Breaking the Age Barrier: Understanding Trauma in Older Adults from the Danish Middle Ages

By

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ABSTRACT

This research undertook osteological methods to assess traumatic lesions in the skeleton with the application of life-course theory and three-dimensional imaging techniques to decipher and permanently record the lesions. The purpose of this research was to decipher patterns of trauma present for adults in medieval Danish samples using more accurate aging techniques. The populations spanned the time-frame from early medieval (11th century) to early modern (17th century) Denmark. During this time in Denmark, the country was establishing trade and commerce that changed farming practices and political and social institutions; all of these changes were expected to provide context to the trauma features seen in the skeleton. For instance, groups were anticipated to differ between urban and rural residents by age and by sex. The results of this study show that trauma rates differed dramatically between male and female groups; male individuals display more traumatic conditions in the skeleton than females. There became key differences in trauma by age group. It is assumed that these groups were more economically active in the community (from 20-41 years-of-age) as they showed the most frequent skeletal injuries. In addition, the oldest-old age group showed an increase in injuries compared to the other age groups. There were no major differences in trauma type or the frequency of trauma between urban and rural locations.

This research undertook a pilot study in which it used three-dimensional data collected using NextEngine and CT to better decipher trauma classification. Results showed that the 3D analyses were not as precise at capturing minute details such as fracture margin texture and appearance compared to other technologies used today, such as Micro-CT.

The research presented here contributes to our understanding of the bioarcheology of trauma and Danish history. Traumatic lesions in the cemetery samples examined in this study

had not been previously investigated; therefore, this research presents preliminary findings that will be helpful in future analyses of trauma in Danish remains housed in the Unit of Anthropology at the Department of Forensic Medicine through the University of Southern Denmark (ADBOU).

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<u>TABLE OF CONTENTS</u> **<u>PAGE</u>**

LIST OF TABLES **PAGE**

LIST OF FIGURES **PAGE**

CHAPTER 1: INTRODUCTION

The study of bioarchaeology, the analysis of skeletal remains from the archaeological past, allows researchers to build a 'picture' of a once living person, by creating an informative and helpful biological profile. Skeletal trauma encompasses an important component of this biological profile as it can provide direct evidence of past lifestyles. Previous researchers focused exclusively on deciphering the patterns and classifying the types and causes of traumatic lesions of the skeleton (e.g. Lovejoy & Heiple, 1981; Larsen, 1997; Lovell, 1997; Judd & Roberts, 1999). More specifically, previous methods have aided the determination of specific fracture types, the timing of different types of trauma, and their classification as perimortem or postmortem (e.g. Ubelaker & Adams, 1995; Galloway, 1999; Moraitis & Spiliopoulou, 2006; Wieberg & Wescott, 2008; Wheatley, 2008; Shattuck, 2010). However, to this day, analyses of the timing of traumatic injury are riddled with problems, especially analyses of archaeological remains. Persistent issues with such research include many studies that do not account for bone preservation and the trauma cannot be compared to other studies due to extreme differences in trauma methods and accounting. Thus, the goal of the present research was to use consistent aging methodologies to provide precise observations of fracture prevalence that would give more accurate frequencies of trauma at the population level. By accounting for the fracture prevalence more accurately, especially within age cohorts, the resulting population frequencies would be expected to be more informative for individuals as well as for portions of the population. Most importantly, more precisely aged cohorts, will demonstrate that the old and oldest-old age groups present trauma patterns that have not been previously accounted for in larger population studies. This should, in turn, lead to a more comprehensive picture of life in the archaeological past.

This thesis examines patterns of adult trauma in medieval Denmark. It focuses on differences in trauma rates by age, sex, and geographical location (i.e., urban and rural). By examining between-group differences, inferences regarding activities and lifestyle could be drawn for different groups and then referenced further using a life-course approach. Perhaps most importantly, this research builds on our current understanding of trauma amongst older adults in past populations by using new approaches to age-at-death estimations (Milner & Boldsen, 2012). These age-at-death approaches can help assess age-specific data for older adults at a level that has not been previously possible. In addition, the thesis presents a pilot study using advanced imaging techniques to help decipher the timing and classification of trauma; this ultimately contributes to defining the cause and manner of trauma in the past. The use of three-dimensional (3D) technology in bioarchaeology recently showed that additional characteristics may be noted at the fracture site. This technological approach captures these characteristics that are not observable by those gross macroscopic or microscopic methods previously employed to record trauma in the archaeological record (Boschin & Crezzini, 2012; Fleming-Farrell et al., 2013). The use of 3D imaging allows more accurate assignment of fractures in archeological remains as perimortem or postmortem (Fleming-Farrell et al., 2013). Additionally, 3D renderings of traumatic lesions provide a permanent visual, digital, and analytical record that can be made widely available to other researchers and the public domain.

This research improves our understanding of differences in trauma experienced between urban and rural populations in medieval and early modern Denmark. Previous studies of these distinctive differences argued that specific patterns occur in different populations (e.g., Judd & Roberts, 1999; Budnik & Liczbinska, 2006). For example, urban English medieval populations have exhibited trauma concentrated in the limbs, hands, feet and cranium, and males tended to possess more trauma than the females. Cranial trauma was more prominent in urban medieval populations due to increased numbers of people in restricted areas, causing more interpersonal conflicts than one might find in their rural counterparts. In rural populations, although males and females were both exposed to a more hardened lifestyle, males still showed more trauma than females. These patterns were thought to result from males partaking in more risky labour practices where they are exposed to dangers from large livestock and heavy farming equipment. In comparison to the urban residents, rural individuals were expected to show trauma lesions concentrated in the torso region and occasionally the limbs (Judd & Roberts, 1999; Budnik & Liczbinska, 2006). This thesis project tested whether these resulting patterns of injury were present in the Danish samples.

1.1 Objectives

There were several objectives at the onset of this research. The main objective was to understand the different patterns of skeletal fractures in adults, particularly in those individuals older than 60. This is important because many studies have typically left the definition of these older age groups "open-ended" because of limitations of age estimation techniques. The method of transition analysis developed by Boldsen et al. (2002) and Milner and Boldsen (2012) shows that age categories can be made more precise by using a combination of age-specific characteristics. As a result, the age-specific differences in frequency, type, and location of the trauma were examined within the samples available to the present research. A second objective of this research was to understand differences in the patterns of trauma type and frequency between urban and rural populations; this would enhance our understanding of the impact of daily activities of each locale. Age and sex differentials will be more apparent among the various groups of individuals within the different locations.

1.2 Theoretical Orientation

The main goal of bioarchaeological analyses of trauma is to determine patterns within a population. The best way for bioarchaeologists to build a picture of trauma in the past is by using the life-course approach, which is defined as biological markers or lesions within the body that are connected with the external environmental influences placed on the individual (Brickley et al., 2014), including the social, political, economic, natural, and physical contexts of the society and culture. The body and its interactive relationship with the surrounding environments (i.e., the effects of the extant social and cultural influences) create a form of "functional adaptation" (Gilchrist, 2012). This theory helps researchers decipher cultural and social contexts of the examined populations. Analysis of how the body experiences its environmental surroundings and how this can be viewed in the physical manifestations of the body is the essential component of a life-course approach. By inspecting periods of trauma throughout the life-course, researchers can better recognise that "individual lives are shaped by their biological sex, socio-economic status within the community, occupations performed, and the environment in which they lived" (Judd & Redfern, 2012: 366).

1.3 Hypotheses

Five hypotheses were explored by this research:

1. Rural populations will possess traumatic lesions in the trunk region and the upper and lower limbs, while urban populations will possess trauma lesions in the forearms, cranium, and facial regions.

2. Urban populations will have a higher proportion of trauma than rural populations.

3. Males will have a higher proportion of trauma than females in the lower or younger (21-30 yrs.) and middle (31-40 & 41-50 yrs.) adult age ranges.

4. Females will have a higher proportion of trauma than males in the old (51-60 & 61-70 yrs.) or oldest-old (71-91+ yrs.) adult age range.

5. Trauma in the oldest-old (71-91+ yrs.) age group will be consistent with osteoporotic fragility fractures in the trabecular portions of the long bones (i.e. distal radius and femoral neck) and compression fractures in the vertebral bodies as compared to younger (21-30 yrs.) adults.

By testing these hypotheses, this research further constructs our understanding of the impacts of the social, political, and economic lifestyles taking place in medieval and early modern Denmark. The patterns revealed in the fracture frequencies and the observed traumatic lesions will help address these lifestyle constructs further, and the information gathered during and gleaned from this research will contribute a considerable amount of bioarchaeological data on Danish skeletal remains. These hypotheses are built on the foundation of the previously stated research and proposed to improve upon established methods of trauma quantification and aging techniques for medieval populations.

1.4 Thesis Overview

The thesis is divided into six chapters following this introduction. In Chapter 2, the reader will be introduced to aspects of Danish history, providing a context for urban and rural Danish lifestyles and the changes Denmark endured politically, socially, and environmentally during the time period under investigation. Chapter 3 reviews human skeletal biology, traumatic conditions in the skeleton, methodology of examining and documenting fractures, and aging in relation to types of injury and fractures observed in individuals at different ages. Chapter 4 sets out the details of the archaeological samples used for this research and the methodologies employed in the study, including standard osteological techniques and 3D imaging methods. The results are presented in Chapter 5, which includes reporting between- and among-group differences for trauma frequency by age, sex, time period, and location (urban versus rural). Chapter 6 presents a discussion of the observed patterns in the context of other literature, positioning the results of this thesis within a broader body of published research. Chapter 7 presents the results and interpretations of the pilot study done on 3D imaging. The final chapter, Chapter 8, revisits the research objectives and hypotheses, summarizes the conclusions of this study, and presents further avenues for future research.

CHAPTER 2: LITERATURE REVIEW – HISTORICAL CONTEXT

Denmark is a small country located in Northern Europe and lies directly on the Baltic Sea. While it has a rich history, it is still considered a relatively "young" country compared to the rest of Europe. Geographically, Denmark is made up of three main lands including Jutland, its largest land component as the main peninsula, along with Zealand and Funen, which are two of the larger islands. Along with these three, Denmark includes several smaller islands, such as Bornholm and SamsØ. During the Middle Ages the climate in Denmark was considered to be quite constant, with little to no major fluctuations in temperatures (Hybel & Poulsen 2007). Rainfall was consistently higher and more frequent in the summer and autumn months than in winter and spring (Hybel & Poulsen, 2007). Although it is a small and relatively young country, there is a deep-set history to Denmark that can be seen in the archaeological evidence.

2.1 Historic Timeline

Denmark has previously thought that there was no evidence of human inhabitants before 8000 BC (Lauring, 1960), suggesting that hunter-gatherer societies from the Mesolithic and Neolithic eras were the first to inhabit the landscape in Denmark. However, archaeological research has found individuals from earlier (8500-8300 BC) from inhumation graves and a single skeleton from Koelbjerg (Bennike et al., 1987; Hansen et al., 2017). The oldest remains thus far found and curated at the ADBOU lab where this research took place, is dated from 10,000 BP-8000 BC (Maglemosian Culture: 9000-6000 BC) and was a peat burial on Funen who appeared to be a probable male (personal comm. with Dr. Jesper Boldsen). People in the Mesolithic (8300-4200 BC) and Neolithic (4200-1800 BC) moved freely across the landscape of Denmark, but towards the end of this period, they resided more closely to the coastal lands which were rich in fish resources (Bennike et al., 1987; Price & Petersen, 1987). People in the Mesolithic were more known for their megalithic graves, boulders and standing stones, as well as being part of a very violent period (personal comm. with Dr. Jesper Boldsen). Into the Neolithic period, groups of people lived in areas where there was less foraging and more permanent or sedentary settlements. Near the middle of this period there was a lot of population movement, leaving the Neolithic the last period where we receive a lot of immigrants from outside of Denmark for some time (personal comm. with Dr. Jesper Boldsen). With settlement came great changes in Danish social and economic society (Fibiger et al., 2013). During the Bronze Age (1800-500 BC) and Iron Age or Pre-Roman Period (500 BC-AD 1), permanent settlements took the form of chiefdoms that divided individuals in the society into a greater hierarchical system (Jørkov et al., 2010). It has been suggested that during the Bronze Age, Denmark saw good, stable conditions for the most part and were performing a range of cattle farming and agricultural activities as they were more sedentary (Bennike et al., 1987). The Roman Period followed (AD 1-500) with movement into the Germanic Period (AD 400-800), maintaining the form of more specialized societies that started in the Pre-Roman Period (Bennike et al., 1987). A part of this specialization was the possible evidence of royalty found on Zealand in the Germanic Period (personal comm. with Dr. Jesper Boldsen).

Around AD 800, Denmark saw the advent of the Viking Age, which lasted to AD 1050 (Lauring, 1960; Crabtree, 2001). Vikings were considered "the men from the fjords" (Lauring, 1960:45). The most important figure during this time was Harald Bluetooth, ruler of Denmark and Norway at the time (Lauring, 1960; Crabtree, 2001) and who would be known for uniting Denmark. This was a period of great political influences, with large and smaller organized chiefdoms (personal comm. with Dr. Jesper Boldsen). Another prominent ruler, sometime after Bluetooth, was Svein Estridson. He was known as the last Viking king of Denmark, by 1076

(Collier & Primeau, 2019), as those that followed fell within the medieval timeframe. After his death, as he did not claim a proper heir, the country was thrown into civil war which would continue until the first Valdemar king (Collier & Primeau, 2019). Estridson's rule from AD 1047-1076, is most recognised for its contribution to Christianity in Denmark. This was a continuance of Bluetooth's belief system (Lauring, 1960). Evidence of the Christian belief system can be seen in the standing stones at Jelling (Jutland, Denmark), where Harold Bluetooth was known to reside (Crabtree, 2001). The earlier monuments show distinct Pagan reliefs, but around AD 965 during Harald's reign, other stones start to show pictures of Christ and are inscribed in remembrance of Harald's parents. It is on these stones that he distinctly claims "Harald who won for himself the whole of Denmark, and Norway, and made the Danes Christian" (Crabtree, 2001: 192). This started a great turning point in Danish history.

The medieval period in Denmark was considerably shorter than for the rest of Europe as it did not begin until the 10th Century (Graham-Campbell, 2007). The start of the medieval period in Denmark can be seen as the Great Period of the Valdemars, which was when the ruling family sought to rebuild Denmark after it had been weakened by the "War of the Princes" (Lauring, 1960; Hybel & Poulsen, 2007); however, the biggest commodities, agriculture and Baltic trade, had yet to collapse. The War of the Princes was a time of political unrest and civil fighting after the death of Prince Knud Lavard (Skovgaard-Petersen, 2003). During the Valdemar rule or better known as the Valdemarian Age of Denmark, Denmark's agriculture and trade flourished with increased village and rural development (Lauring, 1960). The kingdom finally came under a successive rule where "domestic affairs prospered" and there was obvious "royal initiative" (Skovgaard-Petersen, 2003). This royal initiative was in the form of developing a Christian State where duties were distinctly defined due to the sovereign and political organization in society (Andrén, 1989).

Due to the success of agriculture and trade, Denmark was at its richest under the Valdemar Rule (Lauring, 1960). A unique factor during this time was the implementation of the Jutlandic Law (AD 1241), a law named after the main peninsula of Denmark, Jutland. There was no actual written law in the country in the early medieval period; rather, there were rules and regulations for the rural settlements enforced further by a local "lawman" or "statute" (Lauring, 1960). There seemed to be many variable statutes that did not overlap with one another because there were several rural settlements at the same time. Therefore, Valdemar the Victorious in AD 1241, created the Jutlandic Law to unify these rural rules and regulations; unfortunately, he died days later (Lauring, 1960). Although, more positive aspects for Denmark occurred during the Valdemarian Age, the country still faced times of civil unrest as Norway pushed at its borders (Collier & Primeau, 2019). However, by the time of Valdemar IV (AD 1340-1375) the country saw stability that was lacking from its yester-years, and this continued through Queen Margarete I's reign (AD 1353-1412) until the early 15th century (Collier & Primeau, 2019).

During the medieval period, Denmark experienced serious environmental changes in the climate. This period of change is important for Danish history as it played a key role in changing farming practices and in return changing the landscape, both physically and socially. Although weather in medieval Denmark did not differ significantly from today's Danish insular climate, "its influence on societal life was greater" (Hybel & Poulsen, 2007:59). The Medieval Warm Period occurred from the 11th to 14th centuries, covering much of the beginning and middle medieval period. The greatest warming took place in the 13th century (Hybel & Poulsen, 2007).

Farmers turned to cultivating cereal grain crops because of the overly warm weather. These crops were able to support a much larger population. Denmark was one of the biggest trade routes in Northern Europe for the Baltic at the time (Christensen & Mikkelsen, 2006: 485), bringing many people to the area to settle, in both urban and rural landscapes. The high productivity of the arable land during the 12th and 13th centuries led to increased population. By AD 1300, the population was approximately 1.5 million people (Hybel & Poulsen, 2007; Yoder, 2006). With the influx of people, cereal crops could no longer support such large numbers of individuals, so farmers turned to animal husbandry to help. Although the grain trade proved beneficial for the population, it would later be to the detriment of the people as it helped introduce the Black Death in the port cities (Lenz & Hybel, 2016).

As a result of the rural land being overly deforested for planting crops, there was a period of cooling in the 14th century, after the Warming Period, referred to as the Little Ice Age (Lauring, 1960). This drastic cooling that started in 1315 saw excessive rainfall that proved to be harmful to the crops, causing shortages in foods and leading to the Great Famine which lasted for seven years (Scott & Hoppa, 2018). Additionally, during this time temperatures dropped and extremely harsh winters became more common. With this change in weather, crops produced small yields and animal herds were devastated by disease and a lack of hay (Yoder, 2006; Yoder, 2010). Farmers began to abandon their farms and resort to more urban-centred occupations. To intensify this shift to urbanisation, the Black Death hit Denmark in AD 1349 (Hybel & Poulsen, 2007). Researchers suggest that the Black Death in Denmark likely started in Halmstad, eventually reaching Ribe, which was perhaps the biggest port town in Denmark at the time (Crabtree, 2001; Lenz & Hybel, 2016). Although ultimately devastating because it killed more than half of the population in Denmark, the Black Death created changes in subsistence between the social classes (Yoder, 2006). As a result of the decrease in population size, individuals started to move away from rural villages and farms and started to settle in more central areas, so few people still remained, that these urban centres were hardly overpopulated (Yoder, 2006).

After the devastation of the Little Ice Age and the Black Death, Denmark proceeded into the Late Medieval Agrarian Crisis. Many of Denmark's people suffered during this time; although, many had fled to urban centres after the Black Death, most large-scale town development ceased (Scott & Hoppa, 2018). At the start of the 16th century in Denmark, there developed an increase in peasant settlements as the country recovered from the devastation of the Black Death. Although peasant life was at an all-time high, it is at this time that the church was richest because it sought to own the land occupied and worked by the peasants (Hybel & Poulsen, 2007). This created great "social inequality" between farmers, peasants, and other residents of Danish towns, which seemed to be largely controlled by the Church (Skovgaard-Petersen, 2003). By the 1530s, the Reformation started to spread to Denmark. At the time of Luther's teachings in Europe, it was suggested that Hans Tavsen had brought Luther's ideals to Viborg, Denmark (Lauring, 1960). The Protestant Reformation was not only a turning point in Denmark, but in all of Western Europe. The ideals behind this movement were largely economic based, where "work and wealth accumulation influenced European societies by changing values and orientations toward profit-seeking activities" (Becker et al., 2016:3). Specifically, Luther chastised the clergy and how they encouraged divided labour forces, where the clergy possessed a much higher status (Becker et al., 2016). Ultimately, the Church was to blame for social inequalities in the economy. As a result, not only was the church already losing hold of its parishioners but now there was great resentment against the friars, who had complete control over trade in town markets. Therefore, peasants and farmers had little freedom with their choice in trades and wares (Lauring, 1960). As Luther's teachings spread, the friars were ousted from the towns and the churches were abandoned, although not completely. The Reformation in Denmark was unusually peaceful compared to the rest of Europe. This likely had little to do with the actual religious doctrine. Ultimately, the Reformation in Denmark was more about "liberation of enormous areas of church land" than it was about "fanaticism" towards a more Lutheran doctrine (Lauring, 1960:142). Formally, the late medieval period in Denmark ended in 1536. After the year 1536, Denmark was well into the post-medieval period which lasted until 1660.

2.2 Danish Urban and Rural Lifestyle

Historically, the majority of the Danish landscape was considered rural. However, its small size led to an overpopulation before the Black Death in 1350, with most people residing in or around town and city centres (Hybel & Poulsen, 2007). Leading up to and during the early medieval period, Denmark's landscape consisted of fields and woods with very little distinction between the two. As a result, individuals had differing levels of ownership in rural lands. People could privately own an enclosed area, referred to as *enemærker*, they could own assigned lots of land or land could be owned collectively by a village (Hybel & Poulsen, 2007). It was not until AD 1100-1400 that land ownership resided solely with the royalty; it was under the King's complete discretion who could or could not own land and how much land could be held by the peasants (Hybel & Poulsen, 2007). Before the Black Death, individuals lived together in nuclear families among their neighbours; after the population decline from the Black Death, individual nuclear families grouped together to form larger groups of individuals (Hybel & Poulsen, 2007). This type of change in living environment would affect changes in household activities and health.

2.2.1 Rural Landscapes

The majority of the population in Denmark throughout the early Viking Age and much of the Middle Ages, was comprised mostly of the rural class (Benedictow, 2003). Population density varied across the rural landscape in Denmark, with areas that were farmed for cereal grains being more populated than those used for animal husbandry (Hybel & Poulsen, 2007). This was, in large part, because cereal grains were able to support more people than herds of animals could. Smaller villages surrounded the larger areas of arable land that produced the grain crops. As a result, rural areas were associated with individuals who took part in agricultural activities. This ideal held true for other parts of Europe during this time, where rural individuals were agriculturalists and created goods for trade in the larger, more densely populated town centres (Gorecki, 1983).

Although they resided in or around core villages, rural farmers and their families owed their services to the monarchy, as the land they worked was owned by the monarchy itself. Rural life revolved around the village and the cultural and social networks that the village provided. A village in rural Denmark is described as a concentrated community of landowners and tenants, encompassing the household staff and "farmland slaves" (Hybel & Poulsen, 2007). Although the definition of a village suggests a group of sedentary individuals, villages were mobile entities prior to the 12th century (Hybel & Poulsen, 2007). Before becoming permanent settlements, rural villages were considered seasonal settlements; the people residing in villages would follow the seasonal patterns of planting and harvesting in different areas of arable land. Archaeological evidence shows that although villages were not completely static, they would only move within settlement boundaries; this was the pattern until about the 12th century when these movements became more restricted (Hybel & Poulsen, 2007).

Rural farms presented a harsh lifestyle for the villagers and farmers, as their trades led to use of larger livestock, larger machinery, and later relied on forced menial labour in the manor houses that developed in the village areas (Lauring, 1960; Hybel & Poulsen, 2007). It was during this early medieval period, that agricultural productivity accelerated with the invention of the heavy plow (Andersen et al., 2016); the plow serves as a great example of the machinery used in the rural settlements. The change in heavy machinery was essential for the Danish clay-like soils (Andersen et al., 2016). Work and labour were seasonal, but there was never a shortage of things to do or things to tend to. Males predominately worked the fields; this created trade commodities. Trade commodities are goods that the males would take to the markets to sell and many of these were goods from their agricultural activities such as wheat, barley, or milk products. Therefore, the peasant farm itself was the way of production for Denmark. Females created trade commodities, as well as, items for the entire household. Females were more prominent in the household, where gardening, child rearing, and washing was important. Historical records about rural settlements in general, suggest that in rural areas there was less exposure to conflict and interpersonal violence than in urban, more densely populated settlements; the most common cause of death in rural areas was sickness at birth or old age (Budnik and Liczbinska, 2006; Djuric et al., 2006). However, for Denmark during the medieval period, mortality rates were low for rural individuals; they had a much higher life expectancy than individuals who lived in towns (Hybel & Poulsen, 2007). Mortality rates in the larger towns tended to be higher for females than for males in early adulthood, and it was not common for individuals to reach a very old age (Hybel & Poulsen, 2007); an antiquated belief that is not supported by this current research.

