	0.64

Table 6.32: Crude prevalence of rickets in St Hilda's total population in comparison with the comparative sites.

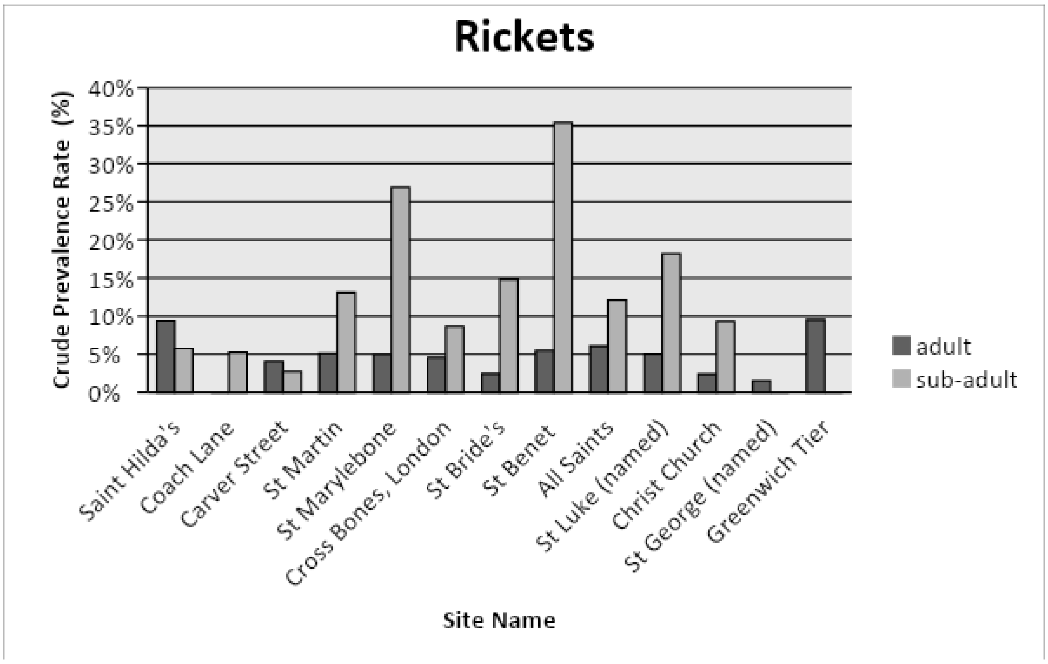


Figure 6.28: Crude prevalence of rickets in St Hilda's adults and sub-adults in comparison with the comparative sites.

Assemblage	CPR Adult Rickets	Total No Adults	CPR Adult Rickets %	z-value	p-value	CPR sub-adult Rickets.	Sub-adults	Rickets %	z-value	p-value
St Hilda's, South Shields	11	117	9.40%			5	87	5.70%		
Coach Lane, North Shields	0	44	0.00%	2.1	0.03	2	38	5.30%	0.1	0.91
Carver Street, Sheffield	4	99	4.04%	1.54	0.12	1	37	2.70%	0.72	0.46
St Martin, Birmingham	18	352	5.11%	1.66	0.09	20	153	13.10%	-1.78	0.07
St Marylebone, London	11	223	4.93%	1.59	0.11	21	78	26.90%	-3.72	0
Cross Bones, London	2	44	4.55%	1	0.31	9	104	8.70%	-0.76	0.44
St Bride's Lower Churchyard, London	9	369	2.44%	3.3	0	26	175	14.90%	-2.15	0.03
St Benet Sherehog, London	9	165	5.45%	1.27	0.2	23	65	35.40%	-4.66	0
All Saints, Chelsea Old Church	10	165	6.06%	1.05	0.29	4	33	12.10%	-1.18	0.23
St Luke's Islington-named, London	11	219	5.02%	1.54	0.12	4	22	18.20%	-1.89	0.05
Christ Church, Spitalfields	15	628	2.39%	3.79	0	20	215	9.30%	-1.01	0.3
St George's Bloomsbury-named, London	1	67	1.49%	2.09	0.03	0	5	0.00%	0.55	0.58
Greenwich Tier	10	105	9.52%	-0.03	0.97	0	2	0.00%	0.34	0.72

Table 6.33: Crude prevalence of rickets in adults and sub-adults in St Hilda's population in comparison with the comparative sites.

Osteomalacia, the adult form of active vitamin D deficiency was observed among the St Hilda's individuals. The total CPR of St Hilda's at 1.96% (4*/204*) as well as the adult CPR at 3.42% (4*/117*) were both compatible with the rates of most of the comparative sites where information on osteomalacia was provided (Figure 6.29; Table 6.34). Consequently, no statistical differences were observed between St Hilda's and the comparative sites, apart from St Bride's (*z = 2.06; p = 0.04*) and St Pancras (*z = 3.29; p = 0.00*) which exhibited statistically lower prevalence than St Hilda's. The difference is more obvious when the adult proportions are observed separately instead of the total population.

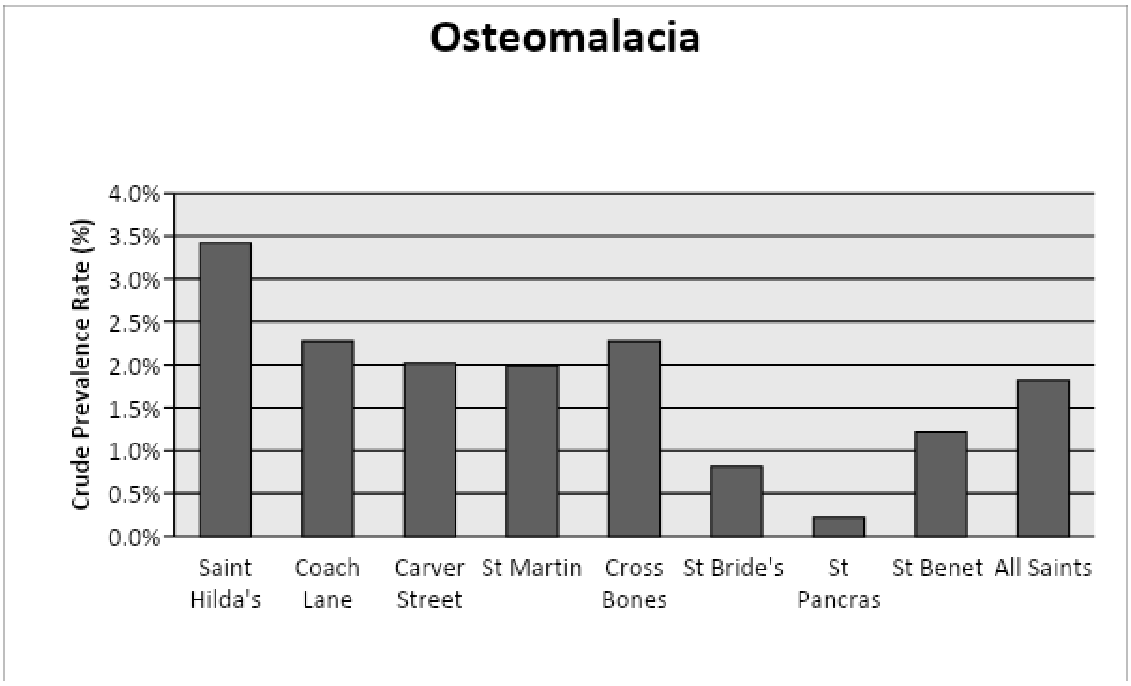


Figure 6.29: Crude prevalence of osteomalacia in St Hilda's adults in comparison with the comparative sites.

Assemblage	CPR Adult Osteomalacia	Adults	Osteomalacia %	z-value	p-value
St Hilda's, South Shields	4	117	3.4%		
Coach Lane, North Shields	1	44	2.3%	0.37	0.71
Carver Street, Sheffield	2	99	2.0%	0.62	0.53
St Martin, Birmingham	7	352	2.0%	0.89	0.38
Cross Bones, London	1	44	2.3%	0.37	0.71
St Bride's Lower Churchyard, London	3	369	0.8%	2.06	0.04
St Pancras, London	1	448	0.2%	3.29	0.00
St Benet Sherehog, London	2	165	1.2%	1.27	0.21
All Saints, Chelsea Old Church	3	165	1.8%	0.85	0.39

Table 6.34: Crude prevalence of osteomalacia in St Hilda's adults in comparison with the comparative sites.

6.7.4 Scurvy

Skeletal changes compatible with the standards for the diagnosis of scurvy were identified in St Hilda's individuals. The total CPR of St Hilda's at 11.27% (*23/204*) was higher compared to most of the comparative sites where scurvy was systematically recorded, apart from the sites of Cross Bones and Greenwich Tier that exhibited similar rates with the population in study, indicating perhaps status similarities (Figure 6.30; Table 6.35). St Hilda's higher prevalence was statistically significant when z-tests of proportions were applied only for the total assemblage, but not for the sub-adults (Figure 6.31). The major reason behind this statistical difference was that St Hilda's adults were affected by scurvy. Whereas, the adults of the comparative sites were not or to say the least the lesions were not systematically recorded for the adult proportions, leading to a possible false impression that only the sub-adults of these sites were affected by scurvy. Therefore, it would appear that the prevalence of scurvy in non-adults was the primary focus of different sites. It was observed that when St Hilda's non-adults were compared to those sites, there were no statistical differences between them apart from St Martin Birmingham which exhibited lower prevalence, indicating perhaps the less detrimental conditions of Birmingham due to its natural advantages (section 3.5). The lack of differences across the rest of the sites, indicated that the non-adults of various backgrounds were equally affected by the lack of vitamin C due to a diet deprived in fresh fruits and vegetables as well as exposure to poor customs and environments so polluted that predisposed the individuals to infections despite the socio-economic differences. As scurvy lesions from these comparative sites were also observed in some preterm cases (e.g. St Marylebone) as well as neonates and infants, it is reasonable to assume the existence of maternal deficiencies and therefore adult scurvy, which was passed on during gestation from the mother to the offspring. It is suspected, therefore, this lack of the lesions in the studied adult samples was related to methodological or excavation sampling strategy and not to the lack of scurvy in adults.

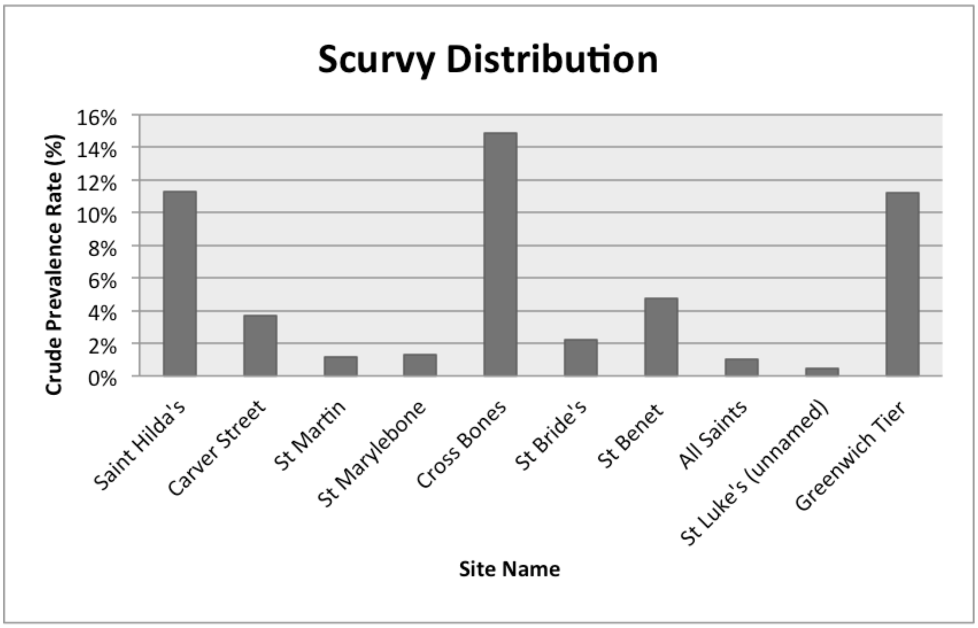


Figure 6.30: Crude prevalence of scurvy in St Hilda's in comparison with the comparative sites.

Assemblage	CPR sub-adult Scurvy	Sub-adults	Scurvy %	z-value	p-value
St Hilda's, South Shields	11	87	12.6%		
Carver Street, Sheffield	3	37	8.1%	0.73	0.46
St Martin, Birmingham	6	153	3.9%	2.53	0.01
St Marylebone, London	4	78	5.1%	1.67	0.09
Cross Bones, London	22	104	21.2%	-1.54	0.12
St Bride's Lower Churchyard, London	12	175	6.9%	1.55	0.11
St Benet Sherehog, London	11	65	16.9%	-0.74	0.45
All Saints, Chelsea Old Church	2	33	6.1%	1.03	0.30

Table 6.35: Crude Prevalence of scurvy in St Hilda's population in comparison with the comparative sites.

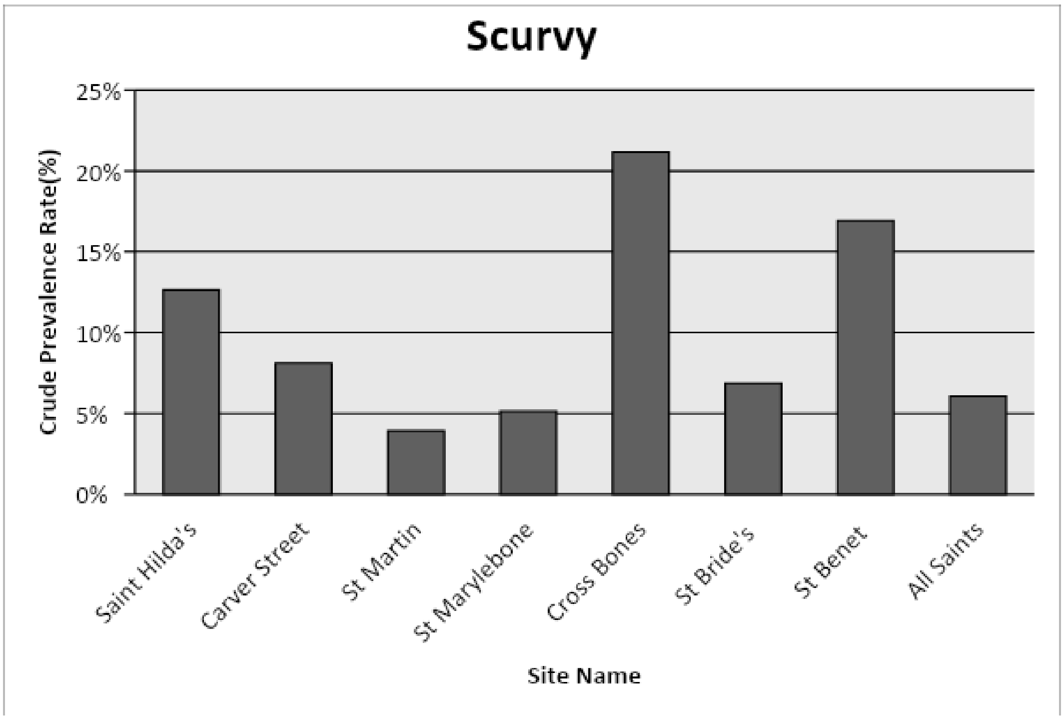


Figure 6.31: Crude prevalence of scurvy in St Hilda' sub-adults in comparison with the comparative sites.

CHAPTER 7

DISCUSSION

7.1 Introduction

The previous two chapters have made a significant attempt to address how the urban environment, social status and geographic location affected the demography and health and disease status of St Hilda's population. A comparative analysis between St Hilda's and other contemporary populations allowed consideration of any similarities or differences between them. The following chapter provides a detailed synthesis and interpretation of the results in order to place them in a wider context. This step facilitates a wider discussion of the impact of industrialisation in terms of individuals as well as the impact of social circumstances (e.g. economic status, education) that influenced the way these individuals lived and behaved during the period of study.

7.2 St Hilda's Assemblage within the wider Context of South Shields and North-East

7.2.1 Proportions of Biological Sex and its Impact in Surviving Prospects

St Hilda's demographic profile was analogous to the profiles provided by the 15 comparative sites, matching the general profile of the period despite the differences in socio-economic and/or geographic origins. The proportion of males and females constituting the total adult population was almost precisely the same, with a very slight female predominance. This observation was also made with the study of burial registers which gave a similar ratio, indicating that the greater proportion of females was not an excavation bias artefact. According to the burial registers the calculated male to female ratio was almost equal with a slight female predominance giving a ratio 1:1.01 indicating that for every hundred males there were hundred-and-one females, a ratio not too far from the osteological 1:1.04, which corresponds to hundred males for every hundred-and-four females. St Hilda's cemetery was the only cemetery serving South Shields until it closed in 1855 with the passing of the Burial

Grounds Act for preventing overcrowding (Raynor *et al.* 2011, 12). Thus, the burial registers reflect an accurate image of South Shields from 1763-1855 as they represent the whole community and demonstrate how representative the skeletal population sample of St Hilda's is.

This slight female predominance was not geographically limited in South Shield, but was noted beyond the borders of the town. Historical records from the 19th century also pointed towards a higher female percentage overall in Newcastle and surrounding areas supporting what was found by the osteological and burial records evidence. In particular, according to the parliamentary returns for Newcastle and Gateshead '...in 1821 there were 3,912 more females than males' (Mackenzie 1827, 735).

The precise explanation behind this slight female predominance in South Shields and surroundings is unclear; however, some possible causes are under consideration. As South Shields was a seaport town like the rest of this region, this slight difference could be hypothetically linked to the high number of seamen who lost their lives at the sea or died on board while travelling outside the region before the termination of voyage and were eventually buried somewhere else. According to the General Register Reports (1859, xivi; 1873, cxviii) a significant number of seamen died annually outside the region. The precise numbers, however, remain unknown as the captains failed systematically to notify the authorities of their crew losses. It would appear that only one tenth of the cases were reported back home. For instance, in 1857 at least 3,444 seamen died at sea or on board, but only 352 of them were reported back home (1859, xivi).

It was impossible to calculate how many seamen from South Shields died outside the town's borders. The study of the burial registers, however, gave an estimation of the town's reliance on the seafaring industry, demonstrating the potential risk of dying outside South Shields due occupational risks. Within South Shields a significant number of water-bound occupations existed. According to the burial registers an increased number of 'mariners' and other seafaring professions was affected by mortality in the 18th and 19th centuries, with 509 deaths out of the total 1,383 individuals where their occupation was given. In particular, the following cases were identified, 438 'mariners', 16 'master mariners', 42 'pilots', 7 'seamen', and 6 'sailors' giving a prevalence at 36.08% from the total deaths based on profession. Other water-bound professions identified were 3 'boatmen', 9 'wherrymen', 11 'keelmen' and 22 'fishermen'. The most common causes of death in mariners and seafarers who lost their lives within South Shields were 'consumption', 'drowning' or 'accident'. Many of these affected individuals were below the age of 40 with a number of kids also being affected by mortality. The greater proportion of females than males within South Shields combined with these occupations and causes of death is revealing of how mobile males of South Shields were during the Industrial Revolution and subsequently shows the hazards of the prevailed industries in the area (e.g. seafaring).

The potential for dying outside South Shields was further supported by the fact that among the buried mariners in St Hilda's, there was a non-native mariner called J.J Vanderveen who was originally from Holland, but died on board a ship on the River Tyne and was buried in St Hilda's cemetery. Since mariners of foreign origin existed in South Shields, it is also possible that locals left for abroad or remained within the British Isles but visited regions outside South Shields. For example, in the case of Royal Navy sailors it has already been discussed in chapter 3 (section 3.16) that the majority of the recruits were derived from the working class and were trying to escape poverty and/or prison in their hometowns (Boston *et al.* 2008, 68). South Shields was primarily a working-class town with increased levels of poverty among many individuals (Foster 1974; Raynor *et al.* 2011). Leaving, thus the poverty of South Shields for a better life during an Era of increased mobility is a possibility. Therefore, it is likely that many local seamen were lost and buried outside this region or admitted to specialist hospitals such as Greenwich Tier and Infirmary Newcastle, where they received care and treatment before being buried at the cemetery associated with the hospital (Boulter *et al.* 2008; Boston *et al.* 2008).

The burial registers and number of deaths extracted from the admissions books of Infirmary Newcastle, revealed a number of buried individuals in Infirmary Newcastle that were originally from South Shields (Nolan 1998). The full list of names of the identified individuals can be found in Appendix 7. Of these identified individuals from South Shields, males were more numerous than females, with the majority of the individuals from both groups being young and early middle adults. It was unclear whether these males were seamen or not as only a few of them had the occupation stated, but Newcastle Infirmary was known to treat not only seafarers, but also cases who could not afford medical treatment in their homes or paupers (Nolan 1998). In the case of the identified females, when their age (mostly young or early middle adults) is combined with the nature of the hospital- which after July 1830 took over the functions of the Lock Hospital, a charitable institution which catered largely for prostitutes- it could be reasonably assumed that these women were either paupers or prostitutes. It seems, however, that this function of the hospital was initially surrounded by certain reticence with certain female entries being simply referred in various records as 'Lock' (Nolan 1998, 37). The 1841 census was unspecific on female occupation too, though ten years later the occupation of prostitutes was explicitly stated in the census and made 41% of the female inmates (Nolan 1998, 37). A number of individuals, mostly males, from North Shields were also found to have been interred in Infirmary burial ground, explaining perhaps why Coach Lane also exhibited a higher number of females than males. The full list of names of the identified individuals from North Shields can be found in Appendix 7.

The higher female percentage observed in St Hilda's population, however, was not in agreement with the annual deaths recorded for the whole of England by the Registrar-General for different years (1839; 1842; 1844; 1845; 1850; 1859; 1875). Males had suffered a higher number of deaths overall, giving for instance a ratio 1.03:1 male to female deaths between 1837 and 1838 and 1:02:1 male to female deaths between 1840 and 1841 (Registrar-General 1839, 270; Registrar-General 1842, 65). Despite the differences with the overall rates of the period, St Hilda's osteological and burial ratio was similar to the modern male to female ratio of South Shields, which according to the last census conducted in 2011 was 1:1.04 the total ratio for England was also 1:1.04 (Office for National Statistics 2011).

Consequently, although the overall male to female ratio in England has changed throughout time, indicating changes in lifestyle which decreased the risk of death for males, the ratios between modern and 18th- and 19th-century South Shields revealed that no significant population composition differences occurred, with South Shields exhibiting a slightly higher number of females. The steady pattern observed in male to female ratio throughout time is perhaps indicative of certain genetic predispositions and/or environmental patterns in the population within this region (Pongou 2013, 421). When the comparative sites were considered, patterns of locality were also observed with North Shields (Coach Lane) exhibiting similar male to female ratios with South Shields, with both sites showing a slightly higher number of females (Proctor *et al.* 2016). These mortality similarities between North and South Shields perhaps could be indicative of genetic predispositions within populations in the region as well as lifestyle similarities and the nature of predominant industries which exposed the highly mobile males to occupational hazards (i.e. seafaring and coal production).

It would appear, based on St Hilda's burial records, that there was a higher male mortality during infancy in comparison to females. Therefore, it could be surmised that boys had a lower immune response at birth and therefore did not live to adulthood, perhaps explaining the larger percentage of females who made it to adulthood in St Hilda's skeletal sample. This suggests that males had a weaker immune and genetic predisposition than females. This has been explained by sex differences in genetic and biological makeup, with boys being biologically weaker and more susceptible to disease and premature death due to X-linked mutations (Waldron 1983; Pongou 2013; Schore 2017). Recent studies indicated that numerous preconceptions or prenatal environmental factors affect the probability of a baby being conceived male or female; environmental factors are also responsible for sex differences in mortality (Pongou 2013, 421). Supporting the theory that preconception environment and child biology increase the mortality of male infants with males being more likely to be born premature and suffer from associated conditions such as respiratory distress syndrome due to biological vulnerability (Drevenstedt *et al.* 2008; Zhao *et al.* 2017). Studies on mixed sex twins have also shown that male twins are at increased odds of neonatal and overall infant mortality in relation to their female co-twins with congenital conditions being by far more common in male co-twins (Zhao *et al.* 2017). The vulnerability of male babies might also generally explain why more male babies are born in living populations in relation to female ones, giving a higher male to female ratio (Chamberlain 2006). This higher number of males born is perhaps a compensatory system due to predetermined male biological vulnerabilities. It could therefore be surmised that more males are born because more males die.

This general higher mortality in male infants was not only exclusively observed in South Shields, but throughout the country (Registrar-General 1842; 1845; 1850; 1875). In the case of South Shields, however, this is perhaps due to the combination of these biological disparities along with environmental effects (i.e. increased use of coal in the area). Coal was by far the most significant pollutant in Britain in the 19th century providing this way an approximation of the local industrial pollution emission levels. Its negative effects had an impact not only on adult health, but also on child mortality (Thompson 1984; Bailey *et al.*

2016; Beach and Hanlon 2018; Bailey *et al.* 2018). Bailey *et al.* (2018) concluded that coal intensity (i.e. production and consumption) during the period of study was elevated in the North, the Midlands as well as in South Wales as these areas contained an abundance of coal. The great reliance of South Shields on the coal industry was known, in the late 1840s around 4,000 seamen were in charge for shifting a million tons of coal per year to London (Foster 1974, 88). This higher coal intensity and subsequent outdoor and indoor air pollution resulted in higher death rates from respiratory diseases due to carbon particles especially among the old and very young in the area (Bailey *et al.* 2016; Bailey *et al.* 2018). These respiratory diseases and infections had an impact on child development as children are generally most sensitive to air pollution due to the limited development of their lungs, their higher ventilation rates, and their slower recovery from the arising damage (Bateson and Schwartz 2008; Ishak *et al.* 2014).

In summary, the majority of the comparative sites appeared to exhibit similar rates to the rates reported by the Registrar-General (1839; 1842; 1844; 1845; 1850; 1859; 1875), with males being more affected by mortality, apart from a few exemptions such the Greenwich Tier Hospital, Infirmary Newcastle, St Bride's Lower and Cross Bones which exhibited atypical male to female ratios, indicating the purposes of use of the cemeteries (Figure 7.1). The general lack of substantial differences in the population composition between different sites indicates that males and females from various sites, including St Hilda's despite the slight female predominance, were similarly affected by mortality regardless of any background differences; It would appear that males irrespective of socio-economic divisions were more affected by mortality than their female counterparts.

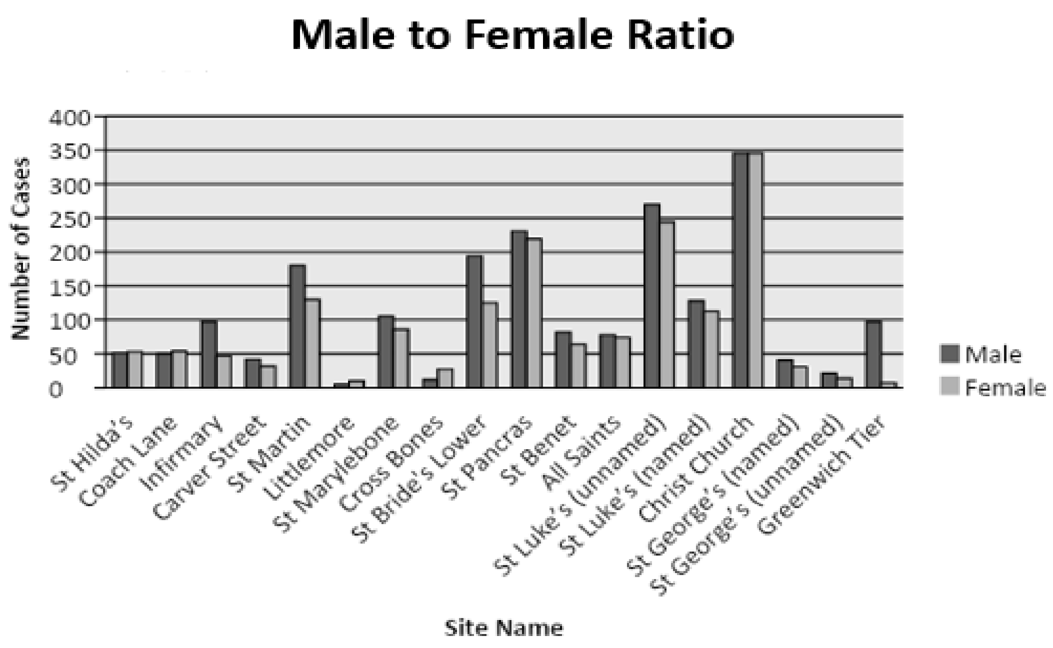


Figure 7.1: Summary of male to female ratios across different sites from the same period of study.

7.2.2 Age of Death Patterns and Survival Prospects across Different Groups

The produced mortality profile of St Hilda's, although it was not based on the study of the entire population but on a population sample, was typical for a general natural population for the period of study. The observed age-at-death pattern as well as the female to male ratio of sexable adults discussed above is indicative of an age-stable population (Chamberlain 2006). An increasing juvenile mortality or decreasing adult mortality would be suggestive of sampling bias. The common problem of infant underrepresentation did not afflict the population sample of St Hilda's assemblage possibly due to its good preservation (Buckberry 2000).

The mortality profile of St Hilda's sample was characterised by a great number of deaths during early life and a gradual decrease to a minimum in the relatively healthy adolescent age group, followed by an increasing mortality risk in adults over the age of 25. The approximate life expectancy in St Hilda's was between 26-45 years, in total 20% (*41/204*) of individuals died within this age range. When this category was further subdivided into early and late middle adulthood, 3.43% (*7/204*) of these deaths occurred between 26-35 and 16.6% (*34/204*) occurred between 36-45; these results were also in accordance with the life expectancy at birth calculated for Newcastle and Gateshead spanning several years in the second half of the 19th century (Szreter and Mooney 1998, 88-90). When the biological sex is taken into consideration middle adult males were more affected by mortality than their female counterparts. In particular more than half of the deaths occurred within this age category were males 68.3% (*28/41*) indicating perhaps that males, especially the unskilled ones, were more susceptible to death due to the physically-demanding lifestyle they faced as the breadwinners. Females had increased chances of reaching senior age categories despite the mortality risks during early adulthood due to pregnancy and childbirth, after overcoming that crucial point they had improved chances of growing older. Therefore, it would appear that St Hilda's was following the general osteological mortality profile of the period, where middle adults were the adult group most affected by mortality. In particular, two thirds of the studied sites including St Hilda's exhibited increased number of deaths in middle adulthood (Boulter *et al.* 1998; Brickley *et al.* 1999; Boston *et al.* 2006; Boyle *et al.* 2005; Brickley *et al.* 2006; Miles *et al.* 2008; Miles and White 2008; Proctor *et al.* 2016).

When St Hilda's burial registers were considered it was also observed that a high number of deaths 9.2% (*2885/31481*) occurred between ages 26-45. Of these, 4.6% (*1451/31481*) were in early middle adulthood between ages 26-35 and 4.6% (*1434/31481*) were in late middle adulthood between ages 36-45. Despite the similarities observed between osteological and burial register evidence with both reporting increased numbers of deaths in middle adulthood, the burial registers revealed some differences. According to the burial registers, an increased number of people lived longer than the age groups of 26-35 and 36-45, indicating that a significant proportion of the population managed to reach later life stages after overcoming the dangers of middle adulthood. That was also observed in other sites which utilised the burial registers such as for instance the Coach Lane, North Shields (Proctor *et al.* 2016). From the burial data it was possible to ascertain that the proportion of adult age-at-death within St Hilda's after the peak in middle adulthood, increased gradually until it peaked between 66-75 years of age and began to drop from 76+ years (Figure 7.2-7.3). This observation was supported by the annual deaths data from the Registrar-General reports (1842; 1850) that reported for the Northern counties increased numbers of deaths ranging between the ages of 66-75, after that point the numbers dropped. Thus, confirming what was observed in St Hilda's burial registers. From the Registrar-General reports (1842; 1850) was also possible to ascertain that the proportion of adult age-at-death within London remained steady and then increased gradually until peaking between 46-55 years of age, and then continued at a steady proportion before beginning to drop from 66-75 and onwards.

In summary, the historical data revealed that an increased number of adult deaths in the 19th century also occurred after the age of 45 with a slightly higher risk of death existing in London throughout adulthood. This could possibly be due to the fact that the metropolis was more overpopulated compared to the Northern regions (Newman 2015, 262). Therefore, the mortality profile based on the osteological data is either skewed by biases in ageing methodologies that tend to under-estimate the age of older skeletal groups or the burial registers profile is different due to its longitudinal nature and the fact that the burial registers contained an increased number of individuals of unknown age (Wood *et al.* 1992). These conclusions can also be generalised for the rest of the comparative sites that exhibited a similar osteological profile with St Hilda's, but differed from the historical data.

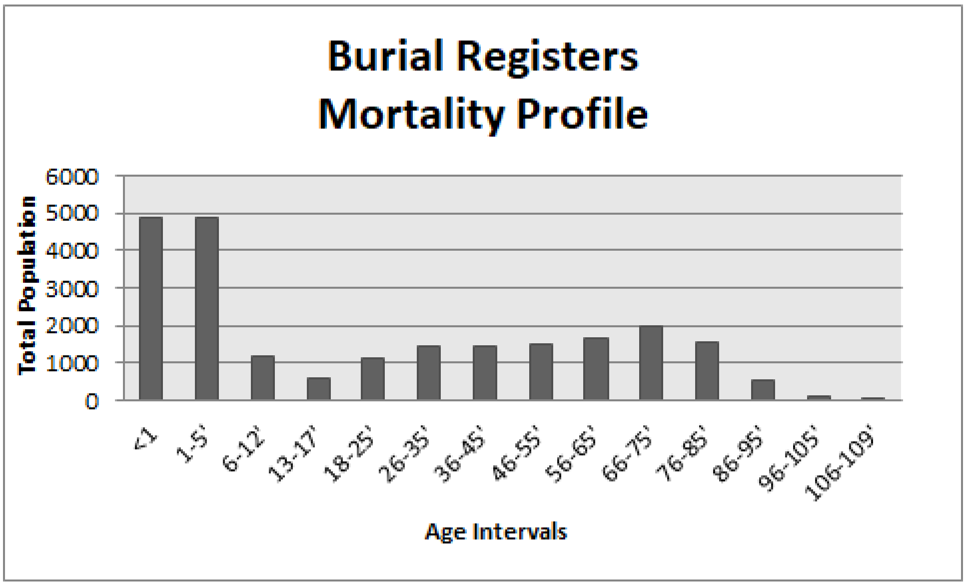


Figure 7.2: Summary of age-at-death distribution in St Hilda's burial ground according to burial registers, represented by the total number of interred population (n= 31481).

