PATTERNS OF SKELETAL HEALTH IN URBAN AND RURAL POST-MEDIEVAL LONDON: A BIOARCHAEOLOGICAL ANALYSIS OF MIDDLE AGED AND OLDER ADULT FEMALES

A Thesis
Presented
to the Faculty of
California State University, Chico

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Anthropology

by

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Fall 2013
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DEDICATION

I dedicate my thesis to my family, for all their love and support, and for always believing in me.

To my parents and sister, for all of the encouragement, edits, indulging my curiosity, and supporting my dreams—no matter how far fetched.

In loving memory of Grandad, Eric William Mitchell.
ACKNOWLEDGMENTS

I would like to acknowledge everyone who aided this work and helped me complete this process. The successful completion of my thesis would not have been possible without the help of my thesis committee, Dr. Colleen Milligan and Dr. Antoinette Martinez. I would sincerely like to thank them for their guidance, advice, and encouragement. I would also like to acknowledge and thank the following California State University, Chico, Department of Anthropology faculty for their continuous support and encouragement: Dr. Eric Bartelink, Dr. P Willey, Dr. Beth Shook, Dr. Frank Bayham, and Dr. David Eaton. I would like to thank the wonderful staff at the Museum of London Centre for Human Bioarchaeology, Jelena Bekvalac and Rebecca Redfern, for their support and for granting me access to the materials that made this research possible.

To my fellow graduate students, close friends, and mentors who supported me throughout the process: I cannot list all the names here, but you are always on my mind. I would especially like to thank Colleen Cheverko who provided feedback, edits, and moral support throughout graduate school, and Emily Woodall, who knew exactly when cake batter ice cream with sprinkles was the answer to my problems. I extend my thanks to the teachers and mentors along the way who encouraged and supported me and helped me to get to graduate school. Special thanks go to Katherine Hanson Sobraske who introduced me to physical anthropology and encouraged me to pursue a graduate degree.
Finally, I would like to thank my family who supported me in every way possible. To my parents who read and edited many drafts, listened patiently, encouraged me to pursue my interests, inspired me, and instilled in me an undying curiosity and a love for learning. To my sister whose strength, kindness, and patience motivate and inspire me every day, I am so proud of you! To my stepparents who are invaluable additions to my family system, and who have been incredibly supportive of my graduate education. And last, but certainly not least, I am grateful to my grandparents, Nana and Pops. So many wonderful hours, during college and graduate school, were spent in the comfort of your home and at your kitchen table. So, thank you all, for being the most supportive family one could hope for.
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This thesis employs a paleopathological approach to examine the impacts of urban versus rural living in the greater London area during the post-medieval period (1550-1850). The post-medieval period in London was characterized by population growth, industrialization, and urban expansion. Studies of contemporary and past populations suggest that urbanization, industrialization, overcrowding, and pollution result in health disparities between rural and urban groups and several studies have shown a higher potential for disease in urban environments. This study compared the skeletal health of middle aged (35-50 years) and older adult (50+ years), upper socioeconomic class females from an urban London sample, St. Bride’s Church, and from rural sample located southwest of London, Chelsea Old Church. It was
hypothesized that skeletal indicators of stress would be more prevalent, indicating worse health, in the urban, St. Bride’s sample. Sex, age, and the skeletal indicators of stress were recorded from a sample of sixty-five individuals curated by the Museum of London’s Centre for Bioarchaeology, thirty-three from the urban sample of St. Brides Church and thirty-two from the more rural sample of Chelsea Old Church. Skeletal indicators of stress, including stature, antemortem tooth loss, caries, abscesses, linear enamel hypoplasias, porotic hyperostosis, cribra orbitalia, maxillary sinusitis, periostitis, and rickets were examined to assess differences in urban sample and rural sample skeletal health. The prevalence of each skeletal indicator of stress was compared, between the samples, to determine whether any statistical association existed between location and disease. Contrary to the expectation, these data suggest that skeletal health was generally similar in the two locations, with a higher prevalence of periostitis in the rural sample. This paleopathological research highlights the potential to identify disease patterns and disease processes that occur in response to, or as a result of, changing environments.
CHAPTER I

INTRODUCTION

Epidemiological and paleopathological studies indicate health disparities occur between urban and rural populations. These disparities are associated with the number of people living in a contained area and their living conditions. High population densities and unsanitary, cramped living spaces result in high rates of disease, infection, and physiological stress. In contrast, lower population densities place less stress on local residents. This thesis considers the relationship between living environments and human skeletal health.

The post-medieval period in London, from 1550 to 1850, was characteristically urban. Dramatic increases in population size, population density, and urbanization occurred during this time span (Roberts and Cox 2003). The living environment in urban London and the living environment on the rural outskirts of London were significantly different. According to historic sources, an urban resident would have encountered air pollution, overcrowding, inadequate waste disposal resulting in unsanitary roads and water sources, and communicable disease. Rural residents may have encountered problems associated with communicable disease, but were less likely to have been exposed to the same extent as urban residents. Furthermore, rural residents would have been less affected by air pollution and crowded living environments when compared with urban residents.
Osteological studies of historic skeletal health can provide important objective information allowing researchers to interpret how humans adapted to such changing living environments. Skeletal indicators of stress can suggest the severity, duration, temporal course and prevalence rate of disease or conditions impacting bones (Goodman and Martin 2002). Several large-scale studies using multiple skeletal indicators of stress to assess health status have contributed to the field of paleopathology recently. For example, osteological evidence suggests that agricultural intensification, increases in population density, and sedentary lifestyles negatively impact human health (Cohen and Armelagos 1984; Cohen and Crane-Kramer 2007; Steckel et al. 2002b). Certain ecological and demographic changes are associated with increases in infectious disease, decreases in stature, dietary deficiencies, and malnutrition.

A number of skeletal studies have addressed skeletal health in post-medieval Britain. Osteological indicators have been used to assess urban and rural infant mortality rates, urban and rural prevalence of maxillary sinusitis, and changes in overall skeletal health from the medieval to the post-medieval period (Lewis 2002; Lewis et al. 1995; Lewis and Gowland 2007; Roberts 2009; Roberts and Cox 2003). However, outside of these investigations, few studies have compared differences in urban and rural health in post-medieval London. Furthermore, while there is information on human skeletal health in post-medieval Britain, a detailed analysis of the skeletal health of middle aged (35-50) and older adult females (50+) is incomplete. Due to the rapid urban growth during this period, skeletal samples from the greater London area offer a unique opportunity to study disease processes and patterns that occur in response to, or as a result of, urbanization.
Research Design

In order to evaluate skeletal health differences between urban and rural environments in greater London area, skeletal remains from two post-medieval English sites, St. Bride’s Crypt (SB79) and Chelsea Old Church (OCU00) were analyzed. Middle aged (35-50 years) and older adult (50 + years) female individuals of higher socioeconomic status were selected so that sex, age, and socioeconomic status remained consistent across the samples. These selection parameters were based on several criteria. A single sex was chosen because there are major differences in male and female immune reactivity and morphology. In addition, there is greater heterogeneity in mixed sex samples and consequently more problems with sample size and statistical power. There are the four standard bioarchaeological adult age cohorts used when recording age-at-death for skeletal samples: subadult (12-18 years), young adult (18-35 years), middle adult (35-50 years), and old adult (50+ years) (Buikstra and Ubelaker 1994). The two oldest age cohorts were selected for this study because they tend to exhibit more pathological indicators of skeletal stress than younger individuals. Finally, higher socioeconomic status individuals were selected for this study because the samples available, and complete enough for comparisons across urban and rural environments, were all higher socioeconomic status.

The main hypothesis for this study is that the urban St. Bride’s sample will show more skeletal indicators of stress, or poor health, and have a higher prevalence of such indicators than the rural Chelsea Old Church sample. This research aims to answer the following questions:
1. Is there a difference in the prevalence of skeletal indicators of stress in the urban, St. Bride’s Church, and rural, Chelsea Old Church, samples?

2. If a difference is found in the prevalence of skeletal indicators of stress, which indicators are more prevalent, and why?

3. What do the prevalence rates tell us about skeletal health in the greater London area for middle aged and older adult females?

In order to evaluate these questions, sex, age, and ten skeletal indicators of stress were assessed. Sex was estimated to exclude all males and to be able to appropriately age the individuals, and age was estimated to exclude females under the age of 35. Each of the following skeletal indicators of stress was used as measure of health: stature, rickets, maxillary sinusitis, periostitis, porotic hyperostosis, cribra orbitalia, linear enamel hypoplasias, caries, dental abscesses, and antemortem tooth loss.

Descriptive statistics were compiled using SAS© version 9.2 and SPSS© version 21 statistical programs. Differences in the prevalence of skeletal indicators of stress in the urban, St. Bride’s, sample and the rural, Chelsea Old Church, were evaluated using tests of association such as chi square, t-tests and logistic regression.

Organization of Thesis

Chapter II provides the theoretical background for the study. The first part of the chapter includes a summary of bioarchaeological and paleopathological theory. The remainder of the section focuses on skeletal evidence of health and the specific indicators of stress used to measure and compare skeletal health in this study.
Chapter III is a review of the biocultural and regional background, middle and older adult and female health, and the background of the St. Bride’s Church and Chelsea Old Church samples. The first part of the chapter discusses the health consequences of urbanization and industrialization. The second section encompasses information on the greater London area during the post-medieval period. This section includes an overview of life and health in post-medieval Britain and London. The middle section of the chapter focuses on the life of middle and older adult females in post-medieval London and also discusses paleopathological trends in middle and older adult females. The last section covers the background and previous work with the St. Bride’s and Chelsea Old Church samples.

Chapter IV summarizes the materials and methods of the analysis. The chapter provides an overview of the archaeological sites, skeletal aging, skeletal sex estimation, and how to analyze skeletal indicators of stress. Furthermore, the chapter provides a brief overview of the statistical methods used to analyze the data.

Chapter V presents on the results of the data analysis. The first section of the chapter focuses on the effect of differences in the age categories at each site. The prevalence rates of each skeletal indicator of stress are then compared across the St. Bride’s Church and the Chelsea Old Church samples.

Finally, Chapter VI discusses the study results and their overall implications. The first section of the chapter focuses on the results and interpretations of the urban and rural sample skeletal health comparison. In the second section, the factors influencing the results for each indicator of stress are discussed. The last section of the chapter discusses the limitations of the study and ideas for future work.
CHAPTER II

THEORETICAL PERSPECTIVE

Introduction

This chapter discusses the study’s theoretical background. The first section of the chapter details the bioarchaeological and paleopathological theory that is the foundation of this study. The remainder of this chapter discusses methods for measuring health in skeletal samples and reviews the specific indicators of stress used to measure skeletal health in this study.

Bioarchaeological and Paleopathological Theory

Studies of human skeletal biology are part of the field of biological or physical anthropology. Within the field of biological anthropology, bioarchaeology is the study of the human skeletons from archaeological contexts. Human skeletal remains are used to interpret or reconstruct information about the way people lived in the past. They can offer information about individual life histories, and information about past populations can be assessed when many individuals can be analyzed (Ubelaker and Pap 1998).

Also, a discipline within biological anthropology, paleopathology specifically examines disease in ancient humans through the study of skeletonized and mummified remains. The discipline is concerned with both identifying disease and determining how
disease may have affected an individual or a population. Although historic documents, such as parish records, reveal important demographic and sometimes health information, otherwise inaccessible biological information is preserved in the hard tissues of past peoples. Thus, paleopathological studies are able to produce important information about patterns of skeletal health in the past. Most research questions in the field of paleopathology are concerned with how disease has changed temporally and geographically as well as how people interacted with and adapted to their environment (Klaus et al. 2009).

This study also utilizes a biocultural approach to examine disease in skeletal remains and to evaluate the skeletal health consequences of urbanization. The biocultural approach considers social, cultural, ecological, and biological data, to understand human adaptation (Wiley and Allen 2009; Zuckerman and Armelagos 2011). In the bioarchaeological and paleopathological fields, this means that patterns of skeletal disease are used to understand the effects of “social, ecological, and political processes on health and between populations” (Zuckerman and Armelagos 2011:20). Therefore, the disease and health of an individual is evaluated based on skeletal and dental heath at the time of death (Buzon 2006). More specifically, skeletal health is assessed through macroscopic observations of stress, specifically pathological lesions, or bony change, occurring throughout the skeleton and dentition. Macroscopic observation of bony change provides non-destructive evidence of how people lived and how healthy they were in the past. In this study, the skeletal analysis is then supplemented by cultural information from the archaeological context, historic documents, and research on the social, economic, and political history of post-medieval London.
Measuring Skeletal Health

Past human health can be evaluated in terms of stress, or measurable physiological perturbation (Goodman and Martin 2002). Stress, as modeled by Goodman et al. (1984) and Goodman and Armelagos (1989), is a product of three major variables: environmental constraints, cultural systems, and host resistance. This model underscores the idea that the environment and cultural systems act both as buffers and as stressors impacting health and that the response to stress is observable in skeletal tissue. Because many variables affect stress, the individual biological stressors may be difficult to disentangle. Consequently, a “general stress perspective” can be employed. If the body responds to the biological stress, regardless of whether one or more variables create the response, a bony reaction may be left as evidence (Goodman and Martin 2002:16). Therefore, we can identify that a stress response has occurred through observation of bony reactions on the skeleton.

Assessment of the severity, duration, temporal course, and prevalence rate of pathologies provides a means of calculating health status and can contribute to our knowledge of the distribution patterns of abnormalities within a population (Goodman and Martin 2002). While most skeletal and dental stress markers are a result of physiological disruptions during childhood, biological responses to stress in adulthood indicate health and quality of life in post-developmental stages. Accordingly, high prevalence rates of bony reactions in a population indicate elevated levels of physiological stress. Therefore, this study uses skeletal indicators of physiological stress as proxy measure for quality of general health.
Skeletal Evidence of Health

Identification of biological stress in skeletal tissues is an empirical means to measure health in the past (Larsen 1997). Goodman et al. (1988) note that biological stress cannot be directly measured; however, the response to biological stress, in the form of skeletal lesions, can act as a gauge of disruption. Skeletal lesions are bony changes that occur in response to biological conditions and can be categorized in three ways: reactive (addition of bone or osteoblastic activity), destructive (resorption of bone or osteoclastic activity), or a mix of both. Bony tissue responds to many persistent conditions such as diet deficiencies, pathogens, and physical activity (Steckel et al. 2002b). A number of different types of skeletal lesions can be used to determine the amount of physiological stressors an individual experienced and, in a broader context, to extrapolate population health. Therefore, unusual formation and destruction of bone act as physical evidence of health can be termed skeletal indicators of stress.

Examining multiple skeletal indicators of stress in relation to one another provides a comprehensive understanding of health and adaptation (Larsen 1997). Most studies attempting to evaluate health status in past populations rely on several types of skeletal lesions as evidence of health. The most common skeletal and dental pathologies used to measure health include enamel hypoplasias, or disruptions in tooth development; dental disease and tooth loss; patterns of trauma; long bone length, to calculate stature; porotic hyperostosis and cribra orbitalia; osteoarthritis or degenerative joint disease; and bony responses to infectious disease (Steckel et al. 2002b).

Several well-known, large-scale paleopathological reviews use multiple skeletal indicators of stress to assess health status. The large-scale reviews include
Paleopathology at the Origins of Agriculture (Cohen and Armelagos 1984) and The Backbone of History: Health and Nutrition in the Western Hemisphere (Steckel et al. 2002b). These reviews, combined with independent research using indicators of stress to measure health status, have contributed a large amount to paleopathology in recent history.

In the compilation of paleopathological studies Paleopathology at the Origins of Agriculture, Cohen and Armelagos (1984) evaluated long-term trends in health by comparing the health of traditional hunter-gatherers with the health of sedentary agriculturalists. While different methodology is used to evaluate health in each chapter, most authors in the compilation discuss the frequency of infection and other lesions to assess physiological stress and health. In their concluding remarks, the editors compare the studies of each author and find clear evidence that health deteriorated with the transition to agriculture.

An extensive survey of health profiles compiled by Steckel et al. (2002b), known as “the study of health in the Western Hemisphere,” is detailed in The Backbone of History: Health and Nutrition in the Western Hemisphere. A health index was used to rank groups from each incorporated study by health status. Health status, which refers to both the quality of life and length of life, was evaluated and compared across samples using skeletal and dental lesions. The compilation of studies was used to analyze long-term health trends.

The health index comparisons by Steckel et al. (2002b) support Cohen and Armelagos’ work. The index indicates that hunter and gatherer populations were the healthiest and large agricultural populations the least healthy in the pre-Columbian era.
Furthermore, the analysis shows that one of the most important factors associated with health index was settlement size. Large settlements were associated with lower health indices, and thus lower health. However, the authors are careful to indicate that many variables influence the health index other than just population size and subsistence practice.

Expanding on *Paleopathology at the Origins of Agriculture*, papers from a 2004 conference (Cohen and Crane-Kramer 2007) reviewed skeletal indicators of agricultural and economic intensification. Health was measured using skeletal and dental lesions, but unlike Steckel et al. (2002b), there was no attempt to standardize techniques across the data presented in each study. The compilation of studies also uses skeletal indicators of stress from a globally diverse set of samples to support the theory that subsistence changes and population size and density increases negatively affect health.

**Skeletal Indicators of Stress Specific to This Study**

The remainder of this chapter will review the skeletal indicators of stress used in this thesis. These skeletal indicators of stress will be evaluated in relation to each other to extrapolate population health. Stature, rickets, maxillary sinusitis, periostitis, porotic hyperostosis and cribra orbitalia, dental linear enamel hypoplasias, caries, dental abscesses, and antemortem tooth loss will be included in the discussion. The discussion will be divided into four sections: stature, dental disease, non-specific indicators of health, and specific disease. While the skeletal indicators of stress are divided into the four sections, it should be noted that stature, dental linear enamel hypoplasias, and rickets are childhood indicators of health. While the other indicators of stress can affect the
skeletal system at any point during life, the childhood indicators of stress affect the skeleton during the process of growth and development.

**Stature**

Stature is determined by long bone growth. There are two major periods of growth during childhood, while a relatively small amount of growth occurs in post-pubescent years. The first period of growth occurs between birth and two years and the second period occurs with puberty (Waldron 2009). Stature, or height, is measured during life with a measuring implement while standing, but must be calculated from the long bones in deceased individuals. It is estimated in archaeological populations by calculating maximum long bone length and inputting the measurements into a regression equation. The resulting predicted average does not directly equate with height during life; however, the averages can be used to compare archaeological populations (Waldron 2009).