2.2.2 Urban Landscapes

Urban centres across medieval Europe consisted of a large population in a concentrated area and are characterised as unsanitary due to the crowded living conditions (Betsinger, 2007). The lack of either a good water supply or a sewage system meant that diseases that spread through human waste were easily contractible, resulting in very poor and crowded working (and living) conditions (Budnik and Liczbinska, 2006). The first towns to appear in the Scandinavian countries, was in Denmark. As Scandinavia was considered the most northern margin of medieval Europe, the more northern countries of Norway and Sweden, saw the replacement of agrarian settlements with those of nomadic Saami-culture (Andrén, 1989). Town development therefore, was highly restricted due to ecological zones. As Denmark resides at the southern edge of Scandinavia, towns developed here more quickly. This southern and fertile ecological zone was considered the nemoral zone (Andrén, 1989). The increased development of towns in Denmark, lead to a more pronounced formation of the Christian State in the early medieval period, compared to the rest of Scandinavia.

During this time in Denmark, urban town centres comprised only 10% of the population, including the town's people, the clergy, and of course, the monarchy and associated nobleman (Hybel & Poulsen, 2007). The size of the town was highly dependent on the structure of its political power (Andrén, 1989). The largest town in Denmark was Lund, as it was where the royal power system resided but the town was considered "multifunctional" as it contained legal, church, and trade systems as well (Andrén, 1989). Some of the first "elite-controlled" urban trade centres started to appear in Denmark around AD 500 with the port settlements of Gudme and Dankitke (Crabtree, 2001). Other researchers have suggested that "the first clear tendencies toward urbanisation," started in the late eighth century, with Ribe appearing in the ninth

(Benedictow, 2003:237). The introduction of the heavy plow into the rural farming practices helped to further increase urbanisation (Andersen et al., 2016). The increased "agricultural productivity" became a "driver of economic development in an agrarian economy" (Andersen et al., 2016:134). According to historians, there were only 100 towns in medieval Denmark and they were predominantly developed for trade; this created divisions of labour amongst the common people (Hybel & Poulsen, 2007). Prior to the Reformation, towns were defined by the number of churches that were present there. The presence of churches encouraged towns to be meeting places for large groups of people. Unlike the rural countryside, townspeople did not focus on making crafts and developing trade commodities. Rather, the townspeople expected to receive these items from their rural counterparts.

From AD 1100-1350, before the Black Death epidemic, urban development flourished and was reinforced further by the presence of the noble and royal classes (Hybel & Poulsen, 2007). The development of social-class divisions may have encouraged greater divisions in labour; as seen in other countries at the time, there were major differences between the poor and the more elite individuals. After the Black Death, this demographic structure changed greatly due to the dwindling size of the population. The higher mortality rates in urban town centres were not just due to the Black Death in AD 1350; there were consistent episodes of epidemics that swept through towns over many years (Petersen et al., 2006). The closer living quarters in towns and the larger numbers of people produced the perfect breeding ground for outbreaks of these epidemic diseases. Therefore, urban settings saw greater mortality rates compared to rural villages; this was especially notable for those individuals who were adolescents and young adults (Petersen et al., 2006). Although the towns experienced higher mortality rates than villages, the entire population size in towns did not decline significantly; this meant that in-migration from the rural villages surrounding a town played a key role in maintaining the populations residing in the town centres (Christensen & Mikkelsen, 2006).

2.3 The Process of Urbanisation in Denmark

Although much of Denmark was rural, the process of urbanisation is important to recognise because it is a process of the rural lifestyle becoming a more urban one. The transitions that occur between rural to urban lifestyles are significant as “changes in landscapes can lead to changes in society and changes in the community values and resources” (Antrop, 2004:9). Furthermore, it is not just the size or number of people that define a place as urban or rural, but it is what the people *do*, the key differences seen in their culture, social landscape and economy (Antrop, 2004; Petersen et al., 2006).

Researchers suggest that the urbanisation process and movement of people starts from the urban centre itself and then affects the surrounding areas moving out away from the city, creating a “process of diffusion” (Antrop, 2004). In actuality, it is not this simple, since the free movement of people was much more complicated. The process of urbanisation in Europe during the Middle Ages took on two different patterns: one was a primary settlement including its surrounding areas and land, the other was clusters of cities that were so close to one another that they would function as one large concentrated population (Antrop, 2004). Antrop (2004) explains urbanisation as having four distinct phases. The first is urbanisation, the simple accumulation of people to a city centre. Second is suburbanisation, where this city centre grows in the amount of people, but the inner city loses people and the outskirts of the city grow as new people migrate to the edges of the city. The third is counterurbanisation or disurbanisation, where the population starts to decline due to losing people both in its centre as well as its outskirts. This may be due to several different reasons such as famine, invasion, war, etc. The fourth and final phase of urbanisation is reurbanisation, where the population recovers its loss in people from the third phase starting at the centre of the city again and then moving to the outskirts. These phases show that urbanisation is a process of gains and losses in people, but the city itself still exists as a starting and ending point. Some cities may die out due to these phases, but they may be maintained depending on how great the loss in people are.

In Denmark, the town centre was regarded as a “gateway” (Christensen & Mikkelsen, 2006). The mere presence of towns was crucial for Danish society itself (Petersen et al., 2006). Perhaps, the existence of these towns, were what enticed movement of people. Petersen and colleagues (2006:112) argue that “it was the monopoly of trade rather than size of the local population that set urban communities apart from large rural villages.” The town was an entity that not only contributed to trade and market, but provided a place where “administrative, religious, and military” acts could take place; in turn, town development involved the Crown and their ability to impose taxations on its people (Christensen & Mikkelsen, 2006). The advent of town development created power shifts within Scandinavian society. The shift in power is best described as being feudal, where the lord overlooked the individuals within the township; making towns inherently subordinate to the crown (Andrén, 1989). However, power was still strictly enforced by creation of town councils. These points show that the towns and villages across the Danish landscape were extremely important in what they brought to society and how they contributed to the economy. Therefore, many studies, including osteological analyses, make it a point to distinguish and analyse the two groups for comparisons. Currently, Denmark still reveres its rich histories in the towns and rural landscapes that have survived through centuries, making skeletal materials a profound resource of research into past Danish lives.

2.4 Bioarchaeology in Denmark

It was not until the 20th century that biological anthropology became a prominent area of research in Denmark (Christensen & Bennike, 2011). Full-scale studies of human skeletons first took place in Denmark by Hans Andreas Nielsen in the early 20th century, who focused on analyzing and cataloguing specimens that had so far been acquired from archaeological excavations in the country (Christensen & Bennike, 2011). Although he performed skeletal research and contributed greatly to the field of Danish anthropology, Nielsen was in fact an anatomist at heart. Just as in other parts of the world, especially in the U.S., biological anthropology got its start from curious anatomists that became further enamored by the skeletal system and the information it could portray. The skeletal remains that have been excavated in Denmark and its colonies reside either at the University of Copenhagen, or in Odense at the University of Southern Denmark in the ADBOU laboratory in the Institute of Forensic Medicine (Christensen & Bennike, 2011). The skeletal materials cover an enormous span of time all the way back to the Mesolithic and Neolithic eras in Denmark.

Previous research based in Denmark analysed all forms of pathological lesions seen in the skeleton. Areas of this research were largely based in age estimation methods and stature research, diet and nutrition through the use of teeth and isotopes, and ancient DNA (aDNA) studies to reconstruct population affinities (e.g., Bennike et al., 1987; Boldsen, 1997; Boldsen, 1998; Arcini, 1999). This research has helped in answering questions about Danish history and have informed bioarchaeological research in other areas of Europe. These studies have been instrumental in contributing to our knowledge about lifestyles in the past, how medieval Denmark was socially comprised, the spread of diseases in both urban and rural populations, and how people moved across the landscape at the time. Although the material spans some 10,000 years, the majority of skeletal data collected and researched stems from the medieval period (AD 1050-1600). These studies (e.g., Boldsen, 1997; Boldsen, 1998; Arcini, 1999; Boldsen, 2009; Christensen & Bennike, 2011) provide a clear trend, where the majority focuses heavily on activity, disease, and non-specific indicators of stress with heavy influence on examining these as differences between urban and rural populations (Yoder, 2006). In general, many of these studies tend to look at paleopathological methods and theories for occurrence of diseases and pathologies in the archaeological record. Early works tend to focus predominately on case studies or only on specific individuals as outliers of the larger sample. Yoder (2006) asserts that the early work of Møller-Christensen (1953) and his studies of archaeological remains helped improve the understanding of bony changes in leprosy (Hansen's disease), a major disease that can be witnessed in the past populations of Denmark. By examining the occurrence of such diseases as leprosy, researchers are able to draw conclusions about the living conditions and lifestyle of individuals at the time. Differences seen between males and females and in the young and old become the main focus of the research.

Leprosy is the most studied pathology in Denmark (Boldsen, 2001). The more recent studies that focus on leprosy tend to explore questions about its broader population distribution, hence the relationship with paleodemographic methods of analysis. The leprosy epidemic appeared in Scandinavia around AD 1300 (Boldsen, 2008). Although there is a high prevalence of leprosy in Danish samples, these individuals did not die from leprosy, but rather they died *with* leprosy (Boldsen, 2008). In other words, it is not a fatal disease, but it may create a disadvantaged lifestyle, leading individuals to become susceptible to other conditions causing death. Individuals could be infected with the disease, but could still show no physical symptoms. It has been further suggested that nearly everyone in Denmark, was likely infected with leprosy, although it seems to have occurred more so in males than in females (Boldsen & Mollerup, 2006). Boldsen (2001) uses a method to account for the differing degrees of leprosy in medieval remains from Denmark, focusing directly on the sensitivity and specificity of leprous changes. Sensitivity is defined as the probability of having the symptom if the individual had the disease and specificity is the probability of not having the symptom if the person did not have the disease (Boldsen, 2001). These probabilities help determine a statistical value for individuals with particular osteological symptoms. They prove to be informative of the "natural history" and evolution of the disease (Boldsen, 2007). Boldsen (2001) found that for symptoms of leprosy in individuals, the specificities were higher than the sensitivities in particular Danish cemeteries. This indicated that there are more individuals in the sample that did not have lesions, but could still be infected with the disease. However, those individuals would not have reached the advanced stages where the skeletal bones are affected.

Paleoepidemiology studies, focused on the spread of disease and pathologies through history, is perhaps the most challenging area in skeletal biology today. The goal of using these methods is to reconstruct not only the living conditions of individuals at the time, but to shed light on the ways in which they were able to combat pathologies (Wanek et al., 2012). The biological reactions to pathogens in different individuals are extremely variable. Consideration of this is recognised by Boldsen (2005), where he suggests that leprosy depends on the person's immune response, so it can be plausible that there are different levels of severity for the disease. Therefore, paleoepidemiology must adopt a multi-disciplinary approach by using clinical and other ethnographic data to contribute to analyses of past health (Wanek et al., 2012). Other researchers have re-evaluated their methodologies for recording pathological lesions in the skeleton. Buckley and Tayles (2003), a study of disease in the Pacific Islands, showed that by developing a new recording method for their lesions they were able to better quantify their results. Along with this, they suggested that their scoring technique was able to move away from assuming diagnosis of particular lesions, resulting in more differential diagnoses. The recording method implemented by Buckley and Tayles (2003) used macroscopic classification of the types of lesions. Those lesions were given a numerical code and determined to be osteoblastic lesions, osteoclastic lesions, or a combination of both. To calculate crude prevalence rates of the lesions, the researchers used the skeletal element (i.e., bone) and the individual as part of the denominator, rather than choosing one or the other. Methods such as these may provide a more complete picture of the disease response in the past than previously thought.

Despite its challenges and difficulties, studies of paleopathology for Danish remains have been extremely informative in exemplifying the lifestyles involved with living with diseases, such as leprosy. Examinations of cemeteries related to a leprosarium have perhaps provided the most information on the reactions of both urban and rural individuals and their treatment of others with the proposed disease. Another area that can contribute greatly to research in paleopathology is the examination of traumatic lesions in the body. Studies that examine these lesions are especially important for this thesis, as they contribute greatly to the conclusions drawn to help explain Danish lifestyles in the past.

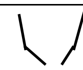
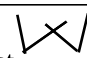
2.5 Burial Arm Positions in Medieval Denmark

The cemetery samples for this research, like all Danish cemeteries from this period, are not C-14 dated. Rather, dating comes from alternative sources, especially the historical research by the museum archaeologists. In Denmark, there is a well-established and recognized technique for establishing (though not perfectly) the period in question, based on burial position of the arms. The specific arm positions have a corresponding date range of when they appeared in cemetery burials. However, these typologies were only in use from early medieval to before the early modern era (Mollerup & Boldsen, 2010); therefore cemeteries that fall before the start of the medieval period (i.e., Bronze Age, Viking Age, etc.) and that fall after the medieval period (i.e. Modern and Industrial Ages) are not dated using this method. The earliest arm position to appear was the arms laid directly down the body on the sides (AD 1050-1250), the following position had the hands of the individual crossed over the lower pelvis (AD 1250-1350), then a transition occurred where the lower arm and hands were laid over the stomach (AD 1350-1450), ending with the lower arms and hands being crossed and laid over the chest (1450-Late 16th Century) (Jantzen et al., 1994). These arm positions are illustrated in Table 2.1 below, in association with the historical timeline. The reliability of this dating method may be questionable, but researchers have compared them to radiocarbon dates with high accuracy (i.e., Lynnerup, 1998). Research has showed that these arm positions are a Scandinavian burial trait and has even been seen in those Norse burials located in Greenland (Lynnerup, 1998; Lynnerup & Nordby, 2004). The gradual changes in the position of the arms may actually coincide with the belief or religious systems of the time period. In the early Christian period the arms started alongside the body, but gradually changed to have them over and crossed on the thorax region (Lynnerup & Nordby, 2004). This change may be due to the "perceptions of the after-life" (Lynnerup & Nordby, 2004:108). For instance the arms to the side of the body earlier on, is seen as the embracing acceptance of the after-life, whereas as time progresses a more "pious" position is made in the burials as the notion of purgatory is established (Lynnerup & Nordby, 2004). Although, position of the entire arm is important, Kieffer-Olsen (1993) notes that the hands may be most important in determining position. Speculation may suggest that they are more likely to stay more stable in their position, more so than the mobile elbow joint. Although the method is fraught with criticism more so than other contemporary methodologies, employing this criteria for burials can help place individuals in a more concise time frame for their time of death, as many cemeteries at this time were used over a span of several years.

Although well-studied, burial practices such as arm placement, were an ever-changing entity as individuals of the past showed agency. Furthermore, the process in which the body decomposes or breaks-down, can cause shifting in the original position of the body. In forensic anthropology, this phenomenon has been well studied. The rib cage is often the last portion of the body to retain any viscera but as that dries and disappears the ribs tend to flatten in many burial contexts, after the distension of the abdomen (Duday & Guillon, 2006). If hands were placed on the stomach area such as those done with the Danish burials, many of the carpals and metacarpals of the hands would be 'scattered' in the abdominal area (Duday & Guillon, 2006). Additionally the pelvic area also sees a shift. With the disappearance of the ligaments and tendons of the pelvis, the os coxae tend to fall slightly back and the sacrum moves more anterior (Duday & Guillon, 2006). These shifts in these areas of the body would likely cause movement of the hands and arms from their original positioning. Researchers suggest that forearms and hands placed here, tend to "slip toward the underlying 'neoformed' empty space" after complete desiccation (Duday & Guillon, 2006:131). Despite these conclusions, more than likely these movements are only slight and the original position should still be easily discerned.

Notwithstanding these challenges, the method is widely recognized and accepted for this region and time period. The analyses in this research employs these time periods as they were assigned to individual burials and cemeteries based on this method or as it was recorded in the anthropological site reports.

<u>Table 2.1:</u> Time periods according to the Danish historical timeline and burial arm positions as used in Danish biological anthropology and bioarchaeology studies. Burial arm positions are adapted from research by Kieffer-Olsen (1993) and Jantzen et al. (1994).

Time Period	**Date**	**Danish Arm Positions**	**Corresponding Dates**
Early Medieval	AD 1050-1300	A: Arms to the Side	AD 1050-1250
Late (High) Medieval	AD 1300-1536	B: Lower arms On the Pelvis 	AD 1250-1350
Post-Medieval	AD 1536-1660	C: Lower arms On the Stomach 	AD 1350-1450
Early Modern Period	AD 1660-1864	D: Lower arms Crossed on Chest 	AD 1450 - Late 16th Century

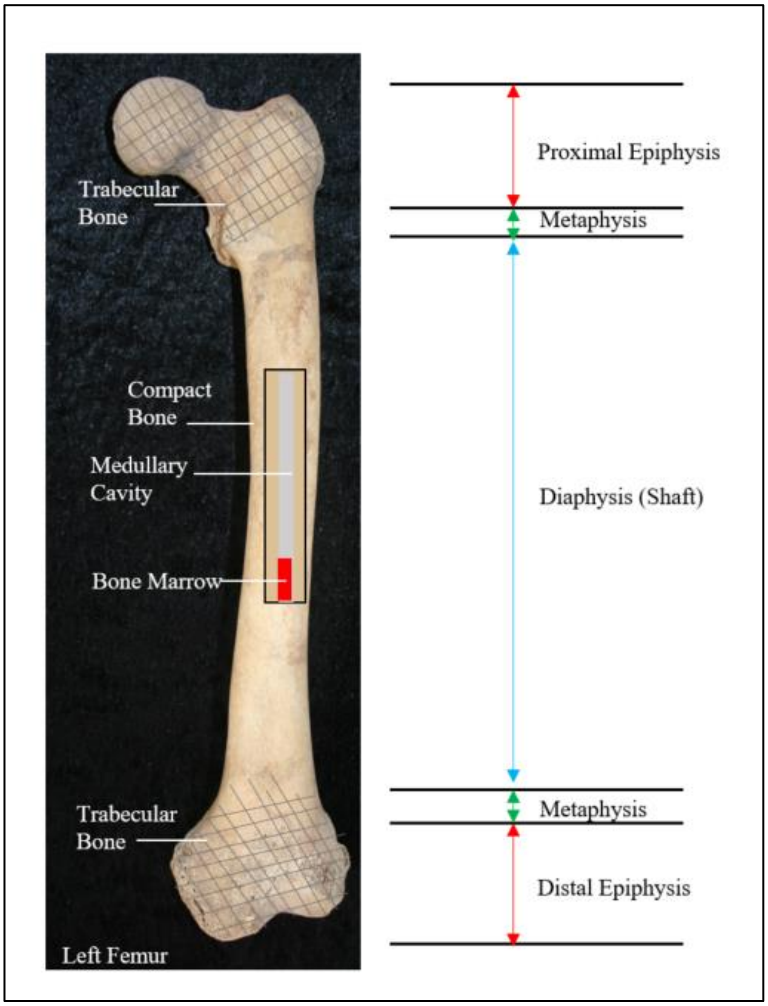
CHAPTER 3: LITERATURE REVIEW – OSTEOLOGICAL CONTEXT

3.1 Basic Bone Structure

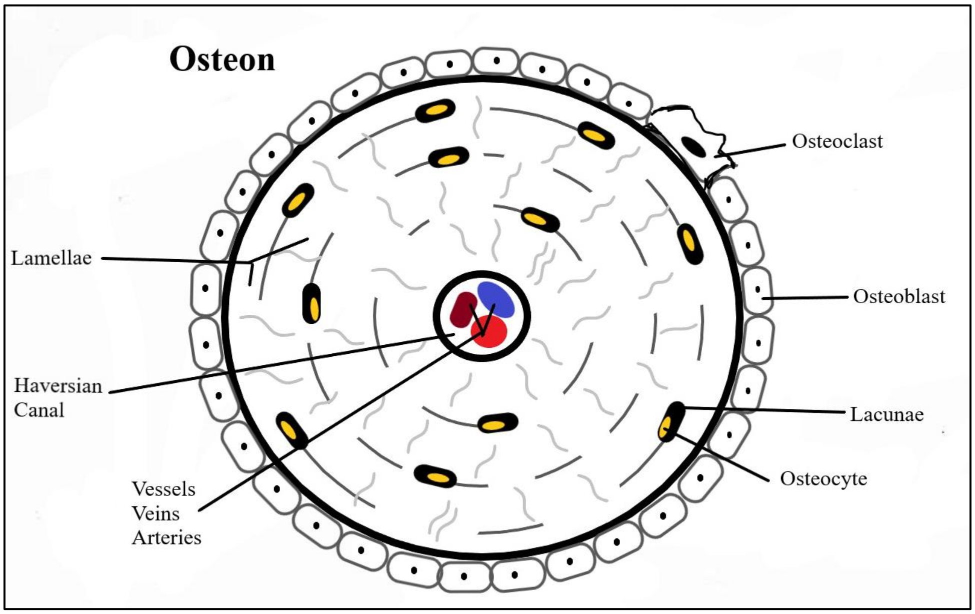
Bone protects our body's organs, provides the structural foundation for our anatomy, and helps develop red blood cells to carry oxygen essential for life; these are only a few, yet there are many amazing things bone can do for the body. Although variable among bones and particular regions of bone, the tissue is the densest and the hardest tissue in the body, next to enamel. As such, bone can survive the test of time better than other tissues; this feature provides anthropologists an important key to examining the human lives of the past. Bone is able to record life's events as if it was a snapshot of that time; it is up to anthropologists to interpret these snapshots in bone so their work can contribute to informing others of the past. Understanding bone formation patterns in the body and the details of its basic structure, mineralisation, and growth processes, is key to interpreting this record of the life in bones.

The structure of bone is unique among tissues, with stages of development and particular types of cells that perform distinct tasks and provide bone with its properties. The basic bone cells are osteoblasts, osteoclasts, and osteocytes. Osteoblasts are the cells that ultimately form bone and lay down the basic structure or template, whereas osteoclasts remove bone to allow it to change throughout the life of an individual during growth and responses to stressors (White et al., 2012). Osteocytes are mature bone cells that reside within the bone to maintain its structure (White et al., 2012). The boney matrix that houses osteocytes is extremely complex. Bone cells and the structures associated with them, ultimately create a Haversian system at the tissue level, which includes canals and canaliculi that link together, providing bone with a system to help diffuse blood and lymph cells throughout the body (White et al., 2012). All of these individual components come together to form an osteon, which are the building blocks that make up the compact portions of bones. The Haversian system and the osteon, are one in the same. Osteons contain components of lamellar rings, canaliculi, and other such structures, that are specifically arranged to provide the proper mechanical properties. For instance, the lamellar rings that surround these Haversian systems or osteons provide the basic structure and size. Both compact and trabecular bone are made up of these minute Haversian systems or osteons. Compact bone is located in the densest portion of a bone and lies predominantly in the diaphyseal region of long bones. Trabecular bone (known as cancellous or spongy bone) resides in the ends of long bones and is the least dense region of the bone; it forms a mesh-work of structures underneath the articular surfaces of the joints throughout the body. These structures discussed here can be referenced further in Figures 3.1a and 3.1b.

<u>Figure 3.1a:</u> Bone schematic of a left femur, indicating the major boney structures and portions of the bone (adapted from Marieb & Hoehn, 2006: Figures 6.3).



<u>Figure 3.1b:</u> The osteon is independent of the above schematic, and shows the major cellular portions of compact bone (adapted from Marieb & Hoehn, 2006: Figure 6.5).



At the molecular level bone tissue is formed from two key acellular portions, collagen and hydroxyapatite crystals, making bone a composite material (White et al., 2012). The osteoblasts mentioned previously, are key for proper bone formation because they lay down layers of osteoid to help support and form the boney matrix. Osteoid in particular is where much of the collagen in bone resides, along with other minor structures. After osteoid is laid down, inorganic salts or hydroxyapatite crystals are deposited within the layers of osteoid to harden and mineralise the structure. Bone possesses its mechanical properties because of the mixture of water, organic material, and minerals that are present within the bone matrix itself (Yamashita et al., 2001). Collagen makes up most of bone (90%) and is key for the body as it is an organic fibrous protein, a structure that is extremely common throughout the body. Collagen ultimately provides bone with its flexibility (McGee et al., 2004). The inorganic portion of bone is composed of hydroxyapatite crystals, simply a calcium phosphate mineral. It provides bone with its rigidity, as it interweaves itself into and around the collagen fibres to harden the tissue

(McGee et al., 2004). These portions of bone will be discussed later, as the roles they provide bone such as its rigidity and flexibility play key parts in the response of bone to stress and the initiation of fractures.