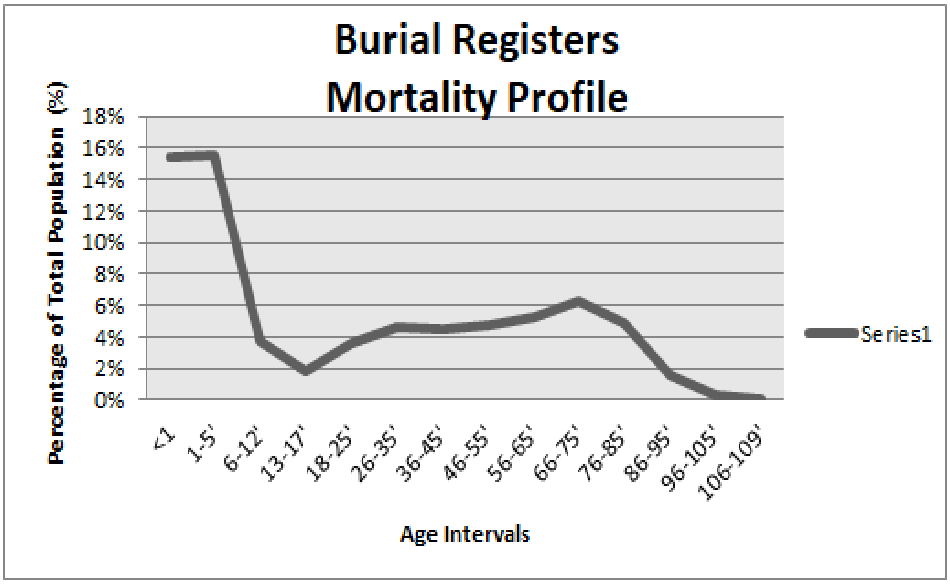


Figure 7.3: Line graph of age-at-death distribution in St Hilda's burial ground according to burial registers, represented by percentage of the total number of the interred population.

Despite the classification issues of early life age categories between sites, which were mentioned in chapter 6 (section 6.1.2), it was clear that all sites during this period were affected by excess deaths below the age of five years. Thus, reflecting the high risk of mortality and morbidity during the vulnerable stage of early childhood. This consistent surge in mortality in very early life across the sites was indicative of the similar environmental, biological and/or cultural stressors which were experienced during this period by these age groups throughout England.

Over 40% of total deaths in England between 1837 and 1838 were below the age of five years. While in London alone for the same period, almost half of the deaths were below the age of five accounting for 42% of the total deaths; a number that remained almost the same (41%) in 1841 and 1842 (Registrar-General 1839, 270; Registrar-General 1842, 19; Registrar-General 1845, 66-67). Pooley and Pooley (1984, 155) estimated for Manchester between 1838 and 1900 that 40-50% of all deaths were children below five (with the bulk of those being under one year), while Thompson (1984, 136-137) estimated for Bradford in the 1840's that around 27% of infants (in parts per thousand) died in the first year of life. Accordingly, an increased number of deaths occurred below the age of five for the St Hilda's skeletal sample as well as the comparative sites.

Within Saint Hilda's assemblage, Individuals aged from birth to five years constituted 39.7% (*81/204*) of the total number deaths and all the non-adults together made up 42.6% (*87/204*) of the total deaths. Hence, confirming that the site's mortality profile was comparable to other populations at this time. Amongst St Hilda's non-adults, neonates were most affected by mortality with 16.2% dying before the end of the first month, indicating the influence of endogenous and exogenous factors. The next affected category was preterm with 11.3%, indicating the impact of endogenous factors such as genetic abnormalities or the health of the population that gave birth to these babies (Lalou 1997; Tymicki 2009). Within St Hilda's skeletal assemblage, approximately 11.3% were born preterm. The presence of these skeletons is probably the result of either foetal deaths or premature births, corresponding to stillbirths or babies born too young to survive. It was impossible, however, to determine from the macroscopic analysis of the skeletons how many of these babies were born dead after 28 weeks *in utero* (Lewis 2007; Liston *et al.* 2018). Nonetheless, premature birth is documented during the period of study (Wohl 1983). In reality, however, birth at less than 37–38 postmenstrual gestational weeks would often have been incompatible with the survival of the preterm infant. While many of these preterm would survive today with medical support, in past populations most if not all of them would have died from complications associated with their immature development. Specific complications of preterm birth include trouble breathing, inability to nurse and swallow adequately due to central nervous system deficiency resulting in reduced weight, intracranial haemorrhage, and infection, which causes sepsis and meningitis. A lack of body fat and ineffective thermoregulation would have further jeopardized a premature infant's chances of survival particularly if born in either winter or the hottest portions of the summer (Beers and Berkow 1999; Liston *et al.* 2018).

The frequency distribution of age-at-death, with its peak at a few gestational weeks before and after birth, also raises questions about the general health of the women that gave birth to the babies. The number of deaths before 40 weeks falls slightly below the normal gestation period; assuming that this peak represents the expected spike in full-time births of new-borns, a large proportion of perinatal infants were small for their gestational age. Of course, gestational-age estimates for the skeletal remains are limited as they are based solely on the length of the long bones. A similar preponderance of small-for-gestational-age infants has been observed among the sites throughout the period, where skeletal size and dental development can provide independent estimates of age, since dental development is buffered from environmental stresses (Newman 2015; Liston *et al.* 2018). It would appear that many of the new-born infants were carried to full term, but were at the small end of the range for full-term pregnancies. Individuals with a low birth weight or were small for their gestational ages are at increased risk of perinatal mortality as well as long-term problems with growth, mental development, and immune response (Newman 2015; Liston *et al.* 2018). The high frequency of deaths among individuals who were less than the optimal size for full-term suggests that low birth weight, rather than actual premature birth, may account for a portion of these deaths. Showing this way, that the health of physiologically stressed mothers and their socio-economic conditions where chronic undernutrition and disease prevailed, had a significant impact on birth weight and size (Liston *et al.* 2018). Owsley and Jantz (1985, 321) after studying Native American cemeteries demonstrated that increases in social and environmental stress result in reduced long bone length of perinatal infant skeletons (Owsley and Jantz 1985, 32).

Cross Bones, London also exhibited a peak in preterm deaths, while most of the other comparative sites exhibited a higher number of neonate and infant deaths. The elevated rates of preterm deaths were perhaps suggestive of elevated mortality risks in early life amongst lower status groups (Owsley and Jantz 1985). The relatively high number of preterm and neonate skeletons in these sites, however, could also be a sampling strategy issue which may have over-indexed these age groups or may be indicative of cultural practices. In many churchyards, graves on the edge of the north side of the graveyard may be occupied by the bodies of stillborn infants, suicides, excommunicated persons and those who were not entitled to the full church rites of burial and are not in consecrated ground. A large proportion of St Hilda's preterm and neonatal population came from the western side of the burial horizon of the excavation site. This section spreads beyond the original cemetery boundaries, therefore it is suggested that this may represent segregation of unbaptised individuals who were buried in unconsecrated grounds (Raynor *et al.* 2011).

Under-ageing of these skeletal remains seems not to be an issue as the employed methods demonstrate increased accuracy among immature individuals (White and Folkens 2005). It would appear the results found by the author were also in accordance with the increased number of preterm noted by Raynor *et al.* (2011) during the commercial excavation and post-excavation assessment of St Hilda's assemblage. In any case, a high number of preterm deaths must have existed since the rapidly growing Northern industrial towns were notorious for many public health problems that led to high infant mortality (Thomson 1984). South Shields, North Shields and Newcastle for instance were suffering not only from their own industry emissions, but also from the numerous steam-boats crossing the Tyne, and the emissions of each town to the neighbouring ones (Commission for Inquiring into the State of Large Towns and Populous Districts 1845b, 44; Robson 1935, 313).

The lack of overall difference between the case study and the comparative analysis revealed that all sites were affected by exogenous factors such as poor sanitary conditions and atmospheric pollution, as well as endogenous factors such as poor maternal health. It should be noted that in many sites the classification systems for allocating individuals to non-adult age categories made it difficult to define to what extent the individuals were affected by endogenous factors because very early life stages and first years of life were merged into one category. The bills of mortality and censuses from various regions, however, supported the evidence of deaths during the neonatal stages (Calvert Holland 1843).

When St Hilda's burial registers were considered it was also noted that deaths below the age of five were elevated; yet, the numbers were below the skeletal numbers observed as part of this study. In particular, individuals from birth to five years made up 30.9% (*9740/31481*) of the total number of individuals in the sample and all the non-adults made up 34.7% (*10914/31481*) of the total number of deaths reported in the burial registers. This difference between osteological and burial evidence could be due to the fact that the burial evidence was more longitudinal while the skeletal evidence was based on a population sample and/or due to the fact that younger children did not always receive the same treatment as the older individuals (Mosley 2002). During this period of study, stillborn babies could be buried without burial registration and with very little questions creating other implications (e.g. ethical and legal) pertaining to the babies' manner of death (Registrar-General 1842, 86; Thomson 1984, 124). It is unsurprising indeed that no stillbirths were recorded in the burial registers may explain the discrepancy observed between the low numbers of individuals below five and the lack of preterm recorded in the burial registers, and the higher proportion of those individuals observed within the osteological sample. Primary documentary sources should not always be used uncritically as they are products of the time in which they were produced and reflect the customs and attitudes of the period which may introduce biases in historical records (e.g. burial registers). This explanatory model was further supported by the fact that in the burial registers there was an increased number of individuals with unknown age-at-death. In particular, from the 31,481 burial registers, 8,721 were of unknown age and of these individuals of unknown age 2,460 were described as 'son', 'daughter', 'son and daughter', 'twin' or 'illegitimate' indicating perhaps cases of stillbirths, preterm or clandestine deaths, again offering a potential explanation for the observed differences between burial records and osteological evidence.

Differences in deaths below the age of five were also observed between St Hilda's burial registers and the data for the Registrar-General report on London which gave a proportion of 40.1% for individuals below five (Registrar-General 1842, 66-68). However, this difference was expected as the higher number of deaths that occurred in London was likely due to how overpopulated the metropolis was compared to South Shields. Higher population levels in London would have resulted in higher birth and death rates compared to Northern regions. This hypothesis was further confirmed by the Registrar-General report for 1842. The report stated that for certain months in 1841, there was a higher number of deaths and births in the metropolis in relation to the Northern and other counties (Registrar-General 1842, 66-68).

It was observed that the St Hilda's records exhibited a high number of deaths in young children followed closely by infants and neonates, whilst the St Hilda's skeletal materials exhibited a higher number of preterm and neonates followed by young children (Figure 7.4). Although both data sources exhibit an increased number of deaths below the age of five, some substantial differences exist, primarily due to differences between chronological and biological age, and the used classification system for allocating individuals to non-adults age categories. For instance, in the case of burial registers, there were no preterm cases recorded but instead there were cases recorded as 'half hour' or 'one day' with no further information on the stage of gestation or the precise age of the baby, making it impossible to classify them as a preterm. Another possible explanation could be that the chronological age of death did not correspond to the biological age, simply because the immature individuals were of smaller size due to the mother's poor health and/or other factors. This problem, however, was not unique to St Hilda's immature individuals. This is simply linked to the osteological methods that are very precise when used in immature remains (White and Folkens 2005).

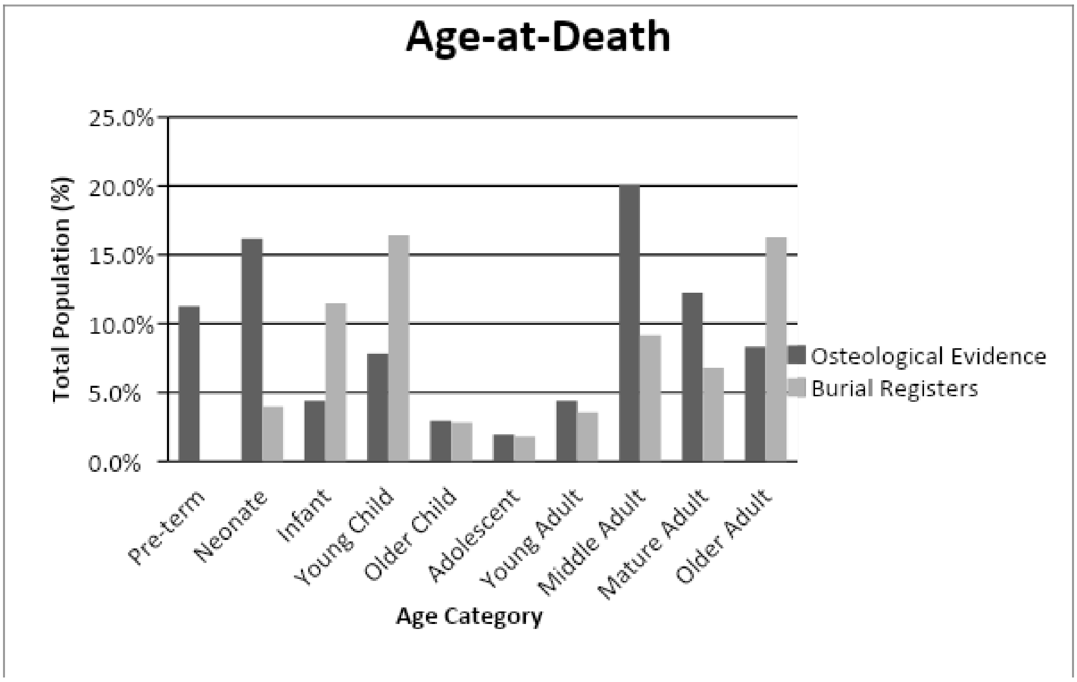


Figure 7.4: Summary of age-at-death distribution between St Hilda's osteological and burial registers evidence, represented by percentage of the total populations.

7.2.3 Possibilities of achieving Potential Stature

St Hilda's individuals had achieved the optimum stature of the period despite their low socio-economic status. The mean stature of St Hilda's males and females compared to the comparative sites revealed that no significant differences existed between them, indicating the extent to which adult stature is governed by genetics (Figure 7.5) (Kant *et al.* 2005; McEvoy and Visscher 2009; Perola 2011; Wood *et al.* 2014; Kaiser 2020). These findings supported the argument that relative status is not reflected in stature during this period (Roberts and Cox 2003). When the stature from all the sites were combined, the results were almost identical to St Hilda's mean stature. Males had a mean stature of 170cm as in the case of St Hilda's, while females were less than a centimetre taller than St Hilda's, with a mean stature of c. 159cm. The obtained figures were certainly very close to the mean stature calculated by Roberts and Cox (2003, 386-396) combining data from different British sites: the mean stature for males was 170cm and 160cm for females. The study undertaken by Roberts and Cox (2003) examined data from all periods in British prehistory and history, and as a result they noticed that average stature had changed very little since the medieval period.

The similar heights between the studied sites generally suggested a combination of genetically determined tall stature and strong immune response (Kant *et al.* 2005; Wood *et* *al.* 2014; Kaiser 2020); despite the exposure to the hazards of childhood during this period, with no apparent North and South division or socio-economic status. The overall lack of substantial differences in adult stature was to a certain extent foreseeable considering the fact that 80% of stature variation is strongly influenced by genetic factors with the rest controlled by environmental factors such as diet and disease exposure (McEvoy and Visscher 2009; Perola 2011). Episodes of stress would have to be chronic in nature for there to be permanent stunting and frequently catch-up growth follows after such episodes (Newman and Gowland 2016). It is also important to consider the fact that these individuals survived the crucial stages of infancy, childhood and adolescence; therefore, they might not have experienced the substantial health stressors or simply were more genetically robust so they reached the optimum height of the period (Wood *et al.* 1992).

The osteological results for stature were also in accordance with various anthropometric data recorded on the living population in the 19th century. According to various studies that used anthropometric data to assess nutritional status the male living population was standing around 170cm while females around 158cm, with some height fluctuations observed in the country throughout the century (Floud *et al.* 1990; Feinstein 1997; Johnson and Nicholas 1997; Floud 1998). In a study by Floud (1998), published anthropometric data on historical heights of men from higher and lower social groups were statistically analysed. The statistical analysis of the anthropometric data revealed that the mean male stature presented increased from 171cm to 173cm during the early 19th century, followed by a decline to 172cm which begun with the birth cohorts of 1830, and ended with the birth cohorts of the 1860s after which progressive stature increases occurred with the stature stabilising around 175cm for the birth cohorts of the 1940s (Floyd 1998, 34). Perhaps these stature fluctuations indicate progressive improvement of living conditions at the beginning of the 19th century, where people moved from rural to urban centres with the creation of new job opportunities, and then a deterioration of the living conditions and environment due to rapid urbanisation followed again by a progressive improvement of the living standards in the 20th century. Comparison between the results from Floyd's analysis and the stature measurements recorded for St Hilda's male stature and the mean stature of the comparative sites both at 170cm, revealed that the osteological results were not far from the recorded anthropometric results during this period. The osteological results were also consistent with other published anthropometric data, in particular military records of the period previously analysed by Floud et al. (1990). The only difference, however, was that the military data were consistently shorter by 1-2cm than those reported later by Floud (1998) in the cross-section analysis, indicating perhaps small differences due to social status since the majority of soldiers were derived from the working class. The observed decline in mean heights in the second and third quarters of the 19th century was also confirmed for the female population in England. A study of 30,000 British female criminals by Johnson and Nicholas (1997, 220-222) found results which confirmed that there was a progressive decline in average female height after 1825, dropping from 157cm to 155cm during the late 1840s. The height declines for female populations roughly began at the same time as that identified by Floud (1998) for male populations. Thus, it appears that the anthropometric evidence of the stature decline from published data is consistent between biological sexes and researchers. The evidence of stature declines during the second half of the 19th century was also consistent with the increased mortality rates in the second quarter of the 19th century. Szreter and Mooney (1998, 86), after the statistical analysis of census and other material such as bills of mortality demonstrated, that there was a pronounced deterioration in mortality levels in the second quarter of the 19th century, indicating deterioration of the urban living standards (increased mortality in the second quarter of the century was also observed in St Hilda's burial registers).

According to the anthropometric analysis of the military and criminal records of the period, it would appear that only minor differences of 1-2cm in the final attained adult stature existed between working and higher-classes (Johnson and Nicholas 1997; Floud 1998). Similar observations were also made for the case study, however, frequently no differences were observed between sites of different status. This finding was indicative of how everybody was affected by the effects of industrialisation, and how social status benefited the higher echelons of society only to a certain extent. Major stature differences, however, existed between males and females, with females being systematically shorter than males for both anthropometric and osteological data. These stature differences ranged from 5-17cm between different sites, and are most likely due to sexual dimorphism. It has, however, also been suggested that the greater variation seen in female stature could also be suggestive of female social disadvantages due to the 'breadwinner' system in England. A study of English and Irish born convicts from 1817-1840 revealed that Irish women - who like other members of the family who go out to work - had a height advantage over urban English women who often remained at home (Nicholas and Steckel 1991). The accuracy of this suggestion is, however, unverified. There is substantial evidence from 19th-century social surveys and remarks by observers of the period, that in times of distress, it was the male breadwinner that was protected, compared to the woman of the household (Wohl 1983). Floud's (1998, 15) analysis of height, weight and body mass does not, however, support the conclusion that during this period male adults were significantly better nourished, and therefore less stunted or wasted than women and children, nor that male children were better nourished than their female siblings.

From the study of the osteological and anthropometric data from the 19th century, it was apparent that no systematic changes occurred in mean height throughout time, despite some variation. This observation was also confirmed in modern English populations where, according to the National Health Service, male and female height has not changed significantly from 1993-2017, with the modern male and female stature currently being around 175cm and 162cm respectively (digital NHS, 2017). This indicates that although stature has increased throughout time due to life improvements, it remains only slightly improved from what it was when the 19th-century conditions were less favourable (Floud 1998). These stature similarities, between historic and modern times, simply display how the finally attained adult stature is governed by genetics and affected by improvement of environmental factors which boost the genetically predisposed height (McEvoy and Visscher 2009; Perola 2011).

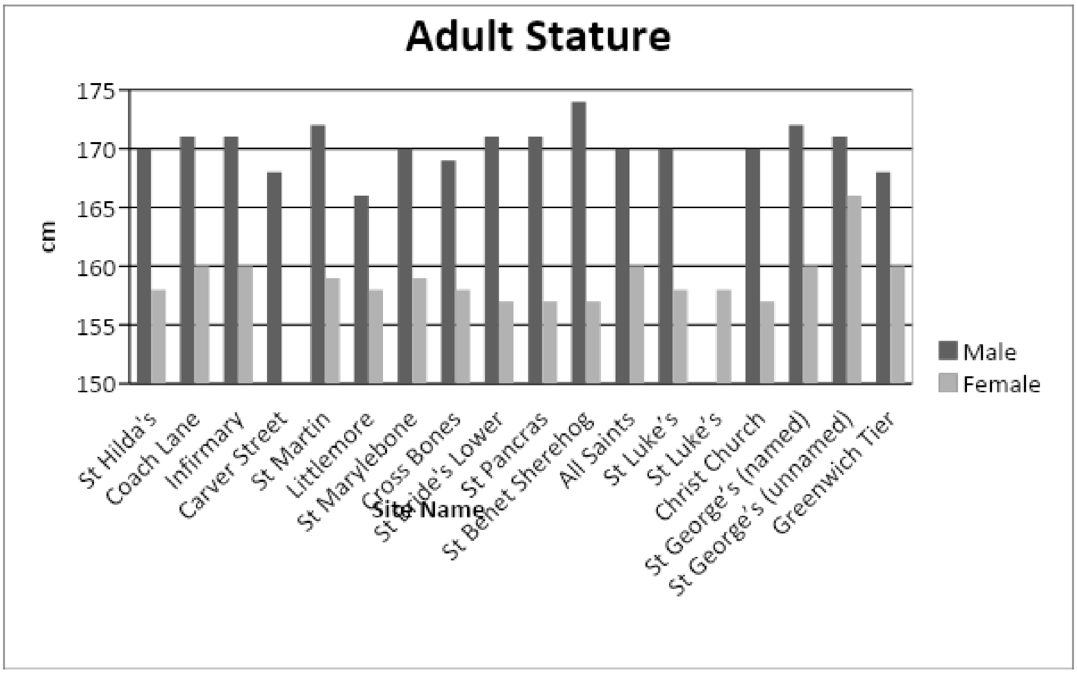


Figure 7.5: Mean stature for males and females from each site calculated using Trotter's (1970) method for long bones and femur/stature ratio by Feldesman et al. (1990).

7.3 Health and Disease Profile

St Hilda's palaeopathological profile was, overall, in compliance with the general skeletal profile of the period despite differences in socio-economic and/or geographic origins. St Hilda's appeared to follow the general trend in terms of pathologies for the period based on the 15 comparative sites used in the study; however, differences did exist between localities. Within St Hilda's population, general indicators of poor health were found. For example, high rates of specific and non-specific infections, trauma, spinal and extra-spinal joint diseases and metabolic diseases were noted among adults indicating a physically-demanding lifestyle within poor living conditions, characterized by poor hygiene standards in a polluted and unsanitary environment.

7.3.1 Morbid Conditions: Specific and Non-specific Infections and Early Life Mortality

Early life mortality combined with a range of specific and non-specific infections was indicative of the morbid conditions people experienced throughout the country. Similar rates of specific infections (i.e. tuberculosis and syphilis) throughout different skeletal assemblages revealed that infectious diseases made no exceptions; individuals across strata in England were unable to isolate themselves from the infectious diseases of the period (Wohl 1983, 1). The overall observed rates for these two diseases were slightly different than the reported rates in historical records (e.g. burial registers), nonetheless still in accordance with the living conditions were infectious diseases such as tuberculosis were endemic (Manchester 2001, 142). Such discrepancies between osteological and historical records could be because no one lived long enough to develop bone lesions indicating a low immune response (Wood *et al.* 1992). Consequently, the twin aspects of how and when these diseases present themselves in skeletons need to be borne in mind while assessing the prevalence of these diseases (Miles *et al.* 2008). In the case of syphilis, the discrepancies between historical and olsteological records, where syphilis was lower in the historical records or even absent, indicated other more complex issues (e.g. social pressures) discussed below. No statistical differences were observed between St Hilda's and the comparative sites for the prevalence of tuberculosis, while in the case of syphilis only the sites of Cross Bones and Christ Church exhibited statistically higher and lower prevalence respectively in relation to the case study. Cross Bones was thought to have originally been used as a burial ground for single women ('prostitutes') and later became a cemetery for paupers. Therefore, a higher prevalence of venereal syphilis was perhaps anticipated due to the nature of the site and the social role of its inhabitants (Mikulski 2007). While Christ Church cemetery was primarily a middle-class cemetery and hence status could perhaps be the reason behind a more conservative behaviour and subsequently a lower prevalence. Frequently, however, males from the upper strata would mingle with the single women from the lower strata for entertainment purposes; prostitutes caught the sexually transmitted disease, syphilis, and infected their clients – who infected their wives. It was not until 1864, with the passing of the Contagious Diseases Act, that 'known prostitutes' working near ports and garrisons, who were found to have venereal syphilis and other sexually transmitted diseases, could be forcibly detained and treated (Curgenven 1868; Deakin 1872). In the case of St Hilda's assemblage, the presence of syphilis was not a surprise; South Shields was a seaport town and during the 19thcentury 150 prostitutes were reported to be immediately dependent on the seamen (Hodgson 1903; Foster 1974, 88). Despite the presence of a few possible cases of syphilis in the skeletal assemblage, where two out of three cases were possible females; entire absence of syphilis was observed among the recorded causes of death in St Hilda's burial registers. Entirely absent from the St Hilda's burial registers were also females recorded as 'prostitutes' or other similar descriptions, despite the relatively high proportion of deaths among young and middle adult females and the possible cases of female skeletons with syphilis. Certain reticence seems to have surrounded this type of information, a practice also noted in Infirmary Newcastle as noted in third chapter (section 3.3). Further to this observation, when data from the Registrar-General (1842, 226) were considered for the Northern division, only 0.06% (*11/17.761*) of the total deaths during this year were caused by syphilis, this number corresponds to only 11 adults for the whole region; while for England in general the rates of syphilis were also very low at 0.05% (*195/359.561*). Similar were the rates and patterns of syphilis reported for other years (Registrar-General 1844; 1845; 1850; 1859). These rates were below the osteological results for St Hilda's at 1.47% (*3/204*) and below the overall skeletal rates of the period at 0.8% noted by Roberts and Cox (2003, 341). It is possible that the osteological prevalence appears elevated due to the fact that it represents a smaller population sample; however, the low numbers of syphilis in the Registrar-General reports reflect another deeper problem, the implications of social stigma for sexually transmitted diseases, this observation could possibly be further extended to St Hilda's burial registers. Medical men of the period simply could not afford to state such facts candidly on open cause of death certificates handed to the relatives and copied into the public records. Consequently, registered causes of death often bear only an approximation to the truth and they should be viewed with a high degree of caution and scepticism (Luckin 1986). To quote Hardy (1994, 489) after studying the General Register Office cause of death statistics between 1837-1920 '…the statistical record of venereal disease is one of the least satisfactory items in the registration data. Unlike the series for cancer and kidney disease, it cannot be used to assess medical awareness of the condition'.

Misleading certifications resulting from social pressure on doctors or from problems inherent in medical practice of the 19th century continued to occur. Just as today deaths from AIDS related illnesses are frequently not so described, so in the 19th century deaths from socially sensitive diseases like syphilis, tuberculosis, and alcoholism were frequently replaced with another cause, because relatives were unable to accept the true cause on the open death certificate (Luckin 1986; Hardy 1994). When the burial registers or the Registrar-General report were studied it was also noted that conditions related to syphilis such as general paralysis of the insane and locomotor ataxy were barely mentioned by the statistical superintendents before the 20th century. Of course this low prevalence could also be attributed to other reasons that affect the recorded cause of death such as (1) irregularities in the published contents of the annual reports, meaning that no continuous annual series can be established for the period 1838-55, (2) non-certification of cause of death, (3) the uncertainty of many medical diagnoses of the 19th century, especially among the chronic diseases, (4) the failure to standardise death rates for comparative purposes and (5) problems caused by boundary allocations and boundary changes to registration districts (Hardy 1994, 473). The cases of syphilis progressively appeared to increase in Registrar-General reports; for example, in 1854 (Registrar-General 1854, 132-133) there were 69 recorded cases of syphilis as a cause of death for the northern division. Despite this progressive increase, these numbers were still low and probably far from actuality.

St Hilda's non-adults despite being affected by increased mortality in early life (i.e. preterm and neonatal deaths), appeared to exhibit relatively low rates of skeletal manifestations of infectious or any other fatal diseases. Exceptions, however, did occur such as in the case of a preterm foetus of 30-32 weeks who suffered from congenital syphilis, indicating the inherited effects of poor maternal health on the offspring. The congenital syphilis rate of St Hilda's was in accordance with a few other sites (i.e. Carver Street, St Luke and St George Bloomsbury) which provided information on the rates of this condition. The presence of other infectious diseases in St Hilda's non-adults such as pulmonary tuberculosis or 'consumption' as it was recorded was also confirmed through the burial registers. Pulmonary tuberculosis affected 0.30% (84/31481) of the total population from the burial registers, with five of these affected individuals recorded as non-adults. Whilst no skeletal cases of pulmonary tuberculosis were identified in St Hilda's non-adults, a case of rib lesions associated with pleurisy was noted, indicating the presence of some sort of pulmonary diseases. The total prevalence of tuberculosis from the burial registers was not too dissimilar to the number of cases reported from the skeletal sample with 0.30% (*84/31481*) and 0.98% (*2/204*) respectively. When the Registrar-General report (1842, 132-133) was considered the numbers appeared very elevated for both Northern regions and England as a whole with 14.7% (*2.606/17.761*) and 16.7% (*59.923/359.561*) respectively. The prevalence of tuberculosis appeared elevated also for different years according to the Registrar-General reports; although some small decrease was observed towards the end of the century, revealing some public health improvements. The accuracy of the numbers has been widely discussed by historians (Luckin 1986; Hardy 1994). As a general rule, it has been established that although levels of mortality were high during the earlier years of registration, there is too much uncertainty in diagnosis for annual or even decennial, fluctuations in recorded mortality to be accepted as reflecting real fluctuations before the 1870s at least (Szreter 1988; Hardy 1994). Further to this, conditions such as bronchitis or pleurisy were frequently confused for tuberculosis and vice versa (Pooley and Pooley 1984).

The lack of skeletal lesions in St Hilda's non-adults is characteristic of diseases which kill relatively swiftly or only affect soft tissue, 'acute,' and leave no marks on the skeleton (e.g. plague, flu) (Wood *et al.* 1992). Indeed, the presence of such specific infections in early life (i.e. small-pox, measles and cholera) was further supported by the identification of acute infectious outbreaks recorded in St Hilda's burial registers. These major epidemic diseases due to excessive unregulated urban growth and rural neglect were conveyed in a variety of ways such as the contamination of water, foodstuffs, clothes and utensils or by other factors such as body lice, flies, or droplets from the mouth and thus all influenced cleanliness, diet, personal hygiene, public sewerage or domestic living arrangements (Wohl 1983). Small-pox', 'measles' and 'cholera' were frequently recorded as the cause of death of many non-adults; which was also observed in Registrar-General reports (Wohl 1983; Rees 2001; Jackson 2015). In the case of smallpox from the burial registers, the CPR for the total population was 0.9% (*278/31481*) and 2.5% (*278/11157*) for the non-adult population, with the affected individuals ranging between 0 and 16 years during specific outbreaks between 1798 and 1802 and late 1808 to early 1809. Measles affected 0.30% (*97/31481*) of the total population and 0.90% (*96/11157*) of the non-adult population respectively, whilst cholera claimed, from the total number of victims, 12.3% (*38/309*) of non-adults during two outbreaks in 1832 and 1834. The total prevalence of cholera was 0.86% (*271/31481*) and 0.34% (*38/11157*) for the non-adult population. Other reported causes of death included 'whooping cough', 'convulsions' and 'fever', some of these terms are actually symptoms of disease and may be caused by many common childhood illnesses such as chickenpox, mumps, polio, diphtheria, tetanus and meningitis (Raynor *et al.* 2011, 54). The reported symptoms or diseases in the burial registers were also in accordance with the reported causes of death by the Annual Report of the

Registrar-General (1842, 230-234) in different districts of the country. Consequently, the observed increased mortality in early life stages during this period was a barometer for the unsanitary and poor living conditions that took their toll on the most sensitive portion of the population (Wohl 1983; Rees 2001; Jackson 2015).

The increased population size and density, poor environmental conditions, poor living conditions and sanitation, and low hygiene standards which people experienced on a day-to-day basis can be better understood when the specific infections are seen in combination with the recorded non-specific infections of the upper respiratory tract such as maxillary sinusitis and pleurisy.

It appears that communal living (eating and sleeping in the same overcrowded, ill-ventilated rooms) whether in a tenement or at the workhouse/poorhouse, was enough to lead to conditions such as chronic sinusitis (DiGangi and Sirianni 2017). Life in the tenements or workhouses where people frequently shared living and working space, coupled with the damp climate, provided the ideal environment for bacteria to spread. In fact, as it was seen earlier (section 2.3), it was not unusual for large families or even multiple families with a total number of 20 or more people to house-share in a single house (Engels 1987; Wohl 1983; Foster 1974). Given the combination of these conditions of overcrowding, poor ventilation, and the cold, damp climate it is not surprising that almost half of the St Hilda's individuals that fulfilled the study criteria had evidence of chronic sinusitis. St Hilda's sample exhibited elevated levels of rhinogenic maxillary sinusitis rather than odontogenic in origin. St Hilda's females were more frequently affected by maxillary sinusitis than males, representing perhaps occupational or behavioural differences whereby females were involved in indoor craft activities or spent more time inside domestic dwellings inhaling irritants from the hearths (Mahoney-Swales 2012, 204). Indoor environments during the Victorian period had a high degree of particulate pollution, which would have caused respiratory diseases as people would have inhaled plenty of toxic fumes and a large amount of carbon particles (Wohl 1983; Cappaso 2000). Males on the other hand were more frequently involved in outdoor activities such as working in the shipyards or on the keels which carried the coal from the banks of the river to the waiting collier ships. In the case of St Hilda's, it may seem that outdoor work reduced exposure to domestic conditions. Despite the surrounding environments where both males and females worked or spent most of their day, it would appear that both sexes were exposed to a considerable amount of smog induced by coal or other atmospheric pollutants.

The prevalence rates of maxillary sinusitis were independent of age-at-death and over half of the affected individuals exhibited active lesions at time of death indicating constant exposure to these irritants. These two observations make the lesions more likely to reflect constant exposure to indoor and outdoor air-borne pollutants brought by the Industrial Revolution in the urban centres (Boocock *et al.* 1995; Lewis *et al.* 1995; Roberts and Manchester 1997; Boyle *et al.* 2005; DiGangi and Sirianni 2017). Roberts and Lewis (1994) revealed that urban communities presented a higher prevalence of maxillary sinusitis than their rural counterparts although both were exposed to it. This was due to the prevailing environmental conditions characteristic of urban living, namely, pollution, overcrowding and occupation. Maxillary sinusitis was commonly encountered in the smoggy overpopulated cities of post-medieval Europe, and its prevalence increased in line with air pollution associated with industry and manufacturing (Boocock *et al.* 1995; Boyle *et al.* 2005; Roberts 2007; Mahoney-Swales 2012). Other studies have linked this chronic and irritating infection to the colder and damper climate and indoor pollution from the presence of open hearths in the smoky, poor ventilated houses (Wells 1977; Boocock *et al.* 1995; Merrett and Pfeiffer 2000; Mahoney-Swales 2012). Consequently, it would appear that maxillary sinusitis was a result of both indoor and outdoor pollution, and whilst it might have made its appearance long before the beginning of the Industrial Revolution the industrialised environment certainly didn't make it any better.