While genetics contribute to stature, studies of adult height across populations suggest that average differences are mainly due to environmental factors (Steckel et al. 2002b). There is a strong correlation between net nutritional status and height (Roberts and Manchester 2007). In addition, physical activity and disease can reduce nutrition and malnourishment impedes growth (Steckel et al. 2002). Therefore, a lower adult stature may indicate a growth disruption that could be caused by poor nutrition, physical activity, or disease. Studies have shown a correlation between other growth disruptions and health status. For example, Ribot and Roberts (1996) found a correlation between lower stature and defects in dental enamel such as linear enamel hypoplasias.
Dental Disease

Mature teeth are composed of different layers: enamel, dentin, cementum and the pulp cavity. The outer layer of a mature tooth is composed of enamel. Enamel is a hard, protective outer surface that is formed during development. Any defects in the enamel are the result of stress early in life. Enamel lacks cells and vascular supply and therefore does not remodel as bone does in the rest of the body. The second layer of the tooth is composed of dentin, which gives support to the enamel and acts as a shock absorber. The cementum covers the root of the tooth and the pulp cavity is the canal in middle of the tooth that contains blood vessels and the nerves. Each tooth is surrounded by and anchored to the alveolar bone of the mandible or maxilla.

Dental disease is common in archaeological skeletal assemblages, and patterns in dental disease provide useful information on nutrition and health in archaeological populations. There are several kinds of dental disease observable in archaeological populations: infectious disease, degenerative disease, and developmental problems. Complex relationships exist between the different types of disease and more than one can be present at one time.

In this study, four types of dental disease were used as skeletal indicators of stress: caries, antemortem tooth loss, linear enamel hypoplasias, and abscesses. Infectious disease includes caries and abscesses, degenerative disease includes antemortem tooth loss, and developmental problems include linear enamel hypoplasias. The following section will discuss each dental indicator separately.

Dental Linear Enamel Hypoplasias. Linear enamel hypoplasias are a disturbance in the formation of dental enamel, visible as linear pits or furrows on the
labial surface of permanent dentition. They are most commonly observed on the maxillary and mandibular incisors and canines (Roberts and Manchester 2007) and occur as a result of a gap or deficiency in enamel matrix secretion (Goodman and Rose 1990). More than one pit or furrow is an indication of separate or episodic disruptive events. The pits and furrows can be recorded using the naked eye or by using magnification (Figure 1).

**Figure 1.** Dental linear enamel hypoplasias expressed on the anterior dentition of a female from Chelsea Old Church. Courtesy of the Museum of London (Catalogue No. OCU00-248). Photograph by Alexandra Perrone.

Linear enamel hypoplasias are commonly used in bioarchaeological studies as a non-specific indicator of systemic stress during infancy and childhood (King et al. 2005). Teeth require specific nutrients during development. If the required nutrients are
not available during tooth development, disruptions in the enamel may occur (Ortner and Puschar 1981). In addition, disease during tooth development can also affect the enamel or dentin causing linear enamel hypoplasias (Ortner and Puschar 1981).

**Dental Caries.** Dental caries is an infectious disease process that destroys the structure of teeth. Tooth tissue demineralization is caused by a bacterial film, or plaque. Acid, caused by bacterial fermentation of dietary carbohydrates, demineralizes the tooth tissue. If the disease progresses, the acid eventually creates holes in the tooth tissue known as cavities. The destructive process can create cavities in both the enamel and the dentin, eventually exposing the pulp cavity. Exposure of the pulp cavity increases the risk of infection and can lead to the creation of an abscess. In addition, if caries is not treated, the crown and root of the tooth may be destroyed. Complications associated with infection can be serious and can be fatal without medical treatment or tooth extraction.

Detection of caries in skeletal remains can be more straightforward than distinguishing the cause of carious lesions. Dental caries can be identified in archaeological skeletal samples by the presence of the carious lesions, or cavities (Figure 2). However, the etiology of dental caries is complex. Factors influencing cariogenesis include: genetics, environment, diet, tooth surface exposure, tooth morphology, and varying mouth bacteria (Powell 1985). In addition, developmental defects in enamel and dentin can weaken the protective surfaces of the tooth, increasing the potential for caries (Ortner and Puschar 1981).

The prevalence of dental caries in archaeological samples has been used to measure patterns of health, especially in relation to subsistence. Research relates caries
prevalence and subsistence change, with some studies noting an increase in caries with the advent of agricultural crops consisting of fermentable carbohydrates (Larsen 1997).

An investigation by Miura et al. (1997) indicates that caries rates may increase with urbanization. This pattern is supported by research in British contexts (Roberts and Manchester 2007). Roberts and Cox (2003) note an increase in dental caries between the late Mesolithic period and the post-medieval period in Britain. The researchers suggested a correlation between sucrose and consumption of refined flour and an increase in caries. While many factors are associated with the development of dental caries, the amount of sugar in the diet is the strongest association (Hillson 2005).
Dental Abscesses. A dental abscess is a rough-walled pocket in the alveolar bone surrounding a tooth root, produced as pus from an infection exerts pressure on the tissues surrounding the root (Waldron 2009). When an infection travels from the dental pulp, through the root canal, and to the apex of the tooth, it can eventually spread to the tissues surrounding the tooth root. Inflammation occurs around the root and pus collects putting forth enough pressure to create an abscess. A hole must develop in the surrounding bone in order for the pus to drain (Figure 3).

Figure 3. Dental abscess in an adult female from St. Bride’s Church. Courtesy of the Museum of London (Catalogue No. SB79-117). Photograph by Alexandra Perrone.

When an abscess reaches the point of needing to drain, it is visible osteologically (Roberts and Manchester 2007). Most authors accept the presence of a
hole or pocket surrounding a tooth root as evidence of a dental abscess. Dental abscesses usually occur as a result of advanced stages of dental caries or periodontal disease. Abscess can be very painful and can result in tooth loss. As with the other forms of dental disease discussed in this section, dental abscesses indicate a decline in oral health.

Antemortem Tooth Loss. Antemortem tooth loss is the loss of teeth during life. Antemortem tooth loss can be identified by new bone growth in a tooth socket, healing in a tooth socket, and resorption of the socket (Figure 4). Tooth loss is an indication that the tooth or surrounding structure is not healthy. For example, tooth loss may occur due to periodontal disease, caries, abscesses, excess attrition, or a combination of the factors (Goodman and Martin 2002).

Figure 4. Antemortem tooth loss expressed in an adult female from Chelsea Old Church. Courtesy of the Museum of London (Catalogue No. SB79-980). Photograph by Alexandra Perrone.
Although the frequency of antemortem tooth loss increases with age, it generally indicates a decline in oral health. Antemortem tooth loss may be associated with changes in subsistence as well as overall health. For example, Steckel et al. (2002b) recorded an increase in both tooth loss and caries at the transition to agriculture. Furthermore, extensive tooth loss can affect nutrition and health. Missing teeth makes eating difficult and limits the type of food consumable (Steckel et al. 2002b). Therefore, extensive tooth loss or complete tooth loss can lead to dietary deficiencies. For instance, a study by Palmer and Pappas (1989) indicated that toothless individuals lose up to twenty percent of their nutrient intake.

Non-specific Indicators of Health

Maxillary Sinusitis. Maxillary sinusitis is a non-specific infection of the largest paranasal sinus located in the maxillary bone, inferior to the eye orbit. The air-filled cavities of the sinuses contain a mucous-lined membrane that traps airborne pathogens before they reach the lungs. When a chronic infection occurs, a bony reaction develops. In skeletal samples, a chronic infection can be distinguished by spiculate bone formation and pitting on the interior walls of the sinus cavity (Figure 5).

The etiology of sinusitis is multifactoral, stemming from a compromised immune system, congenital predisposition, and environmental factors. Paleopathological studies have largely focused on environmental factors that contribute to maxillary sinusitis. Overcrowding, unsanitary living conditions, poor ventilation, house and parasitic dusts, smoke—all conditions associated with urban living—increase the risk of inflammation and infection of the sinuses (Lewis et al. 1995). Evidence of maxillary sinusitis from British skeletal assemblages suggests that this kind of infection occurred
Figure 5. Maxillary sinusitis expressed in the left maxillary sinus of an adult female from Chelsea Old Church.Courtesy of the Museum of London (Catalogue No. OCU00-722). Photograph by Alexandra Perrone.

more often in urban locations with poor air quality, and in general, the prevalence of maxillary sinusitis increased through time (Lewis et al. 1995; Roberts and Cox 2003; Roberts et al. 1998).

Periostitis. Periostitis is a localized inflammation of the periosteum, or the surface layer of the bone. Periostitis is a response to trauma or infection, but can also be a response to strain. The periosteum reacts to strain, trauma, and pathological stimulus by producing new bone. The resulting lesions are characterized by woven, osseous plaque. As the lesion heals, the surface smoothes but retains a slightly swollen appearance (Figure 6).
Periostitis is usually localized and tends to affect the tibia more than any other skeletal element (Waldron 2009). Explanations for this pattern include susceptibility to infection due to lowered surface temperature of the shin, build up of bacteria due to stagnation of blood in the legs, and the lack of soft tissue protecting the anterior surface against trauma (Larsen 1997; Roberts and Manchester 2007).

The etiology of periostitis is difficult to assess in skeletal assemblages. However, it is possible to distinguish periostitis caused by trauma from that caused by infection. Periostitis resulting from traumatic injuries tends to be localized, while periostitis resulting from infection is systemic. Bilateral periostitis, periostitis that affects
multiple elements, and periostitis that affects the entire diaphysis of an element tend to be the result of an infection. Recording the prevalence of periostal lesions and differentiating periostitis resulting from trauma from periostitis resulting from infection can reveal patterns in community health (Larsen 1997).

**Porotic Hyperostosis and Cribra Orbitalia.** Cribra orbitalia and porotic hyperostosis are non-specific infections that lead to porosities in the cranial vault surface (porotic hyperostosis) and orbital roof (cribra orbitalia) (see Figure 7 and Figure 8). The cranial vault and orbital roof lesions are osseous responses to marrow hypertrophy. The porous lesions may occur in both places or only in the roof of the eye orbits. Co-occurrence in the cranial vault and the eye orbits supports the theory that the lesions are a response to the same systemic problem (Walker et al. 2009).

![Figure 7. Cribra orbitalia expressed in the left eye orbit of an adult female from Chelsea Old Church. Courtesy of the Museum of London (Catalogue No. OCU00-446). Photograph by Colleen Milligan.](image)
The etiology of porotic hyperostosis and cribra orbitalia is debated, but worldwide research indicates that the diseases arise from a combination of stressors (Larsen 1997). Conditions common to populations where the diseases are present include parasitism, decreased sanitation, poor diets, infectious disease, and anemia. While iron-deficiency anemia has gained acceptance as the cause of the cranial vault and eye orbit porosities, Walker et al. (2009) build a convincing argument for vitamin $B_{12}$ deficiency as a key predisposing element. Regardless of the specific etiology, the lesions are commonly used as a proxy for health and nutrition status in past populations.
Specific Disease

**Rickets.** Rickets occurs in children and results from chronic vitamin D deficiency during the development and growth period. Vitamin D is a pro-hormone whose synthesis depends on skin exposure to ultraviolet light or dietary sources such as oily fish, eggs, and liver (Brickely and Ives 2008). The availability of vitamin D in the body impacts calcium and phosphorus metabolism, which enables osteoid and cartilage mineralization (Brickely and Ives 2008). Deficiency of the pro-hormone prevents mineralization of the bone, resulting in skeletal abnormalities such as softening of the bone and bending in weight-bearing elements (Roberts and Manchester 2007). Childhood manifestations of vitamin D deficiency are termed rickets, while adult manifestations of vitamin D deficiency is termed osteomalacia.

While there are many reasons vitamin D deficiency may occur, the primary causes are lack of sun exposure and dietary deficiency (Brickely and Ives 2008). A chemical change triggered by sunlight occurs in the skin and accounts for 90 percent of the body’s vitamin D requirement (Roberts and Manchester 2007). In addition to lack of sunlight exposure, poor nutrition, illness, defects affecting the synthesis of vitamin D, and social and cultural practices can result in vitamin D deficiency. The interrelationship between calcium and vitamin D should also be noted. While vitamin D increases calcium absorption, low dietary intake of calcium can also exacerbate vitamin D deficiency. Maternal stores of vitamin D also affect the offspring’s vitamin D stores. Thus, a child’s susceptibility to vitamin D deficiency depends on the placental environment and lactation.
Because infants depend on their mothers for vitamin D during pregnancy and lactation, the amount of vitamin D the mother intakes and stores directly affects her offspring. Fetal bone development requires large amounts of calcium and calcium absorption is dependent on adequate vitamin D (Roberts and Manchester 2007). While osteomalacia (adult vitamin D deficiency) may not be common, low maternal levels of vitamin D greatly affect an infant’s susceptibility to rickets. The upper-class post-medieval women who were mainly sequestered indoors, and who were completely covered in clothing, would have had lower vitamin D reserves available to their offspring. Inadequate sunlight exposure due to clothing, staying indoors, or environmental pollution, as well as insufficient dietary intake, directly affects the infant.

The use of wet nurses is a cultural practice linked to vitamin D absorption. According to Waldron (2009), children of upper-class families who could afford a wet nurse were more at risk for rickets than those of poorer families, since long periods of lactation decrease the calcium content of breast milk. Furthermore, keeping children housebound until till they turned one would have reduced their exposure to sunlight (Roberts and Manchester 2007).

Rickets was highly prevalent in England during the 17th and 18th centuries; as a result, rickets was termed the ‘English Disease’ (Fildes 1986). Rickets are even referenced as a cause of death in the London Bills of Mortality, a compilation of demographic data spanning the mid seventeenth to mid eighteenth century that include a record of baptisms, deaths, age, and cause of death for London. The frequency of rickets increases when exposure to sunlight decreases. Both environmental and cultural factors result in decreased exposure to sunlight, including living at high latitudes and cultural
practices that cover the skin, such as swaddling. Industrialization also was a major factor contributing to rickets in 17th and 18th century England. Industrial smoke blocked sunlight over London and several other northern industrial cities (Waldron 2009). In addition, crowded and overhanging houses blocked most of the remaining sunlight (Roberts and Manchester 2007).

Rickets is not necessarily a fatal disease. Once sun exposure resumes or dietary sources of vitamin D increase, rickets may heal. Healed rickets may be identified in adult skeletons. Changes throughout the adult skeleton indicate residual rickets; however, the most noticeable changes occur in the long bones. Brickley and Ives (2008) include bowing of the tibia and femur, thickening of the femora indicating buttressing of the concavities of bends, and medio-lateral widening of the proximal femora as evidence of healed or residual rickets (Figure 9).

Figure 9. Medial bowing of the femora indicating the presence of rickets in an adult female from Chelsea Old Church. Courtesy of the Museum of London (Catalogue No. OCU00-910). Photograph by Colleen Milligan.
Summary

This research focuses on skeletal health in human remains from archaeological contexts. A bioarchaeological approach with a paleopathological emphasis is employed to explore osteological evidence of health. Bone reacts and adapts to biological stress by forming new bone or destroying bone. The resulting skeletal lesions are skeletal indicators of stress. Multiple skeletal indicators of stress can be used together as a proxy measure of human health and ill health in the past. This chapter reviewed the following indicators of stress: stature, rickets, maxillary sinusitis, periostitis, porotic hyperostosis, cribra orbitalia, dental linear enamel hypoplasias, dental caries, dental abscess, and antemortem tooth loss. These skeletal indicators of stress were used to compare urban and rural health in post-medieval London.
CHAPTER III

BACKGROUND

This study examines the health of middle aged to older adult females in upper class post-medieval London, addressing the impacts of urban versus rural living in the greater London area. The following chapter provides the period and regional background necessary to appropriately address the skeletal health of the sample. Because health represents a complex interplay of social, cultural, ecological, and biological effects, the background section encompasses several topics. The chapter begins with general information and then narrows to a focus on the skeletal collection.

This chapter is divided into four sections. The first section discusses the biological consequences of urbanization and industrialization. In addition, the section reviews post-medieval British health as evidenced in skeletal remains. The second section deals with the socio-cultural and regional background of London during the post-medieval period. Although the whole period will be discussed, most of the information will focus on the second half of the post-medieval period, because the individuals from both skeletal samples were alive during the latter half. The third section discusses middle and older adult females and health. The remainder of the chapter consists of an overview of the background of the urban St. Bride’s Church sample and the rural Chelsea Old Church sample.
Biological Consequences of Urbanization and Industrialization

Human health is affected by both intrinsic and extrinsic factors. Intrinsic factors pertain to the individual, and include immunity, age, sex, and ethnicity. Extrinsic factors are environmental, such as social status, residency, population density, climate, weather, and nutrition. Environmental factors can have a large influence on health. For example, contemporary studies, as well as studies of past populations, show that urbanization and industrialization affect human health. The development of urban areas results in higher levels of infectious disease, metabolic disease, stress, and higher mortality rates. In addition, industrialization exacerbates health problems associated with urbanization and creates occupational health problems.

The effects of urbanization and industrialization can result in health disparities between urban and rural groups. Some of the major contributors to ill health in urban industrial areas are overcrowding, unsanitary conditions, and pollution. For example, high population densities maintain density-dependent disease and theoretical models suggest that the existence of large host populations increase virulence of disease (Cohen and Krane-Cramer, 2003; Martin 2003). Pollution of the air and water is associated with many kinds of health problems, including respiratory and infectious diseases such as cholera, typhoid, bronchitis, and pneumonia (Storey 1992; Woods and Shelton 2000). Furthermore, the risk of food-borne infection from handling, transport, storage and processing increases in urban centers (Cohen and Crane-Kramer 2003) and access to fresh food and variety of food can be restricted in urban areas (Storey 1992).
Trade and migration contribute to disease in urban centers. People and goods become the hosts for disease by moving from one location to the next (Roberts and Manchester 2007; Wilson 1996). People are also drawn to industrial areas for work. This migration can compound existing problems associated with populating density, unsanitary conditions, and pollution, and has the potential to create additional problems. For example, occupational hazards increase in urban centers where certain professions are more susceptible to particular types of illness, such as trauma from machinery, injuries from repetitive strain, and inhalation of particles (Roberts and Cox 2003).