3.2 Bone Mineralisation, Growth and Repair

There are two types of bone growth: intramembranous and endochondral. Intramembranous bone growth takes place in bones such as the cranial bones, and it starts with a mesenchymal precursor and embryonic tissues that will later develop into osteoblasts building the bone up (Brickley & Ives, 2008). Endochondral bone growth, takes place in most of the bones in the body, such as the long bones. This type of growth starts with a cartilage template, forming the shape of the bone and a place where the bone cells can lay down new bone to build upon further (Brickley & Ives, 2008; White et al., 2012). These two types of growth can easily account for the shaping of the basic bone structure. The width of bone comes from the laying down of new bone and the removal of bone as the body allows for stress and movement to shape it further; a process referred to as modelling (Brickley & Ives, 2008). Appositional bone growth occurs to increase the diameter of long bones, where the combination of osteoblasts on the surface of the bone and osteoclasts on the inside, create a duel process working together. Intramembranous bone formation takes place in injuries that do not need a cartilage precursor, such as that seen in endochondral growth. Areas that commonly involve this type of repair and mineralisation is more commonly seen in the cranium and mandible (Vieira et al., 2015). In this healing process there is no development of any cartilage cells during the callus formation; rather, an immune response starts where growth factor hormones greatly influence the interaction of the osteoblasts and osteoclasts (Vieira et al., 2015). It is important to understand that both types of growth can be involved in the repair of bone, but is dependent on where the bone is in the body and the type of bone it is (i.e., long bone, irregular bone, etc.).

Remodelling is the process that targets bone that has been weakened and ultimately needs to be removed and repaired (Brickley & Ives, 2008). As the present research is focused on fractures and the failure of bone structures, the process of bone repair or remodelling is extremely important. As bone becomes damaged or weakened, either by stress or pathologically through disease, the body starts steps to repair the damage. Bone healing is usually broken down into primary and secondary consolidation processes (Cunha & Pinheiro, 2009). The primary consolidation is the setting of the bone where the broken ends meet up with one another again. Sometimes this process may need extra strengthening through splints, nails, and/or screws. Secondary consolidation is the bone mineralisation process. This particular consolidation process is broken down even further into inflammatory, reparative and remodelling phases (Cunha & Pinheiro, 2009). The first phase of inflammatory response is the development of a haematoma, which is a mass of blood that forms at the site of damage (Cunha & Pinheiro, 2009; White et al., 2012). The inflammatory response is extremely important, as it starts the activation of proinflammatory cells, essential for callus development (Marsell & Einhorn, 2011). The blood is ultimately developed from this response and is maintained in boney structures and these blood cells can potentially be damaged as well. The formation of the haematoma helps in protecting the blood cell function in bone, as it allows blood to coagulate, preventing further loss of blood (White et al., 2012). The haematoma forms on the outside of the periosteum, or the protective membrane, of the bone. The periosteum is essential in the process of bone repair as it "provides integrity through vascularisation" (Cunha & Pinheiro, 2009:252). The haematoma formation is seen as an inflammatory response, because it involves the release of growth factor hormones to aid in healing (Vieira et al., 2015). While the haematoma is being developed, other cells and osteoblasts are removing the damaged bone underneath through the other two components of secondary consolidation: reparative and remodelling phases (Cunha & Pinheiro, 2009). The reparative phase starts after around eight hours of the initial injury, where cell proliferation takes place forming a fibrous tissue called a bone callus that helps reunite the damaged bone (Mays, 2010). The soft callus starts to replace the haematoma, in which the haematoma is penetrated by fibroblasts and chondroblasts to help lay down cartilaginous tissue (Cunha & Pinheiro, 2009). Finally, the remodelling stage, is where the callus continues to form as osteoblasts lay down new bone to harden the callus further, and the osteoclasts remove bone as healing continues; resulting in a hard callus. These two types of bone cells are responsible for creating mature lamellar (compact) bone instead of the woven bone that resulted from the soft callus formation (Mays, 2010). After months (or sometimes years) of the initial injury, the callus has smoothed down and the medullary cavity has been reformed, as bone continues to be deposited in those areas where stress is usually greatest (Mays, 2010).

Primary and secondary consolidation processes are the most basic understanding of fracture repair, however, the secondary process is sometimes broken down even further as it is a complex and complicated process. Clinical researchers often see bone remodelling as two distinct processes that occur in the secondary consolidation phase: indirect and direct fracture healing. The most common process of fracture healing is the indirect process which involves the forms of growth discussed above, both endochondral and intramembranous bone healing (Marsell & Einhorn, 2011). This form of healing process is considered indirect, as it does not take medical interventions to heal. Rather the healing results from simple weight bearing and “micro-motion” movements of the injured areas (Marsell & Einhorn, 2011: 551). Through this indirect process, mesenchymal stem cells and inflammatory cells are recruited in order to start regeneration of bone. As the callus initially forms and builds up, collagen cells and growth-factor cells are activated to help with endochondral ossification. The soft cartilaginous callus is then replaced by a hard callus. The hard callus formation is important for the bone to reach its original biomechanical stability before the initial injury. This hard callus reformation is carried out by the balance of osteoclast resorption and osteoblast deposition (Marsell & Einhorn, 2011). The remodelling processes discussed above therefore, clinically fall within indirect fracture healing. Direct fracture healing on the other hand, pertains to intervention by stabilising and reducing the fracture site, often times with screws and plates (Marsell & Einhorn, 2011). Within direct fracture repairs, there are two types of healing that can occur: gap or contact healing. Contact healing involves "re-establishing mechanical continuity" by restoring the bones Haversian systems for remodelling of the lamellar bone without having to develop a periosteal callus such as that seen in the indirect healing (Marsell & Einhorn, 2011: 553). With gap healing the fracture site is filled with lamellar bone perpendicularly, which leaves the bone weak, therefore a secondary contact healing process needs to take place (Marsell & Einhorn, 2011).

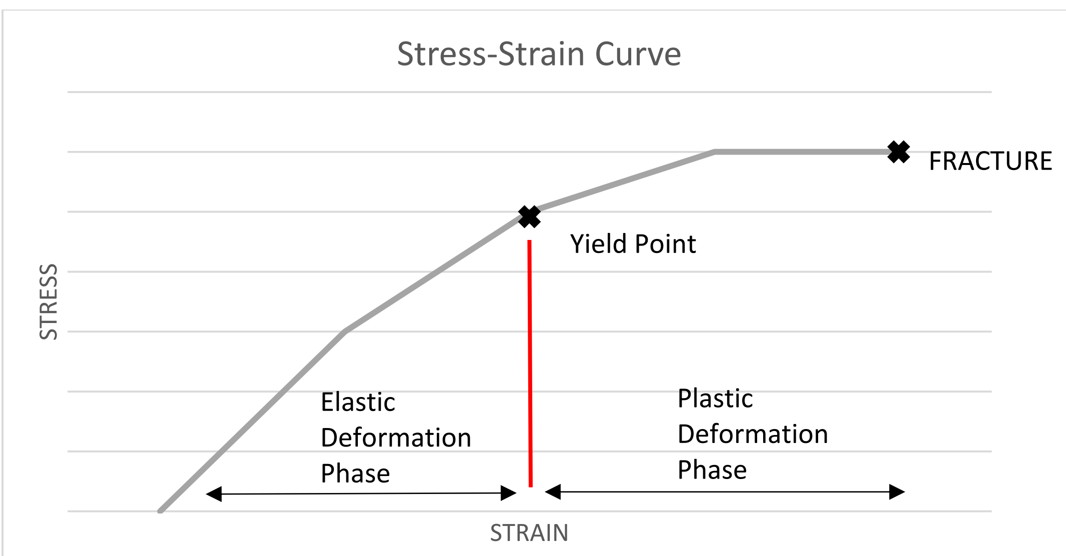
The healing process after a traumatic break or pathological loss of bone, can occur as early as three weeks and as late as 12 or 16 weeks depending on the bone that is damaged (Cunha & Pinheiro, 2009); bigger bones will take much longer to fully heal than smaller bones. However, it is not just bone size that can affect the process of healing. Other considerations may be in the levels of hormones (or growth factor) that is released at the time of injury, the initial stabilisation of the break especially if severe angulation has occurred, and healing is dependent further on the portion of the bone that was broken and the type of bone. Most of all, and that which is a major portion of this research, is the age of the individual will determine the healing process (Cunha & Pinheiro, 2009). The healing process for bony components are important to understand, as fractures sustained by individuals in the past were often well healed. The healing process will be revisited in Chapter 6.

3.3 Osteological Analyses of Trauma

3.3.1 Bone Biomechanics

The ultimate failure in bone structure is a fracture. Fractures are area specific and are dependent on the quality of bone and its make-up. As mentioned above, bone possesses mechanical properties that are area specific with respect to the structure of bone and whether that bone is compact (cortical) or cancellous (trabecular). Compact bone retains mechanical properties that relate to both strength and flexibility, which makes it susceptible to forces such as torsion, shear, and compression. The mechanical properties of bone can ultimately be accredited to the osteons located at the microscopic level. These properties distinctly present a two-fold objective; first to decrease any tensile strength for flexibility, but, at the same time, to add strength and stiffness through the lamellar rings (Johnson, 1985). When these two properties work together, they become stronger than their individual parts, providing bone, according to Johnson (1985), with its 'anisotropic' properties. When a material is anisotropic, it is able to withstand stress equally in all directions (Galloway, 1999). The term when applied to bone is in reference to its structure at both the macroscopic and microscopic levels. The way osteons and their minute structures are arranged and layered, allows for bone to withstand stress or loads from different directions. Another mechanical property that is typically discussed in relation to cortical bone is its plastic deformation, which refers to the stress-strain curve associated with the applied forces and can be seen in Figure 3.2 below (Reilly & Burstein, 1974). Within this stress-strain curve, cortical bone can only withstand so much strain before it succumbs to plastic deformation, resulting in failure and then fracture. Compact bone is weak first in tension before it succumbs to shear and compression forces, which can be associated to its mineral and collagen fibre content. The ability for compact bone to keep its rigidity is due to the minerals, particularly the hydroxyapatite crystals within the boney matrix, and its ability to still be flexible is due to the overlapping and multiple layers of collagen fibres (McGee et al., 2004). The ability for the hydroxyapatite and collagen to work together proves to be a very useful and synergistic relationship when outside forces are applied to bone. However, in some instances the mechanical properties of bone become overstressed and failure in the microstructure occurs, resulting in specific fracture patterns. Johnson (1985) speaks perfectly to this understanding of failure in fractures when fractures are described as a restricted and localized. Ultimately, it is this internal structure that will determine the characteristics or character of the fractures, resulting in failure of the structure (Micozzi, 1991).

Figure 3.2: The stress-strain curve for bone fractures, indicating where both phases of plastic and elastic deformation occur showing that as stress and strain increase, a fracture and yield point take place (adapted from Reilly & Burstein, 1974: 1010).



Skeletal trauma has been defined by many researchers, but in its most simple interpretation for bioarcheologists, trauma is any bodily injury or wound that affects the hard and soft tissues of the body. Bioarchaeologists rarely have the opportunity to deal with the soft tissues, so the focus on trauma is on lesions in and to the bony structures. There are many forms of trauma to the skeleton such as joint dislocations, cut marks (sharp force wounds), and depressions (blunt force wounds), but the most common form of trauma in the archaeological record takes the form of fractures. Fractures are a break in the continuity of bone (Lovell, 1997; Galloway, 1999) and may occur in different sizes and shapes due to differential forces and mechanisms of injury, and differences in the gross anatomical structure and the microscopic cellular architecture across the wide range of bones in the body. Due to the variability seen in fractures of the body, many researchers have developed methods that can examine and encompass the entire range of these differences.

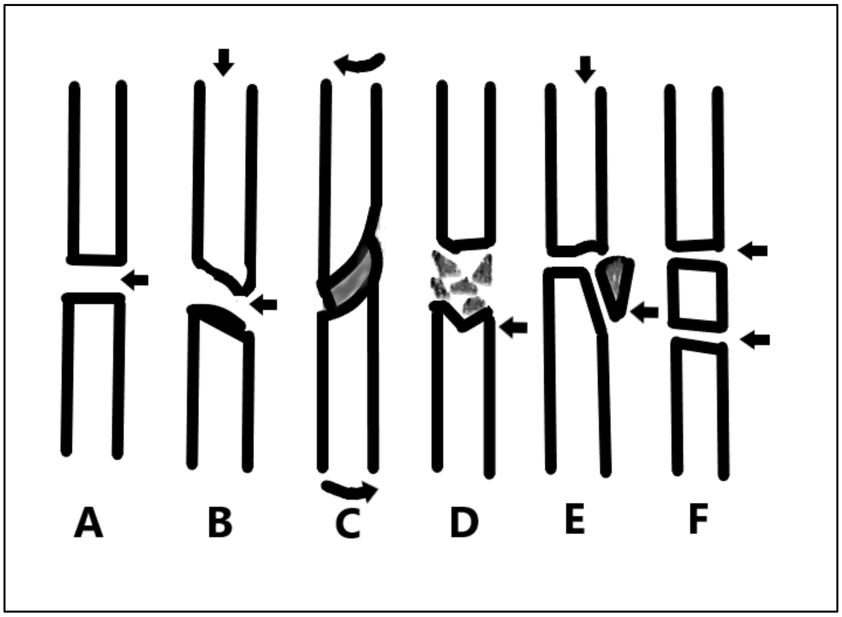
3.3.2 Early Trauma Methodologies

Research on fractures in bioarchaeology specifically, was pursued because there was little knowledge as to how bone acted as a material and how that material responded to different external forces. In other words, bones could possess their own 'life history', which could ultimately influence the entire skeletal assemblage they were a part of (Johnson, 1985). Smith and Wood-Jones (1910) were pioneers in trauma analysis in biological anthropology; however, their focus came from a more clinical standpoint. Early biological anthropology methods focused on general terms and characteristics that best described the lesion seen within skeletal materials, taking on a more clinical or descriptive approach. These early studies tended to focus on describing the materials in front of them, rather than completing a full analysis of the remains (e.g., Smith & Wood-Jones, 1910). Angel (1974) and Lovejoy and Heiple (1981) are some of the earliest forms of bioarchaeological methods in trauma analyses, a speciality within biological anthropology. Their analyses were the start of a less clinical approach at looking at trauma in the past. Rather than being purely descriptive (clinical), these studies focused on changes through time (archaeological) in the lesions and the people that were affected by them, resulting in a more population level analysis. Angel (1974) looked at trauma as it progressed through time in different ancient samples from Greece, which, he then to more modern samples. Lovejoy and Heiple (1981) examined differential age patterns in fractures in the Late Woodland Libben site (located in what is now modern day Ohio; dated 8^{th}-11^{th} Century AD). Their use of graphs in representing years at risk for fractures was vital. These graphs helped determine the age of risk and susceptibility of traumatic episodes throughout the specific individual's life that were present in the sample. The biggest contribution to come from this study was the understanding that rather than being purely descriptive with the analysis; they needed to quantify their results to better understand the differences seen between age groups. These two studies were essential in establishing protocols for later methods in trauma analysis for archaeological remains.

Grauer and Roberts (1996) and Lovell (1997) are great examples of the broader adoption of population approaches. In their study of individuals from the St. Helen-on-the-Walls of York, Grauer and Roberts (1996) focused on preservation issues and fractures and how to best interpret patterns at the population level. Many issues that bioarchaeologists face when determining patterns of trauma stem from a lack of information or context. Determining causes behind the traumatic lesions proves to be more problematic when remains are incomplete due to preservation, damaged by taphonomic processes, the lesions are well-healed, and the ages of individuals are inaccurately estimated (Grauer & Roberts, 1996). It was Grauer and Roberts (1996) that spurred others to conclude that the choice of our methods in looking at trauma must be based on the integrity or preservation of the bones we are studying (Judd, 2002a). The paleopathological study done by Lovell (1997) is considered pivotal for its classification and interpretive protocols. Lovell (1997) suggests that we must be able to identify the skeletal elements involved in the injury as well as the location, appearance, and complications associated with them. It is the Lovell system that many researchers use today to classify and interpret trauma patterns. The method proposed by Lovell suggests that injuries must be sorted due to their characterisation (fracture or dislocation) without haste to assign cause or intent first (e.g., "parry"), which can ultimately bias the analysis. Characterisation of the traumatic lesions involves, first, deciphering direct and indirect trauma as the manner of injury. Direct trauma is classified as a more localized injury, where fractures occur at the site of impact (Galloway, 1999). Indirect trauma is classified as an injury that occurs away from the site of impact and tends to occur when there are compressive forces involved, such as those typically seen in the femoral shafts (Galloway, 1999). This is the first step in establishing and deciphering the "fracture description protocol" where you examine the type of fracture first and then identify manner of the injury (Lovell, 1997). Most importantly, describing the shape, type, location, and healing status of the fracture gives a more concise interpretation of the individual; something that many previous protocols have lacked in trauma analysis.

When comparing methodologies used in trauma analysis, there is a distinct difference between what researchers may consider classification and what is considered interpretation. Classification protocols are numerous in number and most of them are taken from medical or clinical contexts. Early classifications of trauma followed three major groups: fractures caused by injury, stress fractures, and pathological fractures (Hamblen & Simpson, 2007). Fractures that are caused by injury form the largest group and are caused by direct or indirect forces to the bony material. Stress fractures occur due to repeated stress to a bone causing it to eventually become fatigued, resulting in structure failure (Bennell et al., 1999). Pathological fractures are breaks that come secondary to an already present pathological condition, such as those seen in osteoporosis. Within these three major groups there are resulting patterns of fractures: transverse, oblique, spiral, comminuted, compression, “greenstick”, and impacted (Galloway, 1999; Lascombes & Metaizeau, 2010). Transverse fractures occur when a bone fails in tensile strength. They can further be described as occurring perpendicular to the long axis of a long bone, resulting in a right-angled fracture. Different transverse fractures appear due to different loads in the affected areas. However, the typical transverse fracture occurs when direct force is applied to a small area of the bone. The force causes the tensile strength to fail on a transverse plane (McGee et al., 2004). Spiral fractures are a result of torsion that causes failure due to both shear and tension forces. The direction of the torsional forces will cause the bone to fracture at a 45^0 angle, or an oblique angle, to the shaft of the long bone and can result in curved edges. Butterfly fractures are composed of a combination of forces that are applied to bone typically including, but not limited to, both tension and compression forces. The compressive force causes a transverse fracture to appear, which then diminishes at the concave portion of the force, resulting in a butterfly flake. Butterfly fractures are found in many forensic contexts and can be associated with several types of trauma aetiologies, because in many instances there is more than one type of force that is applied to one bone at a time. Butterfly fractures are extremely interesting in that they respond to both tension and compression forces, resulting in an angled piece of bone that can appear concave on one side and convex on the opposite side, all depending on the direction the force is applied. Examples of these types of fractures can be seen in Figure 3.3.

<u>Figure 3.3:</u> A drawing of the types of fracture classifications used in trauma research [(A) Transverse B) Oblique C) Spiral D) Comminuted E) Butterfly F) Segmental]. The black arrows show the direction of the forces and likely impact areas (adapted from Galloway, 1999; Wedel & Galloway, 2014).



Direct and indirect trauma classification will result from the direction of force applied to the bone and how the fracture lines react to the high and low velocities produced by that force (Djuric et al., 2006). Another classification system that is used in bioarchaeology is the LARA method, proposed by Lovell (1997). This method is used specifically to describe long bone fractures because they are so common in the archaeological record. The acronym LARA stands for length, apposition, rotation, and angulation. Length in long bones is important for deciphering whether or not a break has occurred. Typically, malalignment and shortening of the bone can occur when fractured long bones are not set correctly or the healing process is interrupted. The recording for length must be distinguished between normal, extended, or shortened and this must be compared to its counterpart if at all possible (Lovell, 1997). Apposition is a shift in the fragments of the fracture and is recorded as medial, lateral, posterior, or anterior shifts. This portion of the method can only be seen clearly with radiography.

Rotation is when the distal fragment of the long bone has turned in a different direction from the proximal portion and is described as internally or externally rotated. Finally, angulation is measured in degrees and occurs when the distal fragment has been displaced from the midline of the proximal portion and is described as varus (medially) or valgus (laterally). Researchers Neri and Lencellotti (2004) show that using the LARA method can help determine if the fractures were caused by direct or indirect trauma, whether malalignment led to locomotion difficulties, and whether muscle attachment sites differ due to these changes. Individuals that will survive traumatic events may have everlasting effects to their bodily movement, which can cause different interpretations for researchers that are looking at activity patterns.

3.3.3 Fracture Frequencies, Categorisations and Preservation

In an attempt to quantify fractures from bioarchaeological studies researchers have implemented fracture frequencies by bone, using the bone only in the calculations if it was complete and age was heavily controlled for (e.g., Lovejoy & Heiple, 1981; Alvrus 1999; Judd, 2004). Fracture frequencies by bone are what researchers now refer to as the True Prevalence Rate (TPR) for fractures in a population. However, more current methods have expanded on this by considering the Crude Prevalence Rate (CPR) (i.e., Glencross, 2002). The CPR can be considered a more detailed fracture analysis in a population, as it refines or sub-divides what is being observed. It is a refinement, as rather than reporting raw data of how many fractures occurred, we create a numerator and denominator to get a better prevalence frequency. Raw numbers do not tell us much, especially when different populations will have a variable make-up. In addition to the CPR, researchers became more focused on including not just the element, but the placement of fracture, the stage of healing, and the presence of complications such as infections or malignment. A TPR frequency is considered to be the ‘individual count’ which will be seen throughout the paper. This count is the number of individuals with fractures divided by the number of individuals in the sample (Judd, 2002a). This is a 'true' count as consideration of multiple fractures in one individual or where in the body the fracture occurred, is taken into account. A more precise frequency, actually taking these into consideration is the "individual mean trauma count", where the number of fractures observed (regardless if they are in the same individual) are divided by the number of individuals in the sample (Judd, 2002a). The use of fracture frequencies became a more concise way to quantify the lesions that affected the population and the individuals that made up that population. This population-level form, said to represent an ideal analysis, was encouraged by the 'New Physical Anthropology' by Sherwood Washburn (1951). Washburn's 'New Physical Anthropology' (1951) encouraged, the researchers in the field of physical anthropology, to move away from descriptive case studies and towards a better understanding of populations as a whole (Friedl, 2011). This shift embraced the fact that the interactions between biology and environment could be evidenced in the skeleton.

More current studies go beyond patterning and describing trauma lesions and try to adopt a biocultural understanding of the past environment and what contributing factors caused the trauma. This biocultural method of interpretation was first presented by Grauer and Roberts (1996) and has been well-received. In addition to a biocultural theoretical approach, the methodologies in use today continue to quantify fractures for a population; however, the quantification is done differently depending on the preservation or taphonomic condition of the bone. Taphonomy is considered any process that occurs after the death of that individual and how the bones change after death. For instance, taphonomic conditions would include all things occurring during burial and whether the bone was exposed to specific soil conditions during that time after death. One such method is the segment count method, which is good for studies that need to quantify fractures at a population level (White, 1992). Segment counts only consider the portions of the bone that the fracture occurred in, such as the proximal, middle, and distal divisions of the long bone. For these segments to be counted towards the fracture frequencies, 75% or more of that segment needs to be present (Buikstra & Ubelaker, 1994). Individual counts (i.e., CPR) of fractures show the number of people that were "afflicted" with a particular type of fracture as a proportion of the larger sample (Judd, 2002a). The bone-count method (i.e., TPR) uses only those bones that are fully complete and that possess fractures; thus, resulting frequencies should only represent each bony element (Judd, 2002a). As a result of her 2002 study, Judd suggests that the segment count is more informative in that it will enhance our understanding of how the fracture was sustained and how we can determine injury "context and prevalence." The study further built on how variation in preservation can complicate whether a bone is included or not in the calculation of the TPR. Other researchers agree with this form of fracture quantification because there is more detail in characterizing the mechanism and manner of injury when each individual segment is considered as a single entity (Roberts, 2000). Although not all three of these methods are without their short-falls, the bone and individual counts are better for interpretations of a biocultural nature. These counts are more encompassing of the entire population as they include even poorly preserved materials. A summary of these methods can be seen in the table below.