In the case of the comparative analysis between St Hilda's and the comparative sites, it was impossible to define the existence of any substantial differences between geographic and/or socio-economic divisions due to the lack of adequate evidence. This was perhaps because of the methodological complexity of recording maxillary sinusitis, which requires either crania that have undergone post-mortem breakage or require more invasive methods such as the use of an endoscope. Some exceptions, however, occurred such as in the case of Christ Church, Spitalfields where enough evidence existed due to its examination in a non-commercial setting. It would appear that some status differences existed between St Hilda's and Christ Church with the former exhibiting higher and the latter lower prevalence of maxillary sinusitis with 43.27% (*45/104*) and 18% (*71/394*) respectively (Roberts 2007). Unlike

St Hilda's, no biological sex differences were observed in Christ Church with both males and females being equally affected. It is speculated that the higher status of this urban site 'shielded' its individuals against maxillary sinusitis. The presence of these lesions in Christ Church, however, shows that the status of individuals kept them only partially protected from the 'threat' of industrialised living. Consequently, Christ Church like any other site from this period of interest experienced many potential indoor and outdoor sources of particulate pollution, but status may have partially cushioned them from poor indoor air quality as they lived in the most desirable residences, with space, gardens, street lighting, a sewage system, adequate heating, and good sanitation (Roberts 2007, 803). Although smoke pollution due to coal usage increased considerably these people would have benefited from housing ventilated with chimneys. Molleson and Cox (1993, 214) describe the people buried at Spitalfields as '…very much of the 'middling sort': men and women of some substance with strong family ties, working as skilled craftsmen and in the professions.…. their wealth can be assumed to have cushioned them from starvation or nutritional stress…' Therefore, the population may have also been partially protected from poor indoor air quality as well (Roberts 2007). The St Hilda's results here appear to fit a model for the opposite situation, as all individuals in this sample were mostly of low status and had a high prevalence of chronic sinusitis both from indoor and outdoor sources. In the case of St Hilda's females, the aetiology of higher prevalence of maxillary sinusitis can be explained as the result of a combination of direct and indirect effects of smoke emissions; gas and smoke emissions had direct effects (e.g. respiratory and bronchial complaints, and a general feeling of malaise) but also indirect effects. The stench was probably so great that inhabitants were forced to keep their windows tightly shut, increasing the chances of infection (Wohl 1983, 208). Thus, it can be told that most of the females were twice exposed to harmful factors as they were more housebound than their male counterparts that were working outdoors.

In the urban centres of England, the effect of living in a polluted atmosphere and working in various industries had taken its toll on the peoples' respiratory health. One-to-one correlations, in terms of occupation in Christ Church, Spitalfields and St Hilda's were impossible. Information on the occupations of some of the Spitalfields sample, however, indicates that many worked in the silk production industry and respiratory infections were known to be associated with working in the textile industry (Molleson and Cox, 1993; Roberts

2007). While in the case of St Hilda’s, the information on occupations based on the burial registers revealed that a good portion of the male population was working outdoors. In particular, in coal production and the export of coal by sea and in the seafaring and shipbuilding industry, there was also a large portion of craftsmen and unspecialised labourers. This male predominance in outdoor occupations perhaps explains the lower prevalence of maxillary sinusitis observed among St Hilda’s male sample in relation to females, which were working in more domestic environments. According to the burial registers, St Hilda’s females were working as spinsters, salt-makers, mantua makers, and midwives, while many of them were simply described as wives or widows further supporting the initial assumption that they were spending more time indoors.

Pleurisy was another upper respiratory tract infection, a non-specific indicator of environmental stress, which confirmed the constant exposure of St Hilda’s population to polluted environments. Unlike the case of maxillary sinusitis, no biological sex differences were observed in the prevalence of pleurisy; the condition was also independent of age-at-death making it more likely to reflect the surrounding environment resulting in the equal exposure of the population. Over half of the individuals exhibited active lesions indicating constant exposure to pollution. Interestingly, among the affected individuals was a case of a young child with active lesions at time of death on the pleural surface of five out of seven ribs, indicating a possible cause of death.

Differences existed between the rates of pleurisy recorded in St Hilda’s assemblage and the Registrar-General report (1842, 227). St Hilda’s exhibited a CPR at 7.6% (*12/157*) and a TPR at 1.93% (*49/2537*) while the rates for both England as a whole and the Northern regions were much lower with 0.20% (*702/359.561*) and 0.08% (*15/17.761*) respectively. Pulmonary conditions linked to pleurisy as an accompanying symptom, however, such as bronchitis and pneumonia exhibited relatively higher rates; bronchitis for England and the Northern regions was 0.60% (*2053/359.561*) and 0.43% (*77/17.761*) while pneumonia was 5.20% (*18582/359.561*) and 3.73% (*663/17.761*) respectively. As previously discussed in the specific infections section of this chapter (7.3.1) conditions such as bronchitis or pleurisy were frequently misdiagnosed for tuberculosis and vice versa; this perhaps could explain the higher prevalence of pleurisy in St Hilda’s sample in relation to the Registrar-General report and the elevated numbers of TB for both the Northern regions and England as a whole (Szreter 1988;

Hardy 1994). This is not to say that pulmonary tuberculosis was not markedly prevalent in the 19th century, but to highlight the difficulties in diagnosis of pulmonary conditions (Boyle *et al.* 2005). This observation can be further extended to the comparative sites which also exhibited higher prevalence compared to the Registrar-General report. These observed differences, however, could also be due to the fact that the lesions in skeletal remains are of a non-specific nature as there is not much evidence left, and therefore cannot be attributed to a specific condition or pathogen (e.g. pneumonia or bronchitis) like in the living cases. Pleurisy is a complication of several different medical conditions making it difficult to have one-to-one correlations in skeletal remains. In St Hilda' burial registers the only recorded pulmonary condition was pulmonary TB, leaving no option for further comparison of pleurisy with the osteological results or bronchitis and pneumonia with the Registrar-General report.

The prevalence of pleurisy possibly increased in line with air pollution associated with industry and manufacture. Long-term exposure to air-borne pollutants was compounded by many industrial processes, leaving industrial and manufacturing workers (e.g. miners, foundry and cloth workers) at severe risk of diseases of the ears, nose, throat and chest (Boyle *et al.* 2005, 173). Many pulmonary diseases were induced by the manufactured by-products (Sluis-Cremer and Webster 1972). Industrial diseases were an inevitable part of the working life in the 19th century; long hours worked in factories with air-borne dust and chemicals also had a deleterious effect on respiratory health along with the living conditions amongst the slums of the urban working classes (Wohl 1983). In fact, much of this smog and particulate pollution in South Shields and elsewhere was caused by the use of coal as a fuel for domestic fires (Fynes 1873). The negative effects of coal on health were also demonstrated in earlier sections (7.2.1 and 7.2.2) with the increased number of preterm and neonatal deaths in St Hilda's sample and the increased infant mortality as it was seen through the St Hilda's burial registers. It is therefore clear that the negative effects of coal inside and outside the domestic environment had an impact on everybody (Foster 1974; Thompson 1984; Bailey *et al.* 2016; Bailey *et al.* 2018). There can be little doubt that smog greatly increased the chance of illness or death in a population which was also subject to a variety of pulmonary ailments caused by working conditions.

Coal, however, was not the only air pollutant; as seen in section 2.3, alkali manufacture also had deleterious effects on atmospheric pollution (Wohl 1983). South Shields, whose economy was also dependent on alkali production, suffered from these deleterious effects of alkali exhalations which comprised one of the most strongly complaint nuisances by everyone in town (Commission for Inquiring into the State of Large Towns and Populous Districts 1845b, 23 and 44; Hodgson 1903, 152). Alkali pollution would have resulted in difficulty breathing, coughing, choking, smarting of the eyes, and nausea for those exposed to it (Foster 1974). It needs to be mentioned, however, that where alkali was produced there was also considerable production of coal and that it is difficult to tell which of these two industrial processes was responsible for the air pollution, but it is also possible that both were responsible.

The comparative analysis revealed that no statistically significant differences existed between St Hilda's and most of the comparative sites. This equal prevalence was indicative that social status did not cushion the wealthier from outdoor or indoor air pollution, and therefore the risk of exposure to factors that can result in pleurisy which is seen as rib lesions in archaeological populations. Only the sites of St Luke's-unnamed, Greenwich Tier Hospital, and Infirmary Newcastle exhibited statistically significant differences. St Luke's had lower prevalence of rib lesions than St Hilda's whilst Greenwich Tier and Newcastle had higher. In the case of St Luke's Church Islington-unnamed, the reason behind this low prevalence of rib lesions was perhaps methodological given that this population was primarily a working-class sample in an urban setting and thus a higher prevalence would have been expected (Boyle *et al.* 2005, 13). Almost three-quarters of the St Luke's Church collection were subject to low resolution analyses, while the named individuals, middle class, were the primary focus and subject to high resolution analysis (Boyle *et al.* 2005). Further to this, a great part of the analysis was conducted on-site due to the commercial setting of the excavation and subsequently there were time limitations for recording the remains (Boyle *et al.* 2005, 13, 22, 128, 171, 282). In the case of Greenwich Tier and Infirmary Newcastle, however, the higher prevalence could perhaps reflect the nature of the burial sites and subsequently the nature of the populations which were interred; only the 'sick' and 'lame poor' were admitted to these Hospitals (Boulter *et al*. 1996; Nolan 1996; Boston *et al.* 2008). For the most part, general hospitals and asylums did not make any very great addition to local death rates. Specialist hospitals, however, could be another matter and may have influenced the prevalence of specific recorded conditions (Pooley and Pooley 153, 1984; Hardy 1994, 481). For instance, as Hardy (1994, 481) pointed out in Islington, the London Fever Hospital contributed substantially to raising Islington's typhus fever death rate in the 1860s when it was receiving cases from most of the other London sanitary districts during a major and prolonged typhus epidemic. This observation can be extended also to other specialist hospitals, and other large specialist institutions that created complications in estimating local mortality rates in the 19th century (Pooley and Pooley 1984). Consequently, calculations of this sort such as in the case of Greenwich Tier and Infirmary Newcastle may produce misleading results and lead to misrepresentation of the true state of affairs (Hardy 1994).

Finally, a variety of special local factors may also have served to distort reality. Districts with many common lodging houses, like Westminster or the Strand in London, suffered disproportionately from tuberculosis; spa towns may have suffered similarly from unnaturally high rates of diseases of the circulation and digestive systems. Districts with workhouse accommodation on major tramping routes, and other such local factors also probably affected local mortality and morbidity (Hardy 1994, 482). Such as in the case of Cross Bones, discussed previously, which was outside the jurisdiction of the city of London and as a consequence became among other things also famous for its brothels. As it was discussed in sections 7.2.1 and 7.2.2, the site exhibited a higher number of females and preterm deaths and a statistically higher prevalence of syphilis. The cemetery was thought to have been initially established as a ground for single women ('prostitutes') and later became a cemetery for paupers. As such, the bioarchaeological evidence identified from the analysis of the remains may reflect these local factors in shaping this cemetery's profile (Mikulski 2007).

Another studied non-specific stress indicator reflective of the general poor living and working standards was TPNB, which also reflects the body's immunological ability to respond to irregularities whether they are traumatic, infectious, or inflammatory in origin (Boyle *et al.* 2005; Roberts and Manchester 2010). In the case of St Hilda's sample, it would appear that TPNB does not necessarily represent some form of severe physiological stress, but more of a mild irritation to the tibia resulting from aetiologies such as minor chronic localised trauma/stress, or chronic skin ulceration caused by varicose veins, or minor inflammations within the soft tissues, or localised infections related to the wearing of stockings (Roberts and Manchester 1997). In most of the individuals the lesions were isolated on the anterior surface of the tibia, which indicates that the periosteal reaction resulted from direct trauma to the legs.

The lesions were independent of biological sex. The prevalence between males and females was almost equal; the lack of differences between biological sexes indicates that anybody could be susceptible to the factors causing TPNB. Older adults were more affected than any other age groups. Varicose veins are more common in the elderly due to weakness of the veins especially in those with atherosclerosis and diabetes mellitus, and often result in arterial and venous ulcers of the feet and lower legs which heal slowly and are vulnerable to secondary infection and even subsequent sepsis (Roberts and Manchester 2010; Boston *et al.* 2006). Apart from that varicose veins can be indicative of other health issues. Varicose veins can cause complications such as pulmonary embolism and right heart failure when large blood clots travel back to right heart ventricle. The increased blood pressure increases the workload in the right heart ventricle, with time this causes the right ventricle to fail because the right heart has to work more than the left to overcome the resistance due to occlusion of many pulmonary vessels (Kline 2012; Stein 2007)

7.3.2 Inherited Deficiencies, Dietary Insufficiencies and Child-Rearing Practices

The presence of infectious diseases in St Hilda's non-adults was also indirectly supported by the presence of metabolic disorders such as rickets and scurvy, revealing risks of exposure to a range of disorders during early life. The industrial urban centres of the period were notorious for the spread of diseases as well as the presence of malnourished and/or undernourished individuals due to the effects of poverty, unsanitary conditions and poor practices of the period (Wohl 1983; Thompson 1984; Rees 2001; Mays 2008; Jackson 2015). The effects of malnourishment and undernourishment were evident by the high rates of rickets and scurvy observed in St Hilda's, a pattern that was also confirmed by the comparative study. Consequently, the increased numbers of deaths in early life, when combined with the presence of active metabolic disorders such as scurvy and rickets are suggestive of the morbid effects of malnutrition and undernutrition in the mortality profiles of the population(s) under study. As discussed in the second chapter (section 2.4.2), poor diet can weaken and slow down the recovery of the immune system and cause recurrent infections and slow the healing of wounds (Bourke *et al.* 2016). Therefore, undernourished people, especially children, frequently fall ill with not enough time for recovery between various episodes of illness.

When the timing of the metabolic insults is considered, certain observations can be made. The presence of metabolic disorders in some of the preterm and neonate babies could suggest that maternal vitamin C and D deficiencies were passed from mother to child, representing the effects of the physically stressed mother's health and poor diet on the offspring (Morrone *et al.* 2021). The hypothesis of inherited deficiencies and poor maternal health is further supported by the fact that a high number of preterm and neonates existed in St Hilda's sample. Metabolic deficiencies should not be seen during such early life stages as vitamins and nutrients are provided via the maternal diet whilst in utero, or the breast milk following birth (Mays 2008; Morrison and Regnault 2015; Newman and Gowland 2016; Olmos-Ortiz *et al.* 2015).

a. Vitamin C and D Deficiencies and their Manifestations

Rickets rarely start before the fourth month because vitamin D passes from mother to foetus through the placenta and is stored in the infant's liver (Robert and Manchester 1995; Ortner 2003; Mays 2008, 216). The presence of rickets in St Hilda's preterm(s) was indicative of two facts: the mother's diet was deprived of vitamin D and the mother had limited exposure to sunlight (Mays 2018; DeLuca 2014). The second factor is perhaps more important as vitamin D is naturally present in only minor quantities in most foods, therefore the main source of vitamin D is sunlight since vitamin D is synthesised in the epidermis via exposure to sunlight (Olmos-Ortiz 2015). Respectively the same pattern was observed with Vitamin C deficiency. The deficiency rarely occurs in perinatal stages as ascorbic acid freely passes from the mother during gestation, unless the pregnant woman is deprived herself due to a lack of fresh fruits and vegetables, or poor food preparation techniques such as boiling or prolonged storage of foods (Ortner 2003, 384; Mays 2008, 223; Petersone-Gordina *et al.* 2013). As such, the affected individuals in such early stages of life are concrete evidence that the health status of the mothers was severely compromised. The statistically higher prevalence of scurvy amongst St Hilda's young children (ages 1-6) compared to other non-adult groups possibly reflects the time that scurvy needs to manifest. Infantile scurvy, like in case of rickets, is rarely observed before four months of age as it takes a few months until the deficiency becomes a recognisable disease (Ortner 2003, 384; Mays 2008, 223). Consequently, the presence of these deficiencies in early childhood may be suggestive of weaning stress from early cessation of breastfeeding practices and inadequate artificial feeds (Newman and Gowland 2016). The influence of breastfeeding and weaning practices on body sizes, child growth and mortality risk during the first year of life is well known showing the importance of breastfeeding during early development (Saarinen and Siimes, 1979; Rowland *et al.* 1981; Gualdi-Russo and Zaccagni 1998; Meinzen-Derr *et al.* 2009). The interaction between mother and infant via breast milk postpartum is important for the development of the infant immune system. Breast milk contains antibodies, cytokines, and other proteins that protect the infant against environmental pathogens (Cabinian *et al.* 2016). As a rule, the suggested age of weaning is around six months old, which is, incidentally, the time that baby teeth start to erupt. However, during the 18th and 19th centuries, the weaning ages frequently fluctuated and were often reduced for different reasons between different social strata (Wohl 1983; Rees 2001). As a result, the diet of infants during this period was considered an active cause of mortality which often occurred in the first months of life. Premature weaning exposed the infant's vulnerable immune system to bacteria and parasites, making those who suffered from malnourishment as a result of an improper weaning diet more prone to death from infections (Wohl 1983; Thompson 1984; Rees 2001; Lewis 2002).

Although the mother's milk is the ideal food, this option was not always available during the critical period in child development. Working-class mothers often had to accelerate the process of weaning and cease the process of breastfeeding at an early age in order to return to their work commitments (Wohl 1983; Rees 2001; Stevens *et al.* 2009). Among the higher strata of society, accelerated weaning process was also applied but for different reasons, breastfeeding was often seen as inconvenient or unfashionable, and the act had eventually become associated with the poor and lower strata of society. As a result, artificial feeding or wet nurses were employed as an alternative (Kolata 1987; Stevens *et al.* 2009). Of these means, artificial feeding was the most problematic. The immature digestive system was often not able to cope with solid foods resulting in digestive problems. Frequently the food and/or the feeding utensils were contaminated with pathogens resulting in gastrointestinal problems such as diarrhoea and subsequent dehydration and/or anaemia due to the inability to absorb iron (Kent *et al.* 1994; Wohl 1983; Rees 2001; Raynor *et al.* 2011). 'Suitable' weaning foods of the period included ‘pap’, and ‘panada’; pap consisting of bread soaked in water or milk, and panada, which consisted of cereals cooked in broth (Wickes 1953; Radbill 1981). Both substances were used as a supplement to animal's milk, especially when the infant showed a failure to thrive (Stevens *et al.* 2009). This type of diet, however, would provide none of the vitamins or proteins necessary for healthy development, but it would alleviate hunger (Davies and O’Hare 2004). From the 1860s and onwards, it was believed by ‘medical men’ that too many women who could nurse were turning to bottle-feeding and that bottle-feeding killed babies (Local Government Board 1914, xxxxix). That was due to the fact that milk was contaminated with bacteria that could cause infectious diseases such as bovine tuberculosis (Local Government Board 1914; Wohl 1983; Rees 2001). Consequently, because this child-rearing practice was often popular amongst the affluent, both scurvy and rickets cannot be seen solely as a deficiency disease of the poor (Boyle *et al.* 2005).

Another child-rearing practice of the period that might have contributed to the development of deficiencies (i.e. Vitamin D) and other complications in infants less than six months was swaddling, the act of binding a baby’s body tightly in a band of cloth frequently inhibited proper breathing; although the practice was progressively falling out of use from the 17th century and onwards (Cadogan 1748; May 2008). The use of this practice was for a range of health and safety reasons, it was believed that bound limbs grew straight, but this practice would mean reduced exposure to sunlight and therefore limited vitamin D synthesis (Cadogan 1748; Mays 2008).

Previously, in the 17th and 18th centuries, vitamin D deficiency seems mainly to have affected the children of the wealthy as they were trying to protect their children from the ‘evils’ of the outdoor environment by keeping them indoors, while the children of the poor were less affected as they were still bound to the land and therefore spent more time outdoors (Mays 2008). However, rickets became epidemic with the beginning of industrialisation and urbanisation due to brought changes which acted severely to limit also the exposure of the children of the poor to the sunlight. The children of the poor were now required to stay indoors but for different reasons, such as child labour and when they had the opportunity to go outdoors they still could not benefit from the effects of the sun because many of them had to work in indoor environments (Mays 2008, 219). According to the St Hilda’s burial registers, it would appear that the working-class girls were kept in more domestic environments, assisting in the running of the household. This indoor-based labour from morning to evening could have been a requirement of their mothers due to household labour division and/or social expectations which would have had the effect of preventing both mothers and young daughters from spending time outdoors during daylight hours (Gibbs, 1994; Newman 2015). Boys, on the other hand, were typically employed outside the domestic sphere; however, some still would have worked in an indoor-based environment; for instance, boys employed as pitmen in the collieries would have fallen into this category (Commission for Inquiring into the Employment and Condition of Children in Mines and Factories 1842). While these boys also spent most of the daylight hours hidden from the sun, they had the possibility of leaving the house in order to walk to work, whereas their female counterparts would possibly have not seen the sun on a daily basis as they were primarily housebound. Many exceptions, however, did occur as seen in the second chapter (section 2.2), with many female children and also adult females, working in typical male labour environments such as mines. Hence, leaving a possibility of some exposure of female children to sunlight even for limited time per day (Commission for Inquiring into the Employment and Condition of Children in Mines and Factories 1842, 24-30). It should be noted, however, not all male children were engaged in indoor-based jobs, and the burial registers evidence that children of the St Hilda's poor were also employed within the seafaring industry or other outdoor occupations; these individuals would have been engaged in outdoor-based apprenticeships such as shipwrighting, piloting and farming. This is not to say that these boys and males experienced a greater deal of sunlight than their indoor-based counterparts.

During the 19th century rickets was at peak among those who lived in semi-permanent light and whose diet was not adequate to compensate for the lack of sunshine (Roberts and Manchester 1997, 174; Waldron 2009; 128; Mays 2018). Urban dwellers' exposure to sunlight, particularly the poor, was limited (Wohl 1983; Mays 2008). Sunlight failed to penetrate narrow smoked-filled alleys which ran between tenements, and air pollution by industrial processes further exacerbated this problem by attenuating solar ultraviolet so that even when it did penetrate to ground level it was of little potency (Mays 2008 219-220). Consequently, the smoke-filled air prevented sunlight from reaching the skin. This was especially true for the most sensitive part of the population, the children (Ortner 2003, 393; Mays 2008, 219). Therefore, the presence of metabolic disorders such as rickets and scurvy were not only reflective of inherited deficiencies and dietary insufficiencies, or the child-rearing practices (i.e. weaning practices, swaddling etc.), but also reflected the prevailed social circumstances of the period as well as the environmental conditions (Mays 2008). Vitamin D deficiency was not an indicator of dietary deficiency per se but mostly reflects environmental aspects and living conditions that prevented adequate exposure to sunlight (Mays 2008, 219).

The natural climate of England combined with increased pollution in areas such as the North-East was also a predisposing factor to rickets as it resulted in a lower intake of sunshine hours than many other parts of the world. The number of solar hours in England is lower compared to other regions such as the Mediterranean due to the increased latitude. For instance, in Newcastle today, the average hours of sunlight per year is estimated 1,445 with an average of 1,493 for the whole country (Met Office 2019), as opposed to Greece, where there is an average of 3,043 sunlight hours per year (Mazarakis and Katsoulis 2006, 109). Since South Shields has a northern latitude of 55o N no dermal synthesis of vitamin D would have taken place in the winter months and vitamin D deficiency may have been seasonal (Watts and Valme 2018, 64; Veselka 2019, 129). It is likely that people experienced recurrent cases of rickets during the winter months. Typically, rickets are most often observed in children between six months and two years of age with recurrent episodes of seasonality during the sunless winter months (Wohl 1983; Robert and Manchester 1995; Ortner 2003). Seasonal vitamin D deficiency, especially in more northern latitudes, has previously been identified in the collection from St. Martin's, Birmingham (Mays *et al.* 2009). After the fourth year of life usually only a few cases of rickets develop (Robert and Manchester 1995; Ortner 2003). St Hilda's population seemed to fit this profile, as the majority of the affected immatures ranged from 1.5-4 years.

Regardless of the reasons for the lack of exposure to ultraviolet light in childhood, the fact that quite a few adults exhibited residual rickets indicates that this condition was not a cause of death itself in childhood but had long term implications for skeletal health, and might have worsened the overall health condition of those individuals. This indicates that in St Hilda's, despite the lack of sun in the Northern regions as well as the presence of coal smoke that prohibited the sunlight, there were other factors that allowed the recovery of the immature individuals, who eventually made it to adulthood. The value of a diet rich in fatty fish (i.e.

salmon, tuna, and mackerel) for overcoming episodes of Vitamin D deficiency in St Hilda's during childhood, especially in the dark months of the year, should not be overlooked. St Hilda's was a seaport town and fishermen were recorded in the burial registers, showing that fish was a potential source of Vitamin D. Therefore, it is likely that despite the thick coal smoke that diminished the sunlight in the city, the overcrowding, working long hours indoors, and social practices of the time that restricted time spent outdoors, the diet in South Shields perhaps played some role in the eventual recovery of the immature individuals who made it to adulthood (Hardy 2003; Roberts and Cox 2003). Given, however, how polluted the water sources themselves were a pescatarian-based diet itself could also be a further source of health problems (Mays, 1998). Other possible dietary sources of Vitamin D were beef liver, egg yolks, and cheese which may have also been consumed periodically throughout the year (Wohl 1983; Mays 2008).

This above observation for the existence of a recovery mechanism was in accordance with the results of Pinhasi *et al.* (2006) who observed after studying London, Christ Church and Broadgate, that there was no evident difference in growth between non-adults with rickets and non-adults without. Due to the increased number of cases of healed rickets within the sample of this particular study it was suggested that the lack of difference was a result of post-vitamin D deficiency catch-up growth due to a recovery mechanism (Pinhasi *et al.* 2006).

The presence of osteomalacia, the adult form of rickets, shows that despite St Hilda's individuals having overcome the danger of Vitamin D deficiency experienced during growth period, they were still at risk of Vitamin D deficiency after the cessation of growth in later life. The fact that individuals were equally affected by osteomalacia in adulthood is evidence of the prevailed conditions that prohibited the exposure of the individuals to daylight (Mays 2018). The indoor-based, long working hours that many individuals worked are likely to have made many individuals vitamin D deficient. This problem becomes significant when maternal health is considered. As was evident in a possible preterm case of rickets, discussed earlier, maternal deficiencies due to inadequate exposure to sunlight was an existing problem in St Hilda's which compromised the health of the immatures (Robert and Manchester 1995; Ortner 2003).

The combined numbers of individuals affected by rickets, residual rickets and osteomalacia in St Hilda's would appear relatively low in comparison to the reports of the period which described rickets as a major problem brought on by industrialisation. After an exhausting demographic analysis of the distribution of rickets conducted by the British Medical Association in the late 1880s, it was found that although the condition existed everywhere, the main areas of concentration were Tyneside and Tees towns, towns of Durham, Industrial Lancashire, Yorkshire, Cheshire, Derbyshire and Nottingham, the mining and industrial region of South Wales, and London (Wohl 1983; Mays 2018, 91). As Wohl (1983, 57) aptly pointed out, what can be observed in this thorough study is that '….while rickets were caused by both sunlight and dietary deficiency of Vitamin D, its geological distribution would appear to be related far more to the latter than the former'. Although geographically St Hilda's belonged to this group reported above, its prevalence in comparison to what was reported during this period of study appears low. This partially supports the hypothesis of a diet rich in Vitamin D, but what needs to be also considered is that what we see in St Hilda's and other similar sites represents severe cases which resulted in permanent mechanical deformations of the bones, rather than chronic deficiency (Snoddy *et al.* 2016). Once vitamin D levels are restored recovery occurs, and as a result the bowing deformities can be lost (D'Ortenzio *et al.* 2016, 153). This means that there were probably also 'lost deformities' or less severe cases that did not exhibit bowing deformities, but instead had milder symptoms and less apparent skeletal effects. Alternatively, this difference in prevalence could be due to the fact that this geographical analysis was conducted towards the end of the century when the effects of the Industrial Revolution on health were more apparent.

The comparative study revealed that most of the assemblages demonstrated similar rates of rickets between non-adults. No statistical differences were observed in the non-adult prevalence between most of the sites apart from St Marylebone, St Benet and St Bride's which exhibited higher prevalence of rickets than St Hilda's. This higher prevalence in St Marylebone and St Bennet was perhaps linked to the childrearing practices of the higher strata, where for instance they were swaddling their children and keeping them indoors to protect them from the outdoor pollution (Cadogan 1748; Mays 2008). Although the wealthier might have had a seemingly healthier and richer diet than the lower strata, their childrearing practices were questionable as to how beneficial they were to child-health. While in the case of the St Bride's, the site was from the poorest of the metropolis and therefore a poor diet combined with poor health possibly impacted the prevalence of rickets (Miles and Conheeney 2005; Mant and

Roberts 2015). The overall lack of substantial differences, however, indicated that non-adults of various socio-economic backgrounds were equally affected by the lack of vitamin D, thus revealing poor child rearing practices, a diet deprived of fresh fruits and vegetables and an environment so polluted that ultraviolet light failed to penetrate to ground level (Mays 2008, 219-220). When the prevalence rates of rickets were compared between St Hilda's adults and the rest of the sites, St Hilda's exhibited similar rates to most of the sites, apart from Coach Lane, St Bride's lower, Christ Church and St George's-named, which exhibited statistically lower prevalences. It is not unlikely that the different prevalence of rickets between sites was linked to socio-economic differences. In the case of Christ Church and St George's, the lower adult prevalence was perhaps due to favourable socio-economic parameters, such as a good diet, which worked as a 'buffer' to protect these individuals from manifesting rickets in their childhood. While in the case of St Bride's, the lower adult prevalence was perhaps due to the prevailed conditions in one of the most overcrowded parishes of the metropolis, which affected the individuals' survival prospects (Miles and Conheeney 2005; Mant and Roberts 2015). The lower prevalence of rickets (residual) in St Bride's adults, can be better understood when combined with the higher prevalence of the disorder seen in non-adults from this site. This combination can illustrate how the overcrowded unsanitary conditions of the metropolis impacted on the survival prospects of the lower strata non-adults, who failed to reach adulthood due to increased morbidity and mortality in early life (Mahoney-Swales 2012; DeWitte *et al.* 2015; Newman *et al.* 2019). St Bride's adults, who exhibited lower prevalence of rickets, reflect the population portion which was genetically and immunologically more robust and survived the various childhood risks; while, St Bride's non-adults reflect that portion of the population which was weak and did not make it to adulthood due to diseases such as rickets (Armelagos *et al.* 2009). Vitamin D deficiency in St Bride's non-adults would have weakened and slowed down recovery, leaving the immune system exposed to recurrent infections. Consequently, these deficient children from St Bride's would have possibly fallen ill without enough time for recovery between the various episodes of illness (Bourke *et al.* 2016).

When osteomalacia was compared between sites, the total rates of St Hilda's as well as the adult rates were both compatible with the rates of most of the sites where information on osteomalacia was provided. Consequently, no statistical differences were observed between sites, apart from St Bride's and St Pancras which exhibited statistically lower prevalences than St Hilda's. The difference is more obvious when the adult proportions are observed separately instead of the total population. In these two cases, it is suspected that the differences were methodological, mostly due to medium resolution analysis especially in the case of St Pancras where the assemblage was of a fairly large size.

The comparison of both rickets and osteomalacia rates between St Hilda's and various sites has shown that the Vitamin D deficiency targeted all layers of society independent of socio-economic status, confirming that rickets existed everywhere irrespectively. Vitamin D deficiency within St Hilda's and the sites was consequently the result of the prevailed outdoor conditions such as the smog that blocked a good portion of the sunlight, the socio-economic circumstances such as the employment of the working class who were forced to work in indoor environments such as the factories, and the childrearing practices of the period.

As opposed to vitamin D deficiency, which primarily reflects changes brought by Industrial Revolution which acted severely to limit the exposure of children and adults to sunlight, the presence of vitamin C reflects mostly, a diet inadequate in vitamin C due to deprivation in fresh fruits and vegetables, and poor food preparation techniques (boiling or prolonged storage of foods) and even food adulteration. The economy of South Shields, like many of the urban centres on the north coast, was primarily dependent on the production and transport of coal by sea (Foster 1974). When the St Hilda's burial registers were considered it was noted that a very small number of 'farmers' existed among the deceased confirming that this urban site, like the rest of the urban sites, had to rely on the surrounding agricultural regions for the supply of fresh fruits and vegetables and this was accompanied by significant issues. During the 18th and 19th centuries, the supply of fresh vegetables and fruit was erratic with irregular transportation of long duration, where the subsequent storage of the produce was problematic resulting in poor quality foods by the time they reached the consumers. The cost was often beyond the means of the urban poor with the good and healthy food being directly dependent upon the income of a person (Wohl 1983; Boyle *et al.* 2005; Newman 2015). As a result, the diet of the labouring strata was nutritionally poor, but also imbalanced in calories. It is thought that the labouring classes, on average, consumed around 2,099 calories per day. When this caloric intake is placed within the context of the Victorian lifestyle such as long working hours, arduous physical labour, and long walks to and from work, it is clear that the intake was insufficient for many (Wohl 1983; Hay and Rogers 1997). Often 3,500 to 4,000 calories are recommended by modern standards for those engaged in heavy physical labour (Wohl 1983; Shammas 1984).

Differences existed in the diet and subsequent caloric intake between rural and urban populations. Public health reports from the 1860s show per-head calorie levels of indoor workers in domestic industries (silkweavers, glovers, stocking-knitters, and shoemakers) at 2,190 calories, and rural labourers at 2,760 calories. Factory families in normal times consumed amounts similar to those of the rural workers. Single factory operatives did even better although many of their additional calories came from increased intake of sugar (Shammas 1984, 258). It would also appear that differences existed between the North and South in terms of the diets of the working classes. The Northern regions experienced better diets and higher caloric intake, but this is not to say that the diet was much better and the caloric intake adequate, rather that people in the South suffered a poorer diet than in the North. The caloric superiority of the North can be explained primarily by its greater expenditures on oatmeal, milk, and potatoes at a time when the South, having departed more precipitously from the traditional dietary regimen, spent its money on wheaten bread whether due to a lack of availability of other staple food sources or general preference (Shammas 1984; Sinnott 2013; Gowland *et al.* 2019).