Paleopathological literature notes two major causes of population growth: the transition from a hunter-gatherer lifestyle to agriculture and from agriculture to urbanization. Starting with the publication of Paleopathology at the Origins of Agriculture (Cohen and Armelagos 1984), the field of paleopathology has generally recognized the negative impact of agricultural intensification, increases in sedentism and increases in population and population density on human health. Osteological evidence also suggests that urbanization and industrialization negatively impact human health. While not all biological consequences are harmful, analysis of skeletal markers and infectious disease provides strong evidence for health decline associated with urbanization (Cohen 1989; Cohen and Armelagos 1984; Bouquet-Appel et al. 2008; Larsen 1997, 2006; Steckel et al. 2002b; Ubelaker and Newsome 2002; Walker and Thornton 2002). Numerous skeletal studies specifically address and support the hypothesis that urbanization contributes to a decline in health across the world. For example, De la Rua et al. (1995) compared health in agricultural and transitional populations with urban and industrial centers across the world and found an increase in
skeletal and dental markers of stress in the urban populations. Saunders et al. (2002) compared skeletal indicators of chronic biological stress and health in Bellville, Ontario during the 19th Century and found that, regardless of social status, health was negatively affected by urbanization. Storey (1992) combined evidence from historical records and paleopathology to show that urban lifestyles impacted health in Europe. And, Marquez Morfin et al. (2002) discussed the health effects of urban society in pre-Columbian Mesoamerica, finding a general trend of decreased health in the urban samples from Central Mexico.

Paleopathological studies also specifically address urban and rural health in Britain. The comparisons between urban and rural skeletal samples confirm that differences in health also occurred in post-medieval Britain. These studies will be discussed in the remainder of this section.

**Urban and Rural Health in Britain**

As discussed previously, changes in environment affect human health. The post-medieval period in Britain is characterized by dramatic changes in environment. In many cities throughout Britain, population size, population density, and urbanization increased (Roberts and Cox 2003). Furthermore, pollution, climate change, agricultural developments, and industrialization contributed to the changing environment during the time period. Life expectancy in Britain was possibly the lowest at the end of the 18th century and was especially low for the poor in urban areas (Roberts and Cox 2003). Of all the major cities in England, environmental changes were probably the most extreme in London (Roberts and Cox 2003; Wohl 1983).
Most of the disease during the period is not visible osteologically, but is known from historic sources, such as the aforementioned London Bills of Mortality. However, some disease is skeletally visible and can be used to understand human health.

Skeletal studies that measure human health in the past are based on evidence of disease, or stress, in skeletal tissue. Skeletal indicators of stress are helpful in identifying patterns in past human health. Skeletal studies of urban and rural health in Britain show differences in infant mortality rates, stature, dental disease, joint disease, infectious disease, and metabolic disease. Based on a general review of post-medieval British skeletal studies, Roberts and Cox (2003) note a radical change in health from the mid-sixteenth to the mid-nineteenth century. The authors also show that disease in Britain increased with urbanization: rural and urban populations differed in the prevalence rates of several skeletal indicators of health, including maxillary sinusitis, dental enamel hypoplasias, infectious disease, dental caries, cribra orbitalia, and Diffuse Idiopathic Skeletal Hyperostosis (DISH).

Additional skeletal studies of urban and rural health support Roberts and Cox’s (2003) findings. In order to evaluate the impact of both urbanization and industrialization on health, Lewis and Gowland (2007) compared infant mortality rates from urban and rural sites in post-medieval London. Infant mortality rates are frequently used as a measure of population fitness in paleopathology because they have an extreme effect on the crude death rate of a population (Lewis and Gowland 2007). Acknowledging the limitation that increased fertility poses to studies of infant mortality, the authors found that industrial environments impacted neonatal and postneonatal mortality. Neonatal mortality, which the authors consider endogenous, was higher than
post-neonatal mortality in their rural sample. In contrast, the urban sample had a greater proportion of postneonatal deaths, which the authors attribute to environmental or exogenous factors. The authors note that early weaning and poor sanitation may have contributed to post-neonatal mortality rates and proposed that the urban environment negatively impacted infant health.

In paleopathology, child health, like infant mortality rates, is used as a measure of population fitness. This is because children are one of the most sensitive demographic groups to biocultural change (Lewis 2002). To determine whether urbanization and industrialization had an effect on health, Lewis (2002) conducted a comparative study of child health in medieval and post-medieval England. Sub-adult health was examined using skeletal remains from four sites. It was argued that a health difference existed between urban and rural sites, and a comparison of the growth profiles from each site showed that industrialization had the largest impact on child health. Furthermore, Lewis (2002) concluded that the Industrial Revolution contributed to a decrease in health, regardless of social status.

Focusing on all demographic groups, Roberts (2009) discussed health in medieval London, noting that disease increased from the earlier to later medieval periods. While the Roberts (2009) study does not focus on the post-medieval period, it is a reflection of the worsening health conditions described by Roberts and Cox (2003) during the transition from the medieval period to the post-medieval period. The earlier medieval time period represents rural living, while the later medieval period represents urban living. Living environment, economy, and diet contributed to health and disease and changes in these categories from rural to urban living saw a decrease in health. Maxillary
sinusitis, enamel defects in teeth, infectious disease, stature, dental caries, and DISH were among the pathologies noted by Roberts (2009) to increase in the late medieval period.

In summary, according to studies of human health and living environments, both urbanization and industrialization affect health. Although several studies are discussed above, the amount of published research on health in urban and rural settings within the post-medieval period is limited. Nevertheless, most of the limited paleopathological literature on rural and urban health in London suggests that urbanization resulted in decreased in health.

Regional Background

Post-medieval England and London

Urbanization. For the purposes of this study, urban refers to a population living in a city with a high density, whereas rural refers to a population living in the countryside, with a low population density, usually practicing agriculture. The post-medieval period (1550-1850) represented a time of population growth and urban expansion. The population of London increased dramatically, rising from approximately 67,000 to around 127,400 between 1700 and 1820 (Harvey 1968). At the beginning of the period, the populations was mostly rural, with only about 5 percent of the population in urban contexts (Roberts and Cox 2003). In contrast, close to 50 percent of the population was urban by the end of the period (Roberts and Cox 2003).

Rural areas also changed during the post-medieval period. One of the major catalysts of rural change was the process of enclosure. Prior to the enclosure, people had access to communal land and were able to support themselves from an open field system.
However, the process of enclosure resulted in the end of the traditional open field system (Roberts and Cox 2003). In place of open access to communal land, private ownership and farmland restriction, or literal enclosure, took place. Because most people lost access to farmland, farmsteads and seasonal agricultural shelters were abandoned and, in some cases, rural settlements were deserted (Roberts and Cox 2003). The progression of enclosure resulted in accelerated movement to cities and abandonment of rural areas, therefore decreasing rural populations and further adding to urban development and population growth.

**Pollution.** The pace of urban growth in London and other cities throughout England during this period created many problems related to space, water, and air. Victorian London was characterized by densely packed housing and waste in the streets. Contemporary sources, as well as photographs and architectural plans, describe Victorian London as crowded and dirty (Wohl 1983). The city literally smelled of manure and other organic waste; accumulations of dung, animal parts, sewer drainage, and industrial waste were so bad that many residents complained of nausea, headache, and faintness, among other symptoms (Wohl 1983).

River pollution, ground water pollution, and drinking water pollution were also rampant during the post-medieval period, stemming from lack of sanitary measures and industrial contamination. Sewage was drained directly into rivers, animal and human carcasses were dumped into waterways, and industrial pollutants, such as bleaching powders and dyes, were deposited into the water (Wohl 1983). The state of ground water contamination varied both in urban and rural areas; the water in some rural areas was
contaminated, and some urban areas had clean water sources (Roberts and Cox 2003). Regardless, the human and animal refuse was more severe in most urban areas.

Not only were streets and water contaminated, London air was so polluted that the city earned the name ‘old smoke,’ and ‘black fog’ (smog) was commonly referenced (Wohl 1983). “Nausea, vomiting, bronchial and respiratory complaints, poor digestion and lack of appetite, sleeplessness and a general feeling of malaise” were effects of smoke and other atmospheric pollution reported by Victorian health authorities (Wohl 1983:208). The smog also affected the surrounding areas; in the 1840s reports indicated that industrial pollution reached and ruined crops in Chelsea (Wohl 1983).

**Health and Disease.** Most of the archaeological evidence of health and disease during the period comes from skeletal remains in or around London. According to a review of the skeletal studies by Roberts and Cox (2003), the upper socioeconomic class is better represented in samples. This means that health, as evidenced in bone, may not necessarily be as representative of the lower socioeconomic classes. Likewise, some decreases in prevalence of skeletal indicators of stress or disease may be due to the socioeconomic bias in the samples instead of a decrease in the prevalence rate of disease from the medieval period.

Examination of post-medieval skeletal samples suggest a decline in the crude prevalence rate of dental abscesses, porotic hyperostosis, and cribra orbitalia from the Medieval period, but also indicate an increase in rickets, venereal syphilis, tuberculosis, and DISH. This evidence is supplemented by documentation, such as the London *Bills of Mortality*, which aids our understanding of the types of disease that did not manifest in bone. The *Bills of Mortality* include information gathered by women who traveled door to
door to collect age, cause of death, and place of death of recently deceased individuals (Roberts and Cox 2003). Smallpox, bubonic plague, cholera, measles, diphtheria, tuberculosis, respiratory disorders, and gastric disorders were some of the most prevalent types of disease recorded in post-medieval England (Roberts and Cox 2003).

As mentioned, the environment affected the health of the post-medieval socioeconomic classes in different ways. Geographic social segregation as well as differences in infrastructure widened the health gap between classes, with worse conditions for the lower classes (Sharpe 2000). The lower classes in London were most affected by health problems related to nutrition and sanitation and experienced horrendous working and living conditions as compared to the upper classes (Wohl 1983). The middle and upper classes experience both better hygiene and health, and lower mortality rates (Olsen 1999). Accordingly, life expectancy varied between classes, with a death rate almost three times higher in poorer parishes as compared to wealthier ones (Olsen 1999). The wealth of the higher classes mitigated some of the problems faced by the lower classes. However, overall, skeletal evidence and historical sources indicate that by the end of the period in England, the health of the general population reached an “all-time low” (Roberts and Cox 2003:293).

Nutrition and Diet. Nutrition was also influenced by socioeconomic status. Wealth acted as a barrier against the food shortages experienced by lower classes and opened access to variety in the diet. Animal fats and proteins were the main component of the middle and upper class diet during the post-medieval period, but would not have been such a large part of the diet of the lower socioeconomic class (Molleson et al. 1993). The upper classes also had better access to fresh foods during this period, when roads,
and thus transportation of goods, improved (Roberts and Cox 2003). A variety of fresh fruits, vegetables, and cereals were available to those who could afford them; however, it is believed that the upper classes consumed small amounts of these compared to meats (Molleson et al. 1993). In fact, according to many contemporary sources, such as writers and artists, the middle and upper class suffered from dietary excess rather than deficiency (Roberts and Cox 2003). Diffuse idiopathic skeletal hyperostosis (DISH), causing fusion of the vertebrae, is evident from at least six sites during this period (Roberts and Cox 2003). DISH is associated with obesity and Type II diabetes. However, other than DISH, direct evidence of dietary excess is not well represented in post-medieval skeletal samples (Roberts and Cox 2003).

While the upper classes had access to a variety of foods, in many cases, the diet of upper socioeconomic class children lacked nutrients (Roberts and Cox 2003). Wet nurses and formula were common employed by the upper class (Olsen 1999). Panada, a mix of bread, spices and broth or milk, and paps, breadcrumbs or flour in milk, were hand fed to infants in place of breastfeeding (Molleson et al. 1993). Hand feed formulas lacked the nutrients and immunity contained in breast milk.

Even though the wealthier classes had better access a variety of fresh food, all classes during the post medieval period would have been exposed to adulterants in their drinks, food, and food containers. Lead, alum, chalk, and capsicum are some of the toxins commonly added to food and drink (Roberts and Cox 2003). According to Wohl (1983) cow’s milk was the most commonly contaminated food in Victorian Britain, whether by adulterants or by exposure to unsanitary conditions. Likewise, meat and dairy contaminants included bacteria and parasites, such as tapeworms (Wohl 1983).
In summary, the post-medieval period in England was a time of urban expansion, population growth, and severe pollution in large cities, especially London. Upper socioeconomic classes experienced better health and life expectancies, and had access to more variety and overall better nutrition than lower classes. The urban poor most likely suffered from the worst health, diets, living conditions, and life expectancies out of all the socioeconomic classes. Data drawn from skeletal assemblages, as well as historic sources such as The Bills of Mortality, suggest an overall decline in health from the medieval period, with perhaps the worst overall health experienced during any time period in England.

Middle and Older Adult Females

The focus of this thesis is middle aged (35-50) and older adult (50+) female health, as evidenced through skeletal indicators of stress. As contextual evidence is important in bioarchaeological and paleopathological studies, this section focuses on period and osteological information regarding middle aged and older adult females. There is an abundance of information regarding women and women’s work, during the post-medieval period in England and specifically in London. There is also information documenting the lives of upper socioeconomic class women. However, not as much attention has focused on older adult females during this time period. What follows is a summary of available information.

This section begins with an overview of the lives of women during the post-medieval period, reviews cultural conception of old age and attitudes towards the elderly, and then discusses general osteological evidence regarding health patterns of older
females, since specific information on middle aged and older adult females from post-medieval London is not available.

The Lives of Women During the Post-medieval Period

A substantial amount of literature focused on women in the post-medieval period describes women as marginalized and restricted to the private sphere. However, women's experiences were diverse and varied between socioeconomic classes (Barker and Chalus 2005). During this period, especially for the middle and upper classes, the home and family were equated with femininity (Barker and Chalus 2005). Upper socioeconomic class women were prohibited from many of the public and private functions that men attended, but women in towns enjoyed more freedom of action than women of the countryside (Ellis 2000). Women generally did the housework and men earned the income during this period; however, it was not uncommon for some women to earn money as well (Olsen 1999; Sharpe 2000). Rural women helped with work on farms, but did not usually partake in the heavier labor. Both rural and urban women held positions such as domestic servants, artists, weavers, washerwomen, midwives and teachers (Olsen 1999; Sharpe 2000). The upper socioeconomic classes hired servants, and so, the upper class women would not have had the same amount of housework as lower socioeconomic classes, and would not have participated in manual labor (Olsen 1999).

While there was a high rate of infant mortality during the post-medieval period, the proportion of the population composed of children was still high (Sharpe 1987). This means that most women experienced several births during their life. Women married around the age of puberty, which was about 17 years of age (Molleson et al.
Conception before marriage was more common among the lower socioeconomic classes in England than among the upper classes; however, it was also frequent among the upper socioeconomic classes (Molleson et al. 1993; Olsen 1999). The number of births outside marriage rose from close to two percent in 1700 to around five percent in 1790 (Olsen 1999). Childbirth during this period was more dangerous than it is in modern times (Molleson et al. 1993). Most women gave birth at home attended by a midwife or doctor and family (Olsen 1999). Although medical personnel attended women during childbirth, the risk of infection and other complications during or after birth put many women at risk. The *Bills of Mortality* for this period list childbirth as a cause of death under ‘childbed,’ and estimated rates are between 9 and 14 out of every 1000 for London and between 5 and 11 outside of London (Schofield 1986); however, the prevalence rate is unknown.

Many girls, regardless of socioeconomic status, received an education (Olsen 1999). Most girls received their education at home, but some girls, mainly those who could pay for an education, attended schools and boarding schools (Olsen 1999). Upper socioeconomic status women would have had the opportunity to attend elementary schools, but women were not able to attend universities (Barker and Chalus 2005). Lower socioeconomic class girls received an education that provided skills for labor, such as domestic service, and to take care of their family (Simonton 2005). For most middle and upper socioeconomic class girls, school included subjects such as sewing, writing, reading, religion, etiquette, cooking, and some academic content, as it was common for upper class women to attend school to enhance their prospects for marriage (Olsen 1999; Simonton 2005).
The legal rights of women were tied to marriage. Wives relinquished their legal rights to their husband at marriage (Olsen 1999). Property, debts, the contents of the home, and children were all legally the husband’s. However, women’s marital experiences varied depending on class. At the beginning of the 1700s, the upper socioeconomic classes had arranged marriages and dowries (Sharpe 1987). By 1800, marriages were no longer arranged but parents still had to approve of a union and dowries were still important (Olsen 1999). For lower classes, parents had much less influence over marriage and chose their own spouses. This trend was influenced by the fact that most lower class individuals left the home and were working around the age of 15 (Olsen 1999). Remarriage was common for widows of the middle and upper socioeconomic classes, but less common for older women (Earle 1994). In fact, the older age groups, 55 and over, were dominated by widows and spinsters (Earle 1994; Ellis 2000).

The private, domestic sphere of women did not include politics. Women were formally barred from politics in that they were not able to vote, although it should be noted that the majority of men were also excluded from voting. Regardless, exclusion from voting did not mean that women did not participate in, and contribute to, political life during this period. Until the ‘Great’ Reform Act of 1832, a small number of women landowners were allowed to vote (Barker and Chalus 2005). In addition, women were politically active. According to Barker and Chalus (2005), the atmosphere in which the women’s movement and the women’s suffrage movement began, took shape at the end of the period. Although the majority of this period is described in terms of women’s and men’s spheres, and women had few legal rights, the end of this period marked the beginning of a turning point for feminism and women’s rights in Britain.
Cultural Conception of Old Age and Attitudes Towards the Elderly

Although it is sometimes assumed that people in the 18th century and early 19th century did not live very long lives, this is a misconception. Life expectancy was low due to high infant mortality. In London around 30 percent of all deaths occurred before 2 years of age (Roberts and Cox 2003). However, if an individual reached an age of twenty, it was not as unusual to live into the sixties (Roberts and Cox 2003). In Europe, life expectancy for females was around 35, again due in part to high infant mortality, but the maximum age that individuals usually reached was much higher (Looser 2008). However, as might be expected, socioeconomic status factored into life expectancy. Individuals living into very old age were likely to be upper socioeconomic status (Roberts and Cox 2003).

The cultural conception of old age and the experiences of the elderly during the 18th century in England can be drawn from medical texts, essays, personal narratives, and sermons. These historic sources provide evidence of a change in the conception of old age. Prior to the 18th century, general age might have been recognized, but precise age was not necessarily known (Botelho et al. 2008; Molleson et al. 1993). In addition, old age was not treated as a distinct segment of 17th century English society. However, tracking of vital statistics became more important in the 18th century, and thus, documentation of exact ages became more common. Moreover, by the end of the 18th century, old age became a recognized social category (Botelho et al. 2008).

While a precise definition of old age is difficult to ascertain, personal accounts, literary sources, and official documents indicate that the age of sixty was the
beginning of the ‘old age’ category (Botelho et al. 2008; Looser 2008). This may be related to the fact that sixty was the age when pensions could be drawn (Botelho et al. 2008). Some medical texts discuss aging in specific years, but stages of life were still referenced. In general, medical texts from this period describe aging as a slow debilitation and decline in health (Botelho et al. 2008).