<u>Table 3.1:</u> Table showing a compilation of all of the trauma frequency methods studied by Judd (2002a). These frequency methods are not a complete list of available methods, but show those that were most commonly used in early trauma research.

Authors	Subject Tested	Methods	Conclusions
Lovejoy & Heiple (1981)	Include complete bones/exclude fragments	"Bone Count Method" – each whole bone became a % of total number of bones observed	Underestimates fracture frequencies
White (1992)	Bone preservation based on zooarch methods	"Segment Count" – proximal, middle, and distal segments need to be 50% present to be counted towards frequencies	NISP – number of identified specimens of the elements present (bone count), the MNI, and the survival value of the element portions
Melbye & Fairgrieve (1994)	Fragments of bones	"Neighbor Clusters" - Fragments made up whole bones	Trauma was expressed as the occurrence of trauma per identifiable boney element
Robb (1994)	Skeletal inventory by the Paleopathology Association	"Segment Count" – proximal/middle, middle, distal/lateral for shafts; proximal/middle and distal/lateral for epiphyses. 50% of segment needs to be present	Excluded epiphyses in the end. Also excluded depression (impaction) and avulsion fractures
Walker (1997)	Looked at partial remains of the cranial vault by recording fragments as "partial" individuals	"Effective Number of Individuals" – Sum of the scores	Fracture frequency for cranial vault was calculated as a percentage of fractures per effective number of individuals
Lovell (1997)	Trauma in long bones	LARA – Length, Apposition, Rotation, and Angulation	More detailed recordings looking not just at the fracture

			but the resulting effects on the whole bone provides more information than just fracture frequencies
Müller et al. (1990)	Articular segments of bones are included in the frequencies	"System of Squares" – Articular segments (epiphysis and metaphysis) are delimited by a square whose sides are the same length	Subdivisions of proximal, middle, and distal thirds. Incomplete bones still an issue
Judd (2002a) (study of all methods, excluding Lovell)	Healed fractures	Divided bones into 75% segments; used radiographs to account for healed fractures	Bone Count - # of lesions observed per total # of bones Individual Mean Trauma Count - # of fractures observed per # of individuals in sample Mean Multiple Injury Count - # of fractures per # of injured individuals Individual Count - # of individuals with one or more injuries per # of individuals in sample

Judd (2002a)

Segment Count Freq. = (segments w/ fractures ÷ segments observed) X 100%

Survival Index (amount of bone available for observation)

= # of segments observed ÷ # of segments expected

Judd (2002a) Further Conclusions =

- Segment Count does not enhance fracture recording – but good way to assess preservation
- Segment Counts are for bones poorly preserved and helps with locational distribution of injuries and helps with seeing population frequencies of trauma
- Individual and Bone Counts are for more sociocultural interpretations and make it more comparable to other findings
- The best method seems to be Mean Multiple Injury Counts which includes all fractured data to be accounted for including fragments to some extent. Allows for bones to be fragmented, with up to 20% of the bone present for examination.

- Mean number of fractures allows for prevalence of injury to be distributed over the entire population and can help with seeing injury potential in different groups compared to others.

Jurmain (1999) describes traumatic skeletal lesions as easily observed, extremely prevalent, but the "most dramatic" skeletal change we may see in the archaeological record. The only portion of information that cannot be easily interpreted is the direct cause of injury. Certain fractures may tend to show directionality of the force applied, but the instrument of applying that force can only be assumed at best. Although the healing process has distinct phases, there is no way to determine when the trauma occurred. A callus may be present for years or months; there is no way to tell since there are so many variable circumstances that can affect the healing process in an individual. However, again, a distinction must be made between classification and interpretation. Researchers tend to classify the type or kind of fracture, but how is that further interpreted? This is an important component revisited throughout this research and must always be considered.

As will be evidenced in later chapters, specific types of fractures show evidence of particular behaviours. A classified fracture may tell us how the person got that injury; whether it was from something they were doing or if someone else may have caused them that injury. Such conclusions in bioarchaeology are made more difficult by the fact that we are studying a population that is long gone. Therefore the interpretations of these injuries can only be seen as speculation. Where researchers can bridge this gap is the inclusion of well documented populations that have historical accounts to accompany the observations made in the skeletal population as is done in historical bioarchaeology (i.e., Perry, 2007; Fulminante, 2016). Fulminante (2016) examined the occurrence of breastfeeding through historical accounts and compared that to data gathered from skeletal populations through isotopic studies. Despite information gaps in the literary sources for the Bronze and Iron Ages, the study found interesting patterns. Literary resources are inherently biased, as they came from only one point of view in the population, mostly those of the higher elite portions of society (Fulminante, 2016). The bioarcheaological data from the isotopes, also had issues of representing portions of the population. However, the pro of comparing the two types of data, is that bioarchaeology may provide better age ranges that help enhance the literary sources (Fulminante, 2016). The study by Perry (2007), compared historical texts and their applicability to bioarchaeological studies and vice versa, from the Classical Near East. Perry (2007) asserted that bioarchaeologists take into account literary sources, but believe them to be absolute truth. However, when the skeletal data is interpreted, it painted a much different picture of the so-called 'barbaric' population (Perry, 2007). The studied populations actually were found to have similar levels of health when trauma and non-specific health indicators were examined. Leaving researchers to conclude, that despite having severe social disparities as referenced in the literary accounts, the skeletons did not support this and showed no major changes between the populations (Perry, 2007).

As bioarchaeologists study past populations, consideration of binary categories (e.g., male/female, young/old, etc.) sets the basis for many of these studies. Although not bioarchaeological in nature, Buhr and Cooke's (1959) study on the Radcliffe Infirmary in England, focused on injuries by age and sex in their patients from 1938 to 1957. The sample was biased with more females being represented than males, but they were able to still glean particular patterns, fracture types, and differential risk factors for the injuries. The types of fractures were categorised by Buhr and Cooke (1959) based on their observations of who was affected and these fell within four distinct categories. The first type is Type L, where fractures appear in young individuals, but decline as the individuals get older. This type of fracture is common in both males and females. The second type is Type A, which are categorized as fractures that become age-related. The fractures appear most in middle-aged adults and males are predominantly the ones affected. The third type is Type J, where young individuals are injured less, but as they get older they acquire more fractures. This type was seen to occur only in the young if violence was involved and in this case males were affected more. Those fractures that occurred in the much older individuals on the other hand were predominately by females. The last type is the Composite Type, where there are two forms possible. One form is the "double-peak" with fractures accumulating in the young and old. The other form exhibits an "L" pattern in males and a "J" pattern in females (Buhr & Cooke, 1959). In all of the types, Buhr and Cooke (1959) assumed the manner and causes of injury. The fractures that often appeared in youth were activity-related such as running, playing, etc. however, more severe injuries tended to be a result of violence. Fractures seen in the older adults occurred often as a result of a fall. It was concluded that they became more susceptible to these low-impact injuries due to age-related bone loss and the increased 'brittleness' of bone (Buhr & Cooke, 1959). This clinical examination of a large population of individuals provided key patterns and interpretations that ultimately can aid in understanding bioarchaeological evidence of trauma in past populations.

3.4 General Trends in Trauma Analyses

Patterns of trauma at the individual and population level not only help with behavioural reconstruction, but assist with illustrating temporal shifts and cross-cultural comparisons (Alvrus, 1999). Culturally specific patterns of injuries within and between populations allow researchers to make these comparisons. Therefore, consideration of the cultural context is most useful for population level trauma analyses (Brickley & Smith, 2006). Patterns in populations can help reveal information about the people and their behaviours. Interpretation of these patterns, however, needs direct evidence, which can be provided by traumatic lesions and other defects in the skeletal body. This direct evidence makes 'behavioural reconstruction' all that more possible and identifiable (Boyd, 1996). The following studies mentioned below show that variation of fractures may occur cross-culturally, but they may be different *within* one culture.

3.4.1 Violent vs. Accidental Injury Patterns

A question that many researchers intend to answer by examining patterns of trauma in past populations is whether evidence of trauma was violent or non-violent. Although, violence can suggest intent in behaviour, it is not easily reconstructed by bioarchaeologists (Jurmain, 1999). In fact, it is nearly impossible to determine with absolute certainty whether an injury was due to violence or an accident. Violence can exhibit "motivation and culturally defined meaning" and is often "socially sanctioned and organised" (Martin & Harrod, 2015:116). Unfortunately, each population may experience violence at some point in time, making violence-related lesions common in skeletal samples (Brickley & Smith, 2006). However, distinct patterns have been examined and may to some extent, tell us whether the victims of trauma were subjected to deliberate violence (e.g., "parry fractures" and cranial blunt force) or an accidental incident (e.g., distal forearm breaks, "Colles' fractures"). Researchers must keep in mind that interpretations of these patterns of injury can only be assumed, unless supported by accurate historical evidence.

Examples of patterns of violence can be seen in areas of warfare, massacres, and other, more specific, ritualistic behaviours. The Crow Creek Massacre provides an example of trauma patterns that describe one specific event that occurred in a very short period of time (Jurmain, 1999). Sites such as this are important for bioarchaeological interpretations because they act as a ‘snapshot’ of the population that was living at the time, in one specific area, where numerous deaths occurred all at once. Jurmain (1999) found that massacres specifically include individuals who are vulnerable, such as the elderly, and the traumatic lesions can range from specific cut marks near specific areas of the body (e.g., scalping), to fractures due to blunt forces. However, this ‘snapshot’ does not provide an accurate representation of female and child remains because they are more likely to become captives, while those that are typically killed are adult males (Larsen, 1997). Massacre events are often associated to a mass-grave (although not all mass-graves are massacres) with individual portions of individuals spread throughout a site, and with similar demographics (Boucherie et al. 2017; De Vore et al., 2018). Additionally, “massacre” is not well defined in bioarchaeology, nor are there set criteria as to what constitutes a site as a massacre event, beyond that of using simple mass grave construction and minimum number of individual (MNI) counts (De Vore et al., 2018). As with other instances of “violent trauma”, massacre sites need to be further supported by historical evidence that supports our understanding of “political/cultural community, secondary affiliations, and potential temporary groupings that reinforce/support daily social life” (De Vore et al., 2018:17). Bioarchaeologists tend to interpret intentional violence when trauma is concentrated in the cranial and facial regions, the torso or ribs, and the individual possesses several different injuries throughout the body (Larsen, 1997). Although these specific areas are more common for instances of violence in the archaeological record, these areas of the body can also be injured by accidental means, making interpretations very difficult. However, some researchers still believe there is a possibility of discerning violent trauma from accidental trauma. The first step is looking at the timing of the trauma (i.e., perimortem vs. antemortem) and secondly determining the pattern and the extent of the injuries with any supporting evidence (Spencer, 2012). The first step is fraught with problems as, even currently, there are no clear definitions or consistent applications of perimortem trauma. Some researchers believe these are injuries that possess specific characteristics that are distinct, and for which the presence of these characteristics define the perimortem trauma rather than the precise timing of the fracture (Sorg & Haglund, 2002). Others have expressed that despite seeing characteristics of perimortem fracturing, these can still occur well outside the time of death and beyond suggesting that characteristics are not as clear-cut nor as predictable as researchers have suggested (Ubelaker & Adams, 1995). Determining the manner of trauma is extremely difficult for bioarchaeology as witnesses to the event are long gone and there is no context of a 'crime scene', or the weapon is not present in the burial context (Spencer, 2012). Although it is impossible to exact the cause of an injury from past populations, evidence may be present that can suggest manner of trauma by taking into account injury pattern, injury extent, cemetery context, and overall burial positioning and context (Spencer, 2012).

The following patterns are examples that can exist in the bioarchaeological record. For instance, males and females can both be victims and participants of violence. As a result, the researcher will need to closely examine the affected age and sex of the individuals. Further, mechanisms of injury may be hypothesised due to the areas of the body affected, such as when the hands are involved in moments of assault. Most importantly, wounds are non-random because violence and other such conflicts are not seen as random events (Larsen, 1997; Judd, 2004). Violent acts tend to (to some extent), be more premeditated, and can therefore, not be random. The only point in history in which this assumption does not hold, is unplanned events in warfare and massacres. To fully reconstruct behaviours of the past, Walker (2001) suggests taking a two-stage approach. The first stage is determining the biomechanics of the injury and the second stage is determining the cultural context to help determine the manner of injury. This second stage is difficult, but researchers must consider the injury from the population level and use a multi-disciplinary approach to help provide context.

3.4.2 Population Patterns

Population level studies in trauma patterns can help represent the degree of physical stress in a population, the different exposure of age groups and sexes to traumatic events, any divisions in labour, the quality of life for individuals or the entire population, and the kinds of activities that were performed within that society (Lessa, 2011). For example, trauma as a result of violence can occur due to differing subsistence patterns. Threats of famine and drought can cause tempers to flare and increase warring with neighbouring communities over the fight for resources (Scott & Buckley, 2010). Climatic changes are important for deciphering patterns of violence and injuries, so taking a multi-disciplinary approach can help place the trauma within a larger holistic context. The outbreak of violence, due to some form of climatic instability, is a very common cause for many violent interactions of the past (Walker, 2001). However, this relationship between climate and violence is more complex than previously demonstrated. A shortage in resources is not just one culprit of subsistence-patterned violence; rather the damage to resources over time will cause a "disconnect between the people and their surrounding environment" (Harrod & Martin, 2014:4). From this disconnect, the thought of future hardships and the impending danger of subsistence deterioration led individuals, communities, and populations to increased violence (Harrod & Martin, 2014).

An important portion of the population pattern involves considering secular and socioeconomic differences in instances of trauma. Injury recidivism is one such case where differences in trauma can occur between social classes. However, for most individuals of the past, only occasionally did people actually suffer from multiple injuries; if multiple injuries do occur, researchers must take into consideration additional causes of injuries (Judd, 2004). The concept of recidivism, is based on individuals that become repeated victims of trauma and they may have a long history of injuries, which is indicated by multiple antemortem fractures throughout the body (Kuckelman et al., 2002). Victims of repeated trauma are typically young males from the impoverished portions of society, including ethnic minorities (Judd, 2002b). The presence of violence in repeatedly injured individuals may reveal more information about age-related activities in the population, indicating social and political motivations at the time (Judd, 2002b). Studies unfortunately do not always show such differences between social classes, possibly suggesting different underlying causes. Modern clinical studies also confirm that injury recidivism is most typical for males of low socioeconomic status, with a mean age of 26 years, who on average would suffer a fracture or injury within a few years of the first (Reiner et al., 1990). In addition, more recent clinical literature on injury recidivists have looked specifically at gender differentiation and an individuals' exposure to repeated trauma in different cultural environments (Rogers et al., 2014; Alghnam et al., 2016). Rogers and colleagues (2014) looked at contemporary hospital admissions. They did not find a significant difference between genders, however the recidivists tended to have a greater amount of time in hospital on average and were predominantly elderly (>65 years old). These individuals with multiple injuries pertained to falls, but also violent injuries such as car accidents and the like. In addition to these patterns, recidivism was reported more often in individuals from urban communities (Rogers et al., 2014). An additional contemporary clinical study of recidivism was performed by Alghnam and colleagues (2016:2) using the Medical Expenditure Panel Survey, where they argued that recidivists pose a "significant burden on population health." This study found that over a time period of 2 years, there were 44% of injury recidivists for this sample. Compared with those of only single injuries, these patients were more likely to be white, single, urban dwellers, with higher chronic illness conditions such as diabetes. Therefore they found that region, level of urbanisation, race/ethnicity, and even marital status were factors that heavily contributed to injury recidivism in this population (Alghnam et al., 2016). A significant challenge with injury recidivism in bioarchaeology is determining separate episodes of trauma (Judd, 2002b). Levels of healing in antemortem fractures is still being explored by researchers today, but it is still near impossible to decipher exact timing of when these events occurred, therefore making it difficult to determine if a person with multiple injuries is injured due to one event or multiple events over a period of time (Judd, 2002b; Mant, 2019). In the study done by Brickley and Smith (2006), they found that metacarpal fractures and cranial fractures (as a suggestion of violence), did not show differences between social classes. In another study, Brickley (2006) had indicated that the distribution of rib fractures in individuals (another indication of violent behaviour) can shed light on social class and occupations. From both studies, the researchers suggest that if there is a lack of such traumatic evidence then social divisions may not have been as strict as expected or that social classes behaved more similarly to one another. A recent study by Mant (2019), gathered historical information from skeletal assemblages that had been excavated from eighteenth century London (UK). From these excavation records, she observed that males were more likely to have been injured multiple times compared to their female counterparts. However, the age at which these individuals were injured, 36-45 years, does not correspond with the clinical definition of recidivism (Mant, 2019).

3.4.3 Location Patterns: Urban vs. Rural

Interpretation of the location patterns of individuals with trauma lesions are indicated in studies looking at urban and rural communities. The theories behind the cause of these patterns have been previously covered, specifically for Denmark (e.g., Boldsen, 1998; Bennike, 2008; Nielson, 2011; Fibiger et al., 2013). However, the specific interpretations of these patterns are informative. The following literature provides information as to the differences seen in other countries during the medieval period and act as proxies for the Danish samples. Studies showed that there were higher fracture rates in females in rural areas compared to the females in their urban counterparts, as discovered in a medieval sample from Italy (Boccone et al., 2011). Past populations show that, due to agricultural activities in the rural villages, traumatic lesions appeared in the upper arms and torso. Males and females were equally affected by trauma due to both taking part in the agricultural activities. However, causes of the fractures to different skeletal elements suggested different levels or degrees in such activities. Where females tended to show more forearm fractures, males showed fractures throughout the body in a study from England (Judd & Roberts, 1999). The English population also showed that females incurred most of their injuries in the home environment and exhibited fractures associated with falls. Males had more varied elements affected due to their encounter with more labourious activities working with heavy equipment such as plows and dealing with large livestock (Andersen et al., 2016). Furthermore, adult males over the age of 25 typically did most of the heavy farming and other agricultural activities and younger males were trained in simple crafts, but both were exposed to similar risks from the terrain and encounters with livestock, which is further supported in a medieval Serbian sample (Djuric et al., 2010). Agriculture is in fact considered one of the top most dangerous occupations in most societies (Judd & Roberts, 1999), which is seen consistently in the literature. This is especially true when modern technological advances are seen in agricultural communities today.

Urban centres in the past showed markedly different patterns in traumatic lesions when examined in the archeological record. The social environments in urban populations see more increases of lethal and non-lethal trauma because they are political trade centres, where specific economic and social stresses may arise (Alvrus, 1999). Demographic patterns, as a result, show that trauma in urban centres should peak in middle aged adults, whereas rural villages show distribution in young and older aged groups (Judd, 2002b). Although urban lifestyles can present their own dangers, past urban societies have been characterised as 'relatively sedentary' and, due to this kind of lifestyle, are 'leptosomatic', where they are slight and slender in body (Olivier & Bressac, 1980). This statement would leave researchers to interpret urban dwellers as less likely to incur injuries that were related to a more hardened and laborious lifestyle, such as that of the rural villagers.

For modern urban populations, traumatic conditions are the result of day to day living situations, such as traffic accidents and violence, where rural trauma arises predominantly from livestock encounters (Batista et al, 2012). The trends seen for modern populations show that facial fractures are more common in urban areas and the lowest level of trauma is in females that come from rural households (Batista et al., 2012). Modern rural areas tend to see work associated with heavy machinery, mining activities, and the use of large livestock all contribute to the dangerous nature of rural regions (Peek-Asa et al., 2004).

3.5 Trauma in Aging Individuals

Everyone is subject to aging (senescence) with the progression of time. This natural process is universal in the biological sense. As people age, the cells, hormones, bones, etc. in their bodies, go through specific biological changes resulting in degradation of these structures with advancing time. Although important biologically, aging can be seen in a more social or behavioural context. As biological systems become compromised individuals in different age groups will act according to their abilities. For instance, the elderly may be more susceptible to falls as their mobility and eyesight worsen with age. Within this section, these patterns will be revisited, as related to the skeletal aging process and quality of bone structure through life.

3.5.1 Aging Processes and Bone Loss

A major biological component of senescence with respect to the skeleton is age-related bone loss. Parfitt (2003:12) describes age-related bone loss as being "a near universal characteristic of the human species." Although everyone is ultimately affected, there still appear to be differences between individuals and groups of people in their rates of bone loss and the areas of the body that are most affected. Both of these are influenced further by not only age, but sex, environment, and secular trends.

The bone loss process involves the loss of bone mass. Bone growth and development ultimately contributes to an individual's peak bone mass (Riggs, 1991). Bone mass is dependent on the bones' size and density (Schoenau & Fricke, 2008). The bone mineral content refers to the bones' volume, not its actual size (Schoenau & Fricke, 2008). It is the hope that by adolescence and young adulthood, individuals have reached their peak bone mass (Farr & Khosla, 2015). The bone mass they acquire in childhood and adolescence could ultimately determine their risk of fracture in old age. Once bone has become fully fused and fully grown, meaning there is no longer a growth plate present, the individual will maintain their boney structure through activity and biomechanics. It is through these processes that bone cells are continuously laid down to add to the developed structure. As appositional growth, or increase in bone width continues to occur throughout adulthood, cortical thickness increases with age (Mays et al., 2009). Although this is true and activity is responsible for much of the bone growth that occurs in adulthood, there is a point in each person's life when the deposition process transitions into resorption. Bone then starts to decrease in its density and mass.

The two types of bone present in the human body (trabecular and cortical) both provide bone with its strength. However, it is trabecular bone that is most susceptible to bone loss due to aging processes (Ryan & Shaw, 2015). As mentioned previously, trabecular bone resides at the ends of bones and the joint surfaces. Trabecular bone is therefore, more generally in the joints because it is more 'metabolically active' and covers more surface area because of the thin 'struts' that make up its structure (Riggs, 1991; Ryan & Shaw, 2015). According to Riggs and colleagues (2004), there are three major forms of age-related bone loss. One is trabecular loss, which decreases at joint sites because the trabeculae become thin and the microstructure is disrupted. A second is continued bone loss at the endosteal surface. As growth occurs, cortical bone width increases, causing the endosteal surface of the bone to be resorbed with age. The third type of bone loss is a decrease in the cortical bone mass density. This type of loss is dependent upon bone volume and increases over a persons' lifetime because aging causes an increase in bone porosity. The extent that each of these types of bone loss can occur, suggests that bone loss is not uniform throughout the entire body nor uniform within one bone itself (Djuric et al., 2010). Bone loss can either occur rapidly or slowly as age progresses. The loss of trabecular bone and the removal or thinning of complete trabeculae contributes to rapid bone loss, essentially taking place over a shorter period of time (Riggs et al., 2004). The decrease in cortical thickness is a much slower process, starting when bone is fully mature and continuing as we age (Riggs et al., 2004). The two are ultimately caused by imbalanced osteoclast and osteoblast functions and how they remove or deposit bone causing perforations or thinning (Cooper, 1993; Parfitt, 2003). The ability for bone to remodel and build itself up is lost once age progressive bone loss starts to take place. The remodelling process where newer bone is laid down becomes overtly imbalanced, where bone resorption occurs more frequently than bone formation (Riggs, 1991).

Remodelling imbalances can be caused by changing hormone levels. One such hormone is the insulin-like-growth factor-I (IGF-I), which is present in both males and females (Boonen et al., 1997). The purpose of this hormone is to help with cell proliferation and the maintenance of collagen. Boonen and colleagues (1997) found that IGF-I decreased in aging individuals and this was seen in both males and females. However, females lost the hormone at a much greater rate as they aged, but more so in their trabecular bone than in their cortical bone.