Consequently, the Victorian working-class diet was heavy in carbohydrates and fats, low in protein, and deficient in several vitamins (Wohl 1983, 51). Public health reports of the period show that the staple diet of the time for the majority of society was bread and potato. While seasonal fruit and vegetables comprised a very small proportion of the daily diet due to their seasonality as well as rising prices due to crop failures and famines that resulted in increased popularity of cheap foods; sugar, tea and beer became the staples of the working class (Wohl 1983; Shammas 1984; Sinnott 2013). Sugar, with its quick energy release and caffeinated drinks such as tea undoubtedly resulted in a calorie loss for households everywhere in England (Shammas 1984, 258). Other basic products included cheese, butter, treacle broths and stews (Olsen 1999, 235). Meat was also part of the diet but only in small amounts and once per week, many of them had never tested ‘real’ meat apart from bacon. The Privy Council estimated in 1862 that one-fifth of all butcher’s meat in England and Wales came from animals who were considerably diseased or died from pleuropneumonia and anthracid diseases (Wohl 1983, 53). In addition to the public reports, analysis of calculus residues from Victorian population samples conducted by Hendy *et al.* (2018) revealed that the Victorian working-class diet included proteins derived from plant foods including oats, peas, vegetables in the cabbage family, and milk.

There is no doubt that the main foodstuffs consumed by the lower strata were poor in vitamin C, apart from potato which was an important source of vitamin C during this period. The importance of potato in vitamin C intake for the Victorian classes was significant; however, the availability of it was frequently at risk such as in the case of famine and other hardships (Geber and Murphy 2012). The potato became widely grown in Britain during the early 19th century and gained popularity in Northern counties like Lancashire where the soil was ideal for their cultivation (Mason 2004, 30). If potatoes were consumed (even if they were eaten cooked) in larger amounts by the poor, the lower classes would have developed no vitamin C deficiency (Gowland *et al.* 2019). However, the popularity and low price of bread limited the popularity of potatoes. This was true for most of England except some of the Northern regions where the potato gained popularity, possibly due to the Irish populations living there. In Ireland, the potato was the staple food of the whole country (O'Grada 1995). In neighbouring England, white bread was preferred by all classes (Mason 2004, 29). When the potato was removed from the diet due to seasonal unavailability or famine, it also eliminated a vitally important source of Vitamin C.

A common problem of the period linked to the degradation of the nutritional value of these staples was the practice of adulteration which made the potato and some seasonal fruits and vegetables the only source of vitamin C. However, as it was seen in an earlier section (2.4.2), during this period even lime juice - which was crucial for the battle against scurvy - was also frequently adulterated (Anonymous 1866, 9). The majority of the urban inhabitants would have consumed ready-made products such as bread and tea which came with a significant risk of contamination and adulteration and low vitamin concentration (Hassall 1857; Anonymous 1860; Rahman and Rashid 2015; Fisher 2017). Food adulteration also came with many long-term health implications such as chronic gastritis, and fatal food poisoning due to the toxic additives which were used either to give an appealing colour to the food product or to increase their quantity and size (Wohl 1983, 53).

Another poor practice of the period that resulted in the degradation of the nutritional value of the seasonally available fresh fruits and vegetables was the poor food preparation techniques. Fruits and vegetables are rich in vitamin C, however, when they are cooked, stored or preserved for long periods their nutritional value is lost. During the period in study, a common misconception prevailed along the social-classes which is that when left uncooked, the foods had a deleterious effect on health, especially of the children (Bayne-Powell 1939; Sinnott 2013. For example, in Mrs Beeton's 'Book of Household Management' published in 1861 there is a small section in vegetable preparation and recipes (Beeton 1861; Newman 2015). In her recipe for cooking carrots, she recommends they need to be cooked for up to two and a half hours, while for broccoli she recommends twenty-five minutes, and boiled beetroot is to be cooked for up to three hours (Beeton 1861). This method of long cooking effectively would have left no Vitamin C.

Other possible contributory factors to vitamin C deficiency during the period in study include alcohol and smoking which were both consumed, especially by the working class (Wohl 1983; Perry *et al.* 2018). Smokers and second-hand smokers have a higher vitamin C turnover (Schehtman *et al.* 1989; Seri 1999), while alcoholics are among the few groups which regularly present scurvy in modern clinical contexts due to increased vitamin C metabolism (Leger 2008; Sinnott 2013). It is unlikely that it had a huge effect on the population just by itself, but when combined with other poor practices of the period, it may have had an accumulative effect on vitamin C levels. In both South and North Shields as well as Newcastle, a great portion of the population was occupied in the seafaring industry where people indulged in alcohol drinking as well as smoking and the chewing of tobacco (Boston *et al.* 2008, 47). Smoking tobacco aboard ships was a common practice among non-navy seamen as opposed to navy sailors and mariners, such as in the case of Greenwich Tier, where they were forbidden to smoke aboard wooden ships loaded with explosives. Chewing of tobacco aboard navy ships, however, was not prohibited (Boston *et al.* 2002, 47). As scurvy was rife among the seafarers during long voyages due to the lack of fresh fruits and vegetables, it is likely that these long-standing social practices (i.e. smoking and tobacco chewing), maintained the problem of scurvy even in cases were the cure, lemon and lime juice, was provided (Anonymous 1866). Other contributory parameters for the prevalence of scurvy include fever, infections and stress and therefore scurvy can set in quickly when the body is harassed by disease or stress (Sinnott 2013; Carr and Maggini 2017).

Comparison between St Hilda's adults and the various sites in terms of the prevalence of scurvy was problematic due to a lack of adequate evidence on the adult rates of scurvy; scorbutic lesions in adult skeletons tend to be relatively minor and non-specific, making the diagnosis rather difficult, and as a result only the extreme cases are detected (Ortner 2003). St Hilda's total population exhibited a higher prevalence than most of the sites apart from Greenwich Tier and Cross Bones cemetery, indicating perhaps status similarities between these three sites. South Shields was a seaport town with a big portion of the population being occupied in the seafaring industry; Greenwich Tier was also a place where retired sailors and mariners were buried, while Cross Bones was a site of paupers with workhouses in close vicinity. As seen in second chapter, scurvy famously afflicted sailors of Britain's Royal Navy and merchant sailors, but it also occurred sporadically in other social groups such as long-term prisoners and workhouse inmates, and it was prevalent during years of famine (Cook 2004; Boyle *et al.* 2005; Geber and Murphy 2012; DeLuca 2014). For the rest of the sites, it would appear that non-adults were the primary focus for the recording of the lesions, because in terms of diagnosis the lesions were more specific in this group compared to the adults, but also due to the importance of diet to the survival prospects of growing children (Shammas 1984). No statistical differences were observed in the non-adult prevalence between most of the sites apart from St Martin Birmingham which exhibited lower prevalence of scurvy than St Hilda's. The reason for the difference between St Martin and St Hilda's was unclear as both sites were of working-class origin and the living conditions were detrimental (Brickley *et al*. 2001). However, as it was seen in the second chapter, despite the prevailed unsanitary and unhygienic conditions, Birmingham was described as one of the healthiest large towns at the time (Commission for Inquiring into the State of Large Towns and Populous Districts 1845a, 198). The overall lack of substantial differences, however, indicated that non-adults of various socio-economic backgrounds were equally affected by the lack of vitamin C revealing poor child rearing practices, a diet deprived of fresh fruits and vegetables, and poor food preparation techniques (boiling or prolonged storage of foods) and even food adulteration (Mays 2008, 219-220).

During this period of study, scurvy was known to make no exceptions and a number of deaths affecting both adults and non-adults were listed in London Bills of Mortality (Roberts and Cox 2003; Brickley *et al.* 2006). Further to this the evidence of it in individuals under the age of four months across the sites is indicative of maternal scurvy although it appears not to have been recorded among young females, suggesting that the offspring were deficient because the food source (e.g. breast milk) and the mother herself was vitamin C deprived. A possible explanation, however, to the limited number of adult lesions among the rest of the sites could also be the aforementioned decrease in skeletal manifestation with increasing age (Mays 2008, 223).Despite the aetiology behind the limited number of scurvy lesions between many sites, the lack of statistical differences between the non-adults has shown that the Vitamin C deficiency targeted all layers of society independent of socio-economic status, confirming that scurvy existed everywhere irrespective of the low finances of the poor, and also because of the preparatory practices of the period such as adulteration and overcooking. Children, irrespectively of socio-economic status were the most vulnerable part of the population to the effects of the poor urban diet due to their increased demand for high caloric intake as part of the growing process (Shammas 1984). It would appear, however, that adults were not exempt from the effects of a poor and imbalanced diet either.

In St Hilda's, scurvy and/or rickets were also found to simultaneously occur with other non-specific infections or metabolic conditions. Scurvy and/or rickets were found in some cases to simultaneously occur with non-specific infectious conditions positively linked to industrialised environments (i.e. maxillary sinusitis and pleurisy) (Khanna and Gharpure 2012; Krenz-Niedbała and Łukasik 2016). The co-occurrence of metabolic disorders with other infections within St Hilda's assemblage shows immune system vulnerabilities (Ives 2018). Rickets and scurvy were found to simultaneously occur with conditions positively linked to industrialised environments, possibly reflecting the polluted environment that the studied population was exposed to. In five individuals affected by rickets, maxillary sinusitis was also present and rib lesions associated with pleurisy occurred in two. The co-occurrence of maxillary sinusitis and evidence of rickets was in accordance with modern clinical studies which have found that patients with chronic rhinosinusitis exhibit lower vitamin D levels (Stokes and Rimmer 2016). Consequently, within the population under study, individuals deficient in vitamin D and C would have been more prone to contract other infectious diseases due to the susceptibility of their immune system. Pneumonia, tuberculosis and whooping cough were reported to co-occur due to the common origin of dark overcrowded and poorly ventilated houses (Hansen 1938; Hardy 1994).

In the case of vitamin D, the co-occurrence with infections was not unexpected; as seen in the second section, vitamin D plays a major role in modulating both innate and adaptive immunity (Morrison and Regnault 2015; Olmos-Ortiz 2015). As a result, rickets can hinder immunity leaving the patients vulnerable to other infections and slowing down the recovery from episodes of disease (Walker and Modlin 2009). In particular, clinical rickets has been associated with risk of mortality and serious infections such as pneumonia, tuberculosis and whooping cough, as well as susceptibility to common colds and influenza (Hansen 1938; Muhe *et al.* 1997; Thornton *et al.* 2013; Rosen *et al.* 2016; Ives 2018; Ngari *et al.* 2018). Analysis of the patient records of 907 cases of 'whooping cough' from Germany, admitted to Children's Clinic of the Medical Academy Düsseldorf in 1931/32 and 1935/36, showed that the duration of the disease was longer in rachitic children. The incidence of bronchopneumonia in whooping cough was recorded twice as high in rachitic children, and was especially frequent in the second six months of life (Hansen 1938, 136). This co-occurrence of rickets and infectious diseases such as 'whooping cough' also demonstrates the role of a generally compromised nutritional status in the spread of infections (Duncan *et al.* 1996; Duncan *et al.* 1997; Duncan *et al.* 1998; Ives 2018). Children with severe rickets were found to be affected by repeated episodes of severe infections (Ngari *et al.* 2018). This can also be seen through the fact that infectious diseases are frequently followed by another in a short time. For instance, in the 19th century, whooping cough outbreaks often followed measles epidemics due to reduced nutritional status, which left the individuals exposed to contracting other infections due to depleted deficiencies which did not allow recovery (Hardy 1993; Newman 2015). Those who demonstrated both rickets and infectious diseases such as whooping cough were less likely to survive the course due to shrunken chest from rickets and weakened immunity (Wohl 1983, 57).

For those non-adults who had no evidence of infection, but exhibited vitamin C and/or D deficiencies, the presence of deficiencies combined with the premature age of death are indirect indicators which show how compromised the immune system of these individuals was and how vulnerable they were to infections. Perhaps these deficient individuals had either contracted an infection that had no skeletal involvement such as whooping cough or they died by something acute that did not have enough time to affect the skeleton (Wood *et al.* 1992). Regardless of the lack of any infections, the premature age of mortality of these deficient individuals shows that they had compromised immunity, revealing the role of metabolic status in the contraction of infections (Duncan *et al.* 1996; Duncan *et al.* 1997; Duncan *et al.* 1998). The same principle could also be applied to those adults who had only deficiencies, but no other obvious cause of death.

b. Manifestations of Anaemia and Other Indicators of Malnutrition and Illness

CO was also another indicator of poor health, which was noted along with rickets and scurvy; with some individuals exhibiting scurvy and CO and some others exhibiting rickets and CO simultaneously. The co-occurrence of scurvy and/or rickets with CO reflected again a combination of poor diet, maternal deficiencies, bouts of disease episodes, poor environmental conditions, customs and hygiene and lifestyle manifested through a compromised immune system (Stuart-Macadam 1992; Walker *et al.* 2009). Considering the role of vitamin C in iron metabolism, the co-occurrence of scurvy with CO should not come as a surprise, while CO may also be secondary to bleeding on periosteum from scurvy (Ortner 2003; Wapler *et al.* 2004). The co-occurrence of conditions affected not only St Hilda's assemblage but also the comparative sites (e.g. St Benet Sherehog and Cross Bones) once again confirming that the experienced detrimental conditions were irrespective of social status and geographic region as individuals were unable to isolate themselves.

CO was, however, not limited to co-occurrence with metabolic states but it occurred in its own right. CO can frequently be an indicator of iron deficiency anaemia, which was an active cause of death during the period of study among certain age groups such as infants and females of childbearing age (Registrar-General 1875, 151). It would appear, however, that only severe anaemia produces CO (Cole and Waldron 2019). Apart from anaemia related reasons, the lesions can be triggered by other conditions as seen in scurvy due to bleeding on the periosteum from rapid movement of the eyes (Ortner 2003).

The aetiology behind the formation of these non-specific lesions remains up to now multifactorial and frequently complex to understand, therefore one-to-one correlations for the population in study were impossible to make. Given, however, the prevailed unsanitary conditions and circumstances the individuals from this period lived, it is proposed that the poor diet and low standards of hygiene such as inadequate sanitation, crowded living conditions and contaminated water and food sources probably provide ideal nexus for pathogen growth and transmission (Palkovitch 1987; Stuart-Macadam 1987b; Walker *et al.* 2009). Based on that numerous other potential causes for the orbital roof pathology, outside metabolic states, can be proposed ranging from various inflammations of the lacrimal glands known as dacryoadenitis, through common childhood diseases such as whooping cough and measles, to gastrointestinal infections birth trauma and other trauma (Cole and Waldron 2019).

During the period of study lacrimal gland inflammation due to poor hygiene and exposure to widespread fine dust and sand would have kept the eyelids in a continual state of inflammation with children being at higher risk than adults (Cole and Waldron 2019, 617-618). An extreme form of lacrimal gland inflammation during the 19th century was 'ophthalmia neonatorum' which appears in the first 28 days after birth arising from bacterial or viral infection during birth. This form is so particularly dangerous to infants, frequently leading to blindness, that it was listed as a notifiable disease in the Infectious Disease (Notification) Act of 1889 (Cole and Waldron 2019; Castro Ochoa and Mendez 2021).

During the period of study, the large numbers of people living in close proximity would have favoured the spread of disease by direct transmission (Stuart-Macadam 1985; 1992; Pandey *et al.* 2014). These negative effects of unsanitary living conditions on the immune system would have also been manifested through diarrheal diseases and parasitic infections. Diarrheal diseases and parasitic infections were a significant problem during this period, with the reported numbers of deaths from diarrhoea, dysentery or outbreaks of infectious diseases that had diarrhoea as a symptom (e.g. cholera) being significantly high (Registrar-General 1842; 1845; 1850; 1859). Diarrheal diseases would have resulted in inability to absorb nutrients and minerals because the food passed too quickly through the gut, while parasitic and bacterial infections would have induced anaemia due to internal bleeding. In the case of non-adults such acute and chronic infections would have also stimulated their sensitive immune systems to withhold nutrients, particularly iron, from invading microorganisms as a defence mechanism (Walker *et al.* 2009, 113). It has been suggested that mild anaemia is advantageous to the individuals as it hinders the spread of bacterial infections (Roberts and Manchester 1997). Therefore, such depletions may have resulted not only from mal- or under-nutrition or insufficient intake of such nutrients but also from the body's natural defence against chronic diarrheal disease and parasitic infections (e.g. malaria) (Roberts and Manchester 1997; Mahoney-Swales 2012; Ishag 2016).

Maternal iron or B12 deficiencies cannot also be excluded as a possible aetiology in St Hilda's especially when the high number of preterm and neonates is considered (Wapler *et al.* 2004*;* Walker *et al.* 2009, 119). It has been found that maternal anaemia and malnutrition adversely influence the course and outcome of pregnancy, affect foetal growth and birth weight, result in premature birth and contribute to perinatal mortality, and the development of iron deficiency within the first three months of life. Further to that, rapid succession of pregnancies which was common due to a lack of contraceptives may have also aggravated pre-existing nutritional anaemias resulting in infants of low birth weight with early iron deficiency (Zhang *et al.* 2009; Abu-Ouf and Jan, 2015; Figueiredo *et al.* 2018). Genetic anaemias can also be another aetiology especially in the presence of PH (Cole and Waldron 2019, 619). PH has been repeatedly reported in genetic anaemias such as sickle cell anaemia and haemolytic anaemia and in clinical cases of anaemia, but only very rarely in chronic iron deficiency anaemia (Cole and Waldron 2019, 619). Nonetheless, the connection of PH and CO remains complex and not clearly understood. Thus, the similar appearance of some stages of PH and CO does not always imply the same aetiology as it was also established within St Hilda's where not all individuals exhibited both CO and PH.

With childhood diseases being rife during this period, their presence would have also favoured the formation of the lesions by haemorrhage. These would include, for instance, whooping cough and measles. This would be either due to coughing induced trauma or due to compromised nutritional status anaemia due to immunological vulnerability (Duncan *et al*. 1997 and Duncan *et al.* 1997b; Cole and Waldron 2019). While other causes of orbital bleeding could be of traumatic origin caused during difficult births or during heavy weight lifting that caused central vascular constriction (Cole and Waldron 2019).

The negative effects of contaminated water sources and fish and sea mammal-borne parasites should not be overlooked in the case of seaport towns such as South Shields which was heavily polluted (Stuart-Macadam 1985; 1992; Pandey *et al.* 2014). Studies of marine dependent populations indicate that contaminated water sources and fish and sea mammal-borne parasites can also explain the prevalence of anaemia in populations that focus on marine resources (Kent 1986; cited in Mays, 1998, 144). Therefore, it is possible that the presence of anaemia could also be due to a marine dependent diet from contaminated waters. Further to the local sources, the presence of CO within St Hilda's population may also be indicative of a cereal-based diet which would have been detrimental to iron levels, but would have at least seasonally alleviated vitamin deficiencies (Stuart-Macadam 1992). Stock raising practices and subsequent meat consumption would have been helpful to decrease iron deficiency, however meat during the period of study was expensive and frequently came from unsuitable animals (Privy Council, 1862). Consequently, a diet high in cereal content or a diet seemingly rich in iron that had suffered the 'hidden' processes of adulteration would have led to a poor diet with little nutrients, while at the same time resulted in other health complications due to the consumption of contaminated sources. Therefore, the increased prevalence of CO in St Hilda's reflects the function of a diet poor in iron and the low standards of hygiene such as inadequate sanitation, crowded living conditions, sedentism, aggregation and contaminated water sources which provided ideal conditions for pathogen growth and transmission during the 18th and 19th centuries (Palkovitch 1987; Stuart-Macadam 1987b; Walker *et al.* 2009).

No statistical differences were observed between the different age categories of St Hilda's despite the higher prevalence observed among young children and young and older adults. The higher prevalence in these three age categories, although not statistically significant, may indicate that individuals who survived early childhood stress manifested for instance as CO, were stronger individuals and after overcoming the second crucial stage of early adulthood survived to reach older adulthood when compared to those individuals without porotic lesions. Alternatively, individuals of older age groups may have become victims of a decreased immune response and therefore succumbed to pathogens that cause cranial porotic lesions. Study of the 'active' or 'healed' state of the porotic lesions, however, provided a further explanation. More than two thirds of the affected adults exhibited healed lesions, showing that the individuals had survived early episodes of CO due to a strong immune response, while active lesions in senior adult categories would support the hypothesis that they were succumbing to immune system assaults due to increased pathogen load in later life

(Mahoney-Swales 2012, 211). However, the hypothesis of increased prevalence of CO with age due to a decline in immune response was less convincing due to the aforementioned lack of statistical differences between the different adult age categories described above. The pattern of strong immune response due to insults in childhood was also confirmed with the presence of residual rickets.

The hypothesis of a strong immune response due to early life health insults was further confirmed through the study of age-at-death in the osteological and burial registers from St Hilda's. As was discussed earlier, the approximate osteological life expectancy in St Hilda's was between 26-45 years for those who managed to overcome the crucial point of early life, with a great percent of these deaths occurring between 36-45; this observation is further supported by the burial registers that gave an even higher life expectancy. A significant proportion of the population in South Shields managed to reach later life despite the demanding lifestyle of the period, the proportion of adult age-at-death within St Hilda's increased gradually until peaking between 66-75 years of age, and continued at a steady proportion before beginning to drop from 76+ years. This observation was further supported by the annual deaths data from the Registrar-General (1842; 1850), where the adult age-at-death within the Northern counties exhibited an increased number of deaths between the ages of 66-75 and after that point the numbers dropped, thus confirming what was observed in St Hilda's burial registers. Similar was the pattern throughout the rest of the country. For instance, in London, the age-at-death remained steady and then increased gradually until peaking between 46-55 years of age, and then continued at a steady proportion before dropping from 66-75 years and onwards.

This lack of substantial difference for the prevalence of CO is perhaps indicative that everybody during childhood was equally exposed to acquired and maternal dietary deficiencies, poor weaning practices, or even infections arising from increased mobility through the development of crawling and consequently a higher risk of exposure to pathogens (Mays 1998; Mahoney-Swales 2012). In the case of biological sex, the prevalence of CO was in accordance with the findings of Stuart-Macadam whereby no differences between males and females were observed (1985; 1998). Therefore, sexual distribution did not follow any specific pattern; it would be expected, however, despite the lack of any substantial differences that the underlying aetiologies behind these active lesions were different between males and females and different adult age groups. In the case of breadwinners, the presence of the lesions was possibly due to the demanding lifestyle of the working-class males and a diet inadequate to cover the needs of this socio-economic group. Considering the fact that women of childbearing age and infants suffered increased mortality from anaemia during this period (Registrar-General 1875), it is likely that the presence of the lesions among St Hilda's young females was possibly attributable to the blood loss associated with menstruation and multiple childbirths. In the case of the senior adults, it was possibly due to decline in immune response due to the ageing process, as discussed.

The absence of peaks in the prevalence of CO between different groups shows that blood loss due to reproductive functions, or a demanding lifestyle which required a higher caloric intake that was never met, were not the primary cause of CO in this population. The lack of statistical difference between the various groups within the assemblage implies CO was caused by exogenous factors such as pathogens to which the affected individuals did not succumb but through a strong immune response developed anaemia, creating a hostile environment for the pathogens. No statistical differences were also observed between St Hilda's non-adults and the comparative sites on the occurrence of CO apart from the site of Cross Bones which was a pauper site and therefore the maternal and child diet and living conditions were more detrimental in relation to the other sites. Consequently, it would appear that non-adults from various sites were all affected to some extent by anaemia and its multifactorial aetiologies which are linked to iron malabsorption. This is suggestive that non-adults were equally exposed to infectious agents despite any background differences. Alternatively, the presence of CO may indicate an adaptive response as a coping mechanism to the stressful industrialised environment showing a strong immune response to infections.

Another condition frequently seen along with CO is DEH. More than one quarter of St Hilda's adult population was found to have experienced at least one episode of significant illness or malnutrition that lasted more than three weeks during their childhood, as evidenced by the presence of DEH (Hillson 1996). This indicated that the individuals' health was compromised physiologically but they recovered. From the thirty-two adults affected by DEH within St Hilda's, eleven exhibited co-occurrences of DEH with CO with seven having healed CO lesions, while two of them had also residual rickets and scurvy (Hillson 1996, 165-166). These results were in accordance with what was found by other researchers that have linked the co-occurrence of DEH with CO and reported the presence of DEH in the unerupted teeth of children with conditions such as rickets, scurvy, measles and smallpox (Hillson 1996; Keenleyside and Panayotova 2006; Obertova and Thurzo 2007; Ogden *et al.* 2007; Salanitri and Seow 2013). Consequently, the co-occurrence of these conditions within St Hilda's was evidence that the individuals went during childhood through multiple episodes of physiological stress. These metabolic insults could include dietary deficiencies, weaning, bouts of childhood diseases, and nutrient losses due to acute diarrhoeal disease while other possible insults include poor maternal health, premature birth, maternal vitamin D or other maternal deficiencies such as iron deficiency, and low maternal B12 reserves (Purvis *et al.* 1973; Mittler *et al.* 1992; Roberts and Manchester 1997, 58-61; Seow 1997; Aufderheide and Rodriguez-Martin 1998, 405; Hillson 1996, 165-66; King *et al.* 2005; Ogden *et al.* 2007, 957; Ford *et al.* 2009; Mahoney-Swales 2012). Hence, the defect should be seen as the result of a combination of acute infections and malnutrition, which the malnourished individuals are more susceptible to due to low immune response (Wells 1964).

Further to these correlations, it has been found that DEH is more prevalent in younger siblings of individuals affected by acute diarrhoeal disease than in a population as a whole, as is the case with CO (Mittler *et al.* 1992; Aufderheide and Rodriguez-Martin 1998; King *et al.* 2005; Ogden *et al.* 2007). This relationship suggests that CO and DEH may be attributable to endemic disease transmission by close contact or weakened immune systems resulting from prolonged periods of diarrhoea or childhood illnesses, including periods of fever. Such transmission would be exacerbated by poor hygiene levels and overcrowding. Therefore, DEHs may be possible indicators of unhygienic or crowded living conditions (Mahoney-Swales 2014, 124).

Apart from these multiple aetiologies that are applicable to any chronological period, Roberts and Cox (2003, 311-312) discussed that another possible factor for the particular period in study that may have also played a role in the interruption of normal tooth development was food adulteration, which was widely used in the 18^{th} and 19^{th} centuries due to mass production and the developed marketing techniques of this period. During this period much of the food consumed was adulterated by foreign substances and contaminated by chemicals or 'befouled by animal or human excrement' (Anonymous 1860, 86-96; Wohl 1983; Rees 2001). In the case of milk, for example, the Local Government Board found in 1877, that approximately a quarter of the milk that was examined contained excessive water or chalk (Local Government Board 1878, xxxvii). In the case of bread which was one of the dietary staples of the lower classes, Dr Hassall in its investigation into food adulteration demonstrated that half of the bread he examined contained a considerable amount of alum (Hassall 1855, vi). Alum, although it is not itself poisonous, its digestion could lower the nutritional value of other foods (Wohl 1983, 53). According to the Privy Council (1862), one fifth of butcher's meat in England and Wales came from animals that were considerably diseased or had died of pleuro-pneumonia and anthracid or anthracoid diseases (Anonymous 1860, 86-96). Consequently, the processes of adulteration led to a poor diet with little nutrients, especially to the growing individuals, while at the same time resulted in other health complications.

The majority of hypoplastic defects observed in the recorded dentition ranged from 2-4 years, with the results being consistent with those of Christ Church, Spitalfields and St Brides (King *et al.* 2005, 547). The timing of these defects within St Hilda's adults correlates with the observation that young children below the age of five were the most susceptible to nutritional deficiencies and exposure to pathogens due to weaning practices.

DEH has been linked to decreased life expectancy due to biological damage to the immune system of the affected individual during prenatal or postnatal development, which reduces an individual's resistance to disease (Goodman and Armelagos 1989; Duray 1996; Mahoney-Swales 2012). Further to this, whether an individual develops the defects in response to dietary or physiological stress is partially determined by the susceptibility of their immune system (Palubeckaite *et al.* 2002, 190). Consequently, the above explanation might be the reason why middle adults within St Hilda's were more affected in comparison to other age groups. Perhaps the higher prevalence observed in middle adults was to do with the fact that these individuals were born at the peak of industrialisation in South Shields and therefore were more affected in comparison to other groups who were born slightly earlier or later. These individuals were born to immunologically weak parents, suffered from the effects of industrialisation at birth, and after surviving this crucial stage into older childhood, had to contribute to the family earnings from a young age until adulthood. As a result, their immune systems were affected from an early age and subsequently weakened in comparison to other age groups.

When St Hilda's DEH adult rates were compared to the comparative sites, it was impossible to define a particular pattern between sites of similar socio-economic background, showing that no patterns existed between sites of different socio-economic status indicating that everyone was exposed to a certain extent to various insults for longer than three weeks. However, preservation and time-limitation issues across the sites were also suspected (Hillson 1996).

In the case of St Hilda's non-adults, the prevalence of DEH was fairly low given its known working-class origin and the high prevalence of other indicators of childhood stress, such as CO and rickets. This, however, does not imply that the St Hilda's non-adults were unaffected by the factors that cause the formation of DEH but quite the opposite; it shows a weak immune response to the stressful event(s) where the individuals died in less than three weeks' time, which is the required time for the lesions to manifest, leaving behind no evidence of disruption (Hillson 1996, 165-166). Another reason behind such variation between sites may reflect inter-observer differences in identifying DEH; frequently the hypoplastic lesions resemble the normal incremental growth lines of tooth enamel, known as perikymata (Hillson 2002).

Despite the aetiology behind the low prevalence of DEH, the presence of the lesions was evidence that St Hilda's non-adults experienced at least one direct or indirect episode of significant illness or malnutrition which interrupted or slowed down the normal deposition of enamel during crown formation (Boston *et al.* 2008). However, the wide range of metabolic and biological variables involved in both the host and the perceived nature of the stressful events makes any precise correlations impossible (Roberts and Manchester 1997, 58-61; Aufderheide and Rodriguez-Martin 1998, 405; Hillson 1996, 165-66; Ogden *et al.* 2007, 957; Mahoney-Swales 2012).

Another non-specific evidence of episodes of significant illness or malnutrition that St Hilda's non-adults experienced was endocranial lesions. The lesions may be the result of a variety of assaults that result in inflammation or haemorrhage of the meninges (Lewis 2004; Vattoth *et al.* 2013). The exact aetiology, however, of these lesions is still open to debate, the list of possible aetiologies includes; primary or secondary infections of the meninges, tumours, tuberculosis, syphilis, trauma, and vitamin deficiencies of A, C and D which may all result in tearing or inflammation of the meninges causing new bone formation (Lewis 2004, 93).

Regardless of the underlying cause, haemorrhage and infection-causing-meningitis may be manifested endocranially when there is enough time for the lesions to develop (Lewis 2004).

Infectious disease, particularly when there is an involvement of the brain meninges, is both a common cause of infant death in historic populations and in developing countries today (Registrar-General 1842; Bonar 1937; Naidu *et al.* 2001; Liston *et al.* 2018). The infant immune system is underdeveloped, and in the first few weeks of life, babies receive many of their antibodies from maternal milk. Even with this source, however, the young infant may be unable to resist infection effectively and can develop serious complications (Liston *et al.* 2018, 46). Congenital and neonatal infections are a common problem even in modern hospital births, and it was also a significant factor in foetal and infant morbidity and mortality during the period of interest (Registrar-General 1842; Vergano and Heath 2013; Liston *et al.* 2018). Infections, particularly tetanus, remain until today a common cause of perinatal death in underdeveloped countries, and prior to the advent of antibiotics were responsible for 30% of neonatal deaths in London (Bonar 1937; Liston *et al.* 2018). Group B *Streptococcus* and *Escherichia Coli* are among the most common causes of neonatal meningitis (Vergano and Heath 2013, 726). Infections from the umbilical cord are quite common under conditions of poor sanitation; intrauterine infections probably are also a factor in these deaths (Liston *et al*. 2018, 47), while other modes of transmission include via the placenta during pregnancy causing congenital infections, during breastfeeding or from the environment during delivery, and the neonatal period from the environment (Vergano and Heath 2013, 723). Therefore, it is likely that infection played a significant role in the deaths of infants in St Hilda's population.

Intracranial haemorrhage due to birth trauma is a common result of complicated or prolonged labour (Liston *et al.* 2018, 46). Intracranial haemorrhage is also a common complication of premature birth due to fragility of the underdeveloped blood vessels of preterm (Chen and Lorch 1996). Severe dehydration results in intracranial haemorrhage due to brain shrinkage and the tearing of membranes. Dehydration can develop due to excessive fluid loss associated with vomiting or diarrhoea, or to limited fluid intake as a result of inadequate nursing (Beers and Berkow 1999).

Nearly 10% of the immature cranial vault bones had evidence of endocranial pathology. Among the affected cranial bones in this population, lesions were identified on the frontal, parietal, temporal, occipital, and sphenoid bones. At any age, infection, dehydration, and haemorrhage, even when lethal, will result in visible bone involvement in only a small percentage of individuals. It is likely that many more of these infants died from common perinatal diseases, but did not survive long enough for skeletal involvement to occur (Liston *et al.* 2018, 47). In order to narrow down the list of possible aetiologies the lesions were combined with any other skeletal lesions that may suggest a specific pathology. However, where there were no patterns pathognomonic for the diagnosis of a systemic condition, the condition was merely seen as a non-specific indicator of haemorrhage or infection (Lewis 2004). An interesting case was that of an affected young child of 1-1.5 years of age, which exhibited cranial lesions along with a possible case of greenstick rib fracture. In this particular case, haemorrhage of torn meninges may be the result of child abuse, such as shaken baby syndrome, since it was found in association with a possible rib fracture. Subdural and bilateral intraocular bleeding has been associated with habitual shaken babies (Lazoritz and Baldwin 1997). All the non-adults affected by endocranial lesions exhibited active lesions at time of death indicating that these lesions could possibly be a cause of death for these individuals. Unfortunately, there was no possibility of comparing these findings with other comparative sites; that was because these lesions were not reported at any other comparative sites outside St Hilda's, possibly due to a lack of time and the lack of standards (Lewis 2004). Despite the lack of comparative analysis, the presence of the lesions in St Hilda's confirmed once more that detrimental conditions affected the lives of the most sensitive portion of the population, the non-adults.

It can be concluded that the study of metabolic and hematopoietic diseases such as scurvy and rickets and CO and DEH and their co-occurrence combined with the age-at-death rates of non-adults, revealed a high risk of mortality during the vulnerable stages of early life. The lack of differences between geographic regions and socio-economic strata revealed that young children suffered the most, regardless of their origins. This finding confirms that detrimental conditions were a distinguishing feature not only of the South, but also of the North. Regardless of socio-economic origin and the benefits that some strata may have 'enjoyed' such as living further inland instead of back-to-back terraces, no one was too far from the pollution that industrialisation induced (Foster 1974, 88). Although one might assume that the offspring of the wealthier were protected due to their socio-economic status, that was only to a certain extent as children from higher strata had to deal not only with the poor diet, polluted environment, and unsanitary conditions, but also were subject to the fashionable trends of the period which prevailed among the high social strata. As a consequence, the child rearing practices of the period such as infant feeding, resulted in harming the health of the individuals. Nullifying in many instances the influence that socio-economic status could have had on the health profile of non-adults.