For women, marital status also figured into the definition of old age. A specific social category was assigned to old women who had never been married. These women were called ‘old maids.’ The age when a woman became an ‘old maid,’ like the age a woman entered ‘old age,’ is difficult to precisely identify. However, according to a literature review by Looser (2008), 30 or 40 is the age most often cited.

In a summary of personal narratives of the middle and upper classes from the 18th century, Botelho et al. (2008) note several themes. Journal entries highlight the struggle of the elderly to come to terms with the physical as well as social challenges of aging. The social challenges of aging discussed in these narratives include staying connected with and useful to their families. Optimism regarding aging is also apparent during this period. Many medical texts describe ways to extend longevity and mitigate the negative aspects of aging for individuals striving to live to a ‘good old age.’

The individuals who reached old age were expected to assist their families and neighbors, and set their children up financially. The elderly seem to have also played important roles as grandparents, as grandparents are extensively cited in literature (Botelho et al. 2008). Individuals who reached old age were also responsible for taking care of themselves and maintaining their own health. However, when they reached a
point where they were no longer able to work, their family was expected to care for them. Yet, even while being cared for, the elderly typically lived in their own houses.

Much of the period’s historic documents and literature describe the experience for men, not necessarily women. The cultural conception of women in old age and men in old age differed in the 18th and early 19th centuries. The experience of old age probably varied by class, as well as gender. For example, if they had not retired, higher socioeconomic status men might be attributed with experience and wisdom and granted authority, as well as respect (Looser 2008). Mid status men would have faced some difficulties associated with downward mobility. However, higher and mid status women would have faced loss both legally and in terms of property and were judged more harshly on physical signs of aging (Looser 2008).

According to Botelho et al. (2008), most medical and health related literature also addressed old men, not old women. Literature that did address old women mostly mocked them. An exception is the treatment of menopause in 18th century literature. This female life stage was regarded as destructive and “pathological,” but literature suggests that post-menopausal women were regarded as “stronger” and “healthier” (Botelho et al. 2008:xxii).

In summary, for married women who lived in England during the post-medieval period, old age would have started around 60 years. In contrast, unmarried women were considered ‘old maids’ between 30 and 40 years. Higher socioeconomic status women would have experienced old age in a different way than higher socioeconomic status men. Whereas men gained respect in old age, women were more
likely to experience loss, such as the loss of property, and to be judged on their physical appearance in this period of life.

**Osteological Health Trends in Middle Aged and Older Adult Females**

Middle aged and older adult refer to the two oldest (35-50 years and 50+ years), out of the four standard age-at-death cohorts used by bioarchaeologists. Little paleopathological work has specifically focused on middle and older female health in post-medieval London and the surrounding rural areas. On the other hand, discipline wide studies show trends in middle and older adult health, and female health. Work that has focused on both sex and age trends show that females tend to live longer than males, and that females generally have better immune systems than men; however, females are more susceptible to certain types of disease.

The effects of senescence are variable; however, elderly adults are generally more susceptible to disease. Functional decline of the body’s physiological systems may begin around forty and increases substantially around sixty (Wiley and Allen 2009). Somatic mutations, free radicals, and wear and degeneration all contribute to the aging process. In addition, the immune systems of older adults tend to be compromised, or weaker, than in younger individuals. This means that older adults also have a higher risk of infectious disease. These trends contribute to the higher frequency of death in older age categories, and are also observable and supported by skeletal studies (Chamberlain 2006).

Older individuals are expected to exhibit more pathological indicators than younger individuals on the basis that, the longer an individual lives, the more time the
individual has to develop pathology. For example, older individuals usually have more carious lesions than younger individuals (Roberts and Manchester 2007). Additionally, many diseases are age dependent: as people age they become more susceptible to disease and senescence (Chamberlain 2006). Due mainly to sex differences in mortality, sex ratios also vary with age, with more females in the oldest adult age categories (Chamberlain 2006). Moreover, females generally have better immune reactivity than males (Ortner 1998). Ortner (1998) suggests that sex differences in immune reactivity develop in response to pregnancy and result in a lower prevalence of infectious disease and a higher prevalence of long-term chronic infections.

Several skeletally visible diseases are more common in older adults. Diseases associated with excess osteoclastic activity, resulting in resorption, for example, osteoporosis, arthritis, periodontal disease, metastatic cancers, and multiple myeloma, are especially common in older adults (Grauer 2012). It is thought that this type of resorptive bone disease occurs due to oxidative stress (Grauer 2012). Menopause, a life stage which is not easily distinguished in skeletal samples, but that usually occurs around age 50, is another major contributor to the cessation of endosteal bone deposition in females (Roksandic and Armstrong 2011).

Excessive osteoclastic activity may result in osteoporosis, a loss of bone density. Osteoporosis has been noted in modern female subjects as well as in archaeological populations (Mays 2000). Osteoporosis is more common in females, in part due to differences in estrogen production during childbirth, nursing, and menopause (Weaver 1998). Older females, such as the females in this study, would be at greater risk for osteoporosis as a substantial amount of them would have been postmenopausal.
Osteoarthritis is another example of disease commonly associated with the degeneration that occurs with age (Goodman and Martin 2002; Larsen 1998). Furthermore, osteoarthritis is one of the most common diseases found in skeletal samples (Waldron 2009). Age and sex are important factors in the development of the disease. The incidence and prevalence of osteoarthritis increase above the age of forty and the disease affects females at a slightly higher rate than males (Waldron 2009). The form of osteoarthritis that tends to affect older females is called generalized osteoarthritis.

Another disease more common in females and older adults is dental caries. While the caries prevalence for adults is expected to increase with age, some studies show that females are more susceptible to caries. For example, meta-analyses by Lukacs (2008) show that females experience higher rates than men do later in life. In addition, the study by Lukacs (2008) on sex differences in dental caries rates shows that women’s oral health may be negatively influenced by changes in sex hormones. Therefore, higher caries rates may be linked with increased fertility. Older females in general are expected to exhibit higher prevalence rates of caries, but older females who have had several children may be at an even higher risk for caries.

In summary of the osteological evidence, although specific health trend information on middle and older adult females from post-medieval period London is not available, general trends in older and middle aged adults and females are available. Though variation exists in individual physiological aging, aging is associated with a higher risk of disease due to decline, and skeletal disease is more prevalent in older individuals. Sex differences in disease are apparent in middle and older adult age groups and, as evidenced in archaeological skeletal samples, diseases such as osteoporosis,
osteoarthritis, and dental caries may be more prevalent in middle aged and older adult females.

This study addresses general skeletal health of older adult females, rather than conditions typically associated with older aged females, such as osteoporosis and arthritis. Because female older adult health is seldom addressed in bioarchaeological or paleopathological literature, this study provides an opportunity to add to our understanding of the lives and health of older females, and specifically those during the post-medieval period in London. In addition, this study will add to our understanding of how the environment affects human health throughout a lifetime by analyzing human skeletal health in and on the outskirts of a city that experienced an extreme example of urbanization.

Site Background

St. Bride’s Parish and St. Bride’s Crypt

St. Bride’s Church. St. Bride’s Church is in the City of London and was part of urban London during the post-medieval period. The site of St. Bride’s was west of the walled Roman town of Londinium during the first through fifth centuries (Milne 1997). The development was outside and to the east of the tenth century medieval city and on the margin of seventh to ninth century Lundenwic settlement (Milne 997). During the post-medieval period, the Church was within the urban expanse of London.

The Church is west of the River Fleet, a tributary of the Thames. “Modest” size vessels were able to navigate down the Fleet River until it was culverted in the 18th century (Milne 1997). The Church sits between the parish of St. Dunstan’s to the west
and St. Andrew’s Holborn to the north, with the Thames to its south. Artifacts dated to the Roman period suggest that the site was in use starting in the first century, and documentation suggests the church parish was founded by 1180 and later expanded. Eight different church structures were built on the site (Morgan 1973). The most recent work included the rebuilding of the church after the Great Fire of 1666 and after the air raid of December 29, 1940.

The St. Bride’s Crypt Sample. The crypt burials at St. Bride’s date from 1761 to 1851. The skeletal sample is composed of upper socioeconomic class individuals who lived in the urban parish of St. Bride’s. The crypt was excavated after the bombing of 1940. Excavations were directed by Professor W.F. Grimes of the Roman and Medieval London Excavation Council in the 1950s and by MoLAS and University College London from 1993 to 1995 (Milne 1997). The excavations revealed the 227 lead coffins buried in the crypt, dated to before the Church crypts were sealed in 1854 (Milne 1997). Lead coffin plates included the names, age, and date of death of each individual (Milne 1997). No information regarding coffin goods was available.

Detailed records of the skeletal excavations at St. Bride’s have not been published. However, Scheuer and Bowman (1995) discuss the age and sex distribution of the St. Bride’s crypt sample. According to the authors, the present St. Bride’s collection is comprised of about 80 percent of the total excavation sample. Due to extensive handling of the remains by researchers, re-boxing, and differences in documentation methods, published information regarding sex, age, and completeness varies. Milne (1997) documented much of the archaeological research from 1952 to 1960 and from
1992 to 1995, but it does not address information on the skeletal material for the post-
middle period in detail.

Following the designation by the Museum of London and several published
articles, the individuals in the St. Bride’s sample are assumed to be higher socioeconomic
status. Evidence of higher socioeconomic status includes the location of burial, coffin
material, and documentary evidence of occupation. The location of the burials, in the
crypt, alone is an indication of higher socioeconomic status. In addition, a crypt burial in
a lead coffin was expensive during this period (Scheuer and Bowan 1995). The
occupation, or the spouse or father’s occupation, of around 27 percent sample is listed in
a burial register (Scheuer and Bowman 1995). Occupations listed include business
owners, solicitors, and a gold smith. However, information regarding occupation is not as
reliable as burial location and coffin type.

The skeletal sample is currently classified by Museum of London as having
good preservation. Milne (1997) and Scheuer and Bowman (1995) similarly describe the
skeletal sample as being well preserved. Hair and fingernails were included with some
individuals. Although they were not included in the sample, because they were reburied,
adipocere formation was present in two individuals. Considering that the sample
continues to be heavily studied and has been reboxed several times, its preservation
remains surprisingly good.

According to the records held at the Centre for Human Bioarchaeology, which
have not been published and are accessible only through the Museum of London Website,
the current crypt collection consists of 237 individuals. Fourteen are subadults or
children. Of the 213 adult individuals, 109 are male, 103 females, and one individual
could not be sexed. The adult portion of the sample was divided into four age-at-death categories: 18-25, 26-35, 36-45, and >46. One hundred and thirty-six adults comprised the older adult (>46) category, making the older adults the predominant age category.

There are 15 individuals in the 18-25 year category, 24 in the 26-35 year category, and 12 who are unclassified. Although the number of individuals in the subadult category is low, this is common in other excavated post-medieval period samples from the area (Cowie et al. 2008). The sample for this study was selected randomly from the female portion of the 36-45 (middle adult) and >46 (older adult) age-at-death categories.

The St. Brides collection crypt has been studied extensively, with work ranging from sexual dimorphism to non-metric traits. An age-at-death profile of the crypt collection revealed that the individuals of the collection might not be representative of all the people interred at St. Brides Fleet Street; however, this is in part due to the fact that the crypt sample is all upper socioeconomic class and the sample has few subadults under five years (Scheuer and Bowman 1995). The crypt sample is a better approximation of the parish population as assessed from historic parish records, with the exception of the low number of children (Scheuer and Bowman 1995). Explanation of why there are so few children in the crypt burials include lower mortality due to better living conditions of the higher class and differential burial.

**Chelsea and Chelsea Old Church**

**Chelsea Old Church.** During the post-medieval period, Chelsea was situated on the north bank of the Thames, bounded on the west by the Westbourne, and on the east by Counters Creek stream. Brompton and the parish of Kensington lay to the north of Chelsea. Five Fields, which developed into Belgravia during this period, was to the east,
and Fulham on the other side. Chelsea was west of London, and although Chelsea was on the outskirts of urban London and maintained its village character, it was slowly becoming part of the spread of London (Holme 1971).

Archaeological evidence suggests that the location of Chelsea was in use prior to the establishment of a settlement. Dating back to before Roman occupation, sacrificial burials occurred at this location along the Thames. Various artifacts, such as Bronze and Iron Age weapons, pottery, and human remains, have been found on both the Chelsea bank and the opposite bank of the Thames (Russett and Pocock 2004); however, the Church was not built at the location till later. In 1120, the church was granted to the Abbot and Monastery of Westminster, after which the church was likely founded. The oldest stonework among the church structure dates to the early 1300s (Russett and Pocock 2004).

St. Luke’s was built in Chelsea in 1819-24 to accommodate the growing parish population. During this time, the older church was not used as the parish church. In 1941, a bombing raid destroyed the church, and a replica of the church was later built (Walker 1987). The old parish was put back into use 1951 and the structure was renamed All Saints, Chelsea Old Church (Russett and Pocock 2004).

Chelsea During the Post-medieval Period. In the 18th and 19th centuries, Chelsea transformed from a riverside village along the Thames to a suburb of London (Cowie et al. 2008). Chelsea maintained a rural aspect through the beginning of the 19th century (Cowie et al. 2008). At the beginning of the 18th century and into the early 19th century, Chelsea was surrounded by agricultural land worked by locals. By 1830, there
was still open space for agricultural use; however, fewer inhabitants engaged in cultivation (Walker 1987).

By the middle of the 18th century, Chelsea attracted use as a resort for Londoners and “descriptions of Chelsea at this time suggest that it was a relatively healthy and prosperous place compared with many parts of nearby London” (Cowie et al. 2008:13). People were drawn from urban London to Chelsea because of its health benefits, most notably, the fresh air (Holme 1971). Chelsea was also known for its gardens, orchards, and nurseries. In the early part of the 19th century, 50 percent of the vegetables in Covent Garden were derived from Chelsea (Holme 1971). Chelsea was also known for entertainment. Ranelagh Gardens opened in 1742 (Cowie et al. 2008).

The 19th century brought urbanization at the expense of the agricultural land. Although rows of houses slowly encroached on agricultural land and the clean air became polluted by chimney smoke, some fields still existed within the village. While Chelsea still remained on the outskirts of London and could not be described as urban in the 19th century, it was officially a London suburb (Cowie et al. 2008).

The Chelsea Old Church Sample. The post-medieval cemetery of Chelsea Old Church was on the outskirts of London during the 18th and 19th centuries. The burial sample dates from 1712 to 1842, based on coffin plate inscriptions (Cowie et al. 2008). The churchyard was one of eight burial grounds in the area, and the earliest of the three existing parish cemeteries (Cowie et al. 2008). In 2000, the Museum of London Archaeological Services (MoLAS) began excavation north of All Saints, Chelsea Old Church at 2-4 Old Church Street, Chelsea (Cowie et al. 2008). The site is in the historic
center of Chelsea. Excavation revealed evidence of use from the prehistoric period to the
19th century.

The post-medieval burial population includes individuals from the Chelsea Old Church churchyard and Petyt House within the churchyard. The Petyt House, built in 1705-7 and located in the north corner of the churchyard, included a cloister and vestry, both of which were used as a burial ground (Cowie et al. 2008). The churchyard contained graves, brick-lined graves, and burial vaults. MoLAS exhumed 290 post-medieval individuals, spanning a period of about one hundred and fifty years (Cowie et al. 2008). Biographical information from inscriptions and coffin plates was obtained for 26 individuals.

For the purposes of this study, the individuals in this skeletal sample are assumed to be of higher socioeconomic status. This was determined based on the designation by Cowie et al. (2008) in the MoLAS report, as well as the classification used by the Museum of London. Cowie et al. (2008) concluded that the skeletal sample represents a middle to upper socioeconomic status population based on available biographies and known occupation. In addition, items such as fine copper-alloy buttons and remnants of coffin coverings, which may indicate high socioeconomic status, were recovered (Cowie et al. 2008). Therefore, although the burial population may contain individuals of varying status, burial types indicate that the excavated skeletal sample was higher status.

According to the MoLAS report, the preservation of the skeletal assemblage is good. Most of the elements are 89 percent complete, while about a third are 70 percent
complete. As further indicator of good preservation, hair, finger nails, and toe nails survived on some individuals.

One hundred and ninety-eight of the 290 individuals recovered were recorded on the Wellcome Osteological Research Database (WORD) at the Museum of London. Their selection was based on completeness and the 26 individuals with biographical data were included. The age at death, sex, preservation, and disease and health were established, based on the skeletal remains. This information was also included in the WORD database.

According to information listed on the database, 165 individuals were adults, with 78 males and 74 females. Thirty-three of the individuals were children or subadults. The adult portion of the sample was divided into four age-at-death categories: 18-25, 26-35, 36-45, and >46. Seventy-two adults comprised the older adult (>46) category. As was the case in the St. Bride’s crypt, the Chelsea Old Church sample predominantly consists of older adults. Again, the number of individuals in the subadult category is low; a common trend in other excavated post-medieval period samples from the area (Cowie et al. 2008). The sample for this study was selected randomly from the female portion of the 36-45 (middle adult) and >46 (older adult) age-at-death categories.

The Chelsea Old Church collection has been used for research projects ranging from aging, using the auricular surface, to morphological variations related to corset wearing; however, few reports have been published. A site report was published by Cowie et al. (2008) and information was published in the Chelsea Society History Magazine and New Scientist magazine.
Summary

Human health is affected by extrinsic, or environmental, factors. Studies show that increases in population, population density, urbanization, and industrialization impact the health of the population. Furthermore, these factors create other problems for human health, such as air pollution, water pollution, sanitary problems, and the spread of infectious disease. Disparities in urban and rural health are documented worldwide, and this trend is also supported by skeletal evidence. Skeletal data from post-medieval Britain comparing urban and rural populations also confirms this pattern.

Post-medieval London and the outskirts of post-medieval London are important places to study differences in urban and rural health because of the drastic difference in environments. The fast-paced urbanization, population growth, and industrialization greatly impacted the lives and possibly the health of London residents. Historic sources and skeletal studies both indicate that there were differences in urban and rural health in post-medieval London.

This study examined urban and rural health, adding to the information about how the environment influences health. The samples chosen for this study are from upper socioeconomic class individuals from St. Bride’s Church and Chelsea Old Church. St. Brides Church sample, the urban sample, is in the city of London. The Chelsea Old Church sample, a rural sample, was located to the south west of London. This chapter presented the demographic profile of the individuals from each site and discussed the excavation of each site and the previous work on each skeletal sample.
CHAPTER IV

MATERIALS AND METHODS

Introduction

In order to address whether urban and rural environments had an affect on health in post-medieval London, this study compares two archaeological skeletal samples. This chapter provides an overview of the two archaeological samples, the methods used to collect data, and the statistical analysis used to compare the skeletal health of the individuals from the urban and rural samples. Comparing the skeletal health of the individuals from the urban sample and the rural sample helps identify disease patterns and processes that occur in response to or as a result of changing environments.