One process of aging bone is the accumulation of bone microdamage which can occur in trabecular and cortical bone. Microdamage occurs as small linear cracks that can be found within the structure of osteons and is caused by a lifetime of loading and activity as individuals age (Karim & Vashishth, 2013). This microdamage is an example of the breakdown in the repair process. A major contributing factor to the process of microdamage is the amount of mature bone cells that are present. Osteocytes, or mature bone cells, decrease with age. With the decrease in osteocytes, bone loses its structural reliability allowing for microdamage to build up, decreasing bones' overall stiffness (Karim & Vashishth, 2013). This is only one example of how bone loss can damage bone beyond its ability to repair, leaving bone susceptible to failure in structure which leads to fractures.

3.5.2 Traumatic Conditions as a Result of Bone Loss

Due to the extensive and complicated processes associated with aging in the skeleton, there are specific traumatic conditions that result from age-related bone loss. The resulting traumatic condition that individuals may experience depends greatly on the bone quality, especially at the microstructural level (Cooper, 1993; Agarwal et al., 2004). The lower the quality of bone, the greater susceptibility to breakage and fractures. Fractures act as a cumulative record of a person's life (Mays, 2010) and multiple traumatic events may occur in one's lifetime, all leaving behind their own evidence. The fracture frequencies, fracture locations, and nature of the fractures, are influenced heavily by age and each age cohort is defined by a fracture pattern (Glencross & Stuart-Macadam, 2000). Specifically, the location, prevalence, shape, appearance, and severity of the trauma are influenced by intrinsic and extrinsic factors. Intrinsic factors include sex, age, and those variables that can affect fracture healing. Environmental and cultural factors are seen as more extrinsic causes (Steyn et al., 2010).

Fragility fractures make up a large proportion of the traumatic conditions seen in aging or aged individuals. Bone mass and the loss of this mass through time is one such cause of these types of fractures (Glencross & Agarwal, 2011). Agarwal and colleagues (2004) show that age-related changes in the trabecular bone and its stability start around middle-age. By this point the trabecular bone has started to thin, losing its structural integrity, leaving individuals more susceptible to fragility fractures. Many researchers expect to see fragility fractures in older individuals. When this is not the case, there is likely a mortality bias, low life expectancy, or inaccurate age-at-death estimates (Agarwal et al., 2004). The occurrence of fragility fractures is rare in past populations (Glencross & Agarwal, 2011). The rarity of these fractures in past populations is possibly due to individuals not surviving long enough to be able to experience them, they never contracted the pathology, or they were not exposed to a high risk environment. Another suggestion by Ives and colleagues (2017) is that there was simply higher mortality rates in the younger adults for the archeological past. Decreases in bone mass are further correlated with the processes seen in osteoporosis, where fragility fractures are seen the most, especially in modern populations today.

Osteoporosis is "a disease characterised by abnormalities in the amount and architectural arrangement of bone tissue that lead to impaired skeletal strength and an undue susceptibility to fracture risk" (Brickley, 2002:365). Researchers, such as Brickley (2002), suggest that there are two distinct kinds of osteoporosis. Primary osteoporosis, known as Type I, occurs in post-menopausal females. Secondary osteoporosis or senile osteoporosis (Type II), is related to the chronic loss of bone mass due to aging, malnutrition, or other underlying pathological conditions and is experienced by both males and females. Fractures that are commonly the result of osteoporotic processes tend to occur in the proximal femur, the vertebral bodies, and the wrist. These fractures are a result of lowered bone mineral density and they will increase in individuals after 50 years of age (Lewiecki, 2006). As previously stated, bone loss is not uniform across the body and this is also true for osteoporosis. In the aging body, bone loss takes place in both cortical and trabecular bone, however this can occur at different rates, leaving different areas of the body more susceptible to fractures at different times (Brickley, 2002). It seems however, that fractures of the spine are the most common fractures related to osteoporosis (Lewiecki, 2006). Brickley (2002) suggests that these crush (or compression) fractures seen in the spine can occur at younger ages, but they occur most frequently in females over 60 years of age. Brickley (2002) further suggests that the presence of Colles' fractures (those breaks that occur in the distal radius during a fall) and proximal femoral fractures are common; however, femoral fractures are the most serious of these and can often lead to complications and increased risk of death. Fractures of the hip on the other hand, especially femoral neck fractures, are extremely rare in the archaeological record, but appear more often in modern times (Mays et al., 2006b; Ives et al., 2017).

The process of age-related bone loss and fracture occurrence has been well studied in archaeological skeletal samples. A common and non-invasive method that many of these studies have employed is the use of metacarpal radiogrammetry. This technique involves taking radiographs of the second metacarpal and assessing the amount of cortical bone present (Ives & Brickley, 2005). Although metacarpals are commonly seen as non-diagnostic bones, researchers have established that the cortical measurements obtained from the second metacarpal are indeed statistically correlated with the levels of cortical bone seen in those areas most affected by osteoporosis, such as the distal radius and lumbar vertebrae (Ives & Brickley, 2005). The results of this measurement are able to express major differences in cortical bone loss in both age and sex groups. A study by Mays (1998) using this method, showed that females had significantly more bone loss than their male counterparts in the medieval Wharram Percy sample from the areas of Yorkshire (UK). He even demonstrated that amounts of cortical bone differed significantly between older and younger age groups but did not differ in individuals between the ages of 30-49 years. These differences have been used to further support the presence of osteoporosis in aging individuals. However, those studies that focus on the process of bone loss related to osteoporosis tend to over emphasise female aging processes and hormonal differences experienced in menopause.

This thesis does not look at direct levels of bone density, nor does it examine presence of osteoporosis. However, the importance of age-related bone loss cannot be ignored when examining fracture patterns in adult individuals from the past. As bone density and osteoporosis are major components of age-related bone loss, these concepts provide a context of the research.

3.5.3 Fracture Peaks in Age Groups

In general, there are three major peaks in fracture rates that we see within age groups for many societies. Peaks occur in young-adult males, the elderly for both males and females, and females over 40 years (Singer et al., 1998). Fractures for the elderly occur less in males, but they still do have age-related bone loss and fragility fractures. Fractures that occur the most in females over 40 years of age are wrist fractures. These fractures tend to appear also in younger individuals more so than expected, possibly suggesting another cause other than lower levels of estrogen in postmenopausal females (Singer et al., 1998). Although not a part of this thesis research, fracture incidences in young adolescents can be informative as to the health of the population. Therefore, it may set a further precedent as to why the peaks in adults actually take place.

Due to rapid growth, subadults can adapt to an environment much more quickly than adults (Lewis, 2013). The different ways subadults can adapt to their surroundings, causes children to “represent the most demographically variable and sensitive index of biocultural change,” and can be the greatest indicator of a population’s health and fitness (Lewis, 2002:211). A child’s rapid growth can show how populations are impacted by changes in environment, politics, and society. Since children are the ‘vulnerable’ portion of a population, how they are impacted by violence can demonstrate sociopolitical factors at that time (Gaither & Murphy, 2012). Fractures acquired at a young age are important to consider because often times the fracture history of these individuals may cause changes in their susceptibility to fractures later on in life. As suggested by Farr and Khosla (2015), it seems that those with skeletal shortfalls such as fractures that occur at a young age, follows into young adulthood. Furthermore, those individuals in their study that had previous fractures at a younger age were more likely to accrue more as they progressed into old age.

The mechanical properties of bone tissue in younger individuals is responsible for the major fracture differences we see in this age group. Younger individuals have a thick osteogenic periosteum; their bone is more porous, ductile, and very heavily vascularised (Gaither & Murphy, 2012). These separate components affect the fracture mechanics, as well as how fast subadults and adolescents can heal. The younger the individual is, the faster they can heal (Glencross & Stuart-Macadam, 2000). The high vascularisation of subadults allow for a longer elastic phase before failure (Gaither & Murphy, 2012). Therefore, their bones can absorb more energy before they fracture due to “plastic deformation” and not “elastic deformation” (Curry & Butler, 1975). The pliability of subadult bones causes fractures to be incomplete such as those represented by torus (buckle), greenstick, and plastic bowing fractures. As described by Glencross and Stuart-Macadam (2000), torus fractures affect the metaphyseal bone due to compression forces. Greenstick fractures affect the cortex and the periosteum by compression forces but failure occurs on the tensile side. Plastic bowing is a deformation that occurs because of compression in a greenstick fracture, but it occurs by itself. The only complete fracture seen in young individuals is an epiphyseal fracture. These occur in the growth plate and can increase in frequency during early childhood, but they tend to peak most often between the ages of nine to 16 years (Verlinden & Lewis, 2015). These fractures are rarely seen or recognised, but they can cause shortening of the limb since the growth plate is interrupted, which is the weakest area in a child’s bones (Glencross & Stuart-Macadam, 2000). The growth disturbance caused by these fractures typically occurs in the most distal portions of the bones and the most common of those to occur are in the femur (Basener et al., 2009). The long-term effects of epiphyseal fractures can be related to post-traumatic arthritis as the epiphyses are part of the joint surfaces (Wall & May, 2012).

Although the rate of remodelling at a young age may obliterate any evidence of a fracture, fractures sustained in adulthood remain throughout their life-course (Mays, 2010) if sufficient time has not passed. Injury recidivism or recurring traumatic episodes throughout the body therefore become more apparent in adult individuals. Fractures that are seen in this older age group can be the result of natural processes in age-related bone loss (Lewiecki, 2006), as well as the effects of other environmental or biocultural events.

Due to different biological processes (i.e., hormone development, sexual dimorphism) in adult males and females, differences in trauma exist, causing another fracture peak in age groups. Glencross and Agarwal (2011) suggest that young females have thicker cortical bone and small medullary cavities compared to younger males. Although this may be the case, females are still twenty percent smaller in body size than males of the same age (Silva & Jespen, 2013). This is likely due to females laying down more endosteal bone. As females reach middle age, this trait is reversed where they have greater medullary width, suggesting loss of their cortical bone due to episodes that require more calcium such as pregnancy or lactation and the loss of bone mineralisation during this time (Silva & Jespen, 2013). Unlike the females, middle age males have greater cortical thickness due to higher levels of activity. For males, the periosteal expansion is similar, yet they have a much slower rate in medullary expansion leading to slower changes in their cortical area. The level of activity in males may contribute further to this slowed change in the cortical portion of bone. It has been recognised that in the upper extremities females have smaller bones than males, but males have a higher rate of periosteal expansion and “increased moment of inertia,” which contributes to the higher rate of wrist and forearm fractures in females (Silva & Jespen, 2013). In general, males tend to show a much slower rate in bone loss than females during adulthood due to the underlying endocrinological factors that females possess during menopause, birth, and lactation, factors that are seemingly absent in males (Stini, 2003). Due to this differential pattern between the two, it is not surprising that females tend to have more fracture occurrences than males as they age.

In contemporary societies, males tend to show an increase in fractures at adolescence into young adulthood with a decrease in injury until 85 years, where fracture instances increase again; females show an increase of fractures at a young age as well but sustain more fractures after the age of 55 years (Donaldson et al., 2008).

3.6 The Role of Population Genetics, Activity, and Environment in Traumatic Conditions

Other factors that contribute to increased traumatic conditions in societies is geographic region, socio-economic status, and even the time of year (e.g., drought season), all of which can influence the cause, type, and frequency of injuries in all age groups (Batista et al., 2012). These factors are a large component of an individual’s environment and are therefore informative when considering a life-course approach to trauma. Much of this type of information is embedded within the burial context and can be supported further by historical records, beyond what can be gleaned from the skeleton. For example, injuries tend to show up more in urban populations and appear more in those individuals of lower socioeconomic status, although this is more consistent for contemporary populations (Gilbride et al., 2006). Environmental stressors during childhood therefore, are also important to consider when looking at injuries in adults.

More specific trends of injury occurrence, have been observed at the population genetic level. Individuals of African heritage tend to have the lowest rates of fractures in many populations compared to the higher rates seen in Caucasian, or European heritage, females (Cooper, 1993). Reasons for this trend have been linked to higher bone mineral density levels in African Americans, where they are less susceptible to hip fractures and have higher peak bone mass in adolescence (Nelson & Villa, 2003). This trend may be caused by the different levels and rates at which African American individuals acquire their bone mass during growth, leading to reduced affects from osteoporosis at an older age (Nelson & Villa, 2003). Mays and colleagues (2006b) in a study of medieval remains, found that out of all of European ancestries Scandinavian populations were more apt to develop osteoporosis and the fractures associated with this pathology. The researchers concluded that because these populations of Scandinavia were so genetically similar, they possessed a similarity in bone mineral density level, which was caused by underlying genetic influences. Although existing pathological conditions such as osteoporosis are likely contributors as well, it is a heterogeneous condition and is connected to genetics, diet, nutrition, and activity (Agarwal et al., 2004).

Regional differences in migration patterns have been associated with higher or lower instances of trauma. Migrants that try to acclimatise to another region may experience more stress due to their exposure to new terrains and new sociocultural environments that they are least likely to be familiar with (Batsevich et al., 2013). This change in environment may cause disruptions in the adaptive stress response in the body. Individuals that have lowered adaptive stress typically show no growth disturbances, slowed aging, and less presence of pathological conditions associated with aging (Batsevich et al., 2013). As discussed previously, the aging process and conditions related to age such as osteoporosis show a decrease in bone strength and bone quality. Therefore, it makes sense that adaptive processes that slow down these aging processes would show a decrease in traumatic conditions. As a result, Batsevich and colleagues

(2013) suggest that individuals that are part of a more stable environment with stable cultures and households, will be the ones to show these slowed adaptive processes. The differences between individual or regional lifestyles will affect the frequency of skeletal injuries by element type, placement, and appearance (Agnew & Justus, 2014).

A difference in lifestyle may result in conflicting levels of bone mineral density, but indirectly (Ekenman et al., 1995). A study by Ekenman and colleagues (1995) of medieval remains from Stockholm showed that there was a lack of evidence supporting lowered bone density in the older individuals. They suggested that due to the indirect effect of environmental differences there may have been more activity in the past population. Essentially more active individuals were physically stronger and were more capable of surviving to an older age. The researchers conclude that perhaps levels of physical activity may minimise those differences we see in density because of age, sex, and nutrition. It is proposed that "the high physical activity during growth may increase bone mass and continuing this activity level through middle age might slow down the rate of bone loss" (Ekenman et al., 1995:358). Other researchers have agreed with these conclusions. In examining differences in primate and recent human individuals, Ryan and Shaw (2015) show that physical activity is perhaps the greatest influence on skeletal robusticity and strength; this leads to greater levels of bone mineral density. They showed that the differences in bony features between foragers and agriculturalists were likely due to their adoption of different subsistence patterns. Foragers tended to be more mobile and would travel great ranges for their food, showing greater strength in their lower extremities depending on the terrain. Agriculturalists, on the other hand, would show greater strength in their upper extremities. Although they were more sedentary, they adopted food practices that involved grinding, harvesting, or the manipulation of livestock that would have taken greater use of their upper extremities. These activity and behavioural differences contribute to our understanding of trauma related patterns. By understanding the movements, occupation, or activity of individuals, we can better understand why they may have succumbed to trauma or not, thus suggesting a potential cause or manner of the resulting trauma.

As fractures and their resulting patterns become clearer in older populations, it is important to recognise and interpret the differential risks that may have contributed to these patterns. Trauma is much more than a simple break to the bone. As it has been demonstrated, breaks can be the result of a myriad of risks that go well beyond basic biology. Within this concept, it would be best to understand *both* the biological and sociocultural reasons for trauma in individuals. This is only possible by adopting a biocultural viewpoint by assessing the life-course of individuals.

3.7 Life-Course Analyses: A Theoretical Biocultural Approach

The concept of a life-course approach is by no means new to the field. Its emergence was predominantly seen in sociological studies of aging, family dynamics, social stratifications, and social histories (Elder Jr., 1994). The goal of the approach was to take into consideration the surrounding constituents of the environment in an individual's life. Rather than looking directly at the individual and the information that could be gleaned from that individual's experiences, a life-course approach examined the social context and cultural constraints that *contributed* to the specific choices and experiences individuals faced at different points throughout their life. Within anthropological studies of the human skeleton, this is reified in seeing the body as a continuum of life experiences from birth to death. Throughout this continuum from life to death, the body is constantly modified due to its plastic nature, but through the inevitable physiological changes of the body we can, at the same time, see the changes that take place in the social life (Sofaer, 2006; Gilchrist, 2012).

Elder Jr. (1994) suggests that there are four key themes within a life-course approach. These themes are imbedded within sociological studies and are focused more on individual lives of living people, but they can still shed light on themes that are adopted by other disciplines such as anthropology. First, he suggests that individual lives are connected or interplay with historical events, which can bring upon social change. Second, through this social change, social timing becomes important when examining times of aging and the different social events that are encountered during the lifetime of an individual. Third, although social change is occurring at the individual level, there are still those surrounding social relationships, such as those with family and friends that affect our life-course. Finally, and probably most importantly, is the use of human agency. Through the constraints of our social relationships within society, there is still individual choice (agency) which determines our behaviour and helps construct the life-course. Although these themes are inherently a part of sociology, the take-away message is that the life-course approach is all-encompassing and accounts for many aspects of human lives. When studies examine individuals, it must be recognised that individual choice (agency) within the social and cultural constructs play a paramount role in an individual's actions.

As biological anthropologists and bioarchaeologists, we are trained to reconstruct the lives of individuals from their skeletal remains. Of course, this representation of the individual is at their time of death, but from this reconstruction we are able to discern how this individual was represented in their living population. However, if we examine further the social and cultural context of the individual, osteological reconstructions can tell a much more comprehensive story not just about the individual but about the entire population. The life-course approach is a holistic form of study because it examines the course and shift within the human life (Gilchrist, 2004). Essentially, these areas of transition and change are accompanied by physical change in the body and we can further ascribe social meaning to these points of change through time. Sofaer (2006:77) suggests that, “the body responds to social and environmental factors: its plasticity is moulded over the life-course, providing an osteological record of life experiences.”

There must be a clear distinction between the uses of the terms: life cycle and life-course. The term life cycle is embedded with biological and cross-cultural meaning, whereas the life-course becomes more about the experiential perspectives in the life stages of individuals (Gilchrist, 2004). This distinction between the two is not to lay value to them or say one is better. However, it must be recognised that although the term can be used interchangeably, it can assign different meaning to the anthropological analysis. On the other hand, in both biological and social areas of study and their life-course approaches, there is an underlying theme that ultimately defines the life-course. This is recognizing the distinct importance placed on the different aspects of human life, whether they be social, cultural, or biological, and how they result in and shape the behaviours and actions of individuals. For anthropological purposes, these behaviours and actions shape the human skeleton and become the overlying factors that we consider in our analyses. They become the focus of our studies so we can better construct a representation of individuals of the past, and better place them in relation to the living and what we see in contemporary times.

3.7.1 Life-Course in Skeletal Biology

Previous examinations of the social and cultural contexts of the body based their analyses predominantly on the symbolic meanings and significance behind material culture and their relation to the human body (Sofaer, 2006). The body in a sense was seen as an object rather than the focus of analysis; it was an inclusion of the burial site just as any other included funerary material was. The early archaeology of the life-course was more about identifying the grave goods alongside the body and how patterns developed from their direct placement and inclusion within the grave in relation to a physical body (Gilchrist, 2012). The examination of grave goods and their interconnectedness with the human skeleton created analyses of social and cultural patterns without really appreciating the skeleton as a wealth of information, in and of itself.

As the emergence of biocultural and bioarchaeological areas of study became more common in anthropology the notion of the body as static, universal, and unimportant, was thrown to the wind. Rather, there became the realisation that the body was plastic; that its relationship with the surrounding environment (e.g., social and cultural influences) created a form of functional adaptation (Gilchrist, 2012). Specifically, the relationship with the environment created human experiences that could otherwise shape and create differences in the bony structures of the skeleton. Since we have no other means of sensing the world, except through our bodies and minds, the human body is one of the most important lines of evidence for biocultural interaction in the past (Sofaer, 2006:21). Examinations of how the body experiences its environmental surroundings and how this can be viewed in the physical manifestations of the body, is the essential component of a life-course approach that can be seen further in studies of biological anthropology and bioarchaeology.

Within the discipline of biological anthropology, the life-course approach is simply seen as a branch of the biocultural approach. Essentially, the biological markers or lesions seen within the body relate to the cultural and environmental influences that are placed on the individual, where the surrounding environment includes the social, political, economic, natural, and physical environments of the society and culture (Brickley et al., 2014). It is the hope that through this biocultural understanding the experience of groups of individuals at different stages of their life can be reconstructed (Brickley et al., 2014). One major biocultural factor that many biological anthropologists adhere to is the analysis of socioeconomic status. Within different cultures and societies, the difference in socioeconomic status becomes a constraint that many individuals experience, sometimes as an unintentional entity. Individuals are analysed as being of low or high socioeconomic status and each group produces different reactions that take place within the skeleton depending on their exposure to health and disease, trauma, occupational markers, or rural and urban geographies. However, studies that examine different biocultural and sociocultural aspects of the life-course need to consider skeletal differences at diverse life stages (ages) in order to accurately assess what is going on at the skeletal level. Use of the life-course approach in anthropological studies is directly linked with the understanding of how age, ethnicity, gender, and sex directly shape the social uniqueness and the social experiences of individuals of the past (Gilchrist, 2004). Therefore, the differences in life stages between individuals are what the realm of analyses are shaped around for biological anthropology. A life-course approach becomes important for skeletal analyses because within these life stages, consideration of the environmental factors allows us to go above and beyond the basic biological factors of the biological profile that we investigate. Gilchrist (2000) describes the importance of a life-course approach as such:

> ["the human lifecycle is employed as an appropriate scale for archaeological study, one which unites the human body with natural and cultural cycles, and highlights the place of age in constructing personal and social identities."] (pg. 1)

The uses of this type of analysis can take many shapes and forms, but it is essentially an illustration of individual lives that make up pieces of the population in question. It "aims to identify cultural categories of people based on their relative ages and to relate them within a coherent life narrative of a particular historical context" (Gilchrist, 2012:43). For the life-course approach in bioarchaeology the individual is recognised as culturally and socially significant. The individual body bears meaning; this meaning can be interpreted by the ways in which the body was treated and laid to rest by the living individuals of the past. The connection that the human skeletal remains create with the living is important to better understand the social and cultural settings that were taking place at the time of burial. Besides regular material cultures created in the same context, the human remains provide the only real connection between those materials and the living world at the time in which we can interpret the behaviours and intentions of people of the past.

There is an acknowledgement that the body is a continuum and throughout the life-course the experiences the body goes through are accumulated through time (Sofaer, 2006). Human experiences differ from each individual to the next and within different cultures and environments, therefore, the body is constantly changing throughout the life-course (Sofaer, 2006). It is our job as researchers within biological anthropology to augment our expertise to reconstruct those experiences towards a better understanding of the past. Our analyses and reconstructions of the lives of individuals ultimately take the form of an osteobiography. An osteobiography, at the heart of it, is a biography of the bones—the life experiences of an individual evidenced in the hard tissues.

An osteobiography is the life-course of individual actors of the past, written in bone (Knüsel, 2010). The osteobiographic study takes shape as recounting the life history of the bones, since they record the information of life events and this is better interpreted than the measurements and estimates of our rendered biological profiles (Saul & Saul, 1989). Therefore, the creation of an osteobiography becomes an interpretation of the past lives of individuals that are ultimately part of a much greater whole, the population. Although these interpretations are of single individuals it is assumed that this information helps reconstruct the dimensions of the life history of the greater population; "we see the study of individuals as a complementary domain to the populational framework of bioarchaeology" (Stodder & Palkovich, 2012:2). The life-course approach in bioarchaeology becomes a framework for reconstructing the identity of human lives in social and cultural contexts. The creation of an osteobiography of individuals helps us answer questions about the social identities, the behaviours, and intentions behind people's actions in the past (Stodder & Palkovich, 2012). Osteobiographies serve to meet the goal of a life-course approach—to determine the social changes that take place and the impetuses behind the actions that occur at any life stage (Knüsel, 2010). Each individual plays a role in the past society and we can better understand that particular role through the creation of an osteobiography of the life-course. The impact of behaviours on the body through the life-course, can be seen in osteological evidence including interpersonal violence and trauma more generally.