7.3.3 Biomechanical Stress: Trauma, Labour and Lifestyle Differences across Genders

In contrast to St Hilda's females, which were at a higher risk of respiratory problems and subsequent risk of death due to deleterious indoor pollution, males were at a lower risk of such problems due to the outdoor occupations that many of them had but at a higher risk of traumatic accidents which in many cases were fatal. This fact was confirmed with the study of the burial registers, as well as with the study of trauma rates in St Hilda's assemblage.

According to the burial registers, 62 individuals died from some sort of fatal accident giving an overall rate at 0.20% (*62/31.481*); of these, 56 were males giving a rate at 0.35% (*56/15.688*), 3 were females giving a rate at 0.02 (*3/15.770*) while 3 were of unknown sex. In St Hilda's burial registers the recorded accidents included the mining accident of 'St Hilda's pit explosion' on the 28th of June 1839 which cost the lives of 51 men, 25 of whom were buried in St Hilda's grounds (Anonymous-Gateshead Observer 1839).

> *A most dreadful and lamentable explosion, attended with a vast sacrifice of human life, occurred at the St. Hilda's Colliery… A short time after the men and boys, to the number of about 100, were brought to the mouth of the pit …Many of these were nearly exhausted from the effects of the choke-damp, but those who were sufficiently well again, in a short time, descended the pit …making what exertions they possibly could for the rescue of the men and boys who were left behind. However, none were found alive…. The bodies of the sufferers were not much burnt or mutilated, as is generally supposed…. and most of the deaths which occurred in the present case have doubtless resulted from the effects of the carbonic acid gas (or choke-damp of*

> *the miners) …. After 22 or 23 had been brought to bank, however, in the state described, the bodies began to be shockingly mutilated…* (*Anonymous-The Times* 1839)

Other accidents included suffocations, drownings, fire incidents, landslide incidents, and accidents on board the ship such as falls from a ship's mast and gun bursts. Interestingly, and rather telling was the number of children among the deceased males who worked as pitmen and mariners; six were children ranging from 9-12 years of age and twelve were adolescents ranging from 13-17 proving that children from the lower strata of South Shields were also involved in physically-demanding jobs, confirming a reported issue of the period (Factory Enquiry Commission, 1833; Hansard, 4 Aug 1840). From all the industries where children were employed, the mines and collieries were notorious for their debilitating effects on health. Lord Ashley exhibited the state of the collieries by reading an abstract of evidence collected by Mr. Commissioner Tuffnell in parliament in 1833 based on witnesses '….both from what I saw, and the evidence of witnesses given on oath above…that the hardest labour, in the worst room, in the worst conducted factory, is less hard, less cruel, and less demoralising, than the labour of the best of coal mines' (Hansard, 4 Aug 1840).

When the Registrar-General report (1842, 226-237) was considered, the rates of all types of violent deaths combined appeared fairly low for an entire population; however, they were still higher than St Hilda's burial registers rates, but that was expected, due to the size of the region. According to the report the rates of violent death for England as a whole was 3.22% (*11,594/359,561*); the northern regions reported 3.95% (*702/17,761*) for overall violent death with 6.00% (543/9048) and 1.82% (159/8713) for males and females respectively.

It is expected that these rates would have been closer to St Hilda's burial registers rates if each type of violent death (e.g. accidents, suicides and homicides) had been analysed separately instead of being analysed all together. The lack of standardisation between the different historical sources listed above had a negative impact on clear and concise statistics overall. Discrepancies were also observed between the historical and osteological evidence which will be discussed further below; however, it was clear in any form of evidence that males were at a higher risk of accidental deaths and trauma compared to their female counterparts.

St Hilda's working-class status and the risks of working-class life were evidenced through the osteological analysis of trauma which was at 20.6% (*42/204*) for the total population, with 56.9% *(29/51)* and 18.9% *(10/53)* for males and females respectively. Lesions of traumatic origin were relatively commonplace in the adult assemblage and a variety of traumatic lesions were observed ranging from soft-tissue to hard-tissue trauma such as fractures, dislocations and subluxations. It should be mentioned that a higher rate of trauma in comparison to the number of accidental or violent deaths reported in the historical record was expected as not every traumatic event resulted in death. Moreover, the study of trauma in St Hilda's was important because it not only reflected lifestyle and occupation, but also reflected the underlying state of health of the injured individuals.

St Hilda's males were by far more predisposed to injury than their female counterparts, accounting for two-thirds of all cases. The high prevalence of male trauma reflects the gender disparities in injury mortality, where men are at a greater risk. As it was already evidenced through the burial registers the peak in fatal accidents observed in males represents occupational activities whereby males were involved in more physically-demanding outdoor labour and in riskier settings, than females who were primarily indoors. These outdoor environments included ships, collieries, keelboats and other work-related environments where the individuals spent a significant part of their daily lives beginning from an early stage as evidenced by the burial registers. Lifestyle and behavioural risks as well as 'masculine socialisation merit' are other factors that must be considered (Dobson 2006; Sorenson 2011). Within St Hilda's sample, the rates of trauma were found to increase exponentially with age, with the prevalence of trauma being statistically higher in mature adults. When age groups were split by sex, the older adult males were affected the most, possibly reflecting work related accidents that males were exposed to during their lifespan as well as any underlying pathological conditions due to senescence (i.e. osteoporosis) or deficiencies (i.e. osteomalacia) that made their bones more prone to injuries such as fractures.

Fractures were the most commonly encountered type of trauma, with the majority of fractures being closed. Most of these fractures were well healed with minimal misalignment and shortening indicating medical intervention to some degree and possibly after care. Apart from a few exceptions, the lack of major complications revealed that the casualties had a relatively good underlying health which allowed them to heal. However, it is possible that some injuries of a more serious nature, involving open wounds and infections were not recognised as the individual died shortly after the accident.

Rib fractures were commonly encountered within St Hilda's assemblage and especially in males. Rib fractures are common injuries that may be due to blunt force trauma, work related accidents, falls, assault, severe coughing, road accidents or they could be secondary to underlying causes; they have also been associated with high levels of physical activity (Dandy and Edwards 1998, 167-168; Larsen 1997, 110). For St Hilda's, most of the cases of rib fracture were not serious enough to cause death by associated complications as the majority of the rib fractures were healed. However, it has been demonstrated that the risk of morbidity associated with rib fractures increases significantly with age from the age of 45 (Holcomb *et al.* 2003, 553). That was also confirmed in St Hilda's as the rib fractures increased with age, older adult males were affected the most by rib fractures showing also bone susceptibilities due to underlying aetiologies. In individuals above 65 morbidity and mortality due to rib fractures has been shown to be significant, with much higher levels of associated complications and mortality resulting from the initial injury and later complications (Brickley *et al.* 2006, 126).

As to the aetiology of the rib fractures, one-to-one correlations were impossible to be made unless they were accompanied by an underlying condition such as osteoporosis. However, given the living environment and higher prevalence of them observed in males, it is possible that the fractures were work-related accidents due to increased activity outdoors (e.g. coal production and export by sea) combined with pre-existing medical conditions such as osteopenia which made their bones weaker. This explanation becomes even more sustainable when the fact that middle adults were most frequently affected by rib fractures is considered. This may be due to the fact that middle adults comprised the majority of the workforce population actively involved in physically-demanding jobs from a fairly young age. Consequently, these injuries could be treated as work related in the majority of the cases. In most of the cases the affected individuals exhibited multiple rib fractures, it was unclear whether they represented different episodes of injury or if they were acquired at the same time in some sort of large-scale work incident. Another possible explanation is suggested when we consider that multiple rib fractures are also seen in stampede incidents in chaotic, overcrowded, and restricted areas (Dandy and Edwards 1998; Menezes *et al.* 2016). Cases of interpersonal violence, however, should not be excluded given the fact that some cases of facial trauma were also noted amongst the St Hilda's individuals.

It would appear that the non-adult portion of St Hilda's skeletal assemblage was also subject to interpersonal violence as seen through a case of greenstick rib fracture. This young child of 1-1.5 years of age also exhibited woven bone formation, both endocranially and ectocranially. Rib fractures in sub-adults are frequently indicative of child abuse and neglect, although much less common, rib fractures can also occur after serious accidental injuries or secondary bone fragility due to an underlying cause such as metabolic disorders (Lewis 2010). Child abuse, however, as a possible aetiology is most common when the victim is less than two years old, since infants, this young, do not have the strength or mobility to cause such injuries (Lazoritz and Baldwin 1997). The age of the affected child noted in St Hilda's falls into this category, consequently suggesting child abuse as a possible cause. Alternatively, since the same individual exhibited cranial lesions and some pitted lesions on the alveolar bone of maxillae and some new bone formation of the medial shaft of the tibia, a differential diagnosis might be some metabolic disease such as vitamin C deficiency (scurvy), although a combination of both cannot be excluded.

The possibility of interpersonal violence in St Hilda's assemblage, this time in the adult portion, was further demonstrated by the presence of several types of fractures linked to pugilism. Six male individuals from different age groups exhibited Bennet's fracture, a fracture of the thumb extending to the meta-carpometacarpal joint. This type of fracture is often the result of punching. Another male exhibited a hairline fracture of the fifth metacarpal neck, this is known as a 'Boxers fracture' which states the obvious reason of how it was sustained. Fractures of the second metacarpals were also observed in two other males, these injuries are usually sustained by a direct blow or crushing injury (Dandy and Edwards 1998, 224-225). The prevalence of metacarpal fractures was statistically higher in males. No differences were observed between different age groups, but when age groups were split by sex the prevalence of metacarpal fractures was statistically higher in older males. The same observations also were made for metatarsals.

Other types of fractures linked to violence that are present in St Hilda's are facial fractures. Although it is difficult to be certain as accidents can produce similar features to those that would be sustained in interpersonal violence, there were a number of facial fractures in St

Hilda's for which violence could be considered a possible cause. Facial injuries were recorded in three adults, two males and one female. One example was a middle adult male who had evidence of a healed fracture of the left mandibular ramus with displacement, accompanied by soft tissue trauma (myositis ossificans traumatica); the ramus appeared pushed medially with the fracture line being visible due to the induced displacement. Fractures of the mandible often happen during a fight, sometimes after drinking as Dandy and Edwards (1998, 142) have reported. This cause cannot be rejected, especially when it is considered that casualties due to reported episodes of interpersonal violence after excessive drinking were relatively commonplace during the studied period (Tomes 1978, 330; Brickley *et al.* 2006, 127*).* Another example of interpersonal violence was a mature adult female that exhibited healed transfacial fractures of the right zygomatic bone and right side of nose. It is unclear what the cause of this facial injury was; however, modern cases of domestic violence frequently have maxillofacial injuries (Le *et al.* 2002). This fact combined with the biological sex of the injured individual leaves open the possibility of domestic violent event. Domestic violence between working-class husbands and wives was frequently reported in the police courts of the period and this type of assault could result in rib or other fractures in women (Tomes 1978, 331; Brickley *et al.* 2006, 126; Humphries 2010). However, this female did not exhibit any rib fractures. Falls have been reported as one of the most common causes of maxillofacial injuries and are usually discussed together with violent episodes but also with work related accidents, sports, and motor vehicle accidents (Roccia *et al.* 2014). Consequently, a non-violent work-related incident cannot be ruled out such as a work-related fall, especially given the fact that this woman had also suffered from other fractures that appeared healed; an intra-articular fracture of the left distal tibia, a phalangeal fracture of the right intermediate hand phalanx, and also a compression fracture (cod fish) of her 4th thoracic. Road traffic during this period would not have been as common in the period under study as they are today, and prior to the advent of motorised vehicles injuries may not have been as severe. However, accidents involving road traffic did occur and cases of dangerous driving were reported (Brickley *et al.* 2006, 124). Another case was a mature male adult with a healed nasal fracture on the right portion of the nose, who also exhibited multiple healed fractures on the right side. Again, the aetiology behind this incident is unknown; nonetheless an event of interpersonal violence cannot be excluded. No statistical relationships were observed between any age and sex groups when statistical analysis was applied.

Of particular note is the case of a young adult male with a non-union of the sternum. Sternal fractures are fairly uncommon and can be caused either by direct trauma, which requires direct force and is usually associated with other injuries, or by violent flexion of the thoracic spine accompanied by a wedge fracture of the thoracic spine (Dandy and Edwards 1998). The aetiology is unclear, but it is very possible that a traumatic injury, an episode of interpersonal violence or chronic stress during earlier stages of life when fusion of the bone was taking place, interrupted the fusion leading to non-union. However, a definitive answer cannot be put forward.

The upper extremities fractures for the total assemblage were statistically significant in mature adults, and higher in males than females. When age groups were split by sex, the results yielded statistical significance for older adult males. In the case of lower extremities fractures no statistically significant differences were observed between different age groups; however, the prevalence of lower extremities fractures was statistically significantly higher in males than females. When age groups were split by sex, the results yielded no significance. It was impossible to make one-to-one correlations regarding the aetiology of the upper and lower extremities fractures. Accidental injuries predominantly manifested in the long bones reflect the hazards of specific occupations and activities involved in day-to-day living since high levels of physical activity are typically associated with fractures to the lower limb, distal radius, clavicles and ribs (Larsen 1997; Dandy and Edwards 1998).

Within the studied assemblage the number of fractures of the hands and feet observed between males appeared fairly high, showing occupational disparities and risks between the biological sexes. Hand and feet accidents in archaeological and living populations have been positively linked to work related accidents (Islam *et al.* 2001, 142; Judd 2002, 91). Islam *et al.* (2001, 142) found after studying 3490 work related fractures among 634,874 employees from a West Virginia workers compensation database, that the industry-specific incidence rate for all work-related fractures was highest for agriculture (agriculture, forestry and fisheries), followed by mining and the construction sectors. In each industrial sector, the male employees had a significantly higher incidence rate of fractures than the female employees. According to the incidence rates, fracture of the phalanges was the most common injury for male employees, followed by foot bone and carpal bone fractures. St Hilda's seems to be in accordance with this study, supporting the theory that many of the fractures were induced by the outdoor occupations in the mining industry and other industrialised environments. However, fractures of the phalanges are relatively common and can also be caused by falls and finger jams.

In the case of vertebral fractures, no statistically significant differences were observed between different age groups, and their distribution between males and females was even suggesting perhaps similar levels of back stress and activity during life (Miles *et al.* 2008). The results, however, were significant for older male adults when age groups were split by sex. Vertebral compression fracture can be caused due to repetitive or sudden stresses imposed upon the skeleton during an individual's life or osteoporosis and other pre-existing diseases which can lead to pathological fractures. Collapsed vertebrae are often inferred to be a consequence of carrying heavy loads (Dandy and Edwards 1998). Consequently, the statistically significant prevalence of vertebral fractures in older male adults combined with the fact that two-thirds of the affected individuals exhibited osteoporosis, reflects increased mechanical loading of the spine combined with underlying conditions such as osteoporosis that made their bones more prone to fractures.

Another type of vertebral fracture observed in the St Hilda's individuals was spondylolysis. Five individuals were recorded with spondylolysis of the fifth lumbar vertebrae, whilst in two individuals, the exact lumbar vertebra affected was unknown. The predisposition of the fifth lumbar in St Hilda's is consistent with reports from living populations (Stirland, 1996, 93). It has been suggested that spondylolysis can be caused by hyperflexion of the lumbar spine, causing repeated microtrauma of the *pars interarticularis*, which may result in a stress fracture (Fibiger and Knüsel, 2005). A wide range of movements can be responsible for the injury including bending at the waist while keeping legs straight, and the dragging and carrying of heavy loads (Wiltse *et al.* 1975; Aufderheide and Rodríguez-Martin 1998). Given the industrialised environment and how physically-demanding everyday life was, the predisposition of the adults may be more reflective of repeated microtrauma, although genetic predispositions have also been discussed (Fibiger and Knüsel 2005, 165). No statistically significant differences were observed between different age groups and also biological sexes. The results were also not significant for age groups split by sex. The even distribution between different age groups and sexes is perhaps suggesting that the St Hilda's adults were equally exposed to daily risks and similar levels of lower back stress, regardless of occupation, which could cause micro-trauma (Miles *et al.* 2008).

Other types of trauma and micro-trauma identified in St Hilda's, which show localised stress or injuries were dislocations, subluxations, osteochondritis dissecans, and os acromiale. Successfully realigned dislocations and subluxations, however, leave little or no skeletal evidence and hence can be archaeologically invisible (Roberts and Cox 2003, 237; Mahoney-Swales 2012). Therefore, the gathered information on dislocations and subluxations from St Hilda's was simply a minimum prevalence of possible cases that occurred as it was based only on the recording of persistently misaligned bones resulting in skeletal changes at the affected joints. Four examples of joint disruption were identified in St Hilda's skeletal assemblage, two dislocations and two subluxations; however, there was no statistically significant difference between different age groups, males and females, or age groups split by sex. This perhaps indicates that everybody was equally exposed regardless of occupation or lifestyle differences.

Another condition that is frequently associated with repetitive microtrauma is osteochondritis dissecans (OD). Within St Hilda's assemblage three adults exhibited evidence of this minor injury. OD generally occurs more frequently in males and adolescents (Aufderheide and Rodríguez-Martin, 1998, 82). St Hilda's seems to follow this pattern; two of the affected individuals were middle adult males and one was an adolescent, and all were affected on the medial or lateral femoral condyle.

A last indicator of micro-trauma was an accessory bone known as os acromiale, resulting from the non-union of the acromial epiphysis in the scapula (Case *et al.* 2006, 2; Mahoney-Swales 2012). It is believed that the condition has a genetic influence, although biomechanical factors are thought to be involved primarily in its development such as chronic stress which prevents fusion. Certain habitual activities involving the shoulder may increase the frequency of the condition. Os acromiale was observed in five adults; of these, only one had bilateral involvement. There was no statistical difference between different age and sex groups.

The increased prevalence of traumatic lesions in St Hilda's was in accordance with the industrialised environment of South Shields which predisposed the adult inhabitants to a risk of injury. The study of trauma combined with the burial registers revealed that overall there were disparities in the prevalence of trauma between males and females, with males being at a higher risk of traumatic accident and at a higher risk of accidental death. This shows that the results were also in accordance with modern clinical studies where males are at a higher risk (Islam *et al.* 2001; Judd 2002; Giammanco *et. al.* 2005; Batrinos 2012). Specific occupations and activities that the St Hilda's males were exposed to compromised their health and safety, as was also evident through the number of males involved in fatal accidents as recorded in the burial registers. The peak in fatal accidents observed in males represents occupational activities whereby males were involved in more physically-demanding outdoor activities in riskier settings than the females who were more indoor-based.

Overall the stages of healing revealed the existence of some sort of care practices and a good response from the casualty, reflecting their underlying state of health. Within St Hilda's sample, the rates of trauma were found to increase exponentially with age with the prevalence of trauma being statistically higher in mature adults, while older adult males were affected the most. Therefore, it would appear that trauma had an accumulative effect on older male adults due to the combination of a relatively long life in which they were involved in a vigorous lifestyle due to their occupations which commenced early in life, diet, and the effects of senescence (Robert and Manchester 1995).

High prevalence of trauma – especially fractures – was a universal characteristic across sites of various status and region, with males being more frequently affected. St Hilda's prevalence of fractures was in accordance with sites of various backgrounds which provided evidence on fractures; however, only the general rates of fracture were available for comparison across most sites, due to methodological or preservation differences between sites. The sites with similar rates include St Martin, St Bride's Lower, St Marylebone, All Saints Chelsea, St Luke's Islington-named and St George's Bloomsbury-named. The similarities in the overall prevalence perhaps reflect that individuals from different sites were to some extent exposed to the danger of accidental and/or violent injuries (i.e. fractures), and in many cases subsequent death, irrespective of South and North division and/or socio-economic division. Only the sites of Greenwich Tier and St Benet exhibited statistically higher prevalence of trauma than St Hilda's. In the case of Greenwich Tier the difference was expected due to the nature of the site which was a hospital; however, in the case of St Benet the cause of this difference was unclear due to the mixed status of the cemetery. It was also observed that some sites of working-class origin exhibited lower prevalence rates than St Hilda's. It is speculated that this difference could be the result of bias due to poor preservation and selected methodological criteria and the necessity of a medium or low-resolution analysis in some cases (e.g. Carver street, Coach Lane, St Luke's-unnamed, Cross Bones and St Pancras) (Boyle *et al.* 2005, 282). It was noted that in these cases the number of fractures were relatively low in comparison to the very high number of preserved skeletons. There were also cases of higher status sites (e.g. Christ Church, Spitalfields) which exhibited lower prevalence; it is possible that differences existed due to higher socio-economic status, a factor also seen with the study of maxillary sinusitis.

Despite the similarities in prevalence of fractures observed between different sites of various backgrounds, it is likely that differences existed in the underlying causes of fractures between different status sites. As it was evidenced in the remains of St Hilda's, violence-related fractures such as facial fractures and 'Bennett's' and 'Boxers fractures' were present in males of different age groups; it could be surmised that some of the fractures recorded in St Martin's could be attributed to similar violence as both sites represented males from similar social strata, social and working environments. This is further supported by casualty reports from local newspapers in Birmingham (*Aris's Gazette* and *Birmingham Daily Post*) during this period of interest naming excessive drinking as the ultimate cause for the violent outbursts (Brickley *et al.* 2006, 127). Lifestyle and masculine socialisation are not the only factors that must be considered. According to modern studies, the differences in rates of trauma and earlier death between biological sexes can also be attributed to high testosterone levels in males, which put men at risk biologically, but also puts men at risk behaviourally (Giammanco *et al.* 2005; Batrinos 2012). Moreover, interpersonal violence was not only limited to between males, and it was already discussed above that violence between working-class husbands and their wives was 'common practice'. Domestic violence was often reported in the Police Courts and trial accounts of the period (Tomes 1978; Brickley *et al.* 2006). The upper classes, on the other hand, did not condone physical force, and considered the fights between working-class husbands and wives as one part of a generalized 'savagery' of the uncivilized masses (Tomes 1978).

The possible differences for the underlying causes of fractures between social strata is further supported when these population samples were divided in male and female groups. It was noted that although males across various sites exhibited higher prevalence than their female counterparts, St Hilda's males exhibited significantly higher prevalence than most other male groups despite the overall similar prevalence between many sites. The only site in which males were affected by fractures in a similar manner as St Hilda's was St Martin's; while the males of St Benet and Greenwich Tier exhibited higher prevalence than St Hilda's. These two last sites also exhibited very elevated levels of overall fractures; therefore, it seems that the high predilection of male fractures elevated the overall prevalence and this is also applicable for the case of St Hilda's. Consequently, it would appear that the high predilection of male fractures was the reason behind the higher overall prevalence across different sites. As many of these sites were of higher status than the case study, it is likely that the statistically significant male predominance of St Hilda's and St Martin reflects the dangers that working-class males were exposed to, in particular the breadwinners. Despite the differences in social status, it would appear that males across sites were at a higher risk of accidental and/or violent injuries and in many cases subsequent death than females due to their outdoor based occupations and activities.

Females on the other hand appeared to be almost equally affected despite the status differences with only a couple of exceptions. Christ Church and St Pancras exhibited statistically lower prevalence than the case study, whereas St Benet, Sherehog exhibited a statistically higher prevalence. In the case of Christ Church, the lower prevalence in females was perhaps due once more to the higher socio-economic status, while in the case of St Pancras it was due to the increased number of found individuals, which were studied in a commercial setting. In the case of St Benet, Sherehog the cause remains unclear due to the mixed status of the population but as already noted, this particular site presented increased prevalence of fractures overall.

Despite any status or North and South divisions, it would appear that females across sites had lower chances of being affected by injuries due to their mainly indoor lifestyle which shielded them from many outdoor risks. Higher strata females, in particular, were more protected compared to their lower strata counterparts who despite the lower risk of injuries due to their more domestic-based lifestyle were still frequently subject to physical force by their working-class husbands as already mentioned above (Tomes 1978). However, it is possible that exceptions did occur and cases of domestic violence also existed among the wealthier husbands and wives. Consequently, the general high prevalence of fractures observed in males across different sites shows not only occupational differences between males and females, but also lifestyle differences, behavioural risks due to the working environment, and masculine socialisation merit as well as biological differences (e.g. increased testosterone levels).

7.3.4 Further Evidence of Biomechanical Stress: Spinal and Extra-Spinal Joint Disease

As it has already been established, South Shields was a seaport town in which various industries, such as coal production and shipping, were undertaken (Foster 1974, 88). The engagement of individuals in such industries was earlier confirmed through the study of the parish burial registers and the stated occupations of the deceased. The physically-demanding nature of working in these industries was evident through the increased numbers of male deaths recorded as accidents in relation to these industries, as well as the rates of fractures among males in the skeletal sample. The demanding nature of this industrialised environment was further expressed through the degenerative diseases of the joints, which were relatively commonplace in the adult assemblage. A wide range of different conditions which could come under the heading of 'joint disease' were recorded and these are considered in the following section. Joint diseases are important in the study of St Hilda's as they not only reflect the lifestyle and occupation, but also the underlying health of individuals and incidents of traumatic origin.

Rates of joint disease were found to increase exponentially with age with the prevalence of the lesions being statistically higher in older adults, whose joints could no longer sustain the mechanical loading due to degeneration caused by increasing age (Knüsel *et al.* 1997; Ortner 2003; Waldron 2009). Joint disease had equally affected males and females, reflecting that both sexes were equally exposed to degeneration of the joints with age. However, the ageing process should not be seen as the single contributory factor of joint degeneration, but instead should be viewed in combination with repeated stress on joints imposed by strenuous activities which started at early life due to physically-demanding lifestyles (Roberts and

Manchester 1997; Knüsel *et al.* 1997). As males were mostly outdoor-based and females indoor-based, it is clear that the lesions were acquired through different activities; however, both environments placed the individuals at a high risk of joint degeneration which became even worse in combination with the ageing process. This equal prevalence between the sexes was only noted in the case of joint disease. It can, therefore, be told that joint disease in most cases was irrespective of lifestyle and that in both indoor and outdoor environments there were predisposing factors to degeneration with normal aging process being the main contributory factor combined with premature exposure of the spine to mechanical loading (Bridges 1994).

a. Osteoarthritis

The most commonly observed joint disease was osteoarthritis (OA); lesions characteristic of primary OA affected more than half of the adult population with a predilection for the older age categories. A good portion of the population suffered from generalised OA with more than three joints affected, whilst over half of the adults affected by generalised OA were older. Primary OA is idiopathic in its aetiology, which means there is no obvious cause and therefore one-to-one correlations could not be made (Resnick and Niwayama 1981; Roberts and Manchester 1997). In St Hilda's, however, it is clear that the demands of industrialised living which started from an early age had a tremendous impact on joint degeneration (Bridges 1994). As it was already witnessed through the involvement of older children in accidental deaths in the trauma section, employment in the seafaring or mining industry of South Shields frequently commenced in childhood. Cases of secondary OA due to trauma or injury or other underlying pathological causes such as gouty arthritis or rheumatoid arthritis were also noted in St Hilda's individuals; these lesions were analysed separately (Roberts and Manchester 1997; Ortner 2003).

No biological sex differences were observed in the prevalence of OA, males and females were equally affected. Therefore, it reflects that both sexes were exposed to OA, triggered by premature degeneration of the joints that started at a young age due to vigorous physical activity, irrespective of indoor or outdoor environments. The part of the body most frequently affected with OA and other non-specific degenerative changes was the spine which is subject to increased biomechanical loading (Resnick and Niwayama 1981; Roberts and Manchester

1997), but also because of its greater anatomical complexity, specifically the exhibition of multiple joints (Roberts and Manchester 1997). For that reason, the OA lesions were divided into extra-spinal and spinal lesions.

Within St Hilda's over half of the adult population exhibited pathognomonic changes for the diagnosis of extra-spinal OA. In the upper body, the most affected joints were the hands, followed by the shoulders, wrists, and elbows, and from the skull the temporomandibular joints. From the lower body, the most affected joints were in the feet, followed by the knees and hip joints. Of all the adult age groups, older adults were most frequently affected by OA. The most frequently affected joints from the upper body for this group were those of the hands, followed by the wrists and elbows while from the lower body were the two major weight-bearing joints of the hips and knees. These two last joints are the two most frequently affected lower limb joints in living populations (Ortner 2003). No statistical differences were observed between males and females. In the case of hand and hip joints, however, St Hilda's males exhibited some significant differences compared to their female counterparts. Further to this, older male adults exhibited a statistically higher prevalence of hand OA. In living populations, OA of the hips has been linked to excessive weight and hard labour; while OA of the hands has been linked to genetics, hormones and repeated microtrauma (Resnick and Niwayama 1981; Ortner 2003). In the case of the St Hilda's males, however, this statistically higher prevalence of OA in the hands and hips perhaps reflects the overuse of these joints and repeated micro-trauma due to occupational activities which imposed extra biomechanical loading on specific joints (Roberts and Manchester 1997). Hands, in particular, are vulnerable as the tendons, nerve fibres, blood vessels and the fairly thin bones are only superficially protected by a thin layer of muscle and fat (IQWIG 2010). This is not to say that the normal ageing process was not responsible for the degeneration, especially as it was seen within the older adults, but to highlight that biomechanical forces also had a significant impact upon the joints.

Consequently, 'wear-and-tear' over the years, accelerated by intense activity that started at a very early age, resulted in damage of the joint cartilage due to its inability to absorb the exerted force over a prolonged period of time. This multifactorial explanation is further supported when considering the fact that both males and females exhibited similar rates of OA for the rest of the upper and lower joints, indicating that both sexes were equally exposed to intense physical stress of the arms and legs whether in an indoor or outdoor setting. Thus, advanced age combined with a vigorous lifestyle starting from an early age could be why the population under study was particularly vulnerable to OA of the extra-spinal joints (Waldron 2009).

The most frequently affected extra-spinal joints in living populations are those of the hands, knees and hips (Roberts and Manchester 1997; Ortner 2003). St Hilda's sample, as a modern population, presented the same predilection for these specific joints, but also presented higher predilection for shoulder and elbow joints. OA of the shoulder is rare in the living apart from secondary OA due to trauma or local pathology (Roberts and Manchester 1997; Ravalli 2019). In the case of St Hilda's there were no obvious underlying pathological causes; therefore, it is assumed that shoulder OA was caused by repeated microtrauma due to overuse. OA of the elbow is another form of rare OA in the living and is caused by repeated microtrauma, notably related to work and occupation, especially when asymmetrically distributed as in the case of St Hilda's (Roberts and Manchester 1997; Ortner 2003; Waldron 2006; Ravalli 2019). Modern population studies have identified men subjected to heavy daily movements that exhaust the arm are at most risk of elbow OA (Ravalli 2019, 3). As it was seen earlier in St Hilda's, both sexes were equally affected showing that both were subject to daily movements that exhaust the arm irrespective of outdoor and indoor settings.

In the case of OA of the spine, there were two areas of focus: the articular facets or the zygapophyseal joints (spinal OA) and the intervertebral disc (SD). Almost half of the adult population exhibited spinal OA identified posteriorly of the vertebra; the lesions showed predominance in the cervical region for all the adults. The prevalence of spinal OA was statistically higher in older adults, but no statistical differences were observed between males and females showing equal exposure, although females had more vertebrae affected. Older adult males exhibited statistically higher prevalence. The aetiology of spinal OA, like any other degenerative joint disease, is not fully understood, but its prevalence is increasingly common with age (Waldron 2006). Everyday 'wear-and-tear' over the years is believed to underlie this disorder, but it may be accelerated by repeated strenuous activity, particularly when started at a young age, such as carrying heavy loads and/or pushing and pulling heavy objects (Boston *et al.* 2008). Another factor to consider would be poor posture which was adapted from many individuals. Chronic bad posture probably placed abnormal chronic stresses on the body and as a result, these stresses made it harder for the muscles to take the pressure off the joints. The higher predilection of spinal OA at the cervical region indicates that the St Hilda's individuals exhibited bad posture of the skull which was probably not resting directly above the neck but instead 20 degrees in front of the neck, making it difficult for the muscles of the neck and arms (Ryan and Fried 1997). The increased weight from the poorly positioned head fatigued the postural muscles and the forces from the head and neck were translated through the small joints of the cervical vertebrae, which provided insufficient support over an extended period of time resulting in greater wear-and-tear influencing the increased incidence of OA in the cervical region.

The facets joints, however, were not the only part of the spine affected; the vertebral bodies were also affected by OA. The vertebral body variation of OA known as spondylosis deformans (SD) ranged from small to large horizontal bridging osteophytes that bulged at the level of the intervertebral disk (Mann and David 2006, 101). The prevalence of SD was statistically higher in older adults showing increase with age and the lesions exhibited higher prevalence in male individuals. The lesions again showed predominance in the cervical region, which is commonly observed in older adults as part of the degeneration due to the ageing process (Roberts and Manchester 1997) as discussed above. SD has a higher predilection for males in earlier life stages than females as it is related to occupations that are labour intensive physical activities. Despite the male predilection, SD is found in nearly all individuals over the age of sixty (Mann and David 2006, 101). St Hilda's seems to follow this pattern described above. In the case of females, discogenic degeneration of the lower back could also be triggered by pregnancy due to increased biomechanical loading exerted on the spine by the extra carried weight. Lumbar disc herniation is the most common spinal disorder during pregnancy and can cause permanent neurologic deficit; females with pre-existing back problems are even more prone to such complications (Han 2010). During the studied period multiple pregnancies and within a short time were relatively commonplace due to a lack of contraceptive methods (Pooley 2013). Therefore, in the case of the St Hilda's females, multiple pregnancies and pre-existing back problems due to the physically demanding lifestyle would have also been contributing factors to the degeneration of the lower spine, but also of other extra-spinal joints such as the weight bearing joints of the knees.

Consequently, the presence of OA of the zygapophyseal joints and SD observed in St Hilda's adults, especially in the older age category, may represent the cumulative effects of the demands upon the spine in activities requiring prolonged standing, walking or heavy repetitive movements of the spine, such as shovelling along with the normal degenerative process of ageing (Lovell 1994). However, it is really difficult to make one-to-one correlations and to attribute OA to any one particular underlying cause so a multifactorial approach was taken to interpret the results instead. This explanatory model becomes more realistic when considering the fact that both sexes exhibited similar prevalence rates, highlighting that both were equally exposed to heavy biomechanical loading of the spine. OA was observed in higher rates in older adults and increased with age, but age alone is not a sufficient explanation as OA can also be the result of years of bad posture or the result of accelerated 'damage' of the joint cartilage and subsequent friction due to intense activity that started early in life. As was already noted above, in the case of females, degeneration of the spine may even be caused by multiple pregnancies combined with a susceptible spine due to a physically-demanding lifestyle. Thus, a combination of bad posture, premature ageing of the skeleton due to a vigorous lifestyle and other factors (e.g. multiple pregnancies in females) would have rendered the St Hilda's individuals particularly vulnerable to developing OA and other degenerative diseases of the spine.