Archaeological Sites

Two post-medieval skeletal samples from the greater London area were selected for this study. The British post-medieval period dates from 1550 to 1850, but the individuals selected for the samples were from a narrower range, 1712 to 1851. The first sample, St. Bride’s Crypt (SB79), is made up of individuals from the post-medieval St. Bride’s parish. The St. Bride’s Crypt collection is curated at the Church of St. Bride’s in London. The second sample, Chelsea Old Church (OCU00), is made up of individuals from the post-medieval town of Chelsea. The Chelsea Old Church collection is curated by the Museum of London in London.
The samples were analyzed during the summer of 2012 at the Museum of London and at the St. Bride’s Church crypt. Each individual’s age, sex, and pathologies were previously recorded on the Wellcome Osteological Research Database maintained by the Museum of London Centre for Human Bioarchaeology. Both samples were selected from the Museum of London’s curated skeletal collection based on time period, location, age, sex, socioeconomic status, and completeness (see Table 1). The resulting sample consisted of upper socioeconomic status middle aged to older adult females from each skeletal collection.

Table 1. Sample selection criteria and definitions.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Post-Medieval</th>
<th>1550-1850</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Urban</td>
<td>High density population living in a city</td>
</tr>
<tr>
<td></td>
<td>Rural</td>
<td>Low population density living in the country, practicing agriculture</td>
</tr>
<tr>
<td>Sex</td>
<td>Female</td>
<td>Classified as female</td>
</tr>
<tr>
<td>Age at death</td>
<td>Middle Adult</td>
<td>35-50 years</td>
</tr>
<tr>
<td></td>
<td>Older Adult</td>
<td>50 + years</td>
</tr>
<tr>
<td>Socioeconomic Status (SES)</td>
<td>Higher Status</td>
<td>Based on Museum of London and archaeological report designations as well as coffin types, burial location, and occupation</td>
</tr>
<tr>
<td>Completeness</td>
<td>Good Preservation</td>
<td>Based on Museum of London and archaeological report classification</td>
</tr>
</tbody>
</table>

The samples were selected from the post-medieval collection because pronounced urbanization occurred during this period. This urbanization made the period the most appropriate choice to compare the effect of urban and rural living on health.
Next, the samples available from the post-medieval period were selected based on completeness of the individuals, location, and socioeconomic status. This selection criteria narrowed the available choices to samples with good completeness, consistent socioeconomic statuses, and rural urban locations. These criteria resulted in the selection of the upper socioeconomic status St. Bride’s Crypt and Chelsea Old Church samples.

Out of the St. Bride’s Church and Chelsea Old Church samples, only the middle to older adult females were analyzed. The oldest cohort available was studied because skeletal indicators of disease and health are often more prevalent in older individuals. As individuals age they accumulate osseous responses to biological stress. Therefore, more skeletal indicators of stress should be present in older individuals as compared with younger individuals. In addition, these age cohorts are rarely studied. This is most apparent in the post-medieval skeletal samples, as there is a large gap in information about aging and general health in older ages. In addition, information on older adult females is even scarcer. A single sex was chosen to eliminate problems associated with major differences in male and female immune reactivity and morphology. This choice avoided the problems associated with statistical power and sample size related to heterogeneity.

A total of 65 individuals were analyzed, thirty-two from Chelsea Old Church and thirty-three from St. Bride’s Church. A list of individuals who fulfilled the appropriate criteria was generated for each site from the database. Thirty-two individuals were then chosen by random selection from the Chelsea Old Church list. A total of thirty-three individuals fulfilled the criteria for St. Bride’s Church and all thirty-three were used. Once the individuals were selected, data collection began to verify sex, age, and
pathologies. A skeletal inventory was created and measurements were made of each available long bone. If pathology was found, it was documented and photographs were taken.

Sex Estimation

Sex estimation was based on cranial characteristics and pelvic morphology, or on dimorphic dimension measurements if neither cranial nor pelvic morphology could be scored. Morphological sex estimation followed scoring methods established by Acsadi and Nemeskeri (1970) for cranial features and Phenice (1969) for the subpubic region. If morphological features could not be estimated or were not present, the maximum diameter (or vertical diameter) of the femoral head was evaluated after Pearson and Bell (1917-1919), whose study was conducted on 17th century skeletal remains from London. The final sex estimate combined both cranial and pelvic morphology to estimate an overall score. The overall score was recorded following criteria from Buikstra and Ubelaker (1994) and can be seen in Table 2.

Table 2. Criteria for estimating sex.

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Undetermined sex. Insufficient data are available for sex determination.</td>
</tr>
<tr>
<td>1</td>
<td>Female. There is little doubt that the structures represent a female.</td>
</tr>
<tr>
<td>2</td>
<td>Probable female. The structures are more likely female than male.</td>
</tr>
<tr>
<td>3</td>
<td>Ambiguous sex. Sexually diagnostic features are ambiguous.</td>
</tr>
<tr>
<td>4</td>
<td>Probable male. The structures are more likely male than female.</td>
</tr>
<tr>
<td>5</td>
<td>Male. There is little doubt that the structures represent a male.</td>
</tr>
</tbody>
</table>

Age Estimation

Several indicators were used for age estimation: morphological changes of the pubic symphyseal face, the auricular surface of the os coxae, and the sternal rib end if neither pubic symphysis nor auricular surface morphology could be scored. Age-related changes were assessed following phases established by Brooks and Suchey (1990) and Suchey and Katz (1986) for the pubic symphysis, Lovejoy et al. (1985) and Meindl and Lovejoy (1989) for the auricular surface of the ilium, and, if needed, Iscan et al. (1984, 1985) for sternal rib ends. Estimated age was broken down into two ranges: middle adult (35-49), and old adult (50+).

Skeletal Indicators of Stress

In this study, a skeletal indicator of stress is defined as: skeletal evidence of physiological stress used as a proxy measure of the health and disease of an individual during life. The more intuitive measures of stress in this study include dental caries, linear enamel hypoplasias, postmortem tooth loss, dental abscesses, cribra orbitalia, porotic hyperostosis, maxillary sinusitis, periostitis and rickets. Skeletal lesions such as porosity in the eye orbits, due to cribra orbitalia, are clear signs of impaired physiological function. On the other hand, stature, a conceivably less obvious measure of stress, is also included in this category because subadult health influences stature.

A health profile, made up of the skeletal indicators of stress, was assessed for each individual in this study. Eleven skeletal indicators of stress were initially selected to compare health by site. The eleven initial components of the health profile included stature, dental caries, dental abscesses, antemortem tooth loss, linear enamel hypoplasias,
porotic hyperostosis, cribra orbitalia, maxillary sinusitis, periostitis, rickets, and tuberculosis. Ten skeletal indicators of stress were included in the final study.

Tuberculosis was dropped as the tenth indicator due to lack of evidence for the disease in either sample. Postmortem tooth loss was recorded in order to evaluate the completeness of the dentition, but was not used as an indicator of stress.

The components of the health profile, the skeletal indicators of stress, are split into two main categories: stature and pathology. The pathology section is further subdivided into three categories: dental health, metabolic disease, and infectious disease. The pathology section is divided into three categories because different criteria were used to score each type of pathology. Dental health includes dental caries, dental abscesses, linear enamel hypoplasias, and antemortem tooth loss. Metabolic disease includes cribra orbitalia, porotic hyperostosis, and rickets. Infectious disease includes maxillary sinusitis and periostitis.

Stature

In order to calculate stature, the long bones of each individual were measured. These measurements were used with the stature formula developed by Ousley (1995) (Table 3). When possible, the maximum length of the femur, tibia, fibula, humerus, ulna, radius, and clavicle were measured following Buikstra and Ubelaker (1994). If it was available, the left element length was used. If the left element was not available or its length could not be measured, the length of the right element was used to calculate stature. For each individual, the most accurate estimation formula was used. Each individual’s final stature estimation was reported as a range.
### Table 3. Stature estimation formulae.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Measurement(s) in mm</th>
<th>Constant</th>
<th>90% PI</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.06524</td>
<td>Femur Max L + Tibia L</td>
<td>12.94</td>
<td>±2.3”</td>
<td>38</td>
</tr>
<tr>
<td>0.06163</td>
<td>Femur Max L + Fibula L</td>
<td>15.43</td>
<td>±2.4</td>
<td>42</td>
</tr>
<tr>
<td>0.11869</td>
<td>Femur Max L</td>
<td>12.43</td>
<td>±2.4</td>
<td>48</td>
</tr>
<tr>
<td>0.11168</td>
<td>Tibia L</td>
<td>24.65</td>
<td>±3.0</td>
<td>43</td>
</tr>
<tr>
<td>0.11827</td>
<td>Humerus L</td>
<td>28.30</td>
<td>±3.1</td>
<td>45</td>
</tr>
<tr>
<td>0.13353</td>
<td>Ulna L</td>
<td>31.99</td>
<td>±3.1</td>
<td>40</td>
</tr>
<tr>
<td>0.18467</td>
<td>Radius L</td>
<td>22.42</td>
<td>±3.4</td>
<td>38</td>
</tr>
</tbody>
</table>


### Pathology

All pathologies were recorded as absent, present, or unobservable, as noted in Table 4. If present, pathologies were recorded by the degree of each expression. Different criteria were used to score each type of pathology. Frequencies of each pathology were only calculated for those individuals with observable elements. The absence or presence of pathologies along with the severity of the pathologies allowed for a comparison of health status across the two samples.

### Table 4. Criteria for scoring the presence of pathology.

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Unobservable</td>
</tr>
<tr>
<td>1</td>
<td>Absent</td>
</tr>
<tr>
<td>2</td>
<td>Present</td>
</tr>
</tbody>
</table>
Dental Health

The type and location of dental pathologies were recorded. A dental inventory was completed using the Dental Inventory Visual Recording Form: Permanent Dentition from *Standards for Data Collection* (Buikstra and Ubelaker 1994). Each tooth was scored as unobservable, present, or absent. When both the maxilla and mandible were missing, the dentition was scored as unobservable. If all teeth were lost antemortem, the dentition overall was scored as edentulous. The types of dental pathologies recorded included antemortem tooth loss, caries, linear enamel hypoplasias, and abscesses (Table 5). The

Table 5. Criteria for recording dental pathology.

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pathology</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>No lesions present</td>
</tr>
<tr>
<td>1</td>
<td>Postmortem tooth loss</td>
</tr>
<tr>
<td>2</td>
<td>Antemortem tooth loss</td>
</tr>
<tr>
<td>3</td>
<td>Caries</td>
</tr>
<tr>
<td>4</td>
<td>Enamel hypoplasias</td>
</tr>
<tr>
<td>5</td>
<td>Abscess</td>
</tr>
<tr>
<td>6</td>
<td>Unobservable</td>
</tr>
<tr>
<td>Location</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>1</td>
<td>Occlusal</td>
</tr>
<tr>
<td>2</td>
<td>Mesial</td>
</tr>
<tr>
<td>3</td>
<td>Distal</td>
</tr>
<tr>
<td>4</td>
<td>Lingual</td>
</tr>
<tr>
<td>5</td>
<td>Buccal</td>
</tr>
<tr>
<td>6</td>
<td>Interproximal</td>
</tr>
<tr>
<td>7</td>
<td>Cervical</td>
</tr>
<tr>
<td>8</td>
<td>Root</td>
</tr>
<tr>
<td>9</td>
<td>Circumferential</td>
</tr>
</tbody>
</table>
expression of linear enamel hypoplasias was documented by counting the number of hypoplastic lines, following Steckel et al. (2006) (Table 6). If the anterior dentition, consisting of the incisors and canines, was not present, linear enamel hypoplasias were scored as unobservable.

**Table 6.** Criteria for scoring dental enamel hypoplasias.

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Unobservable</td>
</tr>
<tr>
<td>1</td>
<td>Absent</td>
</tr>
<tr>
<td>2</td>
<td>One hypoplastic line present</td>
</tr>
<tr>
<td>3</td>
<td>Two or more hypoplastic lines present.</td>
</tr>
</tbody>
</table>


**Metabolic Disease**

Remodeled sclerotic change and porosity were used to determine the expression of cribra orbitalia and porotic hyperostosis, adapted from Steckel et al. (2006) (Table 7). Eye orbits had to be present to score individuals for cribra orbitalia, and the crania had to be present to score individuals for porotic hyperostosis. If the eye orbits were not present, cribra orbitalia was scored as unobservable. Likewise, if the cranium was not present, porotic hyperostosis was scored as unobservable.

Since all of the individuals analyzed were adult, skeletal manifestation of residual or healed rickets were recorded instead of active rickets. Residual manifestations of rickets were scored as unobservable, absent, or present. In the event that appropriate
Table 7. Criteria for determining degree of porotic hyperostosis and cribra orbitalia.

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Unobservable</td>
</tr>
<tr>
<td>1</td>
<td>Absent</td>
</tr>
<tr>
<td>2</td>
<td>Barely discernible porosity</td>
</tr>
<tr>
<td>3</td>
<td>Porosity only</td>
</tr>
<tr>
<td>4</td>
<td>Porosity with coalescence of foramina, no thickening</td>
</tr>
<tr>
<td>5</td>
<td>Coalescing pores/foramina associated with expansive changes</td>
</tr>
</tbody>
</table>


elements for scoring rickets, such as the femora, were absent, rickets was scored as unobservable. If evidence of residual rickets was present, a description of the pathology was recorded. Criteria for the presence of residual rickets included bowing of the leg bones, as well as bowing of the tibia and femur; thickening of the femora, indicating buttressing of the concavities of bends; and medio-lateral widening of the proximal femora (Brickely and Ives 2008).

Infectious Disease

Spiculate growth and remodeling in the frontal sinuses were used as measures of expression of maxillary sinusitis (Table 8). Maxillary sinusitis was only scored for
Table 8. Criteria for determining degree of maxillary sinusitis.

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Unobservable</td>
</tr>
<tr>
<td>1</td>
<td>Absent</td>
</tr>
<tr>
<td>2</td>
<td>New bone formation (isolated spicules and clusters of spicules)</td>
</tr>
<tr>
<td>3</td>
<td>Remodeling, new bone formation</td>
</tr>
</tbody>
</table>

Individuals where the inner surface of the sinus cavity was visible. If the inner surface of the sinus cavity was not visible, maxillary sinusitis was scored as unobservable. The proliferation of striae was used to measure the expression of periostitis (Table 9). When elements needed to score periostitis were very fragmentary or there was too much dirt on the surface to examine the bone surface, periostitis was scored as unobservable. All skeletal elements were analyzed for evidence of periostitis.

Table 9. Criteria for determining degree of periostitis.

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Unobservable</td>
</tr>
<tr>
<td>1</td>
<td>Absent</td>
</tr>
<tr>
<td>2</td>
<td>Longitudinal striations</td>
</tr>
<tr>
<td>3</td>
<td>Small areas of reactive bone, less than one-quarter of surface</td>
</tr>
<tr>
<td>4</td>
<td>Moderate areas of reactive bone, less than one-half of surface</td>
</tr>
</tbody>
</table>

Final Sample Size

Following the previously mentioned sample parameters, only skeletal remains that could be reliably aged and sexed were included in the final skeletal sample. Three individuals in the St. Bride’s crypt sample could not be aged. These individuals were not included in the final analysis or results; however, they were utilized in the discussion since the ages of the individuals were known from coffin plates and burial records. In total, twenty-nine female individuals aged thirty-five or older were included in the St. Brides crypt sample. Thirty-two female individuals aged thirty-five or older were included in the Chelsea Old Church sample. The final sample size included the sixty-one individuals who fit the criteria to be included in the statistical analysis.

Statistical Analyses

Once the data was collected, statistical analysis was performed using SAS (Version 9.2) and SPSS (Version 20). Descriptive statistics were conducted for both samples as appropriate for categorical and continuous variables. To assess whether health of middle-aged to older adult females differed by location in post-medieval London, the following analysis was completed.

First, the frequencies of the pathologies at each site were compared using non-parametric tests of significance. A chi-square test and a Fisher’s exact test of significance were used, as all the pathology variables were nominal. For each chi-squared test, one category often contained sparse data; therefore, a Fisher’s exact test was used to satisfying the chi-squared conditions when n<5 in any cell (Levin and Fox 2011).
Age is frequently associated with disease. Therefore, to evaluate whether age could possibly confound or modify any association found between site and pathology, the age distribution between sites was compared. Age was recorded in categories, either 35-49 or 50 and above, thus classifying as a nominal measurement. The chi-square and Fisher’s exact tests were used to evaluate whether differences in age were statistically significant. If age was significantly associated with pathology, it was also included as a variable in the final logistic regression analysis models.

Logistic regression is a type of regression analysis that allows for two or more response variables with dichotomous outcomes. The procedure facilitates the incorporation of other possible contributing factors such as age or associated pathologies and allows the risk of multiple factors to be assessed independent of each other. In cases where the dependent variable is dichotomous, logistic regression should be used because it is the most powerful test available (Katz 1997). Logistic regression produces Odds Ratios (OR) which are normally used to evaluate the risk of disease in a situation where the odds of exposure can be calculated, for example, for both the exposed portion of the population who have the disease and who do not, and the unexposed portion of the population who have the disease and who do not (Katz 1997). In this study, outcome can be evaluated, but not the total population at risk. Consequently, the odds ratio is used to compare prevalence rates between two samples. The odds ratio compares the odds of the proportion of the pathology occurring in one group to the odds of the pathology occurring in the second group (Waldron 2009):
\[
\frac{p}{1-p} \quad \frac{q}{1-q}
\]

where \( p \) = proportion of group 1 with pathology
\( q \) = proportion of group 2 with the same pathology
\( 1-p \) = proportion of group 1 without pathology
\( 1-q \) = proportion of group 2 without pathology

A 95 percent confidence interval can be calculated around the estimated OR to indicate whether or not the ratio is likely to be significantly different than equal. If the 95 percent confidence interval crosses the value of one (for example 0.57 to 1.35) then the null hypothesis cannot be rejected. If the 95 percent confidence interval (95% CI) is entirely above or entirely below the value of 1, then the null hypothesis may be rejected.

The relationship between age, site, and pathology was investigated. Chi-square tests and odds ratios were used to determine whether age explains any of the possible association between pathology and site. Similarly, the logistic regression model of maxillary sinusitis and site included caries as well as age to determine whether the presence of caries explains any association between maxillary sinusitis. The process was repeated to determine whether the presence of abscess explains any association between maxillary sinusitis and site.