3.7.2 Applications of a Life-Course Approach: Skeletal Trauma

Trauma analysis is an important component of a life-course approach because it is one of the skeletal manifestations that can link a person's relationship with their physical and cultural environment (Domett & Tayles, 2006). This environment can be informative of other contextual information to better construct social identities, cultural ages, and social agency, which lets us view the human remains as being exposed to a living experience (Glencross, 2011). In particular for research such as trauma, fracture patterns can guide us in determining individual social behaviours because they are the most frequently reported class of injury and become overly prominent in the archaeological record (Glencross, 2011). Fractures are one of the skeletal lesions that can accumulate over a lifetime and can still survive in the archaeological record. As discussed above, these instances of skeletal injury can help in looking deeper into the inequalities seen in society and gender to better interpret instances of interpersonal or accidental violence. We can gain insight into the behaviours of the individuals and those specific behaviours that could have caused the fractures, which are not only applied at the individual level but also at the population level. Fractures are extremely informative in the archaeological record in that they allow us to see the life process of an individual. Violence helps us interpret and analyse different forms of social interactions and social identities due to its role in power relations (Martin, 1998). Furthermore, even instances of bone loss and its contribution to the susceptibility of fractures can be seen in a life-course approach. Bone can be shaped by culture or more importantly what we experience through our lifetime, creating a relationship between bone loss and fractures (Fausto-Sterling, 2005). This ideal goes beyond just examining instances of bone loss in osteoporosis and the differences seen in the age groups. Essentially, the molecular components and their reliability are influenced by much more than just basic biology and bone loss, rather there are several different biocultural influences that affect this process as well (Fausto-Sterling, 2005; Agarwal, 2012).

3.7.3 Patterns and Pitfalls

Deciphering trends and patterns are key to any bioarchaeological study at the population level. Patterns exist and those patterns need to be interpreted. However, when interpretations are being made, researchers must always account for the Osteological Paradox. The paradox was initially proposed by Wood and colleagues (1992) in the 1990's as a caveat to the interpretation of overall health in populations of the past. When we think of individuals showing evidence of sickness or injury, we consider them to be 'unhealthy'. That may be true for living individuals as we can see the entirety of their physical symptoms. However, with only being able to examine the bones or hard tissues of people long dead, the only evidence of symptoms available to us is the mere presence of lesions in the bone. Wood and researchers (1992) suggested that the presence of a lesion may not necessarily mean that the individual was unhealthy, especially if that lesion shows evidence of healing. Boney changes when associated with an underlying pathology (i.e., leprosy), often take quite some time to develop. If this is the case and the individual survived long enough to develop a lesion, are they not healthier than those that died of the disease before being able to develop a physical lesion? This overarching question brings up the issues of mortality bias and hidden heterogeneity. Each individual is exposed to different environments, instances of trauma, and pathogens therefore we can never know the true vulnerabilities and the risks of each individual in the population, leading to issues of hidden heterogeneity (Wood et al., 1992; DeWitte, 2006; DeWitte & Stojanowski, 2015). Mortality bias occurs as we are only observing a small portion of the once living population and are only seeing those that died, making skeletal populations incomplete representations of past populations. Due to this incomplete picture, the composition of different groups in the mortality population (i.e., more males than females, younger versus older individuals) may be ultimately biased. Furthermore, especially with instances of trauma, unique hazards (i.e., subsistence, occupation, genetics, bone mineral densities, etc.) and exposures exist for each individual, causing them to develop their own level of frailty.

Although individual health cannot be determined due to the Osteological Paradox, osteologists suggest focusing instead on the long-term causes of frailty. Due to environmental stressors, the health of individuals decline over-time increasing their frailty (Marklein et al., 2016). As osteologists we are able to observe different aspects of frailty by accounting for presence/absence of skeletal characteristics in past populations. Specific characteristics that may be present and would be further suggestive to the level of frailty in an individual, is presence of growth disruptions, nutritional deficiencies, activity markers, and trauma (Marklein et al., 2016). Observing the traumatic lesions in a population, therefore, may comprise a large component for combatting the effects of the Osteological Paradox.

3.8 Bioarchaeological Studies of Trauma in Medieval Denmark

Next to paleopathological studies, instances of trauma and conflict are the most prominent studies in Danish medieval skeletal samples. Bennike et al. (1987) is one of the earlier researchers that dedicates a major portion of her study to traumatic lesions. When examining fractures in a sample of Danish remains from the Mesolithic to the Middle Ages, she found that there were no differences in fractures through the early periods, but fractures became more prevalent in the Iron Age and medieval period. The majority of individuals with the fractures were adults, particularly males, with few instances of fractures in the lower limbs. Interestingly, vertebral fractures occurred most often in females during the Iron Age and Viking Age. Vertebral depression fractures can often be a result of heavy labour and activity. This could suggest further that females were quite active during this time period. Cranial fractures occurred most in males and were more common in the Neolithic era. The Bennike and colleague's 1987 study is helpful in understanding changes in traumatic conditions through time in Denmark.

Arcini (1999) undertook a large-scale analysis of skeletal trauma in medieval Lund. During this period, Lund was seen as an administrative and religious centre and possessed numerous churches, making this sample population an example of early urban life. Arcini (1999), hypothesised that traumatic injuries should increase with the amount of urbanisation, due to over-crowding and increased building activity, leading to violent interactions and work-related injuries. With these two considerations, the Lund skeletal sample was expected to show a combination of direct and indirect trauma lesions. Her results demonstrated that cranial injuries are uncommon in this sample, but those that did happen only took place in males. Fractures that occurred almost equally or more so in females as in males were those of the ulna, radius, and femur. Vertebral fractures arose often, but more so in males, predominately in the thoracic vertebrae resulting in compression fractures. Trauma occurred in 9.4% of the entirety of individuals, but predominantly in males. The increase in trauma over time, the changes in the placement of fractures especially in the upper and lower extremities, and the fact that young males were mostly affected, suggests the trauma was a result of activities or occupations.

More recent studies of trauma in medieval Denmark have looked at selective mortality, or an increase in mortality, in those individuals that suffered trauma. Boldsen and colleagues (2015) examined Danish samples from the medieval and early modern periods. In this study, only male individuals were examined for cranial trauma. Many of these head injuries were healed depressed fractures, suggesting the males lived for some time after the traumatic event. However, cranial injuries, even today, are very serious in nature and may cause underlying issues that could have long-term health consequences. Boldsen et al. (2015) found that these males had a risk of dying 6.2 times higher than males that were not injured in the sample. Without soft tissue present, we are unable to assess further traumatic issues that may be created by head injuries. However, this analysis shows it is possible to predict their quality of life after such a life-threatening injury.

Milner and colleagues (2015) examined healed fractures exclusively, to determine differences between males and females and who had a higher risk of mortality in Danish medieval skeletal samples from Tirup, St. Mikkel, and Sortebrødre. Tirup and St. Mikkel are located on the main Jutland, but Sortebrødre is located on Fyn. Tirup is a rural cemetery used for the research in this dissertation. Healed fractures were seen in the cranial vault and ulnar shaft (violence), and the clavicles and the distal radii (accidental). Trauma pattern research shows that injuries sustained in the cranium, facial, and ulnar shaft (i.e., Parry fractures) are more consistent with violent related behaviour (Brickley & Smith, 2006). Fractures seen in the clavicle or distal radius are consistent with more accidental injuries as these bones tend to break during a fall on outstretched arms (Judd, 2004; Lessa, 2011). Milner et al. (2015) found that males suffered more fractures than females, although both groups took part in a hardened lifestyle. Males were determined to have three times the number of fractures in the cranial vault and ulnar shafts than females. The only fractures for which females had higher frequencies than males were fractures of the tibiae and radii. When examining radial shaft fractures, the portion of the bone in which they occur in (i.e., distally, proximally, or in the mid-shaft) is an important consideration in the analysis. The majority of such fractures occurred distally in Milner et al. (2015), indicating they had more accidental origins by falling on outstretched arms. Fractures that occurred in the mid-shaft of the radius, and were accompanied by a fracture in the ulna, suggest a more direct form of trauma, possibly a direct blow. The frequency of trauma found in the medieval sample reported by Milner et al. (2015) was considered high for medieval Denmark.

Although historically Denmark was relatively peaceful, researchers have examined injuries that may have been due to large-scale conflict. The study done by Boucherie and colleagues (2017) looks at a mass burial of approximately 60 individuals from the medieval site of Sandbjerget (AD 1300-1350). Despite inconsistencies in the definition of a mass grave in the archaeological literature, these individuals did seem to fit the description as there were multiple people deposited in “a unique context with a demographic profile consistent with a catastrophic event" (Boucherie et al. 2017:68). The individuals in this grave were predominantly male and exhibited a range of sharp force traumas, accompanied by further blunt-force injuries that may have been executed after the males had been initially injured. What is unique about this study is that the authors look at the trauma microscopically, using scanning electron and digital microscopy, which they argue greatly improved their ability to identify injuries as it "enhances the presence of other criteria" (Boucherie et al., 2017:77).

A very recent study by Collier and Primeau (2019) showed some interesting trends and patterns of trauma observed in one rural and one urban Danish sample. Their study focuses on archaeological samples from sites slightly north on the mainland Jutland- more specifically the urban sample from Randers (AD 1150-1550) and the rural sample from Tjærby (pre-medieval-AD 1550). Collier and Primeau (2019) observed that individuals from the urban cemetery were 1.13 times more likely to have evidence of a traumatic lesion than in the rural sample. Cranial trauma in particular was significantly different between the two samples, with rural Tjærby having a higher risk of cranial trauma. Males in both samples showed a higher risk for lower limb trauma, and young adults from the urban cemetery had a much higher risk than young adults from their rural counterparts. Despite conclusions from other skeletal trauma studies, in which the rural samples show higher risks of trauma, the samples here were the opposite. The authors provide some possible explanations for this role reversal in trauma. In particular, the climatic changes that Denmark faced during the medieval period, related to particular farming practices especially for individuals in the rural countryside. Specifically, the 'cultural roles' in relation to age and sex of the individuals in each sample, along with the move to a more urban-centric way of life, may have contributed to the reversal in the skeletal trauma patterns. The high risk of vertebral injuries seen in the sample, specifically urban Randers, may suggest a "greater risk involved in specialized and repetitive crafts like blacksmith and carpentry" (Collier & Primeau, 2019:180).

CHAPTER 4: MATERIALS AND METHODS

4.1 Skeletal Materials

4.1.1 Selection Criteria

The skeletal materials for this research originate from four different cemeteries: Nordby, Tirup, Ole Worms Gade, and Horsens Klosterkirke. The cemetery samples represent two rural (Nordby and Tirup) and two urban populations (Ole Worms Gade and Horsens Klosterkirke), which makes for good comparison between location patterns. The cemeteries represent a broad temporal range from early medieval to late medieval periods, and even into the post-medieval or early modern period (AD 1050-1856). These remains are curated by the Anthropology Laboratory in the Department of Forensic Medicine at the University of Southern Denmark (ADBOU). A total of 345 adult individuals (out of a possible total 1,021 adults) were examined for this research. In order for the individual to be included in this study, the individual needed to be macroscopically (i.e., overall composition of the individual) more than 25% complete. In other words, if the grave was only represented by an individual with only two recovered femora, with no other skeletal elements present, the grave was not included in the analysis. An example of what constituted 25% or more present would be a grave with an individual that had at least the lower limbs present, including the femora, tibiae, fibulae, and both feet. This example is quite common throughout the cemeteries, as sometimes a grave was interrupted prior to excavation (i.e., later graves, modern construction, etc.), leaving only small portions of individuals behind. Of the 345 analysed individuals, 144 were female, 193 were male, and 8 were of indeterminate sex.

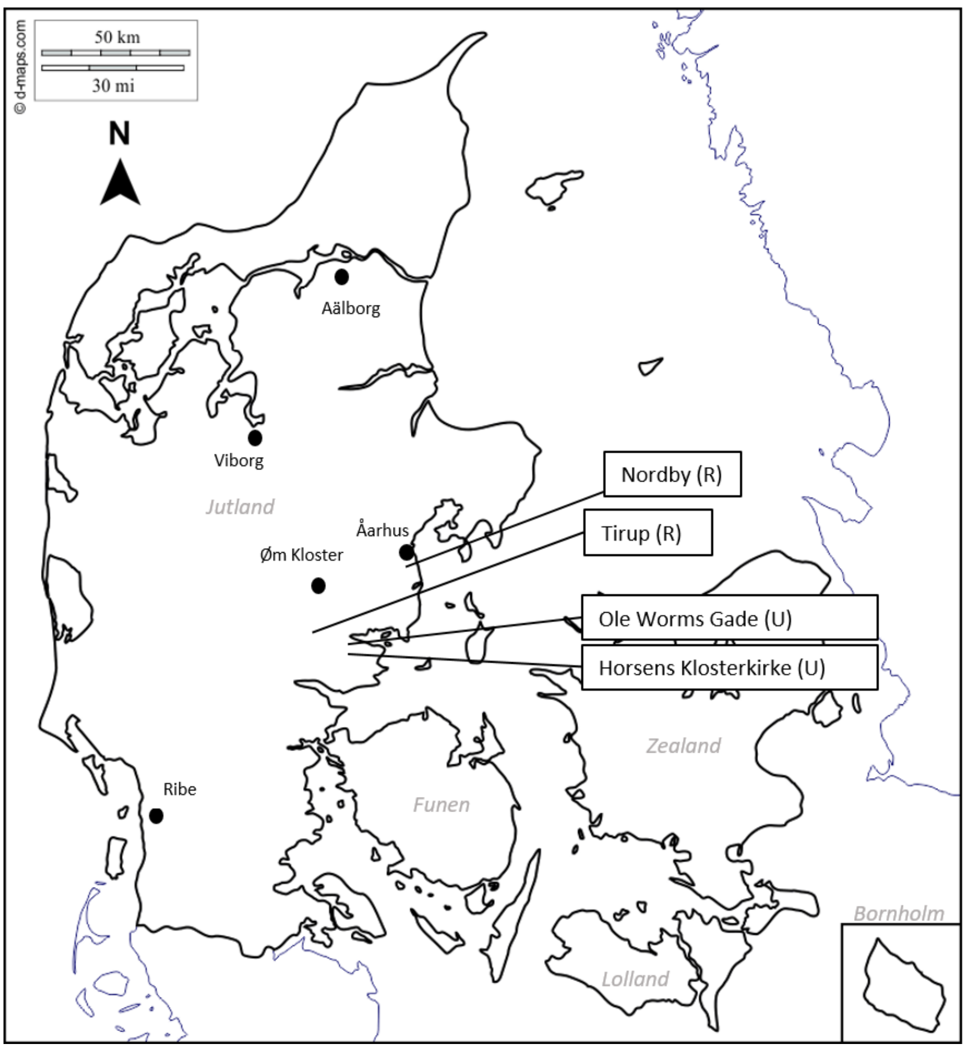
Inventory of the remains was qualitatively assessed by how complete the elements of an individual were present, therefore individuals would range in their completion from 25% to

100%. More precisely, those features of the bone that could attest to sex or age identity of an individual, needed to be present in order to be included into any statistical analyses. Between the cemetery samples, there are differences in levels of preservation. Of the four, Tirup perhaps has the worst preservation overall. Tirup was one of the first samples to be completely excavated in the 1980's, therefore having the most exposure to elements outside of the burial context. Due to this amount of time out of the ground, this sample has also encountered the most handling by researchers which can be a form of taphonomic damage to bone material. Human handling and storage of the remains falls under one of the primary concerns for skeletal preservation, which is postdepositional disturbance and deterioration (Henderson, 1987; Stojanowski, 2002). Nordby cemetery had the best overall preservation and has been less studied by researchers and was excavated much later than the Tirup sample. Deterioration and breakdown of bone also occurs in the depositional environment itself, where acidic or alkaline soil matrixes and ground water may cause breakdown of the bones (Von Endt & Ortner, 1984). Eastern Danish soil matrixes (where these sites are found) have shown higher pH levels and are more acidic, even after they were "limed" during agricultural processes (Peterson, 1991). The acidic nature of the soil would also contribute to bone breakdown. Therefore there are many factors that may have contributed to the overall preservation of the samples, but much of the preservation issues encountered with the cemeteries, were bone degradation or breakage of the identifiable age and sex features. Due to level of trabecular bone that makes up the os coxae, it is not surprising that this element was often times missing or poorly preserved, as those bones with more trabecular structure and is less dense typically are less survivable in the archaeological record (Von Endt & Ortner, 1984; Stojanowski, 2002). The long bones that are denser however, survive more often.

4.2 The Archaeological Sites

These sites will be discussed chronologically in detail. Information about the sites was obtained from previously written Danish archaeological reports. Time periods for each cemetery were extracted from these reports and were based on a combination of historical information and the assessment of arm positions. The location of these cemeteries can be seen in Figure 4.1 below (Kieffer-Olsen et al., 1986; Mollerup, 1996; Pederson, 2010; Tarp, 2010).

<u>Figure 4.1:</u> Detailed map of Denmark with a North arrow and scale. Each portion of the country is seen in gray italics, with some of the major cities as indicated with the black dots. Boxed names indicate the sites and villages used in this research and if they are urban (U) or rural (R) (original blank map from d-maps.com, 2007-2020).



4.2.1 Nordby: FHM 3970

Nordby is a rural cemetery that was excavated in 1996. The use of the cemetery has been dated to the early medieval period from the years AD 1050-1250. The cemetery is in Samsø municipality, and resides on the eastern shore of the mainland Jutland. The initial anthropological analysis suggested that of 122 complete individual graves (out of 235 including loose findings), 43.2% were males, 23% were females, and 20.9% were children (Mollerup, 1996). Mollerup (1996) further suggests that the age distribution of the cemetery was normal for the time period, as it is highly improbable that anyone reached ages above 50 years. As this research will show, there are individuals present in the sample that are older than 50 years old. At the time of the study (1996), this was a common misconception, that due to time period and lack of proper health care methods, individuals did not survive to reach old age (e.g. Grauer & Roberts, 1996; Mays, 1998; Mays et al., 2006a). However, this is an antiquated belief and has since been reconciled further with advances in age estimation techniques and studies of skeletal preservation (e.g. Boldsen et al., 2002; Friedl, 2011; Milner & Boldsen, 2012; Ives et al., 2017; Milner & Boldsen, 2017). According to the skeletal data, the cemetery represents a very homogenous population. The population was, therefore, likely more sedentary as they did not move across the landscape as much (Mollerup, 1996). The skeletal materials indicate that the individuals are small in size for both males and females, but show robust muscular attachments suggesting a hardworking lifestyle (Mollerup, 1996).

4.2.2 Tirup: VKH 1201

Tirup was another rural cemetery and was excavated in July of 1984 by the Vejle Museum (Kieffer-Olsen et al., 1986). Excavations were necessary as old structures were being torn down and new ones were being erected near the town of Horsens. In Scandinavian tradition, most burials around a centre village church have the females buried north of the church and the males buried south, but this was not the case with Tirup (Kieffer-Olsen et al., 1986). As with most Christian burial traditions, the individuals in the cemetery were buried laying down with an east-west orientation: the head was placed west and the feet lay east. A total of 620 burials were found in the Tirup cemetery, but at least 100 more graves were empty of any skeletal remains due to the overly acidic soil (Boldsen, 2000). Of the 620 burials found at Tirup, most of the individuals were children; a little over 50% (Boldsen, 1997; Boldsen, 1998). With a large amount of burials of individuals below that of 20 years of age, the life expectancies would be lower for those in the population (Boldsen, 1998; Boldsen, 2000). The cemetery population showed that the life expectancy for the males averaged 26 years and 22 years for females, 23.8 years for both (Boldsen, 2000). There were more males than females in Tirup, even though there was on average, only about 8-9 farms at one time for the village (Boldsen, 2000). In much of medieval Denmark, the means of dating burial remains comes from their arm positions as discussed earlier in Chapter 3 (Redin, 1976; Kieffer-Olsen, 1993; Jantzen et al., 1994; Mollerup & Boldsen, 2010). For Tirup, there was a mixture of arm positions that showed temporal shifts. Type A was considered early medieval and in use from AD 1000-1100, Type B was in use from 1100-1300, and Types C and D are consistent in the late medieval period from the 1300's and on (Kieffer-Olsen et al., 1986). In Tirup, most individuals had arm position Type A, with Type B being the second most common, and only a few individuals with Type C (Kieffer-Olsen et al., 1986). From this distribution, the Tirup cemetery was in use from AD 1150-1350. Tirup is considered a unique find as it was the first medieval rural cemetery in Denmark to be completely excavated and analysed by experts in the field of biological anthropology (Kieffer-Olsen et al., 1986). It is a significant source of information as to the living conditions leading up to the Black Death that hit Denmark in the 1300's (Boldsen, 1997).

4.2.3 Ole Worms Gade: HOM 1649

The cemetery at Ole Worms Gade is an urban or city cemetery that was excavated from 2007 to 2009. The cemetery was in use from AD 1351-1536, before the crisis of the Black Death as well as during the onset of the Reformation in the 1500's. Although part of the present day city of Horsens, at the time of its use, the cemetery was outside of the main city and was associated with Vor Frue Church (Pederson, 2010). Upon completion of excavation, there were a total of 650 graves with only 578 of these with actual skeletal remains associated with them and only 401 individuals available for a full anthropological analysis. Of these 401 individuals, it was found that the population consisted of 132 children, 100 females, 156 males and 13 adults of indeterminate sex (Pederson, 2010). The average age-at-death was determined to be 27 years and the oldest individuals likely did not live past the age of 70 years (Pederson, 2010). Many individuals buried in this cemetery had presence of several different pathologies that could be further associated with bouts of diseases and malnutrition (Pederson, 2010). The poor preservation of this cemetery results in the underrepresentation of infants and those aged 20-25 years of age (Pederson, 2010). This is not to suggest that there were no individuals of these age groups, but rather a result of preservation of the skeletal material and possibility of a reduced risk of mortality.

4.2.4 Horsens Klosterkirke: HOM 1272

HOM 1272 is the cemetery of Horsens Klosterkirke, which was excavated from 2007-2008. The church itself was connected to a monastery, which was out of use by the end of the 16th century. The cemetery however was in use from AD 1536-1856 and was the only cemetery directly in the town of Horsens (Tarp, 2010). Anthropological analysis at the time of excavation shows that there were 502 individual burials present with less than half (221 individuals) as complete. Of those graves that could be analysed fully the sample consists of 16% of children and 84% of adults (Tarp, 2010). The average age of the population was 34.1 years (Tarp, 2010). Several individuals from the cemetery population showed instances of pathologies such as leprosy, tuberculosis, and traumatic lesions. Unlike the other cemetery populations, Horsens Klosterkirke was not in use during the medieval period. This sample is unique from the other cemeteries because it covers the post-medieval period into the transition of the Early Modern era, providing a chance to see later urban life of Denmark.

4.3 Sex Determination and Age Estimation

For each sample, the adults were inventoried, analysed, and if trauma was present, the traumatic lesions were photographed. The inventory of remains included examining all present portions of bones and examining them in anatomical position. Presence was assessed macroscopically (i.e., overall composition of the element). The cranial bones were assessed individually. Long bones were examined for presence of the proximal, middle, and distal portions and were assigned their own separate percentage of presence from 0-100%. The proximal, middle, and distal portions were important to consider separately, as the calculations for fracture frequencies later on would need this information. The os coxae were split into ilium, ischium, and pubic areas for inventory purposes. Inventory of bones like the carpals, tarsals, metacarpals, metatarsals, vertebral column and ribs were assessed for presence as a group (i.e., metacarpals 1-5, metatarsals 1-5, cervical vertebrae 1-7, thoracic vertebrae 1-12, etc.). All other bones were assessed individually. Those that were partially present were 25% and those that were over half present, but not completely whole in nature were deemed 75% present. Erosion and taphonomic damage to the cortical surface of bones played an important role in assigning these percentages.