When St Hilda's spinal and extra-spinal OA changes were combined and compared with the comparative sites, it was noted once more that socio-economic status differences existed between sites. St Hilda's exhibited a higher prevalence of OA than many of the comparative sites of higher status differences between the lower and upper strata. St Hilda's had a higher prevalence than the higher status sites of All Saints Chelsea, St Luke's Islington-named, and Christ Church Spitalfields, but the same prevalence with the lower status sites of Cross Bones and Greenwich Tier indicating social status similarities. These findings are representative of the fact that lifestyle differences existed between lower and upper strata, with the former being more engaged in a physically challenging lifestyle and the latter in a more sedentary lifestyle. For example, in the case of Christ Church which was a middle-class site, many of the people were skilled craftsmen and artisans and would have had less physically demanding jobs compared to the miners, colliers, sailors or unskilled workers of South Shields (Molleson and Cox 1992). This is not to say that the life of the former was easy, but certainly it was less demanding than the life of the latter. Victorian craftsmen stood at the apex of the labour hierarchy as they possessed the skills and knowledge which gave them command over their materials and tools; this skill almost always entitled them to higher wages and to more regular employment than the unskilled worker. It also released them from the burden of fetching and carrying, preparatory and rough work as in the case of manual labourers whose picks and shovels created railway embankments, cuts, and tunnels (Burnett 1974; Sullivan 1983).

However, there were also sites of similar status that presented lower prevalences than St Hilda's such as Coach Lane, St Bride's Lower and Carver Street. It is suspected that the differences here were due to methodological and preservation issues, or even due to the fact that the recording of spinal lesions was not the primary focus (Boston *et al.* 2008). This possibility was further supported by the fact that only very few sites provided separate information on CPR of extra-spinal joint disease. The sparsely drawn conclusions are indicative of the major problem faced by this research which is the lack of standards and a systematic approach in the recording of lesions. This, however, is inevitable due to the limited time and funds in a commercial setting. The prevalence, however, of lesions between all the sites also shows that everyone was subject to the normal degeneration process due to ageing.

In the case of spinal joint disease, St Hilda's adult CPR was similar to the rates of sites of various backgrounds such as the Infirmary Newcastle, Cross Bones, St Bride's, All Saints and Christ Church. This finding is indicative that among sites of various socio-economic status everybody was equally affected by spinal OA due to everyday activities (i.e. strains, sudden movements or poor body mechanics) (Lovell 1994). What was perhaps different was the underlying aetiology behind the formation of these lesions and the timing that the formation of the lesions commenced; in the case of the lower strata the degeneration possibly started much earlier. St Hilda's prevalence of both CPR and TPR were statistically higher than Coach Lane, Carver Street, St Martin, St Benet Sherehog, St Luke's Islington-unnamed and St Luke's Islington-named, St Marylebone and St George's Bloomsbury-unnamed. This is indicative that some status differences existed between upper and lower strata, but in the case of the lower status sites, it also shows that methodological and preservation issues existed indeed. In regards to methodological issues, it was systematically noted that when the number of the skeletons was much higher than one hundred, the reported prevalence of diseases was relatively low in relation to the number of the individuals in the sample. This problem is probably linked to the medium or low-resolution analysis associated with a limited time of study. St Hilda's CPR for spinal OA is much higher than the 13.49% reported by Roberts and Cox (2003, 352) for other post-medieval sites. It is suspected that in some cases such as Coach Lane, Carver Street, St Marylebone and St George's Bloomsbury, this difference was mainly due to the aforementioned issues. It is possible that these comparative sites had a much higher prevalence than was recorded in their post-excavation analyses and employed as part of the comparative analysis of this study.

b. Marginal Osteophytes and Schmorl's Nodes

Other spinal degenerative conditions, indicative of cumulative effects upon the spine along with the normal degenerative process of ageing, identified within St Hilda's adults included marginal osteophytes and Schmorl's nodes.

Marginal osteophytes may indicate early stage of SD when pitting and densification of the vertebral body surface is also observed. New bone formation around the margins of the joints due to friction of the vertebral bodies stimulated by degeneration of the intervertebral disc was relatively commonplace in St Hilda's (Lawrence 1969; Aufderheide and Rodriguez-Martin 2006). This condition varied from only slight bony spicules on the margins of a couple of vertebral bodies to severe new bone formation, wherein most of the extant elements on the vertebral column were severely affected. The condition was observed in higher rates in older adults, reflecting indeed damage and wear due to degeneration of the joint with increasing age. While males were more frequently affected than their female counterparts, representing a combination of degeneration imposed by biomechanical stress and spinal injuries associated with occupational and behavioural activities or episode(s) of trauma. This is further supported by the fact that the thoracic and lumbar regions were more frequently affected. Caplan *et al.* (1966) after studying a living sample of miners found that trauma appeared to be the single most important element in the development of disc narrowing due to degeneration of the vertebrae. As a result of metabolic or degenerative processes, it was observed that after the age of 30 the intervertebral discs of the sample lost their ability to tolerate mechanical forces. Injuries were the primary mechanical factors which caused measurable disc narrowing (Caplan 1966). Given that a portion of the male population was involved in the mining industry or in other physically intensive jobs it is not a surprise that St

Hilda's males exhibited higher prevalence of SD and marginal lipping due to vertebral disc narrowing induced by trauma.

Schmorl's nodes was another spinal degenerative condition identified within St Hilda's adults. The lesions are the result of herniation of the intervertebral disc and are identified on the superior and inferior surfaces of the vertebrae (Aufderheide and Rodriguez-Martin 2006). Within St Hilda's, middle adults were more frequently affected. The lesions exhibited a higher predilection for males than females; this finding was in accordance with those of Kyere *et al.* (2012) and Diehn *et al.* (2016) based on modern populations. The vast majority of lesions occurred in the thoracic and lumbar regions showing increased biomechanical loading of the spine.

Schmorl's nodes are increasingly common with age and are present in most individuals over forty-five. The process is usually gradual and it is connected to the age-related weakening of the posterior longitudinal ligaments of the vertebrae (Roberts and Manchester 1997; Aufderheide and Rodriguez-Martin 2006). The statistically higher presence of the lesions in middle adults is indicative of this degeneration starting earlier due to involvement in a non-sedentary lifestyle from a very young age. The increased mechanical loading imposed on the spine would have resulted in single or repeated episodes of trauma and subsequent formation of the lesions; however genetic predisposition could also be linked to their formation (Ortner 2003; Aufderheide and Rodriguez-Martin 2006; Williams *et al.* 2007; Waldron 2009). Given the industrial setting in which the individuals lived, however, it is more likely that the lesions represent occupational or behavioural activities combined with episode(s) of trauma, whereby males were involved in a more physically-demanding lifestyle, for example, in the mines and collieries. As was noted earlier with the study of trauma and accidental deaths in St Hilda's, these individuals were engaged in very strenuous labour from a very young age, which could potentially have contributed to disc herniation in middle adulthood as a result of mechanical weakness of their spines. Consequently, this predilection for middle adults and males may simply reflect the portion of the population workforce that was actively involved in notable levels of occupation-related strain as a result of strenuous activity, such as heavy lifting. This was also witnessed through the increased number of deaths in this group, which shows that they were subject to a difficult lifestyle from early life and by the age of middle adulthood their immune systems and bodies were 'exhausted'.

Consequently, these lesions could be treated as micro-injuries due to sudden or repeated episodes of trauma or degenerations of the vertebral body due to biomechanical loading of the spine (Williams *et al.* 2007).

Despite the status differences with some of the sites St Hilda's exhibited statistically similar rates of Schmorl's nodes with Infirmary Newcastle, St Bride's lower, All Saints Chelsea and St George's Bloomsbury-named and statistically higher prevalence than Carver Street, St Martin, St Marylebone, Christ Church, St Luke's Islington-unnamed and St Luke's Islington-named, and statistically lower than the sites of Coach Lane, Cross Bones, St Benet's and Greenwich Tier. The results appeared inconclusive as it was impossible to determine if the differences were due to different social status and activities or merely due to methodology and preservation issues. Nonetheless, it should be noted that a preliminary pattern existed that appears to be status related, most notably in the case of Cross Bones and Greenwich Tier where both sites exhibited a higher prevalence of Schmorl's nodes. In the case of Cross Bones, the comparatively higher prevalence was reflective of its lower social status than St Hilda's, while in the case of Greenwich Tier the higher prevalence could be the result of the nature of the site, which was a hospital for retired sailors. Despite this pattern, it is suspected that in some cases the differences were related to preservation and methodological issues such as in the case of Carver Street and St Luke's-unnamed, however, this problem is not new but appears to be constant throughout this research.

As males tend to be more prone to the lesions, the applied further analysis revealed some meaningful patterns (Diehn *et al.* 2016). When the population sample was divided into males and females, no substantial differences were observed between most of the sites which provided this information suggesting that the lesions are perhaps not the most suitable marker for defining socio-economic differences. Only the sites of Christ Church exhibited a much lower prevalence of Schmorl's nodes in males than St Hilda's, and the site of Cross Bones which exhibited a much higher prevalence than St Hilda's females. In this case it is suspected that the observed differences when the populations were further split into males and females were due to status differences. Christ Church's lower prevalence of the lesions in males and Cross Bone's higher prevalence in females was perhaps due to lifestyle differences; Christ Church was a middle-class site and therefore of higher status than St Hilda's, while Cross Bone's was of a lower status and initially included many single women ('prostitutes') and later became a cemetery for paupers. However, no further conclusions could be drawn, and this theory could not be generalised further as only the sites of Coach Lane, Cross Bones, St Bride's, St Benet, All Saints, Greenwich Tier and Christ Church provided rates on how males and females were affected by the lesions. Based on these sites of various backgrounds, however, it seems that no social status differences existed between the separately studied groups. Thus, the lesions could perhaps occur irrespective of social status differences such as arising from injury due to sudden movements, or poor body mechanics while heavy lifting. The results presented here are in accordance with modern autopsies and radiographies that show that Schmorl's nodes are relatively common lesions from which everyone can be at risk (Pfirmann and Resnick 2001; Williams *et al.* 2007).

c. Miscellaneous Joint Diseases (Non-Biomechanical Stress Related)

Some other joint diseases identified within St Hilda's skeletal assemblage included diffuse idiopathic skeletal hyperostosis and gouty arthritis. These conditions appeared inconclusive, but nonetheless useful for reconstructing the general health status of the population. Evidence of DISH was noted in three male individuals; two were older males, while the third was classified as an 'adult' male due to poor preservation. The higher prevalence for older males was statistically significant, this higher predilection for older males is in accordance with the age of onset in living populations where the condition appears usually after the fifth decade of life, especially in the sixth to seventh decades with a male predominance (Rogers and Waldron 1995, 48). Although it was impossible to make one-to-one correlations to the actual causes of these lesions, the condition was recorded as it has been frequently associated in archaeological populations with diseases linked to dietary excess such as obesity and type II diabetes; it is hence regarded as a disease of affluence and fine living (Roberts and Cox 2003; Miles *et al.* 2008). In modern populations, the condition is reported to range from 6 to 12% of affected people (Roberts and Cox 2003; Boston *et al.* 2008). While the prevalence in skeletons from archaeological sites is reported to be about 5% (Rogers *et al.* 1985). In particular, the prevalence of DISH between the comparative sites varied considerably from 0.00% at the pauper burial site of Cross Bones to 7.48% at the higher status site of Christ Church Spitalfields. Despite the fact that some sites of higher status, including Christ Church, Spitalfields, St George's Bloomsbury-named, and Chelsea Old Church exhibited seemingly higher prevalences than St Hilda's and the other sites, the statistical analysis yielded no differences. When St Hilda's was compared to the other sites, the rates revealed no differences between the different socio-economic groups. Most of the comparative sites exhibited lower prevalence than the modern rates, although some of the higher status sites listed above exhibited rates close to modern ones. In skeletal material the condition in the past was almost certainly misdiagnosed as other diseases, including osteoarthritis or ankylosing spondylitis (Miles *et al.* 2018). Consequently, this could potentially offer an explanation as to why the rates observed in many of the sites were lower than the clinical rates. There is, however, also another potential explanation for the difference between modern clinical and archaeological rates; the modern rates may appear more elevated compared to the archaeological sites because the former is based on hospitalised individuals which makes their nature very specific, and therefore possibly less representative of the total population.

The reason for the lack of differences in the prevalence of DISH between the sites of different socio-economic status was unclear. However, during the period of study, overweight and obesity were relatively rare and were generally identified as a phenomenon associated with the smaller proportion of middle and upper-middle classes such as in the case of Christ Church, where a few cases of obese individuals were identified while the rest of the population appeared to be extremely emaciated at the time of death (Molleson and Cox 1993, 24; Clayton and Rowbotham 2009, 1241). The generally low prevalence and sometimes absence of this condition which reflects over indulgence and excessive diet was possibly due to a different lifestyle and quality of diet. Victorians, especially the working class, had a physically active lifestyle which helped them to maintain an optimum weight (or stay below the optimum weight), but also a diet substantially different in composition from modern diets and frequently inadequate in caloric intake.

Another possible explanation for the lack of differences between social strata in terms of the prevalence of conditions linked to diabetes and obesity such as DISH, was the practice of food adulteration. As previously discussed in section 7.3.2a, during the period of study much of the food consumed was adulterated by foreign substances and contaminated by chemicals or befouled by animal or human excrement (Anonymous 1860, 86-96; Wohl 1983; Rees 2001). Consequently, the processes of adulteration could have led to a diet with little nutrients, even in the cases of individuals with an over indulgent, excessive diet. Despite how much they consumed, this amount was poor in nutrients but rich in harmful substances.

Gouty arthritis was another condition linked to excessive diet and drinking, however, the results appeared inconclusive too between the sites of different status. Gouty arthritis was observed in seven individuals from St Hilda's. Although gout tends to have higher predilection for males than females (Ortner 2003, 583), no statistical differences were observed within the studied assemblage, despite the fact that males exhibited higher prevalence rates than their female counterparts. Within the assemblage, the highest numbers of affected individuals were middle and mature adults; this is in accordance with the onset of gout in living populations after the fourth or fifth decades of life (Rothchild and Heathcote 1995; Roberts and Cox 2003; Fornaciari and Giuffra 2013). However, despite the higher prevalence observed in these groups, no statistically significant differences were observed. Along with the affected adults there were also a few cases of affected individuals from the younger age groups such as adolescents and young adults. This is not unusual as gout in younger age groups and children has been linked to hereditary diseases, kidney diseases and metabolic syndromes (Kedar and Simkin 2012, 393). Therefore, its presence in younger age groups might be indicative of other underlying conditions.

St Hilda's adult CPR at 5.98% was statistically higher compared to the few sites that had this information recorded; apart from Carver Street and All Saints Chelsea which exhibited no differences. As the lesions for both the case study site and Carver Street were recorded by the author, it is suspected that the statistical difference was the result of a thorough analysis in a non-commercial setting where more time was available. The prevalence of gouty arthritis between the various sites ranged from 1.14% to 5.98%, while there were also many sites in which the lesions were not recorded at all; not because they did not occur, but possibly due to methodological difficulties in recognising them. According to Roberts and Cox (2003, 311) there has been limited evidence of the condition in post-medieval skeletons, and this has cast doubt upon the ability to recognise the condition. Consequently, the higher prevalence observed in St Hilda's was not necessarily related to the causes of gout, namely excessive eating or drinking, but to the availability of time needed to recognise and record the lesions. This is something that can be further supported by the fact that no gouty lesions were recorded in sites where excessive alcohol consumption was possible, as in the case of

Greenwich Tier and Infirmary Newcastle where sailors were interred (Boston *et al.* 2008). Therefore, although these lesions would have been very useful in order to determine socio-economic differences, in the case of this study they appear to be problematic due to the methodological issues linked to their identification. It is very likely, however, that if they were recorded accurately, the results would have yielded no significant differences, as in the case of DISH, due to lower levels of diabetes and obesity in comparison to modern populations.

When the Registrar-General report (1842, 229) was considered, the total number of deaths by gout appeared lower in relation to the archaeological sites which provided a prevalence of 0.05% (*211/359.561*) for the total population and 0.01% (*3/17.761*) for the northern regions alone. However, in the case of the Registrar-General report, those reported cases had led to death of the affected individual, while in the case of the archaeological sites possibly not all the lesions necessarily resulted in death. Consequently, this could perhaps be the explanation behind the differences between the historical and osteological evidence for the rates of gout. The fact, however, that the condition had higher predilection for the first metatarsophalangeal joint in most of the sites represents an acute phase of the condition, which means that gout could have potentially killed the affected individuals (Ortner 2003).

A condition frequently misdiagnosed for gout is hallux valgus (Mays 2005). Within St Hilda's the condition appeared to increase with age, with the difference being statistically significant for older adults while both males and females were equally affected. No statistically significant difference was observed when age groups were split by sex. Most of the cases were unilateral possibly reflecting the asymmetry intrinsic in the manufacture of handmade footwear (Mays 2005, 147). The lack of statistically significant differences between sexes within St Hilda's is indicative that both women and men wore restrictive shoes. Whilst the increased prevalence of the deformity in older adults is indicative of a condition advanced with age. Consequently, long-term use of ill-fitting shoes may have led to foot asymmetries that resulted in increased hallux valgus with age (Mafart 2007; Trujillo-Mederos *et al.* 2012). Unfortunately, it was impossible to compare the prevalence of St Hilda's with other comparative sites in order to define socio-economic status differences as the lesions were only recorded in a few sites.

7.3.5 Indicators of General Health, Diet and Social and Occupational Practices: Dental Disease

In general, dental health during the Victorian period was extremely poor along all social class divides, and is often attributed to a combination of a soft cariogenic diet, inadequate oral hygiene, and rudimentary dental treatment (Robert and Cox 2003, 304-308). Two types of dental pathologies were identified in St Hilda's; infectious diseases such as calculus, carious lesions, dental abscesses and periodontal disease, and degenerative diseases such as ante-mortem tooth loss and occlusal dental wear due to attrition and abrasion (Roberts and Manchester 1997, 44-45). The infectious dental pathologies were most informative about oral health and hygiene but also indicative of the diet and provided information on whether the individuals survived chronic underlying systemic infections. By comparison, the degenerative dental pathologies provided information on activity such as habitual and occupational use of the teeth, and age-related changes to the occlusal surface of the teeth. However, these two types of dental pathologies are frequently mutually dependent processes and therefore it can also be hard to separate the underlying aetiologies (Roberts and Manchester 1997; Waldron 2009). A typical example is the occurrence of ante-mortem tooth loss that can either occur due to recession of the alveolar bone with ageing or due to a reaction to periodontal disease arising from the accumulation of calculus on the teeth. The most common condition of the period was caries, however, calculus, ante-mortem tooth loss, periodontal disease, and dental wear were also elevated (Robert and Cox 2003).

Dental caries was the most common dental disease observed within St Hilda's and across sites. The true prevalence of dental caries observed in St Hilda's, especially in adults, were notably high. The prevalence of carious lesions increased with advancing age, with the prevalence being statistically higher in middle adults.

The significantly higher prevalence of caries in middle adults could be linked to the higher number of deaths observed in this age category due to the body's decreasing immune response reaching this age. Across sites, middle adults were more affected by mortality and morbidity in relation to other age groups, showing a weak immune system. The reason behind these relatively early deaths due to weakened immune response to diseases was possibly the physically-demanding lifestyle these middle adults lived, starting from a young age. A weak immune system would have enabled more carious-forming bacteria to colonise the dental plaque and subsequently to produce more acid. The increasing prevalence with age, observed amongst St Hilda's adults, could also represent the consequence of these individuals having had a better immune response during their life, therefore surviving periods of stress, which could instigate carious lesion formation (Hillson 2002; Waldron 2009; Mahoney-Swales 2012, 221). Another explanatory model behind the increased formation of caries among middle adults could be the increased prevalence of dental enamel hypoplasia also observed among them since defects in the dental enamel can lead to a greater susceptibility to dental caries (Wharton and Bishop 2003; Zerofsky *et al.* 2016). Alternatively, the explanatory model could be simpler than the proposed above and the observed difference in this age category may simply represent the prolonged exposure to cariogenic factors throughout life (i.e. teeth have had longer to be affected by carious lesions). The increase in the prevalence of dental caries with age may represent the cumulative effect of age and wear on the dental enamel over time, increasing the chances of fissures and pits into which food can be deposited and trapped. This proposed theory is in accordance with St Hilda's dental wear rates which were age increasing also, until they sharply drop in older adulthood due to ante-mortem tooth loss. Accumulative attrition may have exposed the softer, underlying dentine which would be more susceptible to the formation of dental caries (Hillson 2002). The rates of caries after passing mature adulthood were progressively stabilised and this was possibly linked to the increase observed in periodontal disease and subsequent ante-mortem tooth loss with ageing. The age increasing effect of caries rates was also observed in the few non-adults affected by the lesions. Presence of such lesions was observed mostly in older children showing the time required for the lesions to manifest. However, there were also a few young children with carious lesions, suggesting perhaps the consumption of sugar-based weaning foods. This is not to suggest that dietary differences existed between immature groups but instead shows that immunological differences existed between them resulting in differences in the presence and absence of carious lesions; for some, the carious lesions simply had not had sufficient time to form. Consequently, immunological alterations may be responsible for the favourable formation of caries and the subsequent periodontal disease.

Within St Hilda's, males and females seemed to have suffered similar rates of carious lesions indicating that both were exposed to a diet high in fermentable carbohydrates (i.e. sucrose, fructose and glucose) which would have produced acidogenic bacteria as well as low oral hygiene standards (Hillson 2002, 278). Within the palaeopathological and clinical literature, however, females typically display higher prevalence of dental caries than males (Boylston and Roberts 1996, 176; Mays 2007, 133). The higher rates of dental caries in females are commonly attributed to behavioural factors such as sexual division of labour and differential consumption of food, for example, females snacking on foodstuffs during preparation (Larsen 1995; Roberts and Manchester 1997; Mahoney-Swales 2012; Kim 2013). Hormone fluctuations during pregnancy affecting gingiva and saliva flow are also predisposing factors to periodontal disease while at the same time cause acid reflux which leads to quicker erosion of enamel and subsequent dental caries (Lukacs and Largaespade 2006; Silk 2008). According to clinical tests, caries rates have been found to increase with pregnancy, and the effects are compounded with each pregnancy (Lukacs and Largaespade 2006, 549). When age groups were split by sex, however, no differences were observed between different groups although one might have expected that young females would have been more prone to dental caries due to pregnancies. Earlier stages of the formation of the carious lesion, such as discolouration of the enamel surface, were excluded from this study, which may possibly have resulted in an under-estimation of the number of cases of dental caries in younger females. The lack of recorded differences between the sexes, however, shows that both males and females were equally affected by increased rates of caries in middle adulthood, suggesting that multiple factors such as early life employment, physically vigorous lifestyles and multiple pregnancies had accumulative health effects.

The high figures of dental caries obtained for St Hilda's were similar to those of Coach Lane, Carver Street, Cross Bones and St Bride's lower. These aforementioned sites were of working- or lower- class origin, revealing that some lifestyle and dietary similarities existed. The rest of the various socio-economic sites, however, exhibited lower prevalence suggesting that caries prevalence is clearly not always directly linked to social status (Brickley *et al.* 2006). This is not to say that some of the observed differences could not be due to socio-economic dissimilarities in diet and lifestyle, but rather that the background variation of these sites makes it difficult to come up with some definitive conclusions. Certainly, some similarities in diet, lifestyle and oral hygiene practices must have existed between St Hilda's and the other four sites as they were all of working-class origin or lower, but these sites were not the only working-class sites that were studied (Hillson 2002; Waldron 2009). It is possible that the reason for the differences between these sites and the rest of the study sample which gave lower rates was methodological and related to the size of the collections and the chosen criteria of study based on a medium or lower resolution analysis (Boston *et al.* 2002, 69; Boyle *et al.* 2005, 282). The size and good preservation of St Hilda's (over 85% of adults had observable dentition) as well as the size of Coach Lane, Carver Street and Cross Bones allowed a thorough examination, however, St Bride's lower was subject to large size assemblage issues. Another factor that may have reduced the formation of caries in the comparative sites was dental attrition which resulted in the flattening of the enamel folds of the occlusal surface; this usually reduces the risks of food entrapment and by extension reduces the risk of caries (Roberts and Manchester 1997).

The analysis of carious lesions across the sites showed that caries should be seen as the result of a range of immunological, dietary, behavioural, hormonal and physiological factors. However, the impact of cultural accessibility to dietary sugars during the period of study should not be overlooked as a contributory factor to the increased rates of caries in relation to other periods. During the period of study, sugar had progressively become an inextricable part of the Victorian diet with the consumption of cane sugar gradually increasing between the 18th and 19th centuries and slowly becoming an inexpensive commodity in Europe due to the introduction of sugar cane from the New World (Clarke 1999, 11). By the early 19th century, it was widely available only to the middle class, but later on became available to, and highly consumable by, the working class (Boston *et al.* 2008, 95).

Another frequently observed dental disease was calculus. The true prevalence of dental calculus observed in St Hilda's, especially in the adults, was notably high with the prevalence being age increasing and statistically higher in middle adults. Therefore, the pattern observed in carious lesions with the increased prevalence in middle adults was repeated here with dental calculus, supporting the proposed explanatory model of accumulative effects of the lesions on oral health, combined with the body's decreasing immune response which enabled more plaque-forming bacteria to form with increasing age (Hillson 2002; Waldron 2009). The decrease in calculus observed after passing mature adulthood coincides with the increase observed in periodontal disease and subsequent ante-mortem tooth loss. This pattern is in accordance with modern living populations, where supra-gingival calculus deposits increase with age and their extent is associated with periodontal disease (Hillson 2002, 262). The prevalence of calculus was statistically higher in males than females; this is consistent with reports from modern living populations where men show more and frequently heavier calculus deposits, indicating perhaps routine differences in oral hygiene (Hillson 2002, 259).

The high true prevalence rate for dental calculus within St Hilda's assemblage and the high percentage of individuals expressing moderate calculus deposits indicates that the entire population either consumed a carbohydrate and fat rich diet or had limited access to drinking water and oral hygiene (Lieverse 1999). The levels of dental caries, abscesses and AMTL, however, along with the presence of calculus which ranged from slight to moderate, indicates that calculus resulted from a synergistic interaction of poor oral hygiene, diet and lack of drinking water. The high true prevalence rate for dental calculus within the population confirms what was discussed earlier in the metabolic disorders section (7.3.2a), that the entire population consumed a diet high in carbohydrates. The evidence of increased calculus rates within St Hilda's confirms what is historically known about the diet of the period. The Victorian working-class diet consisted mainly of milk, bread and potatoes, while sugar had increasingly become part of this diet when import duties were lifted on refined sugars making sweetened foods far more affordable by a wider section of society (Boston *et al.* 2002; Hillson 1996). Other carbohydrate sources consumed were seasonal fruits and vegetables, nuts, legumes, whole grains, cheese, butter, treacle and beer (Wohl 1983; Shammas 1984; Olsen 1999; Sinnott 2013). Oatmeal was also part of the working-class diet, and was frequently sweetened by treacle or sugar as were tea and cocoa. The results for the high rates of calculus and the associated consumption of carbohydrates were also in compliance with the results of Hendy *et al.* (2018), who revealed that the protein component of the Victorian diet was related to plant foods including oats, peas, vegetables in the cabbage family, and milk.

When St Hilda's was compared to the various sites, no status patterns could be observed in the prevalence of calculus between the different social strata showing that the lesions were not directly linked to social status. It is reckoned, however, that in some cases such as St Pancras or Carver Street, where the prevalence of calculus was lower than the case study, the difference was linked to preservation, excavation, and post-excavation treatment as well as spent time on the analysis of the assemblage. Calculous is very loosely attached to the tooth and can be easily removed when extra care is not taken (Roberts and Manchester 1997).

Other dental conditions observed within St Hilda's and the rest of the sites, included dental wear, periodontal disease, ante-mortem tooth loss and dental abscess. An increased prevalence of DW was observed with increasing age, with the prevalence of DW being again statistically higher in middle adults. The statistically higher prevalence in this group reflects the cumulative effects of ageing combined with the mouth's normal masseteric activity manifested as attrition and abrasion, and reflects the portion of the population which was actively involved in occupational or domestic activities and had to utilise to a certain extent their teeth as vices. This is further supported by the higher prevalence of both abrasion and attrition among males which were twice as affected as females; revealing indeed that direct and indirect stress was created upon their teeth due to the performance of this type of employment activities, work related stress or social practices during and after work. These lesions in males may even be indicative of cases of awake bruxism, which has been linked to excessive stress brought on, for example, by work pressure or family responsibilities (Shetty *et al.* 2010). The presence of pipe facets found among St Hilda's males shows the effects of long-standing social practices on health and dentition. As seen earlier, smoking tobacco aboard ships was a common practice among non-navy seamen (Boston *et al.* 2002, 47). However, seafarers were not the only social group of men engaged with this long-standing practice. The presence of pipe facets within St Hilda's males confirmed that the dental wear resulted indeed from abrasion (three body wear: teeth (upper)-pipe-teeth (lower), confirming the presence of foreign bodies in the mouth as well as attrition as part of the normal ageing process and masseteric activity. The TPR of pipe facets was statistically significant for males, but no differences were observed between different age groups for either the total population or the adult population alone.

The presence of dental attrition which resulted in the flattening of the enamel folds of the occlusal surfaces may have contributed to the lower prevalence of carious lesions in some of the comparative sites (Roberts and Manchester 1997). However, confirming this explanation was problematic as only the sites of Newcastle Infirmary and Christ Church, Spitalfields had calculated the rates of dental wear; the Infirmary showed lower prevalences than St Hilda's, whilst Christ Church was almost equal (Molleson and Cox 1993; Boulter *et al.* 1998). The problem with most of the sites such as Greenwich Tier was that the lesions were recorded but were not quantified. The general impression, however, was that sites such as Greenwich

Tier had suffered considerably more attrition than other contemporary assemblages, suggesting that seamen of the period suffered from higher prevalence of DW than civilians (Boston *et al.* 2008). The typical daily diet of seamen aboard a ship using the Royal Navy ships as an example, included unrefined flour, pulses, 'hard tack', and salted meat and cheese, making the diet one of the main causes of DW (Boston *et al.* 2008, 100). Incidents of traumatic origin and interpersonal violence can also not be excluded from within the various sites. For example, in St Hilda's there were a few cases of ante-mortem tooth breakage, and it is possible that where seamen were stationed, such as in the case of St Hilda's, activities of social merit, often associated with violence, such as alcohol consumption were inevitable (Boston *et al.* 2002, 47).

Calculus deposits that irritate the dental tissues can lead to subsequent weakening of the periodontal ligament and the resorption of the alveolar bone (periodontal disease) and in many cases this leads to subsequent tooth loss (Roberts and Manchester 1997, 50). Further to this mechanism, periapical abscesses forming as a result of gross carious lesions and exposure of the underlying pulp cavity and/or excessive attrition can lead to the death of the root and loss of the tooth (Hillson 2002, 196).

Hence, within St Hilda's a very high prevalence of periodontal disease was recorded and probably resulted from the type of chronic inflammation of the mouth due to poor dental hygiene (Hillson 2002). The prevalence of PD increased with age for the adult assemblage of St Hilda's, with the rates being statistically higher in mature and older adults. There was no statistically significant difference in the prevalence of PD expressed by females and males. The majority of the affected individuals exhibited generalised inflammation that was expressed as horizontal lowering of the alveolar bone, with more than one tooth involved and often the whole of the dental arch. Consequently, most of the walls surrounding the bone were affected uniformly. It is very likely that PD was induced by an accumulation of calculus in dental pockets due to prolonged exposure with increasing age. However, the aetiology of PD remains multifactorial with diet, hygiene, environment and genetic predisposition all being potential influences (Hillson 2002).

The prevalence rates of PD correlate well with many contemporary sites of various socio-economic status such as St Luke's Islington-named, St George's Bloomsbury-named and St George's Bloomsbury-unnamed. Whilst St Hilda's exhibited statistically higher prevalence than Carver Street, St Marylebone, St Martin, St Luke's Islington-unnamed and Christ Church, and statistically lower than Greenwich Tier. Consequently, no clear socio-economic patterns were observed, however, the fact that sites of different backgrounds exhibited similar rates to the case study was indicative that everybody, irrespective of socio-economic status, was affected to a certain extent by poor oral hygiene.

Within St Hilda's the prevalence of ante-mortem tooth loss also increased with age for the adult assemblage, possibly representing biological influences throughout life. The prevalence of AMTL was statistically higher in mature adults, while no differences were observed between males and females or when age groups were split by sex. Therefore, it is very likely that dental decay due to prolonged exposure to cariogenic factors or gum disease with increasing age was probably the most common reason for tooth loss. The increase in true prevalence of AMTL with age could represent the body's decreasing immune response with increasing age, and may represent the symbiotic relationship between AMTL and other dental conditions. The aetiologies of many dental health indicators are multifactorial; therefore, it is dangerous to make interpretations about the dental health indicators based on single factors alone (e.g. diet). However, a large contributing factor in the prevalence of all the dental health indicators within St Hilda's appears to be the deteriorating effects of age upon the teeth. The true prevalence increase observed amongst St Hilda's senior adults could represent pathological influences throughout life such as the body's decreasing immune response with age and also the symbiotic relationship between dental abscesses, calculus and dental caries, which also increase with age in this population (Roberts and Manchester 1997). Another possible contributing factor to the occurrence of AMTL could be prolonged gum bleeding induced by scurvy. It was noted that six individuals affected by AMTL were also affected by scurvy at the same time; however, no statistical significance was revealed between the two conditions.

Deliberate extraction, however, cannot be excluded as a reason for tooth loss. In general, the link between systemic diseases such as cardiovascular disease, diabetes, and pulmonary disease and periodontal issues resulting in tooth loss is known and since some of these are potentially fatal (Kim and Amar 2006; Arigbede *et al.* 2012), this may have been the reason why so many people were reported as having died of 'teeth' in the London Bills of Mortality (Waldron 2009, 240). When the London (England) Bills of Mortality began listing the causes of death in the early 1600's, 'teeth' were continually listed as the fifth or sixth leading cause of death. This does not include the category of 'teething' which was probably erroneously blamed for many children's deaths. Clarke (1999, 11) by examining several historic factors of this period concluded that the number of deaths attributed to 'teeth' in the 17th and 18th centuries '…was probably fairly accurate, and it was not antibiotics, nor the discovery of asepsis, that brought about the dramatic reduction in these dental mortalities but two much earlier dental innovations, anatomic forceps and anaesthesia'. For most of the 19th century deliberate extraction of teeth, either to alleviate toothache or as a prophylactic elective measure against the pain to come, was frequently performed by 'amateur surgeons' and was a common practice until the Dentist Act passed in 1878, which limited the title of 'dentist' and 'dental surgeon' to registered practitioners (Clarke 1999).