Mean stature and femoral lengths for each site were compared using an independent t-test. A parametric test was appropriate since stature and femoral length were recorded in inches as an interval/ratio level variable with a normal distribution. A t-test was used to examine whether the occurrence of rickets explains any difference in stature and femoral length. Because the mean stature and femoral lengths for both sites were normally distributed and had similar distributions, a pooled t-test was used.
addition, pooled t-tests were used to examine whether average stature and femoral length differ between sites allowing for rickets.

Finally, to develop an overall picture of skeletal health at each site, the number of skeletal indicators of stress exhibited by each individual were compared between sites. First, the total number of stress indicators was tallied for each individual. All skeletal indicators were included in the analysis except for stature, because it is a interval/ratio level variable, and antemortem tooth loss because all individuals with dentition exhibited antemortem tooth loss. Subsequently, chi-square analyses were used to test for an association between total number of skeletal indicators of stress and site. In addition, chi-square tests were used to see if there was an association between age and number of skeletal indicators of stress.

Summary

This research assessed health patterns in different environments through the analysis of skeletal remains from the urban St. Bride’s crypt and the more rural location of Chelsea Old Church. The skeletal samples were selected from the Museum of London Centre for Bioarchaeology database based on time period and location, as well as the age, sex, socioeconomic status, and completeness of the individuals. The osteological study examined stature, dental health, metabolic health, and infectious disease through chi-squared tests, t-tests, and logistic regression. The analysis of these skeletal indicators of health provides information regarding the health status of urban and rural middle aged and older adult females in post-medieval London.
CHAPTER V

RESULTS

Introduction

The results of the health comparison are presented in this chapter. The chapter is divided into two sections. The first section discusses the results of the sex analysis, reviews the age distribution for the St. Bride’s Church (SBC) and Chelsea Old Church (COC) sites, and uses postmortem tooth loss to evaluate the completeness of the individuals in each sample. The second section is a comparison of the health indicators observed in the females from each site, adjusting for age where relevant. The second section is divided further into results for each health indicator.

Estimations of Sex and Age

Table 10 illustrates the frequency of individuals classified as female (62/65 or 95.4%) and frequency of individuals classified as probable female (3/65 or 4.6%) from the two sites. Biographical information from coffin plates was available for each of the individuals classified as probable females. The biographical information supported the

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probable Female</td>
<td>3</td>
<td>4.6</td>
<td>4.62</td>
</tr>
<tr>
<td>Female</td>
<td>62</td>
<td>95.4</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 10. Frequency of individuals classified as female.
sex estimation for all three individuals. Since the three individuals were estimated to be probable females and there is historic documentation supporting this estimation, they were all included in the sample. The total sample size before adjustments made for age was 65 females.

Age estimations were broken down into middle-adult (35-50 years) and old-adult (50+ years) in order to gain insight on the prevalence of disease in the females of the St. Bride’s and Chelsea Old Church samples. As noted previously, this was not an arbitrary selection, these age groups are the two oldest out of four standard bioarchaeological age groups (Buikstra and Ubelaker 1994). Three females could not be aged and were not included in the final sample (see Figure 10 and Table 11). The final sample consisted of 62 females. Table 12 and Figure 11 summarize the overall age distribution by site samples with 69.35 percent (43/62) middle-adult females, and 30.65

![Figure 10. Age distribution for both sites.](image)
Table 11. Overall age distribution.

<table>
<thead>
<tr>
<th>Age</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indeterminate</td>
<td>3</td>
<td>4.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Middle Adult</td>
<td>43</td>
<td>66.2</td>
<td>70.8</td>
</tr>
<tr>
<td>Old Adult</td>
<td>19</td>
<td>29.2</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Percent (19/62) old-adult females. The St. Bride’s sample was made up of 12 middle adults and 18 older adults. The Chelsea Old Church sample consisted of 31 middle adults and 1 older adult.

Table 12. Age distribution by site.

<table>
<thead>
<tr>
<th>Age</th>
<th>Site</th>
<th>SBC</th>
<th>COC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle Adult</td>
<td></td>
<td>12</td>
<td>31</td>
<td>43</td>
</tr>
<tr>
<td>% of Total</td>
<td></td>
<td>19.35</td>
<td>50</td>
<td>69.35</td>
</tr>
<tr>
<td>Old Adult</td>
<td>Frequency</td>
<td>18</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>% of Total</td>
<td></td>
<td>29.03</td>
<td>1.61</td>
<td>30.65</td>
</tr>
<tr>
<td>Total</td>
<td>Frequency</td>
<td>30</td>
<td>32</td>
<td>62</td>
</tr>
<tr>
<td>% of Total</td>
<td></td>
<td>48.39</td>
<td>51.61</td>
<td></td>
</tr>
</tbody>
</table>

Completeness

Postmortem Tooth Loss (PMTL). Figure 12 illustrates the overall frequency of females with observable postmortem tooth loss (PMTL). Out of 50 females with observable dentition, 78 percent (39/50) had PMTL. Chi-square tests revealed no significant difference in PMTL frequencies between sites (Fisher’s Exact $p = .7199$). The
Figure 11. Age distribution by site.

Figure 12. Frequency of PMTL by site.
logistic regression, used to evaluate any difference in prevalence of PMTL by site accounting for differences in age groups, also indicated that there is no significant difference in the prevalence of postmortem tooth loss PMTL at the sites (age = OR = 1.11 [95% CI 0.16 to 7.97] and site = OR = 0.67 [95% CI 0.11 to 4.18]). Therefore, there is no significant difference in the prevalence of PMTL in St. Bride’s sample and the Chelsea Old Church sample. These results are important because they mean that there was not a bias in dental health due to tooth loss during excavation or in the postmortem environment.

Skeletal Indicators of Stress

Skeletal indicators of stress frequently increase with age. If there is a higher proportion of older individuals at one site, it may explain why there is a higher prevalence of skeletal indicators of stress at the site. Therefore, the samples’ age distributions were analyzed to see if there was an association between age and site. A significantly higher proportion of older adult females (50+ years) were present in the SBC sample p-value of .00000065 ($\chi^2 = 23.57$ $df = 1$) with only one older adult female in the COC sample.

Age differences between the sites could be confounding factors in the analysis. To determine whether age is a confounding factor, chi-squared tests were calculated for each health indicator and cohort. Out of the nine health indicators (excluding stature) periostitis was the only indicator approaching significance. The test revealed an approaching, but not significant, association with a $p = 0.056$ between periostitis and age. Overall, the other health indicators were not significantly associated
with age. Because no relation was found between age and the health indicators, it is reasonably safe to assume that any differences found when testing for any association between site and health indicator are due to differences between sites, not age distribution differences.

The results are divided into two sections and will be reviewed in the following order: stature and then pathologies. The pathology section discusses several different statistical tests for each indicator of stress. Therefore, the pathology section will be further sub-divided as follows. The pathology results begin describing the crude prevalence of each indicator of stress by site. Next, a chi-squared test was used to determine if there is a significant difference in the prevalence of each indicator of stress between sites. Third, if another factor such as age or stature was likely to confound the association between pathology and site, then a logistic regression test was conducted. The logistic regression produces an odds ratio, which reveals differences in prevalence of pathologies accounting for confounding variables.

In some cases, the logistic regression test could not be run. In such instances, a supplementary chi-square test was performed. The logistic regression tests whether there are differences in pathology by site accounting for any differences in age by site. However, age and site are moderately correlated ($r = .61$). If cell numbers are low and correlation between age and site is moderate to high, then the standard errors for the estimates may be large and not allow the test to run. So, in cases where the logistic regression test was unusable, the older age group (50+) was removed. Because only the middle aged (35-50 years) cohort was used, chi-square tests could be performed to reveal any differences in health indicators by site.
In summary, the results for stature will be presented first, then the results for the pathologies. The results for the pathology section will contain the following for each skeletal indicator of stress: crude prevalence rates for each site, a chi-square test to determine if there is a significant difference in the prevalence of each skeletal indicator of stress by site; a logistic regression, which produces an odds ratio, to test for confounding factors; and, to account for age in cases where the logistic regression test could not be run, a chi-square test using only the middle aged cohort to reveal any difference in the prevalence of skeletal indicators of stress.

**Stature**

Out of 26 individuals whose stature could be assessed, the mean value for stature at St. Bride’s was 62.46 inches with a standard deviation of 2.61 and a median value of 62.79 inches. Mean stature ranged from 57.20 inches to 66.62 inches. Out of 28 individuals whose stature could be assessed, the mean value for Chelsea Old Church was 63.3 inches with a standard deviation of 2.52 and a median value of 63.64. Mean stature ranged from 55.8 to 67.48 inches. In addition, the same tests were run for femoral length. Out of the 20 individuals whose femoral length could be assessed, the mean value for St. Bride’s was 16.41 inches with a standard deviation of 0.97 inch. For the 23 individuals whose femoral length could be assessed, the mean value for Chelsea Old Church was 16.52 inches with a standard deviation of 0.95 inches.

Both the mean statures and femoral lengths were normally distributed. Because the variances for each site were similar, a pooled t-test could be used. The pooled t-test revealed no significant difference in mean stature ($p = 0.23$) or femoral length ($p = 0.70$) from each site. However, since rickets may affect stature, a pooled t-test
was used to see if there was an association between rickets and stature and rickets and femoral length. Since the variances were similar, a pooled t-test was again used. No statistical association between rickets and stature was found ($p = 0.43$). No statistical association between rickets and femoral length was found ($p = 0.08$). In summary, the results indicate that there is no significant difference in stature or femoral length by site.

**Antemortem Tooth Loss (AMTL)**

Out of 55 females with observable dentition, 100 percent (55/55) of the overall sample exhibited antemortem tooth loss. Since all of the females with observable teeth exhibit antemortem tooth loss, there is no significant difference in antemortem tooth loss by site.

**Caries**

Figure 13 illustrates the overall frequency of females with at least one tooth affected by caries. Thirty-nine total individuals had observable dentition, and 74.36

![Figure 13. Frequency of caries by site.](image)
percent (29/39) of those individuals had caries. Of the 23 SBC individuals with observable dentition, 69.57 percent (16/23) had caries. Out of 16 COC individuals with observable dentition, 81.25 percent (13/16) had caries. A chi-squared analysis was performed to evaluate difference in caries by site. No significant association between caries and site was found (Fisher’s Exact $p = 0.48$). A logistic regression could not be run because there were not enough older adult individuals in the Chelsea Old Church sample. So, in order to verify that age did not influence the prevalence of caries by site, an additional chi square test was computed. A chi-squared test comparing the relative frequency of caries for only the middle-aged females found no association between caries and site (Fisher’s Exact = 0.63). Therefore, there is no significant difference in the frequency of caries in St. Bride’s sample and the Chelsea Old Church sample.

**Abscess**

Figure 14 shows the overall frequency of females with observable abscesses. 29.27 percent (12/41), of the 41 individuals with observable dentition, showed evidence of abscesses. Out of 25 SBC individuals with observable dentition, 32 percent or (8/25) abscesses and twenty five percent (4/16) of 16 COC individuals with observable dentition had abscesses. Since an initial chi-squared test revealed that age and abscesses are not associated, a chi-square analysis was preformed to evaluate differences in abscess frequency by site. No significant association between abscess and site was found (chi-square $= 0.23$ $p = 0.63$ $df = 1$). A logistic regress, used to evaluate any difference in prevalence of abscess by site accounting for differences in age groups, also supported the findings of the chi-square test, indicating that there is no significant difference in the prevalence of abscesses at the sites (age = OR = 2.1 [95% CI = .32-13.61] and
site = OR = 1.17 [95% CI .17 to 8.09]). Therefore, there was no significant difference in the prevalence of abscesses in St. Bride’s sample and the Chelsea Old Church sample.

**Linear Enamel Hypoplasias (LEH)**

Figure 15 illustrates the overall frequency of females with observable linear enamel hypoplasias (LEH). Out of 36 individuals with observable anterior dentition, 8.33 percent (3/36) exhibited evidence of LEH. None of the SCB individuals with observable anterior dentition none had LEH, and of the 15 COC individuals with observable anterior dentition, 25 percent (3/15) had LEH. A chi-square analysis was performed to evaluate differences in LEH frequency by site. No significant association between LEH and site was found (Fisher’s Exact $p = 0.06$). A logistic regression was not used for the prevalence of LEH because the standard error was too high. The high standard error was probably a result of the high correlation between age and site. Chi-square tests comparing the relative frequency of LEH for only the middle-aged females found no association.
between LEH and site (Fisher’s Exact = 0.53). Therefore, no significant difference in the frequency of LEH between St. Bride’s sample and the Chelsea Old Church sample was found.

**Porotic Hyperostosis**

Figure 16 illustrates the overall frequency of females with observable porotic hyperostosis. Out of 42 individuals with observable cranial vault, 4.65 percent (2/42) exhibited evidence of porotic hyperostosis. None of the 25 SBC individuals with observable cranial vaults exhibited porotic hyperostosis and of the 17 COC individuals with observable cranial vaults, 11.76 percent (2/17) had porotic hyperostosis. Since an initial chi-square test revealed that age and porotic hyperostosis are not associated, a chi-square analysis was performed to evaluate differences in porotic hyperostosis frequency by site. No significant association between porotic hyperostosis and site was found (Fisher’s Exact $p = .16$). Chi-square tests comparing the relative frequency of porotic
hyperostosis for only the middle-aged females found no association between porotic hyperostosis and site (Fisher’s Exact = .9999). Therefore, there was no significant difference in the frequency of porotic hyperostosis between St. Bride’s sample and the Chelsea Old Church sample.

Cribra Orbitalia

Figure 17 illustrates the overall frequency of females with observable cribra orbitalia. Out of 44 individuals with observable eye orbits, 4.55 percent (2/44) exhibited evidence of cribra orbitalia. Out of 28 SBC individuals with observable eye orbits, none had cribra orbitalia and of the 16 COC individuals with observable eye orbits, 12.50 percent (2/16) had cribra orbitalia. A chi-squared analysis was preformed to evaluate differences in cribra orbitalia frequency by site. No significant association between cribra orbitalia and site was found (Fisher’s Exact $p = 0.13$). Chi-square tests comparing the
Figure 17. Frequency of cribra orbitalia by site.

relative frequency of cribra orbitalia for only the middle-aged females found no
association between cribra orbitalia and site (Fisher’s Exact = 0.50). Therefore, no
significant difference in the frequency of cribra orbitalia between the St. Bride’s sample
and the Chelsea Old Church sample was found.

Maxillary Sinusitis

Figure 18 illustrates the overall frequency of females with observable
maxillary sinusitis. Out of 23 individuals with observable maxillary sinuses, 20 percent
(5/22) exhibited evidence of maxillary sinusitis. Out of 13 SBC individuals with
observable maxillary sinuses, 7.69 percent (1/13) had maxillary sinusitis and of the 9
COC individuals with observable maxillary sinuses, 44.44 percent (4/9) had maxillary
sinusitis. Since an initial chi-squared test revealed that age and maxillary sinusitis are not
associated, a chi-squared analysis was preformed to evaluate differences in maxillary
sinusitis frequency by site.
No significant association between maxillary sinusitis and site was found (Fisher’s Exact $p = 0.12$). An odds ratio used to evaluate any difference in prevalence of maxillary sinusitis by site accounting for differences in age groups also indicated that there is no significant difference in the prevalence of maxillary sinusitis at the sites (age = OR = $<0.001$ [95% CI = $<0.001$ to $>999.99$] and site = OR = 4.0 [95% CI = 0.32 to 49.6]). Therefore, there was no significant difference in the frequency of maxillary sinusitis between St. Bride’s sample and the Chelsea Old Church sample.

Infections in the teeth can ultimately lead to infections in the maxillary sinuses. Therefore, a logistic regression was run to test whether the presence of caries explains any association between maxillary sinusitis and site. Results indicated that the presence caries did not explain any association between maxillary sinusitis and site (caries = OR = 2.79 [95% CI 0.14 to 56.52] and site = OR = 4.54 [95% CI 0.27 to 76.78]).
Periostitis

Figure 19 illustrates the overall frequency of females with observable periostitis. Out of 60 individuals with observable surfaces for periostitis, 25 percent (15/60) exhibited evidence of periostitis. Out of 29 SBC individuals with observable elements, 3.45 percent (1/29) had periostitis and of the 31 COC individuals with observable elements, 45.16 percent (14/31) had periostitis. Chi-squared analysis was performed to evaluate differences in periostitis by site. Chi-square analysis using Fisher’s Exact test revealed a significant difference in periostitis by site, with a higher frequency of periostitis in the Chelsea Old Church sample (Fisher’s Exact = 0.0002). However, since periostitis and age were likely associated, the high correlation between age and site prevented the logistic regression test from running. In addition, the older adult cohort was too small in the Chelsea Old Church sample to perform the logistic regression. Instead,
the older-adult cohort was removed from the analysis and pathology was compared across the middle-adult groups only. A chi-square test revealed a significant difference in periostitis by site, with a higher frequency of periostits in the Chelsea Old Church sample than in the St. Brides sample (Fisher’s Exact = 0.01).

**Rickets**

Figure 20 illustrates the overall frequency of females with observable rickets. Out of the 61 individuals with observable femora and tibiae, 11.48 percent (7/61) had rickets. Out of the 30 SCB individuals with observable femora and tibiae, 6.67 percent (2/30) had rickets and of the 31 COC individuals with observable femora and tibiae, 16.13 percent (5/31) had rickets. Chi-squared analysis was performed to evaluate differences in rickets by site. Chi-square analysis using Fisher’s Exact test revealed no significant difference in rickets by site (Fisher’s Exact = 0.43). Logistic regression was
used to evaluate any difference in prevalence of rickets by site accounting for differences in age groups. It indicated that there was no significant difference in the prevalence of rickets between the sites (Age = OR = 0.53 [95% CI 0.04 to 7.53] and site = OR = 1.95 [95% CI 0.24 to 15.80]). Therefore, there is no significant difference in the frequency of rickets between St. Bride’s sample and the Chelsea Old Church sample.

**Cumulative Indicators of Skeletal Stress**

Out of the total sample (62 individuals), 18 people had no detectable skeletal indicators of stress (Table 13). When the number of individuals with without evidence of indicators of stress was compared by site, there was no significant difference ($p = 0.87$).

For the 44 individuals who had detectable skeletal indicators of stress, multiple indicators ranged from one to one individual with five. The categories were collapsed into “0”, “1”, or “2 or more” because, as shown in Table 13, there was only one individual with evidence of five skeletal indicators of stress, no individuals with four, and only five individuals with three. There was no significant difference in the number of individuals with zero, one, or two or more skeletal indicators of stress between sites ($p = 0.12$). In

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addition, there was no significant association between age and number of skeletal indicators of stress \((p = 0.54)\).