4.3.1 Sex Determination

Sex was determined using osteological traits in the pelvis and the cranium. Phenice (1969) traits were observed and scored from the os coxae for three characteristics: the ventral arc, sub-pubic concavity, and the medial ischiopubic ramus. The other feature included from the os coxa was the size and shape of the greater sciatic notch (Buikstra & Ubelaker, 1994). Several features of the skull were scored, including: the mastoid process, mandibular shape, supraciliary arches, supraorbital margin, the occipital torus, and the nuchal crest (Buikstra & Ubelaker, 1994). In addition, measurements of the femoral head and humeral head diameters were recorded (Stewart, 1979). Male individuals are more robust than females and tend to have a greater diameter at the joint surfaces than females (Milner & Boldsen, 2012). The contribution of these traits was amassed to determine sex as male (M), likely male (M?), female (F), likely female (F?), or indeterminate (I). A combination of these features was used for sex determination, due to varying degrees of bone completeness among individuals.

4.3.2 Age Estimation

To properly estimate age-at-death for each individual, four methods were implemented. Epiphyseal closure was examined throughout the skeleton, but for only specific areas. Most important for this research was making sure the individual was clearly an adult. Therefore, the epiphyses most important to make that determination were the sternal end of the clavicle, the iliac crest, and the fusion of sacral sections 3 through 5 (Buikstra & Ubelaker, 1994). The second age estimation method used was analysis of the auricular surface. The auricular surface is helpful for age estimation as it is prominently thicker than the pubic symphysis, allowing for a greater level of survival in the archaeological context (Buikstra & Ubelaker, 1994). Changes that are more prominent in this area would be presence of transverse striae or billowing, lipping or osteophytic lipping around the margins of the surface, and porosity (Meindl & Lovejoy, 1985). A third method used was the pubic symphysis method by Todd (1921). Changes to this surface include examining the presence of billowing or ridges, presence of a pubic torus, development of a marginal rim, and porosity (Todd, 1921). Phases of these changes are equated with a wide age range, but the method can only equate specific age ranges up to 60+ years.

The method of transition analysis, developed by ADBOU was the ultimate determining factor for age estimation for statistical analyses (Boldsen et al., 2002; Milner & Boldsen, 2012). As individuals age, precise transitions can be seen in features in the skeleton since "osteological structures often age in a regular manner" (Boldsen et al., 2002:74). This method focuses on the pubic symphysis, the retroauricular and auricular surfaces, and specific areas of the cranial sutures. For each area, scores were assigned as to the appearance and presence/absence of changes in the boney surfaces. This research used the stages described in Milner & Boldsen (2016). After stages were assigned, results were inputted into ADBOU Version 2.1.046 (ADBOU, 2016) to provide a corrected age range and a point estimate of age-at-death.

4.4 Trauma Lesion Analysis

Skeletal trauma is commonly seen as lesions that are the result of an injury, due to a culmination of different forces from extrinsic mechanisms (Lovell, 1997; Galloway, 1999). A more clinically derived definition is simply any bodily injury or wound (Redfern, 2017). In paying particular attention to these definitions, traumatic lesions were assessed for each individual by noting the presence of skeletal lesions. The lesions were not all necessarily due to traumatic events, but were still recorded. For instance non-traumatic lesions, such as those of a pathological, taphonomic or congenital nature, were noted to encompass the variation but not included in any of the trauma calculations or the overall trauma analysis. Lesions were recorded using the LARA method (Lovell, 1997). This method was originally used for the purpose of assessing long-bone fractures, however many of the components can be adopted for other areas of the body, especially since rotation or angulation can occur in other bones such as in the vertebral column. Some of the observed lesions included antemortem callus formation (indicating possible fractures), perimortem trauma lesions, postmortem alterations likely from excavation, presence of spondylolysis, presence of *os acromiale*, major enthesophytes, dislocations at joint surfaces, and compression of vertebral elements. However, of those listed, only the antemortem fractures, perimortem trauma, dislocations, and compressed vertebrae were included for overall trauma frequencies. Further, pathological, taphonomic, or congenital lesions observed were not included in the calculation of the True Prevalence Rate, Crude Prevalence Rate, or any of the calculated frequencies of trauma. Recording the presence of other skeletal lesions, in addition to those of traumatic nature, allowed for a broader exploration of trauma and associated conditions in the populations. Although determining cause and manner of trauma may be impossible, the presence of non-traumatic lesions may provide a more detailed picture of the individual. For example, if an individual had congenital hip dysplasia, but also had a tibial fracture, these may be associated. The hip dysplasia may have caused severe immobility and as a result the individual fell and fractured their tibia. Therefore, all skeletal lesions including trauma, pathologies, congenital conditions, skeletal anomalies, and so forth were noted.

Antemortem lesions were accounted for by recognizing a boney callus formation in the bone. Many of these lesions may have been accompanied by malalignment of the bone, leaving a change in shape or angle of the bone. Perimortem lesions were very few in number, but were recognised when fracture margins were apparent and colouration could be examined. Postmortem lesions needed to be accounted for as to not include them in the traumatic frequency counts later on. These types of lesions were represented by breaks in the bone, but those that had very light colouration, presence of adhering bone, and rough/stepping texture at the fracture margin with no healing present. Special lesions or anomalies , such as spondylolysis, *os acromiale*, or joint dislocations, were all noted when there were major changes noted in the boney element and were further diagnosed due to presence or absence of descriptive features. In particular, joint dislocations were noted when there was disfigurement to the joint surfaces, over-excessive boney growth due to osteophytic lipping, or if the dislocation was accompanied with a fracture. All of these conditions are explained below. If trauma was found to be present, the lesion was described distinctly including the position in the bone (proximal, midshaft, and distal), appearance of the lesion, and measurement of the area. Appearance of lesions were accounted for to determine if pathology, such as infection, may have been involved. How a lesion looks will be suggestive of the type of trauma it is (i.e., perimortem, antemortem, postmortem). Placement of fractures in the proximal, distal, or midshaft regions is paramount to record so more accurate fracture frequencies may be calculated. Measurements of the lesions, such as length (mm) and width (mm) of the callus, were taken to determine how severe a malalignment or break had been. This type of information will be informative later on as to the degree of healing in the wound and whether or not healing efforts had been implemented. Afterwards, all lesions were photographed for reference and select cases showing the variability in trauma were scanned for three-dimensional analyses.

Fracture type classification was completed when able to be assessed and categorised as transverse, oblique, spiral, segmental, butterfly, crush, depression or compression (as described in Chapter 3). Depression fractures were evidenced in cranial bones or ribs when the outer cortical surface created a concave appearance to the rest of the smooth bone. When well healed, these fractures lacked radial lines or flakes of the outer table of cortical bone. These were often evident when change in cranial topography was assessed, as many of these were well healed. Compression fractures are different from these, as they reside predominately in the vertebral column (Lovell, 1997; Galloway, 1999). These show a distinct reduction in vertebral body height and can be easily discernable from 'normal' vertebral body size and dimensions. After the specific classification of the type of fracture, type of trauma was then assessed. Those individuals that had depression fractures in the cranium were seen as those with cranial blunt-force trauma or sometimes cranial blunt- and sharp- force, in the form of 'chop' wounds. Sharp-force injuries to the cranium are much more extensive and go well beyond a small depression in the cortical bone. These types of injuries are typically accompanied by deep indentations in the bone that are more long and narrow and are concentrated in a smaller area of bone. Although these classifications of type and then categorization of blunt- or sharp-force traumas, may seem redundant, they are necessary. The cranium is so distinctly different in its composition, size, and shape, that different types of trauma are specific to that region and must be accounted for. Ultimately, when antemortem calluses are extremely well healed, the analysis of these fracture types can be extremely difficult, therefore a category of unclassifiable was added.

Fractures that are common in individuals, but that require some knowledge of clinical literature were recorded as well. Examples of these types of fractures would be the Colles', Bennett's, and avulsion fractures. These fractures were easily discerned as they were classic or 'textbook' cases and were therefore separated from other more generalized categories of fractures. Colles' fractures occur in the distal radius and are often caused by a fall on an outstretched hand. A common feature of this type of fracture is shortening of the bone compared to its counterpart or angulation of the distal portion. A Bennett fracture occurs in the base of the first metacarpal (Billing & Gedda, 1952; Butt, 1962). This is the most common type of fracture to the thumb and is usually located in the inter-articular space of the first metacarpal and the scaphoid. Avulsion fractures are quite common, but have several different aetiologies depending on the bone that is fractured. These fractures are most typical when a tendon, ligament, or muscle is over strained and pulls away from the bone, causing a portion of the bone to splinter off from the main structure. Some of the most common avulsions are seen in the patella and due to this, these avulsions will have their own distinct classification.

4.4.1 Vertebral Fractures

Vertebral elements that were more complete and well preserved were easier to assess for vertebral fractures. The presence of the vertebral bodies were accounted for by determining percentage of completeness by group (i.e., cervical, thoracic, and lumbar groups). Those that were severely incomplete were those missing their vertebral bodies and little information could be gleaned from them.   Completeness was highly varied by individual, and in many cases the lumbar vertebrae survived better than the upper vertebrae. Presence of vertebral fusions were noted and recorded as to their extent and completeness. A very specific and somewhat common vertebral fracture is the result of spondylolysis. This is the condition in which there is a fracture in the *pars interarticularis* or lamina of the posterior portion of the vertebrae (Le & Lebwohl, 2015). Spondylolysis is a common lumbar condition seen throughout different populations. It is not always a result of trauma to the spine, but can also have genetic, activity-related, or bone density (i.e., aging processes) implications. Unfortunately, it is extremely difficult for researchers to tease apart the causation of spondylolysis. It was included in this analysis as it is still considered, at its most basic level, a complete or incomplete break in the bone.

4.4.2 Unique Lesions

Not all forms of skeletal trauma take the form of a fracture. Some may take the form of a dislocation, a strained muscle pull, or fusion caused by strenuous movements. Dislocations at the joint surfaces can appear with extreme osteophytic lipping or bone growth around the joint surface, they can be associated with a fracture or depression of the joint, or as a full collapse of the joint such as seen in the hip. An enthesophyte is the site at which a muscle or tendon has attached to the bone (Villotte et al., 2010). If the soft tissue is strained, the tendon or muscle create a pulling action on the bone surface, resulting in a deep and irregular depression of bone at the site of attachment. The greater the surface of bone, the more severe these appear with deeper depressions. However, enthesophytes may also show boney growth that go beyond normal variation of common muscle origins and insertions. In these cases, due to the stress and strain of the muscles and tendons, bone has built-up at this site to account for the increased activity.

Fusion of fully developed elements can occur in any portion of the body. The fusion of boney elements should be noted, since many of these are the result of a traumatic event. Fusion of vertebrae are extremely common, but they can result from strain in the back, neck or hip. They can also occur secondary to another pathological condition that is present in the body, such as DISH (Diffuse Idiopathic Skeletal Hyperostosis) or tuberculosis. Bones that are subject to fusion due to traumatic causes can occur in the hands and feet. The appendages are subject to being overstrained, fractured, or crushed and a fusion may occur with these instances. Non-fusions were made note of; however, these are likely due to a congenital defect. Non-functional clefts are examples of these congenital defects and can occur often in the lower vertebrae and sacrum; these defects are not necessarily due to spina bifida. Another congenital condition that could be the result of non-fusion is incomplete fusion of the acromion process, which is classified as *os acromiale*. Although due to congenital reasons, these conditions are still important to note as they may be further included or excluded from trauma frequencies. The types and classifications mentioned above are condensed and clarified in Table 4.8 below and will be discussed in more detail in Chapter 6.

Table 4.1: Table describing the type of fracture and type of trauma most commonly found in trauma research, but also the type of fractures and trauma that were observed in this research. These classifications coincide with those observed in Table 5.7.

Fracture Type	Definition/Description
Fracture Classifications	
Transverse	A complete fracture that occurs at a right angle to the axis of the bone (Galloway, 1999).
Spiral	A complete fracture caused by rotational forces in the diaphysis, usually seen circling the shaft (Galloway, 1999).
Oblique	A complete fracture that runs diagonally to the axis of the bone. Typically 45^0 angle (Galloway, 1999).
Segmental	A complete fracture that is expressed by two or more transverse fractures in different areas of the diaphysis, often resulting in intervening segments of the bone shaft (Galloway, 1999).
Butterfly	Complete fracture with two large segments of bone and a “butterfly” flake on the concave side of the fracture (Galloway, 1999).
Crush	Incomplete fracture where a large force impacts a large area. Bone appears as cracked or crushed (Galloway, 1999).
Stress	Incomplete fractures that are due to repetitive stress that sometimes not easily discernable (Galloway, 1999).
Depression	Incomplete fracture primarily located in the skull, where the surface has “caved-in” (Galloway, 1999).
Compression	Incomplete fracture where the cortical bone is compressed down into the trabecular structure underneath. In vertebrae, the body is fully collapsed (Galloway, 1999).
Re-fracture of a Fusion	Complete or incomplete fracture of elements previously fused.
Spondylolysis	Complete or incomplete transverse fracture of the *pars interarticularis* of the 5^{th} lumbar vertebra (D’Angelo del Campo et al., 2017).

Avulsion	Complete or incomplete fracture where fragments of bone are detached from the main body due to over exertion of the tendon or ligament attached at that site (Galloway, 1999).
Bennett's	Incomplete fracture of the base of metacarpal one at the inter-articular joint surface (Billing & Gedda, 1952; Butt, 1962).
Colles'	Incomplete "bending fracture" at the most distal portion of the radial diaphysis, before the epiphysis (Galloway, 1999).
Burst	Incomplete fracture where the vertebral body is collapsed as in a compression fracture, but there is presence of severe fragmentation of the body. Usually caused by superior vertebral disc crushing into the vertebral body (Galloway, 1999).
Other Types of Conditions	
Traumatic Fusion	More than one element that are fractured or dislocated, but then fuse to one another during the healing process.
Joint Dislocations	Complete or incomplete injuries to the skeletal joints involving consistent displacement of the articular surfaces of the bones making up the joint (Aufderheide et al., 1998).
Os Acromiale	Complete non-fusion. A portion of the acromion process fails to fuse to the rest of the process (Barnes, 1994).
Congenital Hip Dysplasia	Congenital musculoskeletal disorder often times caused from subluxation of the hip (Mitchell & Redfern, 2010).
Non-Functional Cleft	Complete failure of the neural arch in the vertebrae to fuse (Case et al., 2006)
Non-traumatic Fusion	Complete fusion of two or more elements as a result of trauma.
Trauma Type	
Direct Trauma	Trauma where an object is struck by a "non-moving or slowly moving body" or the body hitting a stationary object (Galloway, 1999:57).
Indirect Trauma	Trauma where fractures are seen beyond the point of impact, typically during a combination of forces to include compression (Galloway, 1999).
Complete Fracture	A fracture where complete separation or "discontinuity" occurs between two or more bone fragments (Galloway, 1999).
Incomplete Fracture	A fracture where bones remain continuous in their fractured fragments (Galloway, 1999).
Sharp Force	Trauma caused by a small area sharpened object to a small area of bone.
Cranial Blunt-/Sharp-Force (Chop Wound)	Blunt-force are low-impact injuries over a large surface area. When combined with an object that has a blunt or sharpened end, the resulting wound becomes a 'chop wound'.
Unclassifiable	Injuries where the etiology is undetermined.

4.4.3 Quantifying Fractures

After all fractures were accounted for and recorded, frequencies were calculated following Judd (2002a). Only long bone trauma that is classified as a fracture was included in the calculations and instances of trauma that were classified as a dislocation were not included. These counts will not represent fully the true amounts of trauma in the populations (Judd, 2002a). There are five approaches to quantifying the frequency of fractures that are informative of trauma at the population level: the bone count, segment count, individual mean trauma count, mean multiple injury count, and the individual count. The bone count and segment count frequencies indicate areas of the body and specific bones that are injured more than others. The three additional counts, however, are more informative of the amount of people injured compared to the rest of the accounted for population. As a result, these counts should be a more precise interpretation of the fractures that have occurred and the individuals in the population that present the injuries.

<u>Table 4.2:</u> Table indicates how to calculate fracture frequencies as described and defined by Judd (2002a).

Count	Formula
Bone Count	# of lesions observed ÷ total # of bones
Segment Count	(segments w/ fractures ÷ segments observed) X 100%
Individual Mean Trauma Count	# of fractures observed ÷ # of individual in the sample
Mean Multiple Injury Count	# of fractures ÷ # of injured individuals
Individual Count	# of individuals with one or more injuries ÷ # of individuals in sample

4.5 Statistical Analyses

Statistical analyses were performed using SPSS Version 22.0 (IBM Corps., 2013). The raw data imported to SPSS was coded for separate categories (i.e., trauma presence, age groups, males and females, etc.). Comparisons were performed first to determine the presence of population biases in age and sex composition that might confound inter-site comparisons. These comparisons were made using paired t-tests and assessing significance (p= <0.05). After these initial analyses for bias, chi-square tests were performed to address population group differences. Significance was assessed (p= <0.05) to see how the age, sex, temporal period and geographic location, impacted the observed patterns of trauma.

Additional analyses were performed to examine specific sex and age comparisons. The most basic form of examining these group differences is chi-square analyses. Another such method of doing this, is using the Person-Years Construct. As each individual ages, the time they are exposed to the potential of disease or trauma, increases (Glencross & Sawchuck, 2003). Therefore, this method looks at all of the individuals in a sample and calculates “the sum of the various lengths of exposure experienced by all subjects in a sample, measured in years” (Glencross & Sawchuck, 2003:369). Rather than determining raw frequencies, the person-years can look at age-specific rates for presence of a lesion (Steckel, 2005). This will not only paint a picture of individuals and their exposure to specific conditions, but it will provide a better understanding of the age structure in a population. The person-years frequencies were calculated for this research, to better understand the occurrence or extent of fractures at the population level. The numerator was assessed using only long bone fractures seen in the long bones of the upper and lower limbs (Glencross, 2002; Glencross & Sawchuck, 2003). The denominator was calculated by taking the midpoint of each age cohort and multiplying by the absolute number of individuals in that cohort for the sample. The final sum was calculated by adding data from all of the representative age cohorts in the sample. The resulting calculation represents the length of exposure for each individual. Implementing this method allows for a greater understanding of injury and fracture patterns with respect to age cohorts. The person-years calculations were then compared to the Crude Prevalence Rates of the samples.

Crude Prevalence Rates were calculated by taking the total number of long-bone fractures in a population divided by the total number of individuals in the sample. The counts were compiled from only the long bone fractures out of the complete long bones present. The CPR calculations should be much higher than the person-years, as much smaller numbers make up the numerator and denominator. But how do these rates compare and do they relay different information? In order to answer this, the three rates (person-years, CPR, and Corrected CPR) were placed within an odds ratio calculation following Sahai and Khurshid (1996) and Glencross (2002). In these equations A-D represented different sub-groups in the population such as males and females, age groups, or geographical location. Odds ratios, Crude Prevalence Rates, Corrected Crude Prevalence Rates and Person-Years, were all calculated by hand using the proper formula and were not placed in SPSS. Odds ratios were accompanied with their calculated 95% Confidence Interval. Confidence Interval ranges that are large, show low proficiency and those that are smaller show higher proficiency. Those intervals that did not cross the value of one, were considered significant.

$$(A \div C) \div (B \div D) = AD \div BC$$

In addition to looking at the odds ratio of different sub-groups, a survival analysis was undertaken to compare individuals that had trauma present and those that had no trauma present. The sub-groups examined in the survival analysis were urban and rural individuals. Comparisons between groups were made using a Kaplan Meier survival analysis. Survival analyses do not quantify fractures in any way, but instead provide an overview of age structure in different groups. Since each individual has their own risk of sustaining trauma, these tables should indicate which individuals are living longer with or without trauma (Usher, 2000). Such analyses therefore help to illustrate differential mortality profiles within a population and can help examine whether there may be mortality bias, instances of frailty, or heterogeneity (Vaupel & Yashin, 1985; DeWitte, 2006).

4.6 Three-Dimensional Analyses

The use of three-dimensional imaging techniques for examining traumatic lesions, is a recent practise. Trauma lesions are assessed by their colouration, smoothness, and texture by the naked eye. Many of these aspects can be extremely hard to extrapolate and are dependent upon observer experience (Fleming-Farrell et al., 2013). These characteristics are important to note to determine the direction and timing of trauma to the tissue. However, with only naked eye observation, the characteristics are meagre at best. To see these minute characteristics, the use of three-dimensional imaging may provide a more concrete observation method that can provide better details for analysis. Most importantly, 3D methods can create a permanent record of the trauma without being overly invasive compromising the integrity of the bone (Fleming-Farrell et al., 2013). The research here implemented two types of three-dimensional imaging, the NextEngine 3D scanner and computed tomography (CT), each of which provide two different types of 3D data. The NextEngine was employed to record topographical geometric information and images, whereas the CT was used to gather changes in internal and external bone structures.

4.6.1 NextEngine

The NextEngine 3D scanner is a portable digital scanner that can detect the topography of an object. After specimens were determined to have existent trauma, select individuals were chosen for scanning in order to portray the variability in trauma lesions. These individuals were specifically scanned with the NextEngine to capture the topographical changes in the bone. The

NextEngine was set up at the work station with a black backdrop. The natural light in the lab created reflections in the scans if the backdrop was not in place. Skeletal elements were placed singularly on a rotating platform and then scanned. Some of the elements needed to be braced with putty material to prevent movement while scanning. This set up can be seen in Figure 4.2. The NextEngine Scan Studio software renders the data into 3D models, and includes the ability to crop, fill in any missing portions, and to smooth out the image for the best image quality. The scans were set to Texture Capture Mode (RGB) and scanned in either a 360- or 180-degree range depending on size and shape of bone. As such, for each specimen, multiple views and scans are taken including a colour image of the surface, which are subsequently stitched together. For instance, the long bones such as femora and tibiae were unable to complete a 360 turn due to room constraints, therefore multiple 180-degree scans were taken in order to capture the entirety of the bone. The scan platform was set at a range of 16.51-20.32 cm (6.5-8 inches) away from the scanning module, resulting in a 7.62-12.7 cm (3x5 in.) field of view, with a 0.127 cm (0.005 in.) accuracy. This range allows for the scan to be taken in the macro setting in order to obtain the desired resolution. With a precision of macro, the standard speed of each scan is 95 seconds. Macro high definition results in a decimation of 10k to 40k points/in^2. Once multiple scans have been taken, you can splice the scans into one, in order for the entire topographical appearance to be rendered. Once aligned, a single scan can be polished and trimmed. The polish tool includes a filling implement, where holes in the scans can be filled and matched up together so there are no missing portions of the scanned object. The trimming tool allows the user to extract any portion of the scan that does not need to be in the final image, for example, the platform table is an additional material that can be trimmed out. Remeshing (rendering) after these steps occurred anywhere from a 0.5 to 0.9 resolution depending on the bone. The scans can be generated in their natural colour or some other neutral colour. The object may be put into a point cloud or pixelated frame, which is extremely helpful in determining differences in topography for depressions or changes in shape.

<u>Figure 4.2:</u> A photo showing the NextEngine scanner set-up. The platform is connected to the main scanner and is stretched to its maximum length. The platform is raised to help capture the entirety of the bone. A black drop is used to minimize any reflective surface that would be captured in the scan.