Secondary AMTL could also be another possible explanation for the low prevalence of carious lesions in some of the comparative sites; presumably because of the large tooth decay there were fewer teeth to analyse in the comparative sites' assemblages. In fact, it was observed that some of the comparative sites exhibited higher AMTL in relation to a lower prevalence of caries. These observed differences could be partially attributed to the symbiotic relationship with caries; this explanatory model was partially confirmed for the sites of Chelsea Old Church, St Luke's Islington-named, St George's Bloomsbury-named, St George's Bloomsbury-unnamed and Greenwich Tier, where their AMTL rates were statistically higher than St Hilda's and the rates of carious lesions were statistically lower than St Hilda's. However, there were also sites where both diseases were lower than St Hilda's such as the Infirmary Newcastle, St Martin, St Benet, Cross Bones and Christ Church. Similarities in the rates were observed between St Hilda's and Carver Street, Coach Lane and St Marylebone. Regardless of the aetiology, the fact that individuals from different social strata exhibited both conditions is indicative that the poor and the rich were exposed to poor dental hygiene and diet, suggesting that the conditions were independent of socio-economic status.

The aetiology of these localised infections that spread from the pulp cavity to the roots of the tooth and from there into the surrounding bone, was not straightforward to determine, especially where the affected tooth was lost ante-mortem. However, where the involved tooth/teeth were present it was assumed that the most common cause of periapical lesions was a synergistic interaction between tooth caries, calculus, and PD (Roberts and Manchester

1997, 50). Less commonly, a tooth injury where the tooth was broken and the pulp exposed could also be responsible (Hillson 1996; Waldron 2009). The low prevalence of abscesses and other periapical voids in St Hilda's adults suggests either a reasonable level of oral hygiene or a stronger immune response due to different factors (e.g. nutrition, health) (Dias and Tyles 1997, 548). Alternatively, it could reflect a poor immune response due to environmental stressors, such as poor health and nutrition, whereby the adults died before the lesions were manifested skeletally (Wood *et al.* 1992).

The prevalence of abscesses was statistically higher in middle adults, while the prevalence of cysts was statistically higher in mature adults. The increased prevalence of abscesses in middle adults reflects, perhaps, the decreasing immune response of the most physically exhausted group of the working-class population. Many of these (male) individuals were the breadwinners and had to work from an early age, and as a result, by the time they reached middle adulthood their immune systems were exhausted; likewise, those mature adults may have had a decreased immune reaction with increasing age along with the effects of a premature physically demanding lifestyle. No statistically significant differences were observed in the prevalence of abscesses and cysts expressed by females and males, suggesting that both sexes were equally exposed to the risk of forming dental voids. Consequently, the number of affected individuals was virtually the same. No statistically significant difference was observed when age groups were split by sex.

St Hilda's population exhibited a lower prevalence of periapical voids than many of the comparative sites apart from Coach Lane, Infirmary Newcastle and St Luke's Islington-named, which exhibited equal prevalences. The prevalence of St Hilda's falls below the prevalence of St Martin, St Marylebone, Cross Bones, Greenwich and St George's-named, but above the prevalences of St Benet, St George's-unnamed and Carver Street. The reason behind these differences remains unclear due to the fact that the condition cannot be easily attributed to a single aetiology, but also because there was no socio-economic pattern observed between the lower and upper strata sites. This is perhaps indicative that the condition has nothing to do with socio-economic status, but a more perplexed aetiology of multifactorial origin linked to diet but also the immune system. The fact, however, that the lesions were not so elevated among St Hilda's individuals shows perhaps a good immune response in overall combined with some oral hygiene practices. It is also necessary to keep in mind that these calculations across the sites were approximations as no X-rays were used to inspect the jaws, and as a result only extreme cases, which had time to manifest on the external part of the jaws, were recorded.

7.3.6 Indicators of Genetic and Environmental Stress: Congenital Disorders

Congenital abnormalities are the result of pathological changes to normal development during the intra-uterine stage of life (Aufderheide and Rodrigues-Martin 2006, 51). Such conditions can either be caused by an inherent genetic defect, by extrinsic factors, or a combination of both which affect the foetus during its development. Contributory extrinsic factors could be infectious, nutritional, or environmental in nature (Brickley *et al.* 2006). The full range of diseases that could be placed under this heading is very large, ranging from very slight skeletal changes that are not detrimental and may not be noticed by the affected individual, to serious defects that are incompatible with life. The study of these congenital disorders revealed that congenital defects may not be good indicators of past living conditions as the genetic components cannot be fully separated from environmental causes. Nonetheless, the recording of the disorders was very informative as it further defined the profile of St Hilda's population.

A range of developmental defects of the vertebral column, ribs and associated areas of the skull were recorded in St Hilda's material, with defects of the vertebral column being by far the most commonly observed. Within the total assemblage, thirty-nine individuals exhibited defects present at birth; of these, four were non-adults and the rest were adults. In most of the cases, the defects were minor asymptomatic developmental variations and likely to have had little or no clinical impact on the individuals' lives (Barnes 1994).

A variety of vertebral column defects were recorded in thirty-two individuals including sacralisation, lumbarisation, sacrococcygeal shifting, bifurcated neural arch, spina bifida occulta, hemi-vertebra, fused vertebrae, and supernumerary vertebrae. It was common for more than one congenital defect to occur in the spine of a single individual.

Developmental defects occurring at the lumbosacral junction can result in transitional vertebrae that have a mixture of lumbar and sacral characteristics (Barnes 1994; Savage

2005). The resulting combination of such characteristics produces a variety of morphological configurations collectively referred to as lumbosacral transitional vertebrae. Disruptions during the vulnerable time when developmental thresholds are reached can cause developmental fields to overlap or expand beyond normal parameters, resulting in boundary shifts at the transitional areas of the vertebral column (Barnes 1994, 35). Boundary shifts at the lumbosacral junction can occur cranially (sacralisation) or caudally (lumbarization). Sacralisation refers to a cranial shift where the last lumbar vertebra assumes sacral characteristics and frequently becomes incorporated into the sacrum. Lumbarization refers to a caudal shift where the first sacral segment assumes some characteristics of the lumbar vertebra (Barnes 1994, 110). Depending on the direction of the shift, an individual may end up with either an extra lumbar segment or one fewer segment, which can have significant biomechanical and clinical implications (Savage 2005, 1).

Within the St Hilda’s skeletal assemblage, sacralisation was the most frequently observed spinal defect, in particular, a total of seventeen individuals displayed partial or complete incorporation of the fifth lumbar vertebra into the sacrum. The prevalence of sacralisation was statistically higher for middle adults with twelve affected individuals; this predilection possibly shows genetic vulnerabilities for this group (Crump 2019). Partial or complete separation of the first sacral vertebra from the rest of the sacrum, known as lumbarisation, was noted in six individuals. Boundary shifts can also occur at the sacral-caudal border. Much variation is found in the configuration and position of the coccyx, which normally articulates with the apex of the sacrum (Barnes 1994, 114). Cranial shifting of the sacral-caudal border affected the last sacral segment of a middle male adult. The last segment of this individual was completely disengaged from the rest of the sacrum and exhibited accessory facets for articulation with the rest.

Cranial shifting at the thoracolumbar border can sometimes lead to numerical errors in segmentation expressed as an extra, transitional, vertebral segment that takes the appearance of the last thoracic vertebrae with transitional facets and a small pair of thoracic-shaped ribs (Barnes 1994, 105). Supernumerary vertebrae were observed in two mature females. In particular, both females exhibited six lumbar vertebrae as well as an extra pair of ribs each. Indeed, one of the females had an extra pair of thoracic-shaped ribs due to cranial shifting of the thoracolumbar border in order to accompany the extra lumbar vertebrae. The second female exhibited a pair of cervical ribs resulting from cranial shifting of the cervicothoracic border (Barnes 1994, 100). The cervical rib is a product of the elongation of the transverse process of the last cervical vertebra (Aufderheide and Rodrigues-Martin 2006).

Another observed condition of the sacrum arising from developmental disruptions was spina bifida occulta (Aufderheide and Rodrigues-Martin 2006). A major delay in the development of the neural arches during the first month of embryonic development leads to failure of the two halves to come together, leaving a cleft in the neural arch (Barnes 1994, 117-119). Spina bifida occulta, although not common, is considered to be the most frequent type of spina bifida and in most cases is asymptomatic (Roberts and Manchester 1997, 36). A case of spina bifida occulta was identified on the sacrum of an adolescent; the neural arch hiatus extends from the second to fifth sacral segment. During life this bony opening was probably covered with tough fibrous tissue, leaving little chance of disturbance of the underlying soft tissue.

Four individuals had bifurcated neural arches of the vertebrae and first or second sacral segment. This is the most common defect of the vertebral column and generally occurs in the border regions particularly the lumbosacral border, and usually only one or two vertebrae are affected. In most of the cases the condition is asymptomatic. Failure of the two halves of the neural arch to coalesce results from minor developmental delays that lead to hypoplasia or aplasia of one or both parts of the precursors of the pedicles, laminae, or spinous process (Barnes 1994, 117-119). Within St Hilda's three out of four affected individuals seem to follow this pattern of the lumbosacral border. Once more, middle adults were more affected showing genetic vulnerabilities.

Segmental disarrangement of the vertebral ossification centres may result in congenital fusion of the vertebral segments (Weinstein 2005, 494; Ortner 2003, 463). The developmental unit fails to separate into all or some of its different parts and a block vertebra is formed (Weinstein 2005, 494; Barnes 1994, 63-67). The degree of failure of segmentation depends upon the timing of the delay during the developmental stages. Within St Hilda's, block vertebrae with failure to segment between the neural arches was noted in two individuals. A case of hemi-vertebra was noted in a middle adult male, possibly demonstrating again the genetic vulnerability that middle adults were exposed to from very early life stages (before they were even born), although no statistical differences were observed. Hemi-vertebra is defined as the result of a failure in normal segmentation and is expressed as aplasia of the vertebral body (Weinstein 2005). This condition occurs when half of the vertebral body fails to develop during the normal process of vertebral formation (Barnes 1994; Aufderheide and Rodrigues-Martin 2006; Strati 2012).

Cranial abnormalities such as metopism, craniosynostosis and brachycephaly were also present in eight individuals. Congenital cephalic disorders stem in general from the damage to, or abnormal development of, the budding nervous system. They are not necessarily caused by a single factor but may be influenced by hereditary or genetic conditions, or by environmental exposures during pregnancy, birth, and development (Storm 2008). The majority of the affected individuals were again middle adults, especially males, showing once again a possible genetic vulnerability for this age group; however, no statistical differences were observed. The most commonly encountered cranial anomaly was metopism, which is described as a persistent metopic suture in the adult human skull. Fusion of the metopic suture usually commences between the second and fourth years of life, although there are divergences in the literature regarding the exact time at which it closes and which ranges from the first to the seventh year of life, with the upper limit extending up to the tenth year (Collins 1995; Hemalatha and Subba Rao 2016). There are several causes for the failed fusion of the metopic suture, but genetic influences are currently the factor most accepted (Storm 2008). In addition to metopism, one of the affected middle adult males exhibited features of brachycephaly, which is described as flat head syndrome with a broad and round calvarium (Kelly et al 2018, 1). The opposite process of metopism is called craniosynostosis, which is described as a premature closure of the cranial sutures (Johnson and Wilkie 2011, 1). The phenomenon occurs during the early foetal development and continues until the age of seven when the brain has reached most of its adult size. The exact aetiology of premature suture closure is hard to determine, but can be separated into primary and secondary synostosis. The primary type can either have an isolated cause, like birth trauma or can be related to a congenital syndrome. The secondary type can be caused by thalassemia, metabolic conditions (such as rickets and hyperparathyroidism), bone dysplasias, and foetal insults (Storm 2008). Within St Hilda’s, a case of craniosynostosis was identified in an infant; given the age of the individual it could be the primary type due to a congenital syndrome although one-to-one correlations are impossible to make.

Despite these early life anomalies, most of the affected individuals made it to middle adulthood, although with immune weaknesses. Of course, there were also individuals who did not make it as far and the effects of congenital disorders were too apparent. A possible case of thanatophoric dwarfism or dysplasia was diagnosed in a preterm individual. The term thanatophoric means 'death bearing' reflecting the nature of the congenital disorder that usually results in stillbirth or death shortly after birth from respiratory failure due to poorly developed lungs and a narrow chest (Griffis 1994, 24). Considerable skeletal changes had affected the skeletal morphology, making difficult to estimate the age of the individual. Skeletal development and long bone length were clearly abnormal. The abnormalities of the available bones comprised the premature fusion of the squamous temporal to the pars petrosa, and premature fusion of the vertebral body, malformed femoral epiphyses, and fibular bowing. All long bones were short and wide. Epiphyses were present on the ends of some long bones suggesting premature fusion (Raynor *et al.* 2011). The length of the petrous portion gave an age range between 34 to 38 weeks, while the long bones, due to shortening, gave an age comparable to 20 to 26 weeks. It is unclear whether this form of defect was the result of the industrialised urban environment as the genetic component cannot be completely separated from the environmental component. For the whole population sample of St Hilda's, middle adults seemed to be more frequently affected by congenital disorders (both spinal and cranial) This information is important as it potentially offers an explanation as to why middle adults were so frequently afflicted by mortality and morbidity in relation to other age groups. Up to now, the systematic study of adult pathologies and age at death within this study has revealed that middle adults were the most vulnerable age group. However, the reasons behind the susceptibility of this group were unknown. It was assumed that these individuals were the population workforce that had a very physically-demanding lifestyle from early life, a lifestyle that inevitably suppressed their immune systems thus affecting their survival prospects. This supported the historical sources which suggested that death most frequently occurred in middle adulthood among the labouring strata of the working class (Foster 1974; Wohl 1983). These results were also in accordance with other studied sites of the period, where middle adults were more frequently afflicted by mortality and also morbidity (Boulter *et al.* 1998; Brickley *et al.* 1999; Boston *et al.* 2006; Boyle *et al.* 2005; Brickley *et al.* 2006; Miles *et al.* 2008; Miles and White 2008; Proctor *et al.* 2016). What is new here is that through the study of the congenital defects within St Hilda's population, it was revealed that middle adults were possibly also genetically weakened before birth, and this is perhaps the true reason they were more affected by mortality and disease from early in life. This idea falls under what is known as the *Development Origins of Health and Disease* or *Barker theory* where early life stressors such as undernutrition, starting as early as in foetal stages, can affect adult health and disease susceptibility by 'reprogramming' and adaptations of metabolism during gestation (Barker and Osmond 1986; Barker *et al.* 1989; Barker *et al.*1993; Wadhwa 2009; McKerracher *et al.* 2020). Therefore, there is an apparent link between poor maternal health during gestation and exogenous stressors in early life, that can expose the individual to increased risk of morbidity and mortality in adulthood. Consequently, evidence of reduced longevity among adult samples, such as in the case of middle adults from St Hilda's who exhibited increased prevalence of congenital disorders possibly reflects bioarchaeological applications of Barker's theory in human skeletal populations (Gowland 2015).

Eight studies of contemporary populations from Sweden, Norway and Australia revealed that poor maternal health, nutrition and cultural habits as well as poor environmental conditions would have resulted in premature births with long-term health effects on the survivors (Koupil *et al.* 2005; Crump *et al.* 2011; Crump *et al.* 2013; Crump *et al.* 2019; D'Onofrio *et al.* 2013; Juarez *et al.* 2016; Risnes *et al.* 2016; Srinivasjois *et al.* 2017). According to Crump (2019), who reviewed these studies, survivors of early neonatal intensive care are now reaching middle adulthood and may be at higher risk of chronic diseases and premature death. The health problems linked to early life death included respiratory, cardiovascular, endocrine and neurologic disorders. Therefore, premature births and their effects on later life reflects a combination of genetic and extrinsic factors. Consequently, it could be that within St Hilda's, individuals were genetically weakened due to a combination of aetiologies; these individuals were not only immunologically weakened due to the physically-demanding lifestyle they lived from early age, but also due to the effects of poor genetics. This could reflect inter-generational health effects on offspring as it was evidenced through the presence of an increased number of congenital anomalies within this group. Although premature individuals managed to survive and reach adulthood, they were left susceptible to various diseases and early death in middle adulthood. Thus, death in middle adulthood was the result of a weakened immune system induced by poor genetics, and/or maternal health and cultural habits, as well as suboptimal environmental conditions due to industrialisation and a physically-demanding lifestyle from an early stage. It would appear that these people were born at the peak of the Industrial Revolution and somehow managed to temporarily overcome the negative effects of industrialisation, only to die in the middle of life due to a combination of weak immune responses and genetic predispositions.

The occurrence of various congenital defects such as spina bifida occulta and sacralisation was not limited to St Hilda's, but was commonly reported across various sites (e.g. North Shields, St Martin's, and Chelsea Old Church) (Miles *et al.* 2008). However, no statistical comparison was applied as the deformities were not systematically recorded but were more casually reported across many sites wherever feasible.

7.3.7 Miscellaneous Pathology

During analysis, lesions uncharacteristic of the standard diseases outlined above were also recorded in order to give a deeper insight into the lifestyle of this working-class population from Northern England. It was also useful for demonstrating how inconvenient life could be for some individuals who had to carry on their daily routines by having to deal with conditions induced by day-to-day discomforts, or by their own jobs. Signs of corset wearing, poor posture and industrial diseases were observed in the population.

Flattening of the angle of the lower ribs from the 4th rib downwards was recorded in an older female. These types of changes have been recorded previously in post-medieval assemblages and are attributed to tight fitting corsets worn over a long period of time (Miles *et al.* 2008; Raynor *et al.* 2011). In this particular female, the rib deformation due to corset-wearing was exacerbated by osteopenia which had affected the ribs along with the long bones. The ribs of the female appeared gracile, with a flattened angle and anteriorly projecting sternal ends. The age of this female and the induced rib deformities indicated that she wore restrictive undergarments for many decades. Presumably more females within St Hilda's wore corsets, however, exaggerated permanent changes were only identified in this older woman.

The presence of tight clothing like corsets even amongst the working-class population of St Hilda's should not come as a surprise. Women during this period were expected to wear stays from the age of 15 into adulthood including during pregnancy when they would have provided some support. Men resorted to corsetry for medical reasons, and more frequently wore girdle-like belts (Mile *et al.* 2008). With the introduction of machine-made metal eyelets in the 1820s, stays could be laced far more tightly allowing corsetry to be taken to the extremes. Manufacture and the development of the sewing machine in the 19th century also meant that restrictive undergarments became more mass produced and popular. Although many corsets were still stitched by hand, the speed of sewing on a machine meant that manufacturers could produce corsets in far greater numbers and increase the variety of designs. Corsetry and underwear manufacture therefore became a major industry (Johnston 1983). These technological innovations resulted in new designs and in some cases made the life of women more comfortable, but by the same token, also more complicated due to the detrimental effects that corsets had on their bodies.

Although undergarments varied with fashion, all acted in the same way; bringing the sides of the thorax inwards and projecting the chest forwards to give the illusion of a smaller waist-line. The result would have been to restrict the rib cage laterally, projecting the sternal ends of the ribs forwards. Once corsets had been worn for some time, it would have been difficult to revert to less supportive undergarments as the disuse of the pectoral muscles resulted in atrophy and lower back pain which would have prevented women from standing upright unsupported. Spinal deformities and organ restriction, which could cause poor breathing and digestive problems, have been reported as a consequence of corset-wearing (Kunzle 1982; Steel 2005; Miles 2008; Raynor *et al.* 2011). This also caused fainting because they could barely breathe, and it has also been suggested that corset wearing may have aggravated infectious conditions such as pneumonia and pulmonary tuberculosis (Knuzle 1982; Steel 2005).

St Hilda's was not the only site where women were affected by corset wearing; similar skeletal cases were observed in St Marylebone (Miles *et al.* 2008). However, no statistical comparison was applied because the deformities were not systematically recorded across the sites, but reported more casually wherever feasible. It would appear, however, that females irrespective of socio-economic strata were similarly affected as the condition is not status attributable, but linked to the social practices of the period that females were subjected to.

Spinal deformities as a consequence of corset wearing have already been mentioned, however, it would appear that this older female discussed above exhibited no evidence of spinal deformities. In the following section, spinal deformities will be seen individually mostly as an idiopathic cause as one-to-one correlations were impossible in most of the cases. Within St Hilda's, two types of spinal deformities were recorded; kyphosis and scoliosis, evidenced as a pathological increase in the normal curvature of the spinal column present at birth (congenital) or arising spontaneously (idiopathic). It was not within the scope of the thesis to systematically assess the individuals for spinal deformities, but an assessment was performed only when exaggerated curvature was noted by chance.

Kyphosis is defined as a pathological increase in the anterior concave curvature (greater than 40 degrees) of the thoracic spine (Ortner 2003; Strati 2012). Kyphosis is caused by changes in the intervertebral discs (primary kyphosis), or in the vertebrae themselves (secondary kyphosis). Primary kyphosis is divided into juvenile and senile forms (Ortner 2003, 463), whereas scoliosis is defined as a lateral deviation of the spine with rotation of the vertebrae towards the concavity; the curve usually takes the form of a C- or S- shape (Aufderheide and Rodriquez-Martin 2006). The factors leading to this deformity are varied and usually not obvious. Scoliosis often starts in childhood and progresses throughout growing age and into early adult life (Ortner 2003, 466).

A possible case of Scheuermann's disease, a form of idiopathic kyphosis which develops during adolescence was recorded in a middle adult male who also exhibited cranial shifting of the sacral-caudal border (Üstündağ and Deveci 2011). In modern populations, juvenile kyphosis has a greater predilection for males, and St Hilda's seems to fit this pattern. The deformity of the above individual was greater than 60 degrees extending from the seventh to the eleventh thoracic vertebrae, accompanied by wedged vertebrae, Schmorl's nodes at the ends of the wedged vertebrae due to protrusion of the vertebral disc, marginal osteophyte-lipping arising from the vertebral end plate, and anterior extension of the vertebral bodies outside the annular rings (Strati 2012, 23). Although the aetiology is still controversial and many theories have been proposed such as vascular necrosis, growth disorders of the spine, mechanical factors, genetic factors, and endocrine or nutritional anomalies, it appears to resemble a growth disorder of the spine in a genetically predisposed individual, which may have resulted from postural kyphosis or excessive loading (Bradford *et al.* 1974; Moe *et al.* 1978). Until now, it is difficult to determine how the genetic factor may have affected its occurrence.

The presence of Scheuermann’s disease in the archaeological population is rare; this is perhaps due to the difficulties in identifying the condition that requires multiple diagnostic criteria (Üstündağ and Deveci 2011). Therefore, the recognition of this condition within this population was very important for the determination of the osteobiography of this individual. Scheuermann’s disease is known for causing mid- and lower-back pain, which can be debilitating. Thus, the individual may have experienced pain at the apex of the curve, which would have been aggravated by physical activity and/or by prolonged periods of standing or sitting. His physical discomfort probably became even worse by the physically-demanding lifestyle of the working class. ‘Hunchback’ or ‘roundback’ was also another feature that this individual would have exhibited during his lifetime (Blumenthal *et al.* 1987; Summers *et al.* 2008).

Evidence of dextroscoliosis of the thoracic spine combined with levoscoliosis of the lumbar spine was noted in a mature female adult. The curvature had affected the right side of thoracic spine extending from the first to sixth thoracic vertebra, but also had affected the left side of the lumbar spine, forming an ‘S’ shape. While another female adult exhibited pathognomonic features for the diagnosis of kyphoscoliosis secondary to Pott’s disease making it, in this case, a one-to-one correlation. This case of kyphoscoliosis was the result of tuberculosis occurring in the vertebrae and therefore outside the lungs area. The age of this female was not very clear, however, the fact that the lesions affected the skeleton show that they l had a strong immune response and lived for a while after the condition spread to the skeleton.

It is hard to determine the exact impact these postural deformities had on the daily lives of the affected individuals. It is known, however, that deformities of this type are associated with diminished function, especially performance of mobility tasks due to the back pain caused by the compression of the nerves and spinal cord, muscle fatigue, weakening of the lower extremities, and stiffness in the back (Ryan and Fried 1997). In the case of scoliosis, breathing problems are also known to occur due to the reduced area in the chest for the lungs to expand (Ortner 2003). Similar cases of spinal deformities were reported in St Martin’s in-the-Bull Ring and St Marylebone (Brickley *et al.* 2006; Miles *et al.* 2008); again, no statistical comparison was applied as the lesions were reported casually, but the observed pattern shows that bad posture was not a socio-economically induced trait.

Unlike spinal deformities that is hard to determine the exact impact they had on the affected individuals, the debilitating effects of many industrial diseases were apparent. Phosphorus necrosis due to prolonged exposure to white phosphorus vapour was one of them. Severe osteomyelitis resulting in bone loss of the left mandible adjacent to the gonial angle was noted in a mature male. Proposed differential diagnoses included a bad case of tooth abscess or a specific infection such as syphilis; however, in phosphorus necrosis the lower jaw is more affected than the upper, as in this individual (Roberts *et al.* 2016, 10s). Phosphorus necrosis or 'phossy jaw', as it has already been seen in the second chapter, was an occupational disease of the 19th and early 20th centuries, most commonly encountered in matchstick industry workers who were working with white phosphorus without proper safeguarding. Any factor that involved contact with the bone or periosteum of the oral cavity such as dental caries was a possible source of osteopathy expressed as the destruction of the jaw bones. Dental caries was considered to be a predisposing factor to the development of the disease and a main route for phosphorus to enter the dental pulp cavity and subsequently the alveolar bone. As already discussed in the dental diseases section, during the 19th century dental caries was highly prevalent, particularly amongst the poorer classes due to the availability of cheap sugar (Roberts and Cox 2003, 326). However, the link between caries and 'phossy jaw' may have been uncertain as individuals with healthy teeth were also known to be affected showing other potential routes of absorption (Roberts *et al.* 2016). According to clinical studies, it would appear that brittle and necrotic bone develops in areas of the skeleton that there is the highest bone turnover in response to compressive and bending forces such as in the case of the alveolar bone, and this is perhaps the reason behind the predilection of the mandible to phosphorus necrosis (Marx 2012).

It would be impossible to precisely describe what this particular male individual from St Hilda's experienced, however, according to descriptions from the period those with 'phossy jaw' would usually begin suffering painful toothaches and swelling of the gums. The pain was characterised as persistent yet progressive, spreading to neighbouring teeth and the jawbone. Over time, pus formation developed penetrating the oral mucosa with the formation of fistula, tooth loss, and recurrent abscesses. Further progression led to the formation of sequestrum (dead bone that has separated from the living bone) after three months, and necrosis of the jaw within six months. The distinguishing feature of this disease was the eventual separation of the sequestrum which was described as porous and light in weight such as in the case of this individual (Pickerill 1923, 380). The non-surgical removal of the necrotic bone could further cause septicaemia, meningitis and even death.

Although it is not certain that this particular individual from St Hilda's exhibited mandibular osteomyelitis due to the exposure to phosphorus during matchmaking, the historical data suggest that such factories did exist in the broader region, such as in the Newcastle area, at the time this person was alive (Simon 1863). The St Hilda's burial registers did not suggest the existence of this occupation amongst the individuals; however, some 'braziers' were identified among St Hilda's individuals and that was another industry in which white phosphorus was in use. Two of these males described as 'braziers' within the burial registers had matching ages with the affected male skeleton; their skeletal changes were also very similar to clinical descriptions of people with 'phossy jaw'. If indeed the individual was affected by this industrial disease, not only would this person have appeared facially disfigured, with swelling and suppurations of the affected side of the face, the foul discharge from the mouth as a result of osteomyelitis would have been odorous, thus potentially resulting in social stigma. The person affected would also likely have suffered respiratory problems, such as shortness of breath and chest pain, due to pulmonary involvement (Pickerill 1923; Roberts *et al.* 2016). The lesions of this individual appeared active at time of death, leaving also a possible cause of death due to associated complications.

Similar cases of 'phossy jaw' from this era were reported in North Shields and in Gloucester; both cases were young individuals, in particular the first was an adolescent while the second was a late adolescent-young adult, possibly male (Roberts *et al.* 2016; Satu *et al.* 2019). The few osteological cases mostly appear to be males, although this might be just coincidental. Historical accounts, however, show that until the very end of the period, when the use of white phosphorus was abolished from match-making production in 1910 in Britain, more than 75% of the industry was dominated by women (Harrison 1995, 22). In particular there were twenty-five match factories registered in Britain employing 4,311 persons. Of the adults, 617 were men, 2,283 were women, 390 were young males under 18, 1,015 were young females under 18, and 6 boys were under 14 (Thorpe, Oliver and Cunningham 1899, 130). Less than half of these were engaged in processes which involved direct exposure to phosphorus. The amount of outwork or home work in the making of boxes for packaging matches, and the number of children involved in the production in general, were not reported at that point. However, it was mostly women, and also inevitably other family members including children, who were engaged in the making of boxes in their own homes. The weekly average earnings 'in this miserable industry was reported by trade union activists to be at something under seven shillings for 84 hours of labour' (Harrison 1995, 23).

These three osteological cases of ‘phossy jaw’ reflect the difficult conditions in which individuals worked and lived in the past. Phosphorus necrosis was an occupational disease that allows us not only to understand the value of palaeopathological indicators to reconstruct historical environments, but also stress the importance of health and safety regulations in the workplace (Satu et al. 2019, 77).

7.4 Charnel and Disarticulated Material

The study of the charnel, as well as disarticulated material, revealed a similar health and disease profile to the articulated sample. The majority of the individuals within the charnel and disarticulated samples were adults, and the proportion of males and females constituting the charnel sub-set was similar to the articulated sample, showing a slight female predominance. This profile was statistically confirmed, revealing no difference between male and female ratios, which were 1:1.05 and 1:1.15 for the articulated and charnel material respectively. It was impossible to accurately determine how different groups experienced mortality due to the nature of the sample; however, some basic conclusions were drawn. The mortality profile for adults showed that young and middle adults had suffered higher mortality rates, while young children from non-adult groups seemed to have suffered higher death rates. Consequently, a similar mortality profile was revealed between the articulated and disarticulated samples.

In terms of stature, it was impossible to accurately calculate the stature of the charnel material; however, from a small sample of femoral bones that were studied the mean adult stature was calculated at 169cm with a range of 149-187cm. The results initially appeared higher than the calculated stature of the articulated sample at 164cm, with a range of 140-182.50cm; however, the comparative statistical analysis revealed no statistical differences in the stature means between St Hilda’s articulated and charnel material, confirming that both sets of individuals were derived from the same general population.

The recorded pathological conditions within the charnel and disarticulated material, although not statistically analysed, followed the general pathological trend; spinal diseases, trauma, surgical interventions, specific and non-specific infection, hematopoietic disorders, congenital disorders, benign neoplasms, and dental diseases were commonplace. It can, therefore, be concluded through this qualitative assessment that St Hilda's charnel and disarticulated material was following the same exact pathological pattern as the articulated material, indicating that the charnel material came from the same general population that the articulated sample came from.

7.5 Osteological versus Biographical Evidence: Osteobiographies

Biographical evidence derived from *depositum plates* from St Hilda's churchyard was available for only three individuals. In order to place these specific individuals within a context (Table 7.1), the osteological and epigraphic information was combined with the burial register entries. However, only in the case of one individual (i.e. Ann Purvis) the biographic evidence from the *depositum plates* could be matched to the burial register entries. According to the burial registers, Anne Purvis of Shadwell St was born in 1793 and died on the 17th October 1849 at the age of 56, as stated in the *depositum plates*. According to the osteological evidence, Anne was around 157cm tall and she was edentulous, having lost all her teeth antemortem. The woman exhibited a variety of pathological lesions such as maxillary sinusitis, osteoarthritis of the spine, as well as gout of the first toe digits. She also exhibited extra basal facet on the medial side of her second left metatarsal bone which articulated with the basal lateral facet of her first left metatarsal bone, the facets exhibit DJD changes and it seems that the second metatarsal slipped further anteriorly (subluxation). No other information could be retrieved. At least seven 27-year-old females were identified under the name Isabella; all died between 1801 to 1851 and had various statuses; some were married, some were single women, but it seems all were from the working-class strata. Lastly, no case of Jane Prince was identified within the burial registers.

Skeleton No	Name	Preservation	Chronological Age	Osteological Age	Osteological Sex

381	Jane Prince	Poor	?	Adult, +18	N/R
472	Ann Purvis	Poor	56	Adult, +18	F??
942	Isabella	Poor	27	Young Adult	F

Table 7.1: Biographical evidence derived from depositum plates of St Hilda's Church.

7.6 Summary

The effects of the Industrial Revolution during the 18th and 19th centuries had severely affected the country's demography and health and disease profile. Through this research, the well recorded through historical records effects on the populations living in England during this era were also confirmed through the osteological and palaeopathological record.

The St Hilda's results were in accordance with the comparative studies. No major geographic divisions were observed across sites throughout England, but a certain degree of socio-economic status dependency existed. Hence, location appeared to have little impact on population demographics and health and disease profile, with increased mortality observed in early life between birth and six years of life and then middle adulthood. Males across sites were more likely to die in middle adulthood due to biological sex and gender disparities as they were exposed to various occupational and lifestyle hazards. Females had increased chances of reaching senior ages after overcoming certain dangers of earlier adulthood (e.g. pregnancy, childbirth) due to their more indoor-based living. The effects of indoor-based living were also demonstrated through the higher prevalence of maxillary sinusitis among St Hilda's females. The bioarchaeological observation of increased mortality in middle adulthood was in accordance with Barker's theory for living populations; indicating that early life stressors linked to poor maternal health and exogenous factors during gestation shortened the life course in adulthood (Morrone *et al.* 2021). These genetic weaknesses were also evident through increased prevalence of congenital disorders observed in St Hilda's middle adults and the increased numbers of preterm and neonates. Similar rates of specific and non-specific indicators, were revealed across sites indicating morbid conditions throughout England. The morbid conditions as well as poor maternal health, exogenous factors and poor diet were also revealed through the presence of early life metabolic and hematopoietic disorders across sites. In the case of active rickets geographic influences existed, with London exhibiting higher rates for some sites, thus reflecting the problem of overpopulation experienced by the metropolis.

Unlike geographic location, a degree of socio-economic status dependency was revealed for the mortality profile, with a few sites of higher status exceeding middle adulthood; showing that the socio-economic circumstances, influenced the longevity of these individuals. A socio-economic status denominator also existed for particular conditions (e.g. maxillary sinusitis and fractures) among adults. Residual rickets in some assemblages showed some socio-economic dependency, demonstrating that it was status which helped these individuals to overcome these episodes in early life, it could also point to differences in childrearing practices. Despite these differences in mortality and morbidity, no significant differences were observed in adult stature across sites.