Summary

The purpose of this study was to investigate the effect of urban and rural environments on the health of females above the age of thirty-five using the research collections from post-medieval St. Bride’s crypt and Chelsea Old Church. It was expected that the rural Chelsea Old Church skeletal sample would be healthier, or have less skeletal indicators of stress, than the urban St. Bride’s crypt skeletal sample. This hypothesis was based on evidence suggesting that urban locations have a negative impact on health.

Chi-square tests revealed a significant association between site and age. The St. Bride’s Church sample had more individuals in the older adult category than the Chelsea Old Church sample, which only had one older adult female. To reveal differences in health, additional tests had to be preformed adjusting for age or other health conditions.

Generally, no major difference in urban and rural skeletal health was found. Out of the ten skeletal indicators of health analyzed in this study, only one indicator represented a significant difference in disease prevalence. No significant differences were found in stature, antemortem tooth loss, caries, abscesses, linear enamel hypoplasias, porotic hyperostosis, cribra orbitalia, maxillary sinusitis, or rickets. However, periostitis was more prevalent in the rural Chelsea Old Church sample.
Interestingly, porotic hyperostosis and cribra orbitalia were noted in the Chelsea Old Church sample, but were absent in the St. Bride’s sample. One individual exhibited evidence of porotic hyperostosis, one individual exhibited evidence of cribra orbitalia, and one individual exhibited evidence of both porotic hyperostosis and cribra orbitalia. Although these results are not significant, it is important to note that these two types of non-specific disease affected only the Chelsea Old Church sample.

In addition, there was no significant difference in the number of individuals with multiple skeletal indicators of stress when compared by site. These results support the initial findings. The tests reveal no major difference in urban and rural sample skeletal health.

Although a higher prevalence of one skeletal indicator of stress does not necessarily signify there was a difference in health, it does represent a difference in the samples. A higher prevalence of periostitis at Chelsea Old Church does reveal a health pattern at Chelsea Old Church. However, one significant difference in ten skeletal indicators of stress is not enough to conclude that one sample was healthier than the other. Therefore, the hypothesis that the rural population would be healthier than the urban population was rejected.
CHAPTER VI

DISCUSSION

Introduction

This chapter discusses the results and interpretations of this study. The first part of the chapter focuses the results and what they suggest about health in urban and rural post-medieval London. Three main categories are discussed: disease during developmental stages, infection, and cumulative skeletal indicators of stress. The second section reviews factors influencing the results including age and socioeconomic status. The subsequent section discusses the limitations and future directions of study, and the chapter concludes with a summary section.

Interpretations of Disease During Developmental Stages

Presence of Linear Enamel Hypoplasias (LEH) and difference in LEH

The presence of LEH is an indicator of growth disturbance during tooth crown formation. If an individual exhibits evidence of the defect, it signifies that they suffered some kind of stress during childhood. While indentifying the specific mechanisms by which the LEH were created is difficult, the presence of the defect speaks to the conditions in which the individual grew up. This means that two of the individuals in the Chelsea Old Church sample experienced an event or circumstances that lead to
growth disruption during childhood. Since there is no statistical association between site and prevalence of LEH, this information cannot be extrapolated to the population level; however, it is important to note that the p-value was approaching significance. A factor associated with the rural environment, such as nutrition during the years of growth and development, or some kind of disease, may have been associated with the development of LEH. Unfortunately, as with the other dental indicators of stress, prevalence rates of LEH could not be compared across post-medieval sites due to differences in recording methodology.

**Presence of Rickets**

Individuals in both samples exhibited evidence of residual rickets. Evidence of residual rickets indicates that a period of vitamin D deficiency or malabsorption occurred during development. Although there was no significant difference in the prevalence of rickets, with two cases in the St. Bride’s sample and five cases in the Chelsea Old Church sample, the occurrence of rickets indicates a lack of vitamin D or vitamin D absorption in both the rural and the urban sample.

Infant feeding practices and clothing fashions have been linked to an increase in the prevalence of rickets during the post-medieval period in London (Molleson et al. 1993; Roberts and Cox 2003). Infant feeding practices, swaddling, and clothes that hindered sun exposure may have reduced the vitamin D availability in both rural and urban populations. Records from the post-medieval period indicate that adequate dietary sources of vitamin D were available to upper class adults. Maternal breast milk should not have lacked vitamin D from dietary sources for either sample. However, 90 percent of the required vitamin D comes from exposure to sunlight (Roberts and Manchester 2007).
It is possible that clothing fashion could have influenced vitamin D production. Women’s fashion during this period consisted of clothing that covered most of the surface area of the skin. This could have lead to decreased sun exposure resulting in inadequate vitamin D in breast milk, especially for upper socioeconomic class women who did not work outside. It should be noted that if this were the case, the mother’s would have been so depleted that their skeleton might exhibit evidence of osteomalacia. Osteomalacia was not noted in either the St. Bride’s sample of the Chelsea Old Church sample; however, osteomalacia is hard to detect without radiographic evidence.

Regardless, many upper class women employed wet nurses or used formula to feed their babies (Roberts and Cox 2003). Formula was very low in nutrients including vitamin D, and wet nurses of lower socioeconomic status may not have been exposed to adequate sunlight or had access to adequate dietary sources of vitamin D. Thus, formula and wet nurses had the potential to predispose infants to rickets.

Differences in urban and rural population sun exposure fall into 3 main categories: sunlight blocked by air pollution, sunlight blocked by overhanging housing, and underexposure to sunlight due to vast amounts of time spent indoors. Air pollution, mainly in the form of smog, blocked sunlight in the urban areas. During the beginning of the post-medieval period, it is unlikely that pollution blocked sunlight in Chelsea; however, it is possible that the smog began to affect the rural population towards the end of the post-medieval period. On the other hand, some upper class families sent their children to the countryside to wet nurses during major periods of childhood development.

Overhanging buildings would not have caused a problem in rural areas, but could have been a factor for urban children. Additionally, children during this period
were sometimes kept housebound for the first year of life (Roberts and Manchester 2007). It is unknown if urban children were kept indoors longer or more often than rural children, but a difference in the time spent indoors would influence sun exposure.

Accounting for every factor influencing rickets is not possible. Regardless, it is less likely that pollution caused rickets in the Chelsea Old Church sample, and more likely that it had an influence on the St. Bride’s parish population. The prevalence of rickets was higher, although not significant, in the Chelsea Old Church sample. This pattern may indicate that keeping infants housebound, clothing fashions and infant swaddling, and feeding practices affected the prevalence of vitamin D deficiency.

Rickets progressed through the late 1800s to the point where, in 1880, the British Medical association was so concerned that they began an investigation into the distribution of rickets (Wohl 1983). The Great Ormond Street Hospital reported that about a third of the children admitted had rickets in 1867. Subsequently, in 1884, the hospital on Clydeside reported that 100 percent of the children examined had rickets (Wohl 1983). The most likely cause of rickets in children of all socioeconomic groups residing in London during this period was air pollution.

The high prevalence of rickets referenced in historic sources including the Bills of Mortality is corroborated by skeletal evidence of rickets (Roberts and Cox 2003). For the post-medieval period, the female crude prevalence for the lower socioeconomic status New Bunhill Fields sample is zero and the female crude prevalence for the lower socioeconomic status Cross Bones sample is 1 percent. In comparison, the prevalence rates for rickets reported in this study are 6.67 percent for the females in the St. Bride’s Church sample and 16.13 percent of females in the Chelsea Old Church sample. Both of
this studies crude prevalence rates fall above the range reported for lower socioeconomic status sites.

Stature

Urban and rural stature did not differ in this study with an average of 62.46 inches (5 feet, 2.5 inches) at St. Bride’s and 63.3 inches (5 feet, 3 inches) at Chelsea Old Church. Although it is biologically plausible that rickets would have influenced height, there was no significant difference in the prevalence of rickets at either site nor association between stature and rickets or femoral length and rickets.

According to an analysis of post-medieval health in Britain from archaeological contexts, stature remained the same for males and increased for females. The increase in height form the medieval period may be related to nutrition, since the post-medieval samples are represented by higher socioeconomic classes who had better access to the nutritious foods necessary for growth. The reported average height for females during this period is 160 cm or 5 feet, 3 inches. The majority of the samples referenced in Roberts and Cox’s (2003) analysis were that of higher socioeconomic status Londoners, and therefore, representative of St. Bride’s and Chelsea Old Church samples. As there was no real difference in stature between rural and urban sites, it appears social status was the most important influence on height.

Interpretations of Infection

Presence of Porotic hyperostosis (PH) and Cribra Orbitalia (CO)

Parasitism, decreased sanitation, poor diets, infectious disease, anemia, and vitamin B_{12} deficiency are all indicated as causes of porotic hyperostosis (PH) and cribra
orbitalia (CO). Although no statistically significant difference was found in the prevalence of PH or CO between urban and rural locations, porotic hyperostosis was present in one individual, cribra orbitalia was present in one individual, and porotic hyperostosis and cribra orbitalia were both present in one individual, in the Chelsea Old Church sample.

In total, three of the individuals at Chelsea Old Church exhibited a nutritional deficiency or disease at or around the time of death. Out of the three individuals, two exhibited active lesions at the time of death. The individual with PH exhibited porosity that was active at the time of death. One individual with CO exhibited porosity that was mixed, active, and remodeled at the time of death. The other individual with CO exhibited barely discernable porosity that was healed at the time of death.

Information on prevalence rates of female CO and PH for British skeletal samples was not available for females only, but the prevalence rate of CO for males and females in post-medieval London ranged from 0.28 to 6.9 percent. In comparison, the prevalence of CO for the individuals in this study are as follows: zero for the St. Bride’s Church sample and 12.5 percent for the Chelsea Old Church sample. The prevalence of CO for the St. Bride’s Church middle aged and older adult females is on the low end of the range for the post-medieval British skeletal samples, while the prevalence of CO in the Chelsea Old Church middle aged and older adult females is above the prevalence range reported for post-medieval British skeletal samples. However, the Chelsea Old Church prevalence rate generally represents an older portion of the population than the rates reported for the contemporary sites so a higher prevalence rate would be expected.
Presence of and Differences in Periostitis

Infection and trauma are typically indicated in development of periostitis. Periostitis is most common on the surface of the tibiae, and this pattern held true for the samples in this study. The rural Chelsea Old Church sample experienced a higher prevalence of periostitis. More recent studies suggest that periostitis is a chronic response to pathology (Weston 2008; 2009), but the etiology of periostitis is multifactoral. Extensive research indicates that our current state of knowledge is not complete enough to tease out a singular cause of the periostitis exhibited in the individuals in the Chelsea Old Church sample.

Although the reason for the higher prevalence in the Chelsea Old Church sample is unclear, possible factors may include immune response, agricultural practices, and exposure to infectious agents. Increased population density has also been indicated in the development of periostitis; however, this trend is not supported by the results of this study.

Because periostitis is a type of infection, individuals with better immune responses are able to fight off infection more effectively. Overall immune response could account for the differences in the samples. Some research suggests that periostitis is found in populations that practice agriculture, although this is not necessarily a consistent pattern (Roberts and Manchester 2007). Following this reasoning, it might be expected that the Chelsea Old Church individuals would experience a higher rate of periostitis. Rural populations might have a higher potential for exposure to causative agents including some forms of agriculture and contact with animal dung and other factors that urban residents would not be exposed to. However, it is unlikely that upper-class women
took part in agricultural practice or labor that is sometimes associated with periostitis. On the other hand, contact with infectious agents in dirt or excrement in the streets would have been possible for rural women. Although urban women would have been exposed to waste in the streets, the type of waste or potential infectious agents might differ by location.

It is also possible that local conditions account for differences in periostitis prevalence, but are not linked to a rural or urban context. For example, it is possible that some kind of infectious agent, unassociated with the rural environment, was present in the soil or in the food or water in the Chelsea Old Church parish, but not in St. Bride’s. Overall, this study shows that the causes of periostitis should be ascertained before we can understand differences in the prevalence of the disease. Due to differences in data collection methodology, no appropriate comparative post-medieval British skeletal sample data was available.

**Presence of Maxillary Sinusitis**

The increase in urban air pollution during the post-medieval period was expected to contribute to respiratory disease such as maxillary sinusitis. However, there was no difference in the prevalence of maxillary sinusitis in the urban St. Bride’s and rural Chelsea Old Church samples. The results of the statistical procedures further indicate that the presence of dental disease was not correlated with presence of maxillary sinusitis.

The London *Bills of Mortality* suggest that illnesses associated with air pollution, such as asthma, increased after the 17th century. However, most of the recorded disease would not have affected the skeleton (Roberts and Cox 2003). Data from this
period suggests that the prevalence rate of sinusitis in post-medieval Britain may have dropped close to fifteen percent form the medieval period; though, very few studies have addressed sinusitis (Roberts and Cox 2003). The reported female prevalence of maxillary sinusitis for higher socioeconomic status Spitalfields is 18.3 percent (Roberts 2007). In comparison, the prevalence for St. Bride’s Church is 7.69 percent and 44.44 percent for Chelsea Old Church. While the St. Bride’s Church sample prevalence is lower than the reported skeletal sample for this period, the Chelsea Old Church is substantially higher.

In a review of maxillary sinusitis in urban and rural locations across time and throughout the world, Roberts (2007) found that the female prevalence of maxillary sinusitis ranged from 18 percent to 76.5 percent. In urban locations, the prevalence of maxillary sinusitis ranged from 18.3 to 69.2 with a mean of 48.2, and in rural locations from 18.0 to 92.9 with a mean of 55.4. Overall, the review by Roberts (2007) established that rural sites had higher prevalence rates of maxillary sinusitis. According to crude prevalence rates, the urban St. Brides Church and rural Chelsea Old Church sample generally follow this pattern, although the prevalence rate for St. Bride’s Church falls below the reported range for all urban and rural samples.

British studies of skeletal remains from the medieval and post-medieval period note different patterns in the prevalence of maxillary sinusitis. Lewis et al. (1995) recorded a higher prevalence of maxillary sinusitis in their urban medieval sample, while Lewis (2002) found that the post-medieval rural location had a higher prevalence of maxillary sinusitis. According to Lewis (2002), a higher prevalence in the rural population may be attributed to allergic reactions to animals and soil irritants. Roberts (2007) also noted that indoor air pollution, especially from smoke, was possible cause of
maxillary sinusitis in rural locations. Therefore, it is possible that the substantially higher prevalence of maxillary sinusitis in the Chelsea Old Church sample may be attributed to allergic reaction to animals or soil irritants or to indoor air pollution.

In this study, maxillary sinuses were only accessible in cases where there was damage to the maxillary bone and the internal surfaces of the sinus cavities could be observed. Methodology increasing the access to the sinus cavities could refine these results. For example, use of an endoscope to view the sinus cavities would allow for better analysis of maxillary sinusitis.

**Presence of Caries, Tooth Loss, and Abscesses**

The prevalence of caries, antemortem tooth loss, and abscesses did not differ significantly by site. General trends from the period suggest that dental disease was very common, regardless of socioeconomic class and location (Roberts and Cox 2003; Moore and Corbett 1975). Detailed analysis of caries was not preformed on either of the samples due to time constrains and therefore, results cannot be compared with other data from this time period. However, no difference in caries, tooth loss, or abscesses in urban and rural locations is consistent with British post-medieval samples from other sites.

Among other factors, the rate of tooth loss and caries may be influenced by both age and diet. All of the individuals included in this study experienced the loss of at least one tooth during life. The frequency of caries and tooth loss increases with age (Mays 1998). This, together with the influence of a highly cariogenic diet, especially high levels of sucrose and refined flour popular with the upper classes during this time, may account for the high frequency of tooth loss and caries in both post-medieval samples. It
is estimated that the rate of sugar consumption was at about twenty pounds a year by the 19th century (Roberts and Manchester 2007).

Interpretation of Cumulative Skeletal Indicators of Stress

In order to gain a more comprehensive understanding of the skeletal stress experienced by the middle aged and older adult females in the samples, the number of detectable skeletal indicators of stress exhibited by each individual was tallied and tested statistically. There was no significant difference in the number of individuals without skeletal indicators stress by site. In addition, there was no significant difference in the number of individuals with multiple, detectable skeletal indicators of stress at each site.

These data support the conclusion that there is no major difference in skeletal health in the urban and rural contexts. In fact, these tests produced a summary of skeletal health. To a limited degree, the tests reveal the extent of the biological stress experienced by individuals at each site. No difference in the frequency of individuals without detectable indicators of skeletal stress demonstrates that there was also no difference in the number of healthy individuals, or at least individuals lacking evidence of physiological perturbation. In addition, there is no difference in number of individuals with multiple episodes of physiological stress.

Alternative Interpretation

As summarized by the preceding sections, a statistically rigorous evaluation of skeletal indicators of stress demonstrated no general difference in urban and rural sample skeletal health. This ran contrary to the initial hypothesis that predicted worse skeletal
health in the urban context. In the following section, possible reasons for this disparity will be discussed. However, before explanations are given, an alternative interpretation will be examined.

Interestingly, considering only the crude data, the rural Chelsea Old Church sample appears less skeletally healthy than the urban St. Bride’s Church sample. It seems possible that, the Chelsea Old Church individuals were in fact worse off. Therefore, this idea will be explored.

The crude prevalence rates for most of the skeletal indicators of stress were higher in the Chelsea Old Church sample. The main exception was a higher crude prevalence rate of dental abscesses in the St. Bride’s Church sample. Reviewing the results of the totaled skeletal indicators of stress exhibited by each individual, one individual, from the Chelsea Old Church sample, exhibited 5 skeletal indicators of stress. Five individuals displayed evidence of three indicators of stress and four of those individuals were from the Chelsea Old Church sample. Again, although there was no statistically significant difference by site in the number of indicators exhibited by each individual, the majority of the individuals who showed evidence of more than two stress indicators were from the Chelsea Old Church sample. In terms of physiological perturbation, this indicates that more individuals experienced stress and some of the Chelsea Old Church individuals experienced various stressors at one time.

If the rural Chelsea Old Church sample was in fact less healthy, the results would compel a different interpretation than the original hypothesis. Therefore it is worth discussing what factors could have caused Chelsea Old Church to be a less healthy location. While there are many different factors could account for differences in skeletal
health, this discussion will be limited to three main variables: social status, nutrition, and living environment.