CHAPTER 8

CONCLUSIONS

Industrialisation and its effects upon the populations living in England during the 18th and 19th century has been frequently investigated from a historical perspective, both in terms of regional and social divisions. By contrast, the archaeological study of those populations, including the potential for osteological analysis, have only recently come to the fore. As a consequence, the purpose of this study was to contribute an osteological perspective to our understanding of a north-eastern working-class population, namely that of St Hilda's, and to contribute to the current understanding of the effects of the Industrial Revolution on the people at that time. As the industrial centres and population grew with the creation of new job opportunities brought by industrialisation, the health and well-being of many, especially those from the lower classes, declined due to neglect and a lack of public health foundations. Consequently, this study explored the effect of industrialisation on St Hilda's population by establishing their demographic and health and disease status. The study also aimed to provide a deeper insight into this primarily working-class community through a multifactorial research approach, whereby the osteological evidence was combined with evidence from historical burial registers and other accounts spanning several years in the late 18thand early 19th century. This combined approach granted an optimal understanding of the community under study. It also allowed a comparison between sites from a wider geographic area across England, and populations of different socio-economic status.

The following sections provide a summary of the key points discussed in the thesis in relation to the research aims. In the following section, the three research questions outlined in the introductory chapter of this thesis will be revised. This step is necessary in order to determine if the questions were addressed, and hence if the aims of this research were fulfilled. Lastly, along with these consolidated findings, this section considers the limitations and future potential of the research in question.

8.1 Research Questions in Context

1. What effects did industrialisation have on the health and disease status of St Hilda's population?

St Hilda's demographic profile was in accordance with the overall profile of the period. The site population was affected by increased deaths below the age of five followed by a gradual decrease to a minimum in the relatively healthy adolescent age group, and then followed by increased risk of mortality over the age of 25. Middle adults were the most sensitive portion of the adult population, exhibiting increased risk of mortality and morbidity, reflecting the cumulative effects of vigorous living from early age on the immune system of the subjects. The influence of genetic conditions affecting those born at the peak of industrialisation were also seen through the increased rates of congenital defects in this group.

Within the population, the mortality and morbidity profiles revealed disparities between biological sex and gender. Males were more likely to die prematurely, reaching at most middle adulthood, as they were exposed to various hazards associated with the town's predominant industries (i.e. seafaring, coal production, and export of coal). Females, on the other hand, due to their primarily domestic-based working and living environment had increased chances of reaching older age despite their sensitivity during early adulthood and the risks from pregnancy and childbirth. The slight female predominance in Saint Hilda's skeletal assemblage and in the burial registers, aside from sex and gender disparities, also reflected the hazards of industrialisation and occupational risks associated with the town's main industry (i.e. seafaring). The predominance of women may reflect the number of men who lost their lives at the sea or died on board while travelling outside South Shields. These differences demonstrated how industrialisation affected males, who had to be more mobile, and thus were exposed to diverse occupational dangers.

The various indicators of disease and ill-health recorded in Saint Hilda's were typical of the period suggesting that the site was equally affected by the effects of industrialisation as the rest of urban England. St Hilda's non-adult morbidity profile followed the general pathological profile of the period, with early life stressors being limited mostly to metabolic and hematopoietic disorders (i.e. rickets, scurvy, cribra orbitalia, dental enamel hypoplasia). These are indicative of the morbid conditions experienced by the community, revealing exposure to infectious agents. The increased numbers of preterm and neonatal deaths were equally evident of the morbid conditions experienced by the population. The presence of early life specific infections was further supported by the identification of acute infectious outbreaks recorded in the burial registers (e.g. small-pox, measles and cholera). Pulmonary tuberculosis was yet another cause of death, and indicators of specific infections such as tuberculosis and syphilis were also seen skeletally. Despite the various dangers in early life during the Industrial Revolution, those who survived achieved the optimum height of the period, indicating a good immune response and revealing the extent that adult stature is governed by a good genetic component.

The morbid conditions experienced by the community were also confirmed by the presence of lesions consistent with maxillary sinusitis, pleurisy, and tibial periosteal new bone formation within the adult population. The increased prevalence of maxillary sinusitis, in particular, revealed indoor and outdoor pollution confirming what was established through historical records, namely that South Shields and the North East was exposed to considerable amounts of smog induced by coal and/or other atmospheric pollutants. At the same time, the data also exhibited labour and lifestyle divisions between the sexes, with females being thrice affected than males due to domestic living. Lifestyle and labour divisions between the sexes were also revealed through the increased prevalence of trauma, especially fractures, which were in accordance with the industrialised environment of South Shields which predisposed the inhabitants, particularly males, to the risk of injury. The study of trauma combined with the burial registers revealed disparities among males and females, with males being at higher risk of traumatic accident and accidental death. In accordance with trauma, were also joint disease, especially of the spine, with males being more frequently affected demonstrating the mechanical loading of the spine due physical work such as manual labour. The presence of spinal osteoarthritis, spondylosis deformans, Schmorl's nodes and osteophytes reflected vigorous living for both sexes and the accumulative effects with age. Further disparities were also revealed through osteoarthritis of the hands and hip, where males exhibited higher prevalences than females. Other types of joint disease included diffuse idiopathic skeletal hyperostosis, ankylosing spondylitis, gouty arthritis, rheumatoid arthritis and septic arthritis; the rates were, however, too low to reveal any patterns. The analysis of the dental diseases revealed multifactorial aetiologies with the normal ageing-process having a deteriorating effect upon the teeth.

Consequently, the effects of the Industrial Revolution in Saint Hilda's individuals were manifested in a variety of ways such as increased rates of mortality, as well as morbidity manifested in the form of increased maxillary sinusitis, fractures and joint disease. These manifestations reflected the detrimental conditions and demanding living brought by the Industrial Revolution, where overcrowding, poor sanitation, infectious disease outbreaks, atmospheric pollution, lack of sun exposure, poor and inadequate diet, and arduous labour prevailed. Despite these conditions, it can be concluded that the community demonstrated generally good health with some having a strong immune response. For instance, the combination of stature with the low levels of dental enamel hypoplasia in relation to the comparative sites suggested a generally nutritious diet but not overly abstemious.

2. Who was buried in St Hilda's cemetery? Demography and social status.

To answer this second question, the exploration of the cemetery's interred population, in terms of demography and social status, was necessary. The burial registers were examined in conjunction with the burial record evidence, including the coffins and available personal effects. This step was essential as it has been frequently demonstrated such as in the case of Quakerism (e.g. at Coach Lane, Quaker burial ground) that the lack of grave goods is not always indicative of social status *per se*.

The comparison of the recorded demographic (age, sex, cause of death) and socio-economic data (job description) from the burial registers, combined with the mass-produced coffins, and limited personal effects, revealed that the interred population, and the town of South Shields more broadly, belonged primarily to the working class. The site incorporated various individuals of different socio-economic circumstances such as paupers and those employed in the industries, as well as a few higher status individuals. Only in the case of one individual (i.e. Ann Purvis) was it possible to match the biographical evidence from *depositum plates* to the burial register entries.

3. Were there noticeable differences in the health and disease profile of urban populations from different (a) geographical regions of Industrial England (North and South) and (b). different socio-economic classes/backgrounds?

The morbidity profile(s) established through the osteological analysis determined that no major health and/or lifestyle differences existed between the urban regions of the North and South of England during the Industrial Period. The data for disease and ill health (e.g. specific and non-specific infections, trauma, metabolic disorders), as well as the similar prevalence rates, made it evident that people in the North experienced the same conditions as those in the South. This also confirmed the validity of the historical evidence in terms of what is known about the detrimental conditions that were prevalent in the northern and southern regions during the 18th and 19th centuries. The recorded demographic data (i.e. sex and age-at-death), revealed that the North was in accordance with the osteological mortality profile of the South. The lack of substantial differences in the population composition between chosen sites indicated that the populations were similarly susceptible by death regardless of geographical differences. This evidence demonstrates that all sites were affected by exogenous factors such as poor sanitary conditions and atmospheric pollution as well as endogenous factors such as poor maternal health. Some patterns of locality, however, were observed in the North East such as the slightly greater proportion of females than males seen in South Shields, a pattern also noted in North Shields (at Coach Lane) and Newcastle (at Newcastle Infirmary) and its surroundings, reflecting similarities between these North East towns such as lifestyle similarities and prevailing industries within these seaport towns.

In the case of those populations of higher socio-economic status, only a small degree of socio-economic status dependency was revealed by the mortality profile, with a few sites of higher status having individuals who exceeded middle adulthood. This suggests that the socio-economic circumstances, and especially the less urbanised areas where the sites were located, influenced the longevity of the populace. Despite these minor observations, no significant differences were observed in adult stature across the sites supporting the argument that relative status is not reflected in stature during this period. Male individuals across the study sites were standing around 170cm tall and females around 158cm tall; this data was in accordance with anthropometric studies of the living population from the 19th century.

Similar morbidity profiles were observed across the comparative sites. The similar rates of specific infections (i.e. TB and syphilis) between the North and the South revealed that infections were independent of geographic divisions. No matter where the individuals resided, they were unable to isolate themselves from the health hazards of the period. Despite the lack of differences in the prevalence of TB and syphilis between the geographic regions, a small degree of socio-economic dependency was revealed in syphilis showing a greater prevalence amongst the lower-class populations. No significant differences were observed between the prevalence of non-specific indicators according to various geographical and socio-economic divisions, except in the case of maxillary sinusitis which revealed some correlations with socio-economic status, with the higher strata being partially protected from poor indoor air quality. The presence of similar morbid conditions throughout England was also revealed through the presence of early life metabolic and hematopoietic disorders across the sites. No statistical differences were observed in the prevalence of this type of disorder, showing that non-adults across the sites were exposed to similar dangers (e.g. infectious agents, atmospheric pollution, poor diet) in early life. Only in the case of active rickets can we observe small geographic influences, with London exhibiting higher rates for some sites, thus reflecting the problem of overpopulation (at least in certain areas) experienced by those in the metropolis. In contrast, residual rickets in some assemblages showed socio-economic dependency, demonstrating that status helped some individuals overcome these early life episodes, or that differences in child rearing practices varied across the different social groups. No differences were observed across many sites in the prevalence of osteomalacia or porotic hyperostosis in adults.

High prevalence of trauma – especially fractures – was a universal characteristic across the sites of various status and region, with males being affected more frequently. The similarities in the overall prevalence perhaps reflects that individuals from different sites were exposed to the risk of trauma irrespective of the South and North divide and/or socio-economic divisions. The underlying aetiologies of trauma between the socio-economic groups, were, however, different. It was noted that although males across the various sites exhibited higher prevalence of trauma than their female counterparts, some of the working-class male populations had higher prevalences than other male groups, reflecting the dangers that working-class males were exposed to. Despite the differences in social status, it would appear that males across the sites were at a higher risk of accidental and/or violent injuries, and in many cases subsequent death, than females due to their mostly outdoor occupations, activities, male socialisation, and overall lifestyle differences.

In the case of joint diseases such as osteoarthritis, it was very difficult to draw any clear conclusions, although it would appear that some differences existed which were influenced by socio-economic factors. The prevalence, however, of lesions between all the sites also shows that everyone was subject to the normal degeneration process due to ageing making it difficult to identify any clear association based on social divisions. In the case of spinal joint disease, St Hilda's adult CPR was similar to the rates seen in sites of various backgrounds, thus demonstrating that everyone was equally affected by osteoarthritis because of everyday activities (i.e. strains, sudden movements, or poor body mechanics). What was different was the underlying aetiology behind the formation of these lesions. Consequently, spinal diseases might not be a straightforward indicator of socio-economic and geographic divisions.

From the analysis of the dental diseases it was concluded that no clear patterns existed across the sites showing that the lesions were not associated with socio-economic status, but rather with more perplexed aetiologies of multifactorial origin linked to an individual's diet, oral hygiene, increasing age, and immune system. The fact that sites of different backgrounds exhibited similar rates to the case study site was indicative that everyone – irrespective of their socio-economic status – was affected by poor oral practices thus revealing that some lifestyle and dietary similarities existed across the sites. This is not to say that some socio-economic dissimilarities did not exist, but that the background variation of these sites makes it difficult to come up with any safe conclusions. Consequently, dental diseases might not be a straightforward indicator of socio-economic and geographic divisions.

8.2 Limitations

The analysis of the health and disease parameters within the skeletal populations does not come without its limitations, and this must be considered in reference to the study results. The skeletal sample of St Hilda's and its analysis are restricted by factors such as sample size, extent of the excavation, recovery during the excavation, as well as methodological and preservation issues. These limitations are not unique to the case study, but also affect the comparative sites from the various industrialised urban centres across England.

The osteological data is representative of a cross-sectional sample rather than a longitudinal study (Gowland 2007). Consequently, the conclusions are not reflective of the whole population that lived in South Shields and buried in St Hilda's cemetery during this period of study, but rather a sample of the total population. Luckily, in the case of Saint Hilda's, the burial registers were available, allowing comparisons between the two types of data. However, the extent to which dead populations reflect the life and health of the corresponding surviving ones at this time is questioned. Any interpretation of the demographic, health and disease profiles, as well as the prevalence and severity of the skeletal indicators are representative of the people who died, and not necessarily of the living population (Mahoney-Swales 2012). Waldron (1994, 20) has debated the extent to which it is possible to reconstruct the demography of an open and dynamic population from such information since the frequency of diseases in the skeletal material would be higher compared to the surviving population from which it was derived.

Cemetery samples, due to the long-term use of cemeteries, often include a wide range of osteological material. As a result, individuals interred when the cemetery was first used may have experienced vastly different stressors and health conditions compared to those buried towards the end of the cemetery's use (Newman 2015, 299). This observation becomes even more relevant when considered along with the fast-paced declined living conditions of urban centres in the 18th and 19th centuries. The grouping of individuals from different phases of cemetery use may lead to the loss of fluctuations in mortality, morbidity, and rates of longevity (Waldron 1994). Further to this, cemeteries of the period in study – particularly within urban centres – were likely to be very heterogeneous due to the migration of people to the growing urban centres such as in the case of St Pancras, London. Migration from rural areas to the fast-growing cities was common practice as the population sought new employment opportunities (Foster 1974). This could mean those adult individuals buried at St Hilda's could have lived somewhere else during the crucial point of infancy and childhood.

The 'Osteological Paradox', which is a term coined by Wood *et al.* (1992), addressed the issue of 'survivors' versus 'non-survivors', and therefore the issue of a strong immune response versus a weak immune response is also a limitation that affected this population as well as the comparative populations, especially their non-adult groups. According to the Osteological Paradox, those individuals who did not exhibit indicators of pathology may have died of a particular disease before it could manifest in the skeleton, either due to weak immune system or due to other infectious agents and deficiencies (Bourbou 2014; Gowland *et al.* 2018). Only those diseases which are present in the body for a sufficient amount of time (i.e. 'chronic') will leave identifiable markings on the skeleton (e.g. syphilis, tuberculosis, leprosy). Diseases which kill relatively swiftly, or only affect soft tissue (i.e. 'acute' diseases) will not leave any evidence on the skeleton (e.g. plague, flu).

Therefore, the lack of indicators of pathology is not proof that the person was healthy, but could indicate a weak immune response, or the fact that the individual died of a different reason such as an 'acute' condition (e.g. heart attack, stroke). Individuals exhibiting particular pathology represent those members of society who were infected by the disease but were also the 'healthiest' or most 'resilient' to that disease, indicating a stronger immune response since they did not die suddenly. Hence, healthy individuals tend to manifest skeletal markers of stress and disease more often than less healthy individuals because they have the immunological tolerance to fight the disease for longer (Mahoney-Swales 2012). Skeletal samples represent non-survivors, and hence it is possible that the St Hilda's non-adults were affected from acute diseases, and did not survive long enough for skeletal involvement to occur (Wood *et al.* 1992). Consequently, due to the nature of osteology which allows only the recording of chronic lesions, a large bulk of valuable information on acute, soft tissue, and mental diseases amongst St Hilda's sample was unavailable. Paradoxically, the adult samples of St Hilda's do not necessarily reflect the weak portion of the population; rather, they reflect those who survived the crucial points of early life. Therefore, they were either not exposed to those harsh social and environmental stressors which lead to premature death of those in the non-adult sample, or they represent the population sample that had a stronger immune response compared to the immature population sample (Wood *et al.* 1992).

Another restriction to this study concerns the extent to which a reliance was placed on other people's work in terms of the comparative sites. While the majority of the data presented within the primary analysis of the case study were collected by the author, the demographic and pathological data for the comparative sites were based mostly on published reports and therefore that data were collected by other researchers during the primary analysis of those sites. Wherever possible, precautions were taken to limit any inter-observer errors in the present study, such as the implementation of the same age categories and recording standards. One problem that was encountered, however, arose with the study of certain collections such as those of Christ Church, Spitalfields and Cross Bones. The criteria for the diagnosis of certain pathological conditions such as scurvy appears to have changed in the time between the original analysis and the present study. While this is not a significant issue for the majority of the sites since the original skeletal recording occurred relatively recently, the reports for sites such as Christ Church and Cross Bones were published over than twenty years ago. Consequently, if this study could be repeated from the beginning, the comparative data would be collected by the author in accordance with up-to-date publications as were employed in the study of St Hilda's; however, at this time, this was not feasible.

Relating to these aforementioned problems is the lack of 'universal' methodological standards in relation to the study of the skeletons from the comparative sites, and their basic statistical analyses. This limitation turned out to be one of the main impediments in this study, combined with the various levels of preservation from site to site which is an inherent problem between osteological collections. As Boston *et al.* (2008, 69) concluded, the osteological analysis of many of the comparative sites was undertaken in a commercial setting, in which time and even funding can be frequently limited, and all results are presented with full appreciation that the analysis is far from exhaustive (Boston *et al.* 2008, 102). A study in a commercial setting means that the materials are subject to a medium or even low-resolution analysis whereas academic research projects such as the present one allows for a more thorough investigation due to different time restraints (Roberts and Cox 2003; Brickley *et al.* 2006; Boston *et al.* 2008). Consequently, comparing research projects to commercial projects, the latter being subject to time and other restrictions, does not always allow for a fair comparison.

During this research project, it was noted that in those sites where the number of skeletons was large, their study was either not systematic or only a small proportion of the skeletons with excellent preservation, and/or skeletons of known identity, were chosen for study (e.g. St Coach Lane and George's Bloomsbury). This excluded skeletons that were not in such a great condition, but could still provide basic information, or unknown individuals. This selective approach created problems in the actual prevalence rates of specific conditions which appeared too low in comparison to St Hilda's, such as in the case of joint disease. Another methodological issue which created comparative problems between the sites was the fact that some researchers were focused only on recording the CPR values while others were focused on recording the TPR values, suggesting a lack of consistency in recording. As it has been mentioned in chapter 4, the calculation of TPR values is a more accurate method for statistical analysis. It is, however, a time-consuming process which requires the individual counting of the number of bones instead of the full skeleton, and therefore, it is not very suitable for medium or low-resolution analysis, particularly those under time constraints.

Consequently, it is surmised that the lower prevalence observed for specific conditions (e.g. joint disease) from some sites, especially for those sites of a similar status to St Hilda's, were methodological due to the medium or low-resolution analysis undertaken, and the fact that the recording of specific lesions was not the primary focus of the research, and/or the methodological complexity of recording particular conditions was not feasible (e.g. maxillary sinusitis). Arguably, it can also be attributed to different research interests between authors. Therefore, the unclear conclusions drawn for some specific conditions revealed that one challenge to this research was the lack of a standardised and systematic approach in the recorded lesions amongst the comparative sites. As Boston *et al.* (2008, 69) concluded, it is expected that the re-analysis of particular collections in a non-commercial setting will undoubtedly change the calculated prevalence rates of diseases, and will reveal further valuable information for future researchers. This presumption was indeed confirmed in a few cases when some collections were re-studied for the recording of specific conditions. For instance, in the case of Chelsea Old Church and St Bride's Lower, where the original studies recorded no prevalence of carious lesions and AMTL whilst a recent study by Mant and Roberts (2015) revealed the rates of these conditions to be comparable to those of St Hilda's. Conversely, the re-analysis of Christ Church, Spitalfields for the recording of maxillary sinusitis by Roberts (2007) revealed a higher prevalence than that of St Hilda's. Both examples therefore illustrate the merit of re-visiting those populations studied some time ago, or those which were recorded under the constraints of a commercial setting.

8.3 Future Directions - Further Potential of the Study

While this study has used a multifactorial approach to build on our knowledge of health and disease in the 18th and 19th centuries, it would be of great interest to implement other methodological approaches such as the application of stable isotope analysis. Analysis of dietary carbon and nitrogen isotopes could provide information on the type of diet that individuals of different status sites consumed. The nutritional status of juvenile individuals would also benefit from isotope analysis; for example, nitrogen and oxygen isotope analysis of the immatures could determine the age of weaning and potentially determine how periods of stress related to breastfeeding practices. This study would be two-fold as it would also reveal if working-class females had to stop breastfeeding their babies prematurely in order to return to work. The analysis of oxygen, strontium and lead stable isotopes could identify potential evidence of migration, specifically patterns of rural to urban mobility. For example, this could determine if the taller, older males were born in more rural areas before they migrated to the urban centres later in life. Isotope analysis will also help determine if this urban centre was attracting people from further afield, something that was proposed from the study of the burial registers and the identification of individuals from abroad (Chenery *et al.* 2010; Eerkens *et al*. 2011; Beaumont *et al.* 2013; Tsutaya *et al.* 2014; Beaumont and Montgomery 2016; Dwaliwal *et al.* 2020). The importance of the St Hilda's assemblage in contributing to our understanding of the population in the North of England during this period has been highlighted in this thesis. Developmental disparities in certain parts of England resulted in a bias towards urban samples in the South, in particular Greater London (Renshaw and Powers 2016). As a result, the North has received less attention, with the majority of evidence for the health and lifestyles of the working-class Industrial population in this region being mostly based on documentary accounts. Consequently, northern- and North-East based osteological studies for this time period are necessary alongside those from western and South-Western regions of England, in order to counteract the current weighting of evidence from the Midlands and the South East. In conclusion, this study has revealed the impact that the Industrial Revolution and the disparities in the socio-economic opportunities available to the population at the time had on the health and everyday lives of the working class.

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APPENDICES

APPENDIX 1

Given	Surname	Age	Birthyear
THOMAS	COOPER	13	1826
JONATHAN	DOUGLAS	10	1829
GEORGE	LONGSTAFF	46	1793
WILLIAM	LONGSTAFF	12	1827
HANNIBEL	LONGSTAFF	10	1829
GEORGE	HALL	18	1821
JOHN	HALL	16	1823
CHARLES	GIBSON	20	1819
ALEXANDER	FORSYTH	19	1820
JOHN	SNOWDON	25	1814
WILLIAM	WRIGHT	46	1793
THOMAS	ELSTOB	32	1807
THOMAS	ELSTOB	9	1830
ANDREW	STEPHENSON	21	1818
ALEXANDER	FALKENER	21	1818
ROBERT	JOHNSON	23	1816
BENJAMIN	GIBSON	53	1786
RICHARD	GIBSON	16	1823
THOMAS	GIBSON	14	1825
WILLIAM	TODD	25	1814
EDWARD	HARDY	17	1822
MICHAEL	BROWN	12	1827
JOSEPH	ARGYLE	45	1794
WILLIAM	YOUNG	28	1811
THOMAS	CLEGG	33	1806

Appendix 1: List of 25 men who lost their lives in St Hilda's pit explosion and buried in St Hilda's cemetery

APPENDIX 2

AGENT
ATTORNEY
BAKER
BARBER
BARONET
BELLMAN
BLACKSMITH
BLOCK MAKER
BOAT BUILDER
BOATMAN
BOTTLE MAKER
BRAZIER
BREWER
BRICK MAKER
BRICKLAYER
BUILDER
BUTCHER
CABINET MAKER
CARPENTER
CARRIER
CART MAN
CHANDLER
CLERK
COBLE MAN
COMEDIAN
CORDWAINER
COUNTRY MAN
CUSTOMS OFFICER
DOCK & SHIP OWNER
DOCKMAN
DOCTOR
DRAPER
DYER
ENGINEMAN
ESQUIRE
FARMER
FISHERMAN
GARDENER
GENTLEMAN
GLASS CUTTER
GLASS MAKER
GLASSMAN
GLAZIER
GOLDSMITH
GROCER
GROOM
HAIRDRESSER
HATTER
HOUSE CARPENTER
JOINER
KEELMAN
LABOURER
LINEN DRAPER
MALT MAKER
MANTUA MAKER
MARINER
MASON
MAST MAKER
MASTER MARINER
MERCHANT
MIDWIFE
MILLER
MUSICIAN
OSTLER
PAINTER
PAINTER & GLAZIER
PAN SMITH
PAUPER
PAWNBROKER
PEASANT
PEDDLER
PILOT
PIT MAN
POSTMASTER
PUMPWRIGHT
ROPE MAKER
ROPER
SADDLER
SAIL MAKER
SAILOR
SALT MAKER
SALT OFFICER
SALTER
SAWYER
SCHOOLMASTER
SCOTCH DROVER
SCULLERMAN
SEAMAN
SENIOR
SERVANT
SEXTON
SHIP BUILDER
SHIP CARPENTER
SHIP CHANDLER
SHIP OWNER
SHIP WRIGHT

SHOE MAKER	SUPERVISOR	WATCH MAKER
SHOP KEEPER	SURGEON	WATERMAN
SINKER	TAILOR	WEAVER
SMITH	TIDEWAITER	WHERRYMAN
SOLDIER	TOBACCONIST	WHITE GLASSMAKER
SPINSTER	TRAVELLER	WHITESMITH
SPIRIT MERCHANT	TRIMMER	WINE MERCHANT
STRANGER	VIEWER	YEOMAN

Appendix 2: List of occupations and other social descriptions in alphabetic order transcribed from St Hilda's burial registers.

APPENDIX 3

Bone	Cases Affected	Count Affected	Count Present	Percentage (TPR %)
Nasal Bones	2	2	117	1.71%
Mandible	1	1	147	0.68%
Zygomatic	1	1	262	0.38%
Ribs	18	47	2537	1.85%
Clavicle	1	1	264	0.38%
Scapula	1	1	275	0.36%
Sternum	1	1	91	1.10%
Vertebra	7	8	2604	0.31%
Humerus	2	2	297	0.67%
Radius	3	3	282	1.06%
Ulna	1	1	286	0.35%
Carpals (scaphoids)	1	1	108	0.93%
MTC - 1st	5	5	157	3.18%
MTC - 2nd	2	2	175	1.14%
MTC - 5th	1	1	150	0.67%
Hand Phalanges - 2nd	2	2	122	1.64%
Hand Phalanges - 3rd	1	1	124	0.81%
Hand Phalanges - 4th	1	1	119	0.84%
Hand Phalanges - 5th	1	1	115	0.87%
Hand Phalanges - 3rd intermediate	1	1	101	0.99%
Femur	3	3	301	1.00%
Tibia	6	6	292	2.05%
Fibula	3	3	251	1.20%
Tarsals (Talus)	1	1	165	0.61%
Tarsals (Navicular)	1	1	129	0.78%
MTT - 2nd	3	3	159	1.89%
MTT - 3rd	1	1	163	0.61%
MTT - 5th	2	2	157	1.27%
Foot phalanges	3	3	80	3.75%

Appendix 3: True prevalence rates in percentages for distribution of fractures within St Hilda's total population.

APPENDIX 4

Bone	Cases Affected	Count Affected	Count Present	Percentage (TPR %)
Nasal Bones	2	2	70	2.86%
Mandible	1	1	92	1.09%
Zygomatic	1	1	177	0.56%
Ribs	17	46	1495	3.08%
Clavicle	1	1	162	0.62%
Scapula	1	1	171	0.58%
Sternum	1	1	67	1.49%
Vertebra	7	8	1801	0.44%
Humerus	2	2	177	1.13%
Radius	3	3	172	1.74%
Ulna	1	1	171	0.58%
Carpals (scaphoids)	1	1	108	0.93%
MTC - 1st	5	5	129	3.88%
MTC - 2nd	2	2	146	1.37%
MTC - 5th	1	1	122	0.82%
Hand Phalanges - 2nd	2	2	120	1.67%
Hand Phalanges - 3rd	1	1	122	0.82%
Hand Phalanges - 4th	1	1	117	0.85%
Hand Phalanges - 5th	1	1	113	0.88%
Hand Phalanges - 3rd inter.	1	1	101	0.99%
Femur	3	3	175	1.71%
Tibia	6	6	172	3.49%
Fibula	3	3	158	1.90%
Tarsals (Talus)	1	1	150	0.67%
Tarsals (Navicular)	1	1	129	0.78%
MTT - 2nd	3	3	137	2.19%
MTT - 3rd	1	1	141	0.71%
MTT - 5th	2	2	135	1.48%
Foot phalanges	3	3	80	3.75%

Appendix 4: True prevalence rates in percentages for distribution of fractures within St Hilda's adult population

APPENDIX 5

All Adult Ages	Young Adult			Middle Adult		
	Count Affected	Young Adult	Young Adult	Count Affected	Middle Adult	Middle Adult
Temporomandibular	0	16	0%	4	74	5,4%
Costovertebral	0	95	0%	13	680	1,9%
Strernoclavicular	0	13	0%	6	62	9,7%
Shoulder	0	12	0%	7	64	10,9%
Elbow	0	14	0%	4	72	5,6%
Wrist	0	9	0%	1	61	1,6%
Hand	0	9	0%	9	61	14,8%
Hip	0	12	0%	8	63	12,7%
Knee	1	5	20%	1	34	2,9%
Foot (1MTT)	2	10	20%	6	50	12,0%

All Adult Ages	Mature Adult			Older Adult		
	Count Affected	Mature Adult	Mature Adult	Count Affected	Older Adult	Older Adult
Temporomandibular	4	48	8,3%	1	32	3,1%
Costovertebral	28	389	7,2%	0	224	0,0%
Strernoclavicular	1	41	2,4%	4	27	14,8%
Shoulder	4	40	10,0%	3	30	10,0%
Elbow	0	44	0,0%	5	30	16,7%
Wrist	3	39	7,7%	8	26	30,8%
Hand	1	41	2,4%	8	31	25,8%
Hip	2	39	5,1%	6	34	17,6%
Knee	4	37	10,8%	8	23	34,8%
Foot (1MTT)	8	43	18,6%	9	29	31,0%

All Adult Ages	Adult		
	Count Affected	Adult	Adult
Temporomandibular	2	24	8,3%
Costovertebral	3	53	5,7%
Strernoclavicular	0	13	0,0%
Shoulder	1	16	6,3%
Elbow	1	18	5,6%
Wrist	0	4	0,0%
Hand	1	6	16,7%
Hip	2	21	9,5%
Knee	2	10	20,0%
Foot (1MTT)	4	15	26,7%

Appendix 5: True prevalence rates in percentages for distribution of extra-spinal OA by joint within St Hilda's different adult age categories.

APPENDIX 6

No of vertebrae affected	SpinalOA (zygapophyseal)	Spondylosis Deformans	Schmorl's Nodes	Osteophytes
C1	21	8	1	19
C2	23	11	1	23
C3	17	11	1	23
C4	18	12	1	24
C5	18	12	1	24
C6	18	12	1	25
C7	18	12	1	24
T1	18	4	34	43
T2	19	5	35	43
T3	18	4	35	45
T4	17	4	35	46
T5	18	5	37	46
T6	17	5	37	45
T7	17	5	38	46
T8	18	5	38	45
T9	17	6	36	43
T10	17	6	35	44
T11	17	5	34	43
T12	17	4	32	40
L1	15	6	20	33
L2	15	6	19	33
L3	15	6	20	34
L4	16	5	19	35
L5	15	6	16	32
L6	2	1	–	2

Appendix 6: Number of affected vertebrae by spinal degenerative diseases within the adult population of St Hilda's.

APPENDIX 7

NAME	PARISH	AGE	HOW LONG	YEAR	CAUSE OF DEATH	OTHER
THOMAS HOPPER	N. SHIELDS	56	2MTHS		ASTHMA	
ELEANOR ROBSON	N. SHIELDS	22	6MTHS		NERVOUS ASTHMA	
ALEXANDER MILER	N. SHIELDS	15	7MTHS		TUMOR ON BELLY	
PETER BRASS	N. SHIELDS	18	2WKS		HECTIC FEVER	
ISAAC WARD	S. SHIELDS	26	18MTHS		DIARRHOEA	
CHARLES WEBSTER	S. SHIELDS	47	7MTHS		RHEUMATISM	
WM DIXON	S. SHIELDS	16	ACCIDENT		VIOLT. CONTUSION	
THOMAS WIGHAM	N. SHIELDS	58	4YRS		STONE IN BLADDER	
ROBT. CHRLETON	N. SHIELDS	44	ACCIDENT		COMPOUND FRACTURE ON ANKLE	
THOMAS WHITE	N. SHIELDS	17	ACCIDENT		COMPOUND FRACTURE IN LEG	
ROGER SNOWDOWNN	N. SHIELDS	19	5MTHS		SCIATICA	
MARY SMITH	SHIELDS	30		1803	HAEMORRHAGE	FORMERLY FROM IRELAND
BENJAMIN FLETCHER	SHIELDS	44		1805	PALSY	SAILOR
SARAH PERT	S. SHIELDS	53		1806	DROPSY	
JAMES ALLEN	S. SHIELDS	21		1809	PSOAS ABSCESS	
JOHN NEWMAN	N. SHIELDS	36		1810	RHEUMATISM	
JOHN ISBISTER	S. SHIELDS	16		1811	HEART DISEASE	
JOSEPH TROTTER	N. SHIELDS	27		1812	MORTIFICATION	
JAMES JONES	S. SHIELDS	26		1813	VOMICA	
ELEANOR SAUNDERS	N. SHIELDS	32		1814	PSTHISIS	
MARY THOMSON	SHIELDS			1815		
JAMES HUTCHINSON	N. SHIELDS	32		1827		
ANDREW STORM	S. SHIELDS	25		1827		
JAMES BLYTHE	SHIELDS	17		1831		
ANN LANSLOR	N. SHIELDS	20		1834		
WILLIAM BOOTH	N. SHIELDS	36		1835		
JOHN MUNNOLLY	S. SHIELDS	24		1838		

WILLIAM DELAPIDO	S. SHIELDS	14	1838	
JOHN CREG	N. SHIELDS	18	1839	
BENJAIN YAXLEY	N. SHIELDS	55	1839	
GEORGE STEPHENSON	N. SHIELDS	46	1839	
JOHN ARSLEY	N. SHIELDS	68	1839	
WILLIAM WHITE	N. SHIELDS	23	1841	
DOROTHY HILL	S. SHIELDS	55	1841	
JOHN RUBEY	N. SHIELDS	27	1841	
EDWARD JOHNSON	S. SHIELDS	30	1842	
MARY SIDY	N. SHIELDS	32	1843	
THOS PRINGLE	S. SHIELDS	59	1843	POOR HOUSE
MARGARET LALLAND	S. SHIELDS	30	1843	
MARY WALKER	S. SHIELDS	28	1843	
JANE FRAZER	S. SHIELDS	24	1843	

Appendix 7: Newcastle Infirmary deaths and interments, individuals originally transferred from South and North Shields. Deaths extracted from the admissions books and burial registers.