Although both sites are assumed to be higher socioeconomic status, the St. Bride’s Church individuals were all buried in a Church crypt. Burial in a church was certainly more expensive than in burial in a churchyard during the post-medieval period as evidenced by church records (Milne 1997). Therefore, the St. Bride’s individuals may have been wealthier than the Chelsea Old Church individuals may. And, as indicated by previous studies, wealth has been show to buffer individuals against ill health (Molleson et al. 1993; Roberts and Cox 2003).

If the St. Bride’s individuals were wealthier than the Chelsea Old Church individuals they may have been better protected against inadequate diets. However, an even more likely health advantage was that the St. Bride’s individuals resided in a major urban trading center. It was initially hypothesized that urban diets would have had less variety and been inadequate compared to rural diets, where individuals had access to fresh produce and variety from gardens. Nevertheless, the opposite might hold true. Because London was a major European trading center, higher status individuals would have had access to foreign goods such as fruits, rice, spices (Connell et al. 2012). This would have contributed variety their diets and potentially provided them with better nutrition than rural residents.

Even if the wealth of the two samples was comparable, or the nutrition was comparable, it is possible that the living environment differed in manners not previously considered. Since the urban individuals were wealthy, it is likely that they lived in affluent neighborhoods. Although post-medieval London is known for unsanitary living
conditions, the wealthy neighborhoods may have had better infrastructure than those of the higher status rural individuals. As evidenced by John Snow’s 1848 cholera investigation in London, functioning sewage systems and clean water pumps positively impact of human health.

In summary, if the urban St. Bride’s individuals in fact experienced better skeletal health than the rural individuals did, some of the initial assumptions about urban and rural health should be re-evaluated. Many different angles could be pursued. The three main variables discussed here include differences in wealth, diet, or living conditions which could potentially contribute to worse health in the urban environment.

Influencing Factors

As mentioned previously, the hypothesis that the urban environment would be less healthy than the rural environment was not supported. Therefore, the initial assumptions that helped formulate the hypothesis should be re-examined. While it is possible that the rural environment was actually less healthy than the urban environment, the statistical tests demonstrate generally similar skeletal health in the St. Bride’s Church and Chelsea Old Church samples. Consequently, two main factors may explain the similarity witnessed in urban and rural skeletal health status: age and socioeconomic status. In this section, the association between age and site will be explored and then the relationship between socioeconomic status and health will be discussed.

Age

As with many paleopathological studies, age is a major influencing factor in this study. The results indicate an association between age and site, which is due to a
disproportionate amount of individuals in the older adult category in the Chelsea Old Church sample. The St. Bride’s sample is made up of 12 middle adults (35-49) and 18 old adults (50+) and the Chelsea Old Church sample consists of 31 middle adults (35-49), and 1 older adult (50+). The Chelsea Old Church sample contains more that double the amount of individuals in the middle adult category and one eighteenth of the individuals in the old adult category. While there is a difference in the frequency of individuals in the middle adult category, the disparity in the older age category posed more of a problem for running statistical tests. Both chi-square tests and logistic regression require five individuals in each cell. Despite the fact that Fisher’s exact tests can be used for small sample sizes, the logistic regression could not adjust for Chelsea Old Church’s small older adult sample. No statistically significant difference in health indicator prevalence may be attributed to a type II error. In other words, due to the sample size, true differences that might exist between the samples are not detectable.

While all of the available middle aged to older adult females from the St. Bride’s Church crypt were included in this sample, it is possible that the Chelsea Old Church sample was skewed towards middle aged adults because some of the older adult females were not excavated, were buried somewhere else, or were misclassified differentially to St. Brides. The Chelsea Old Church sample used in this analysis was randomly generated from, and should be representative of, the whole Museum of London Chelsea Old Church sample. However, the Museum of London Chelsea Old Church sample consists of a major portion of the Chelsea Old Church burial ground, but not the whole burial ground. Given a larger sample size, it is possible that the results for linear enamel hypoplasias would have resulted in a statistically significant difference between
urban and rural samples, with a higher prevalence of disease in the Chelsea Old Church sample. Larger sample sizes may also have an effect on the prevalence of other indicators as well.

Generally, the St. Bride’s Church and Chelsea Old Church samples, including both males and females, had a larger proportion of middle aged and older adult individuals than contemporary archaeological skeletal samples and than were expected compared to written records such as the *Bills of Mortality*. A survey of the post-medieval London archaeological samples accessible through the Museum of London online database also supports this trend (Table 14).

**Table 14.** Percent of middle aged and older adult individuals in post-medieval cemeteries.

<table>
<thead>
<tr>
<th>Site</th>
<th>SES</th>
<th>35-50</th>
<th>50 +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chelsea Old Church</td>
<td>higher</td>
<td>23.23</td>
<td>36.36</td>
</tr>
<tr>
<td>St. Bride's Church</td>
<td>higher</td>
<td>11</td>
<td>59.5</td>
</tr>
<tr>
<td>St. Marylebone</td>
<td>higher</td>
<td>22.9</td>
<td>17.3</td>
</tr>
<tr>
<td>St. Benet Sherehog</td>
<td>medium</td>
<td>21.6</td>
<td>13.9</td>
</tr>
<tr>
<td>St. Thomas' Hospital</td>
<td>mass grave/lower</td>
<td>16.6</td>
<td>9.3</td>
</tr>
<tr>
<td>St. Bride's Lower</td>
<td>lower</td>
<td>16.2</td>
<td>11.9</td>
</tr>
<tr>
<td>Broadgate</td>
<td>lower</td>
<td>11.7</td>
<td>11.7</td>
</tr>
</tbody>
</table>

It is common for archaeological samples, in general, to show a mortality distribution with a peak between 30 and 45 years and relatively few individuals above 60 years (Chamberlain 2006). Furthermore, according to the *Bills of Mortality* at the beginning of the period, close to half of the London population died before their twentieth birthday and those who survived into adulthood might live to their 60’s and later in the period, their 70s (Cowie et al. 2008; Roberts and Cox 2003). The *Bills of*
Mortality for the 18th and 19th Centuries should be more representative of the age distribution for St Bride’s Church and Chelsea Old Church than the archaeological samples. However, in contrast to common archaeological skeletal sample patterns and evidence from the London Bills of Mortality, peak mortality in the St. Bride’s Church and the Chelsea Old Church sample occurs in the above 45-year age cohort (Chamberlain 2006). While life expectancy during the post-medieval period was low for the poor and working classes, the higher socioeconomic status of the individuals in this study’s samples may partially explain this age distribution.

Research shows that the use of standard skeletal aging methods, in both the St. Bride’s crypt sample and the Chelsea Old Church sample, underage both samples’ individuals (Falys et al. 2006; Kausmally et al. 2005). This bias has the potential to further widen the difference between the expected age-at-death profile for the period and St. Bride’s Church crypt and Chelsea Old Church mortality profiles. Likewise, Molleson et al. (1993) compared the estimated ages of the post-medieval London skeletal sample from Spitalfields with the known ages of the individuals and found that they systematically overaged individuals under 40 and underaged individuals over 70. Possible explanations for the underaging will be discussed further in the limitations section of this chapter. Nevertheless, the proportion of older individuals in both samples used in this study is unusual for this time period.

Social Status

A review of health in Britain by Roberts and Cox (2003), from the late Upper Paleolithic through present, indicates that health most likely declined, or the prevalence of skeletal indicators of stress increased, from the medieval period to the post-medieval
period. This health decline is attributed to increased population densities, urbanization, and eventually industrialization. However, the number of skeletal samples from the post-medieval period is significantly smaller than other periods in the past. Furthermore, the available samples are mostly from London and composed of upper socioeconomic status individuals. This information indicates that we should be careful comparing the post-medieval skeletal samples to the skeletal samples from other periods in British history. However, this problem also presents the first indication that status may have affected the current study’s samples’ health status.

The review by Roberts and Cox (2003) suggests that working conditions as well as diet would have declined in both rural and urban locations. Under such conditions, stature should be expected to decrease; yet skeletal studies indicate that stature remained constant from the medieval period. The authors maintain that this trend is a result of bias due to the socioeconomic status of the samples. As mentioned, most of the samples from this period contain higher socioeconomic status individuals. Better access to food and nutrients by the individuals represented in the samples kept higher socioeconomic status stature constant, but lower socioeconomic status almost certainly would have dropped from the medieval period. Likewise, according to historical sources, dental health and overall health decreased during this period. However, the skeletal samples from the period do not necessarily reflect a decrease in dental or overall health (Roberts and Cox 2003). Based on these post-medieval health trends reported by Roberts and Cox (2003), it is likely that higher socioeconomic status protected against environmental conditions that would normally negatively impact health.
No major differences were found in the prevalence of most of the indicators of stress analyzed from St. Bride’s Church and Chelsea Old Church samples. It is possible that upper socioeconomic status buffered both populations from many of the factors influencing the health decline documented by historic sources. Better nutrition and living conditions may have protected upper socioeconomic classes against biological stressors in the environment. For example, while there were frequent food shortages and high food prices during the 18th century in London, Molleson et al. (1993) note that wealth could buy access to enough food and to high enough quality of food to reduce the impact of these factors for higher socioeconomic status individuals. In accordance, the mean female stature for both of this study’s samples is consistent with reported stature for other post-medieval London sites. Again, Roberts and Cox (2003) suggest that the mean stature is biased towards higher socioeconomic status, so if the St. Bride’s and Chelsea Old Church samples are similar to other period samples, they are probably consistent with the mean for higher socioeconomic status individuals.

Improved living conditions were likely a major advantage in keeping the wealthy healthy. Post-medieval London, like many large cities, was divided in to different sectors based on class (Wohl 1983). The wealthy neighborhoods usually had better infrastructure, including superior housing, improved sewer systems, better waste disposal, and piped water (Roberts and Cox 2003; Wohl 1983). Although taxation on windows likely discouraged their construction, the homes of the rich were probably more likely to have more windows and thus better ventilation (Olsen 1999). In addition, higher status individuals from London may have had the means to afford summer homes in the
countryside, or as some sources indicate, vacationed outside of London to escape unhealthy conditions in the city (Holme 1971).

On a personal level, the wealthier classes adopted better hygiene during the end of the period. Soap was both expensive and heavily taxed, discouraging use by the lower socioeconomic classes (Olsen 1999). However, the higher socioeconomic classes began bathing daily, decreasing the potential for illness, especially louse born disease (Roberts and Cox 2003). Medical care was very also very expensive. The upper classes had better access to doctors and dentists, whereas the poor commonly waited until conditions were very bad to call on a physician (Olsen 1999). As evidenced by both samples in this study, dental problems were prevalent during the period. While dental hygiene was almost non-existent, the rich could afford fillings (usually gold or silver amalgam) or to have teeth extracted (Olsen 1999; Roberts and Cox 2003) preventing infection, and might have been able to afford prosthetics (Roberts and Cox 2003), which helped with nutrient intake. Although there was no evidence of fillings in the females analyzed, according to the archaeological records, SB79-97, Judith MacFarlane, had a gold denture. Other individuals in the larger St. Bride’s Church crypt collection also had dental prosthetics, including several individuals with dentures made from human teeth.

Reviewing the conditions in which post-medieval higher socioeconomic status individuals lived, a pattern becomes apparent. Not only did the wealthy have an advantage nutritionally, but also in respect to housing conditions, sanitation, water supplies, and hygiene. Considering all these factors, it seems highly likely that socioeconomic status would have protected the health of the St. Bride’s and Chelsea Old Church sample individuals. In addition, it is very possible that wealth could have
mitigated many of the negative impacts of the urban living environment making higher socioeconomic status health more equal in urban ad rural locations.

Limitations of Study and Future Directions

There are several limitations inherent to the study of bioarchaeology. For one, paleopathology is the study of disease in human remains from the past; paleopathologists study skeletal populations, not living populations (Buzon and Judd 2008). Most diseases do not leave marks on the skeleton. Therefore, disease in a population may not be represented in the bones of a skeletal sample (Roberts and Manchester 2007). Second, it has been argued that individuals exhibiting skeletal lesions may actually represent healthier individuals, since they were able to live through the disease long enough for it to manifest in skeletal tissue (Wood et al. 1992). Additionally, in bones exhibiting evidence of disease or a departure from normal variation, it may be difficult to conclusively diagnose disease. Third, London was a large city with a substantial amount of migration and mobility. It is possible that the individuals in both samples did not grow up in the locations where they died (Wood et al. 1992). Therefore, the developmental indicators of skeletal health may represent exposure to an environment other than the one they died in. Fourth, misclassification of age-at-death increases in the older adult cohorts. Finally, the portion of the population sampled may not represent the total population. In light of these limitations, it may be difficult to accurately assess how well the frequency of disease in the samples matches the disease incidence in the post-medieval population from which the skeleton sample was derived (Ubelaker and Newsome 2002; Waldron 1992).
Several other potential confounders relate to the samples themselves. The total sample is small, only 61 individuals. The sample was randomly selected; however, the size of the sample limits the power of the statistical tests. For many of the tests, there were not enough older adult individuals in the Chelsea Old Church sample to run statistical tests. In other cases, results indicated that site might have had an impact on disease; however, the sample was too small to reveal any significant trends. In the future, the sample size should be increased in order to better address research questions regarding differences in skeletal samples, or the study should be extended to other post-medieval urban and rural sites.

Age estimation biases are frequently encountered in paleopathology. Documented ages were available for some of the individuals in the Chelsea Old Church sample and all of the individuals in the St. Bride’s sample. When the estimated ages were compared with the recorded ages, it was apparent that many of the individuals were underaged. This was not surprising. A systematic trend of underestimating the age at death of older-adult skeletons is recognized within the paleopathological discipline (Weiss 1972). This trend was also noted by researchers analyzing both the St. Bride’s collection and the Chelsea Old Church collection (Falys et al. 2006; Kausmally et al. 2005). Part of the aging bias may be due to the fact that methods for age determination, developed mostly using modern skeletal reference series, contain biases associated with the age distribution of the reference series. Furthermore, intrinsic factors may differ greatly between populations. Modern populations, in most cases, vary significantly from archaeological populations in terms of nutrition, health, and lifestyle. In addition, not all individuals follow the same pattern of skeletal maturation. For example, pubic symphysis
morphology varies greatly between individuals of the same chronological age (Mays 1998). Age estimation becomes more difficult, especially so for the oldest categories (35-49 and 50+), as skeletal morphology increasingly differs with age.

It is highly likely the proportion of individuals in the older age category (50+) for both St. Bride’s and Chelsea Old Church should be higher, not only because the sample consists of mainly older aged individuals (35+), but also because the sample is archaeological. If the aging standards better reflected the actual ages of the individuals, there may have been enough older adult individuals to produce statistically significant differences in the prevalence of indicators of stress at each site. These problems with aging standards need to be addressed. Work on adjusting the aging standards for both the time period, and in general, is necessary.

In addition, knowing the association between reported ages and skeletal indicators of stress could be especially beneficial for understanding how much the aging bias in paleopathological studies affects information about health. While this study did not include analysis of the known ages of individuals, a direction for future study could include an analysis of reported age and skeletal indicators of stress. Based on similar studies of the post-medieval period, it is possible that some of the reported ages are not correct (Molleson et al. 1993); however, much information can be gained from individuals of known age. In this study, older age (the 35-50 and >50 age cohorts) and disease were not associated. Determining whether reported age and skeletal indicators of stress are associated would be helpful in determining the relevance of the results of this study.
Differential preservation of skeletal remains, burial outside of the main cemetery, and biases related to excavation of the cemetery may affect the representativeness of the sample. Cemetery layout and disposal of individuals can potentially affect both the recovery process and composition of a cemetery. Social selection in the placement of burials or differential disposal of individuals depending on factors such as age, sex, and disease are frequently encountered in archaeological samples (Roberts and Manchester 2007). Additionally, partial excavation of a cemetery is common in archaeology and adds to the bias of differential disposal of remains. These biases likely affected both the Chelsea Old Church and the St. Bride’s Fleet Street samples.

In conclusion, there was a significant difference in the number of older adult skeletons in the samples. Only one older adult was present in the Chelsea Old Church sample. The reason may have been due to under aging, burial practices, excavation practices, or that the sample is representative of the age at death profile of the St. Bride’s sample. However, it is reasonable to assume that if the whole Chelsea Old Church cemetery was exhumed, the age-at-death profiles of the two sites would have been similar.

Future directions may include a larger sample size to analyze the skeletal health of older, upper class females, and possibly pooling several rural and several urban sites. The study could also be expanded to include males and well as females. A second potential direction would be incorporating new methods for aging skeletons. Third, a comparison of the skeletal health of medieval urban and rural upper socioeconomic status individuals could add to our understanding of environment and health through time.
Finally, the study could be expanded to look at differences in older female adults of lower socioeconomic status urban and rural locations.

Summary

From these analyses, it can be concluded that the prevalence of one skeletal indicator of stress differed between the post-medieval St. Bride’s and Chelsea Old Church higher socioeconomic status, middle and older adult females. Contrary to the expectation that the skeletal indicators of stress would be more prevalent in the urban, St. Bride’s, the prevalence of periostitis was higher in the Chelsea Old Church sample. However, there was no statistically significant difference in nine out of the ten indicators, suggesting that health, as evidenced in bone, did not differ much between the two sites.

The higher prevalence of periostitis in the Chelsea Old Church sample cannot be easily explained. The number of individuals with periostitis could be related to low immune response, agricultural practices, and exposure to infectious agents. It seems likely that local conditions may account for the prevalence of the disease, although it is unclear whether or not the causal factors specifically relate to the rural environment.

Three major factors could have influenced the prevalence of health indicators at the sites: sample size, age misclassification, and socioeconomic status. The first, and undoubtedly influential factor is the sample sizes. The samples were too small to achieve statistically significant differences in prevalence of health indicators. Because there was only one older adult in the Chelsea Old Church sample, there was a significant difference in the age between the sites. Without more older adult individuals at Chelsea Old Church, statistical comparison between the two samples is likely to result in a type II error:
finding no significant difference when there is a difference. Second, the Chelsea Old Church older adult sample size may have been affected by differential underaging. Finally, the third potentially influencing factor relates to the social status of the individuals in both samples. The upper socioeconomic status of the individuals may have buffered both samples from some of the health problems associated with the living environment.

This type of paleopathological research highlights the potential to identify disease patterns and disease processes that occur in response to, or as a result of, changing environments. This study addressed a gap in current paleopathology and bioarchaeology by examining the skeletal indicators of stress of older adult upper class females in the post-medieval greater London area. The analysis contributed to our understanding of how the environment affects human health through the lifetime by investigating skeletal indicators of stress in urban and rural locations during a period of rapid and extreme urbanization. In conclusion, the benefits of upper class socioeconomic status outweighed any potential health effects of urban versus rural environment.
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