4.6.2 Computed Tomography (CT)

The bone specimens that were scanned with the NextEngine were CT scanned using a Somatom Spirit with two detectors, seen in Figure 4.3. Settings worth noting for the scans are the tube current (mA), the pitch, and the slice. The tube current is the number of x-rays that are taken for the full 360-degree rotation of the scanner. The slower the rotation, the greater number of x-ray images that are taken and the better the details are for the resulting image. The pitch is the overlap of the x-rays between each rotation of the scanner. The pitch has a value of 0.5-2.0, with 1.0 being no overlap or gaps in the image rotation. Therefore, the lower the pitch value, the better the image quality. Lastly, the slice is the slice thickness for each rotation. The scanner can create slice thickness from 1mm-10mm. For the best quality of image, the thinner the slices the better the detail. It is the thickness that creates the image quality. Scans for groups of bones differed in some of their settings, depending on what the CT found acceptable for the size and length of the bones being scanned. The setting that changed the most, was the pitch size. The mA ranged from 50-100. Most scans were taken in 3mm slices as this is what captured the most amount of information the scanner would allow. The pitch fell between 0.95-1.6. Each individual scan was mapped and recorded as different bones from several individuals were included in one single scan. This mapping helped during the rendering process so the x-ray slices could be more easily identifiable. DICOMM datasets were archived and rendered for analysis at BDIAL using MIMICS Version 19.0 (Materialise NV, 2015). During the rendering, the CT slices are trimmed of any materials that should not be included in the bone model, such as the table or mat surface. Once the slices are properly trimmed where the bone is the only remaining material left, MIMICS can then create a full 3D model of the scanned bones. The 3D images can be rotated and even transected to capture angles and measurements of the bones. The images can even be wire-meshed (pixelated), which is similar to the point cloud frame in the NextEngine. The rendering process in MIMICS, should allow for greater details to be captured so complicated or minute structures can be seen. Furthermore, the objects can later be 3D printed if the capabilities are there to do so. However, the final rendered 3D images can only be as good as the integrity of the original CT scans.

<u>Figure 4.3:</u> A photo of the Somatom Spirit CT scanner with an example of bone set-up (os coxae).

CHAPTER 5: RESULTS

The raw data presented in this chapter can be observed in Appendices A-D.

5.1 Population Distributions

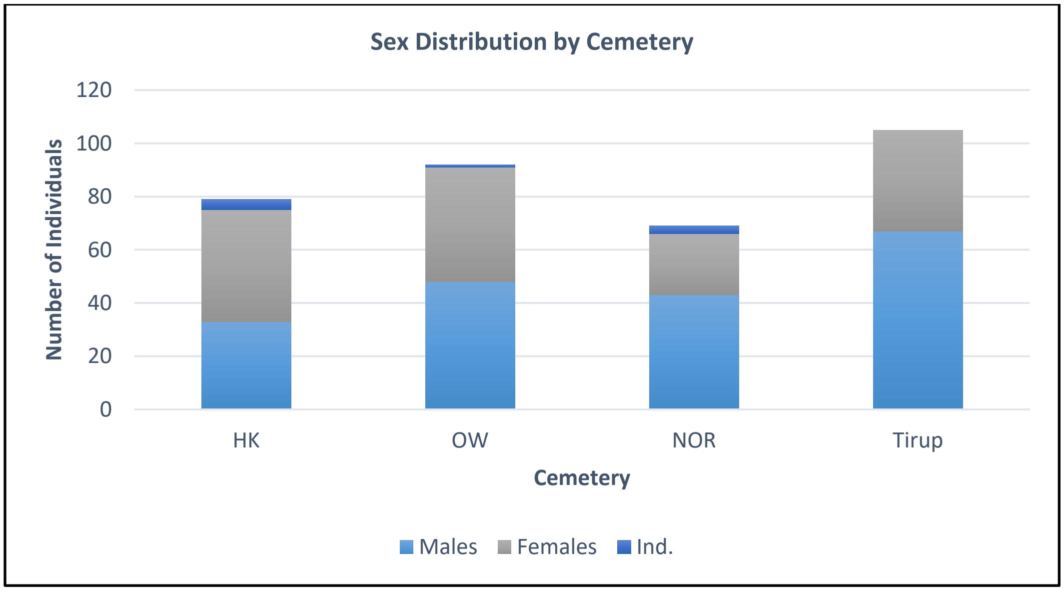
5.1.1 Sex Distributions in the Cemeteries

The age and sex distributions of the four samples are shown in Table 5.1 and Figure 5.1. There are more males than females in all four samples, the cemetery with the closest to an equal distribution between the sexes was Ole Worms Gade. The sex distributions in the four cemeteries was not found to be significantly different (χ^2= 7.445, df= 6, *p*= 0.282).

Table 5.1: Raw counts of the sex distributions for each cemetery, along with their calculated percentage of each cemetery total and research sample total.

	Males	% of the Total	Females	% of the Total	Ind.	% of the Total	Total # of Indivs.	% of the Total (n= 345)
HK	42	53%	33	42%	4	5%	79	23%
OW	48	52%	43	47%	1	1%	92	27%
NOR	43	65%	23	35%	0	0%	66	19%
Tirup	60	55.5%	45	42%	3	2.5%	108	31%
TOTAL	**193**	**56%**	**144**	**42%**	**8**	**2%**	**345**	

Figure 5.1: Bar graph illustrating the sex distributions as listed in Table 5.1.



5.1.2 Age Distributions in the Cemeteries

The age distribution (Tables 5.2, 5.3, and 5.4; Figures 5.2a-d) differs greatly between the cemeteries. However, no statistical differences in the number of individuals by age group were observed (χ^2= 8.436, df= 15, *p*= 0.905) between the four cemetery samples. Independent sample t-tests for mean age by location (urban and rural) were found not to be statistically significant (t= -1.584, df= 343, *p*= 0.114). Males and females showed no statistically significant difference in mean age (t= -1.535, df= 335, *p*= 0.126).

When age groups are further broken down by sex, there are two groups that show overrepresentation of males versus females. When the indeterminate individuals are excluded, the age group distributions between sexes are significantly different in all age categories (χ^2= 11.344, df= 5, *p*= 0.045). When this comparison is broken down further by cemetery, as seen in Tables 5.4 and 5.5, there are no differences.

<u>Table 5.2:</u> Raw counts of age groups as statistically calculated by Transition Analysis (TA) using Boldsen et al. (2002).

	Skeletally Mature <20 yrs.	21-30 yrs.	31-40 yrs.	41-50 yrs.	51-60 yrs.	61-70 yrs.	71-91+ yrs.	
	Late Adolescent	Young Adult	Middle Adult	Adult	Old Adult	Older Adult	Oldest-Old Adult	Unk.
HK	2	20	20	8	1	1	16	11
OW	3	24	24	8	2	4	15	12
NOR	0	20	15	9	1	8	11	2
Tirup	4	25	40	5	6	5	16	1
TOTAL	**9**	**89**	**99**	**30**	**10**	**18**	**58**	**32**

<u>Table 5.3:</u> Raw counts of age groups as observed by the author, using Buikstra & Ubelaker (1994), Meindl & Lovejoy (1985), and Todd (1921). Groupings are condensed, due to the overlapping of the observed ranges.

	Skeletally Mature <20 yrs.	21-30 yrs.	31-50 yrs.	51-70 yrs.	71-91+ yrs.	
	Late Adolescent	Young Adult	Adult	Old Adult	Oldest-Old Adult	Unk.
HK	0	8	39	14	0	18
OW	0	2	57	5	0	27
NOR	0	7	43	5	0	11
Tirup	1	8	69	22	0	9
TOTAL	**1**	**25**	**208**	**46**	**0**	**65**

<u>Figures 5.2a to 5.2d:</u> Line graphs illustrating the comparison of the author's observed age groups and the statistically calculated Transition Analysis age groups for each cemetery.

Figure 5.2a

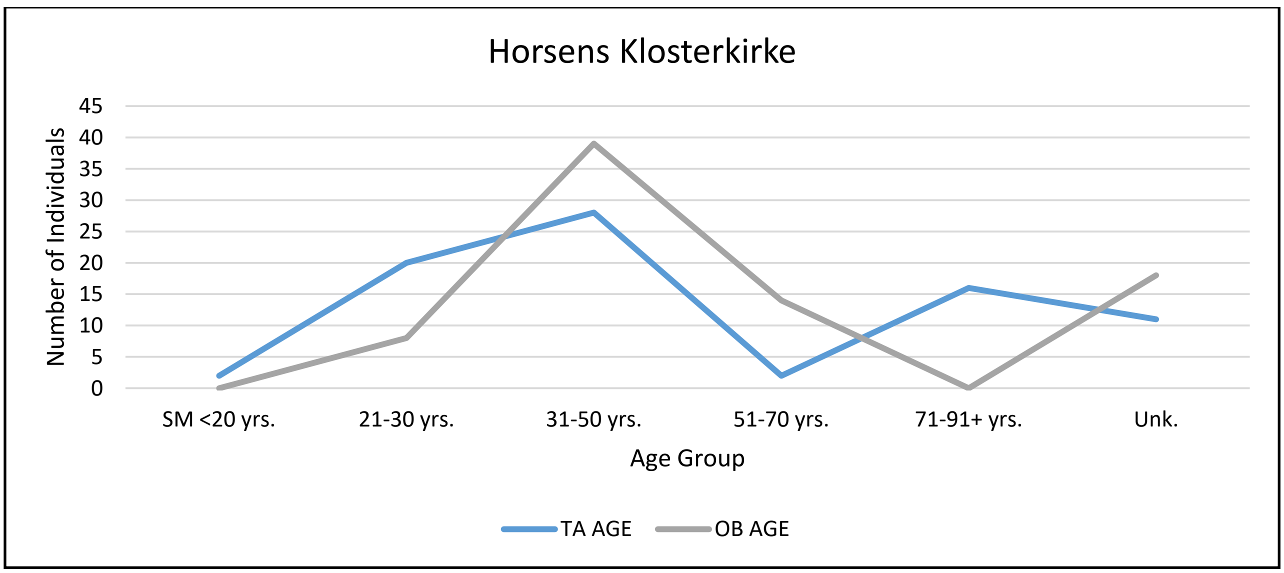


Figure 5.2b

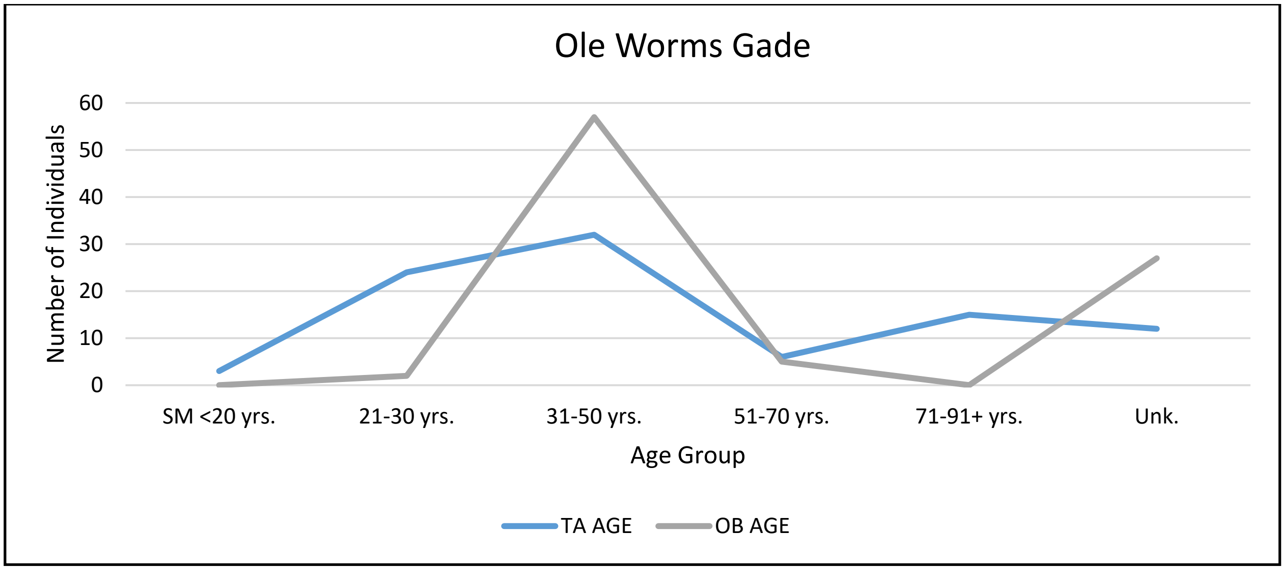


Figure 5.2c

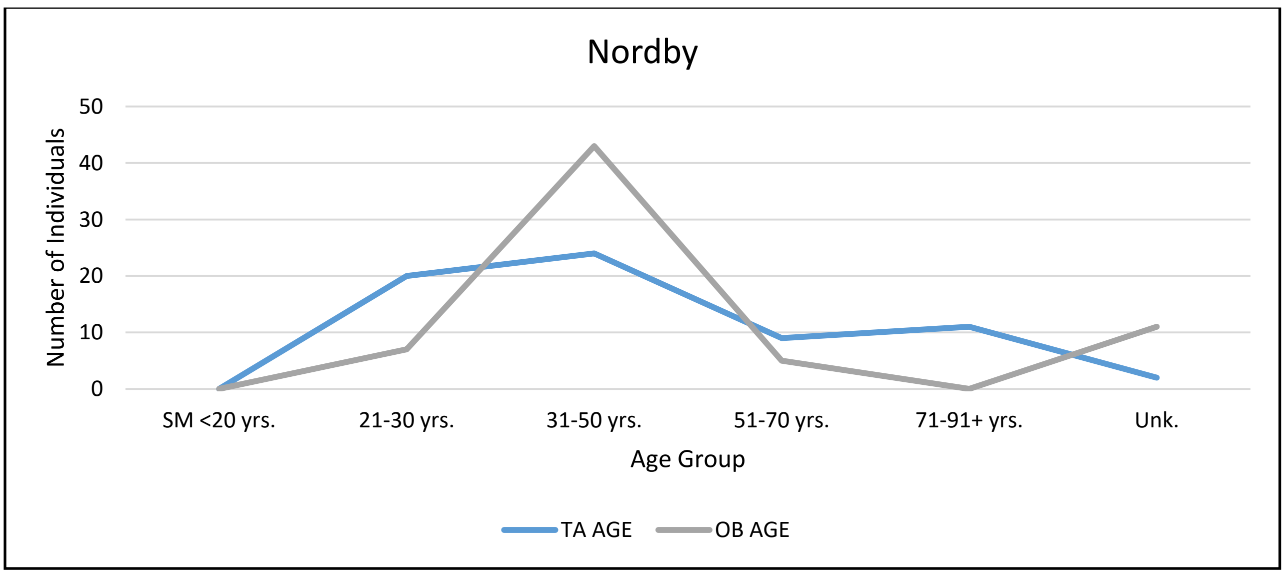
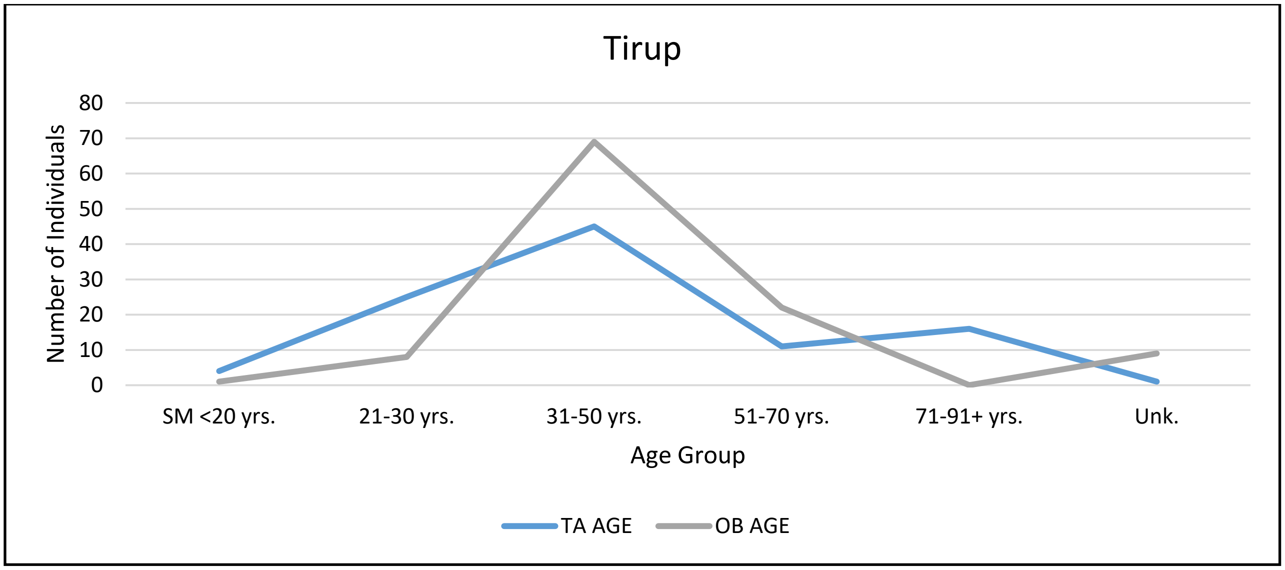


Figure 5.2d



<u>Table 5.4:</u> Crosstabulations for the sex distributions (no indeterminate individuals) for each age group (TA) by cemetery. Raw counts are accompanied by percentages of the total cemetery sample.

Cemetery		**Sex**	**Unk.**	**SM <20 yrs.**	**21-30 yrs.**	**31-40 yrs.**	**41-50 yrs.**	**51-60 yrs.**	**61-70 yrs.**	**71-91+ yrs.**	**Total**
HK	Count	F	2	2	9	7	5	0	1	7	33
		M	7	0	10	12	3	1	0	9	42
	Total		**9**	**2**	**19**	**19**	**8**	**1**	**1**	**16**	**75**
Percentage of the Cemetery Total		F	3%	3%	12%	9%	7%	0%	1%	9%	44%
(n = 75)		M	9%	0%	13%	16%	4%	1%	0%	12%	56%
NOR	Count	F	0	0	7	4	4	0	4	4	23
		M	2	0	13	11	5	1	4	7	43
	Total		**2**	**0**	**20**	**15**	**9**	**1**	**8**	**11**	**66**
Percentage of the Cemetery Total		F	0%	0%	11%	6%	6%	0%	6%	6%	35%
(n = 66)		M	3%	0%	20%	17%	8%	2%	6%	11%	65%
OW	Count	F	3	2	11	9	5	1	4	7	42
		M	8	1	13	15	3	1	0	8	49
	Total		**11**	**3**	**24**	**32**	**8**	**2**	**4**	**15**	**91**
Percentage of the Cemetery Total		F	3%	2%	12%	10%	6%	1%	4%	8%	46%
(n = 91)		M	9%	1%	14%	16%	3%	1%	0%	9%	54%
Tirup	Count	F	4	1	12	11	2	5	4	6	45

		M	2	3	13	27	3	1	1	10	60
	Total		**6**	**4**	**25**	**38**	**5**	**6**	**5**	**16**	**105**
Percentage of the Cemetery Total		F	9%	1%	11%	10%	2%	5%	4%	6%	43%
(n = 105)		M	2%	3%	12%	26%	3%	1%	1%	10%	57%

<u>Table 5.5:</u> Chi-square analysis for the sex and age (TA) distributions by each cemetery as depicted above in Table 5.5.

Cemetery		Value	df	Asymptotic Significance (2-sided)
HK	Pearson Chi-Square	5.722[a]	4	.221
	Likelihood Ratio	7.204	4	.125
	N of Valid Cases	75		
NOR	Pearson Chi-Square	.567[b]	3	.904
	Likelihood Ratio	.558	3	.906
	N of Valid Cases	66		
OW	Pearson Chi-Square	3.068[c]	4	.547
	Likelihood Ratio	3.121	4	.538
	N of Valid Cases	91		
TIRUP	Pearson Chi-Square	9.619[d]	5	.087
	Likelihood Ratio	10.116	5	.072
	N of Valid Cases	105		

5.2 Population Analysis

5.2.1 Sex Groups

In the overall sample for trauma presence, females represent 13% and males represent 27% of the total number of individuals (Table 5.6). Within the cemeteries, raw counts show that males are the most frequently observed with fractures, across all age groups. Absence of trauma in both male and female groups however, were nearly equal to one another.

The distribution of trauma varied significantly (χ^2= 11.452, df= 2, p= 0.003) between males, females, and indeterminate individuals (Table 5.6). The analysis included those individuals of indeterminate sex (8 individuals), two of whom had trauma observed.

Table 5.6: **Crosstabulation of trauma presence and absence for each sex; provided with percentages of the total research sample (n= 345).**

Sex		Trauma			Percentage of the Total	
		Absent	Present	Total	Absent	Present
F	Count	101	43	144	28.5%	12%
Ind.	Count	6	2	8	2%	1%
M	Count	100	93	193	28.5%	27%
TOTAL	**Count**	**207**	**138**	**345**	**60%**	**40%**

With respect to dislocations, males possessed more joint dislocations than females (Table 5.7). This was not statistically significant (χ^2= 5.131, df= 2, p= 0.077). Individuals with cranial blunt-force trauma and sharp-force trauma were not well represented in the total sample, with only eight individuals (with 12 separate impact sites) present with these injuries (Table 5.8). These injuries were observed out of a total of 260 crania (2%) out of the 345 total individuals. Two examples of the cranial trauma are provided below (Figures 5.3 and 5.4).

Table 5.7: **Breakdown of the dislocations observed in each sex, by cemetery and age group. Raw counts are included with percentages of the total.**

Cemetery	Dislocations	Sex				Percentage of the Total (n)			
		F	M	Ind.	Total	F	M	Ind.	Total
HK (n=79)	Count	2	6	0	8	3%	8%	0%	10%
OW (n=92)	Count	1	1	0	2	1%	1%	0%	2%
NOR (n=66)	Count	0	6	0	6	0%	9%	0%	9%
Tirup (n=108)	Count	0	2	0	2	0%	2%	0%	2%
TOTAL (n=345)		**3**	**15**	**0**	**18**	**1%**	**4%**	**0%**	**5%**
Age Group		**F**	**M**	**Ind.**	**Total**	**F**	**M**	**Ind.**	**Total**
Unk. (n=32)	Count	0	3	0	3	0%	9%	0%	9%
SM <20 yrs. (n=9)	Count	0	0	0	0	0%	0%	0%	%
21-30 yrs. (n=89)	Count	1	1	0	2	1%	1%	0%	2%

31-40 yrs. (n=99)	Count	1	5	0	6	1%	5%	0%	6%
41-50 yrs. (n=30)	Count	1	2	0	3	3%	7%	0%	10%
51-60 yrs. (n=10)	Count	0	2	0	2	0%	20%	0%	20%
61-70 yrs. (n=18)	Count	0	0	0	0	0%	0%	0%	0%
71-91+ yrs. (n=58)	Count	0	2	0	2	0%	3%	0%	3%
TOTAL (n=345)		**3**	**15**	**0**	**18**	**1%**	**4%**	**0%**	**5%**

<u>Table 5.8:</u> Breakdown of the cranial blunt force (to include chop wounds) that were observed in females and males by cemetery and age group. Raw counts are included with percentages of the total sample.

Cemetery	**Cranial Trauma**	**Sex**				**Percentage of the Total (n)**			
		F	**M**	**Ind.**	**Total**	**F**	**M**	**Ind.**	**Total**
HK (n=79)	Count	0	1	0	1	0%	1%	0%	1%
OW (n=92)	Count	1	0	0	1	1%	0%	0%	1%
NOR (n=66)	Count	0	3	0	3	0%	5%	0%	5%
Tirup (n=108)	Count	0	3	0	3	0%	3%	0%	3%
TOTAL (n=345)		**1**	**7**	**0**	**8**	**0.5%**	**2%**	**0%**	**2.5%**
Age Group		**F**	**M**	**Ind.**	**Total**	**F**	**M**	**Ind.**	**Total**
Unk. (n=32)	Count	0	0	0	0	0%	0%	0%	0%
SM <20 yrs. (n=9)	Count	0	0	0	0	0%	0%	0%	0%
21-30 yrs. (n=89)	Count	0	3	0	3	0%	3%	0%	3%
31-40 yrs. (n=99)	Count	0	2	0	2	0%	2%	0%	2%
41-50 yrs. (n=30)	Count	1	0	0	1	3%	0%	0%	3%
51-60 yrs. (n=10)	Count	0	0	0	0	0%	0%	0%	0%
61-70 yrs. (n=18)	Count	0	1	0	1	0%	6%	0%	6%
71-91+ yrs. (n=58)	Count	0	1	0	1	0%	2%	0%	2%
TOTAL (n=345)		**1**	**7**	**0**	**8**	**0.5%**	**2%**	**0%**	**2.5%**

<u>Figure 5.3:</u> An example of a cranial blunt/sharp force (chop wound) injury to the right posterior parietal (as indicated in red). The injury is very well healed. The crania is Grave CZ from Nordby (FHM 3970), male, 21-30 yrs.

<u>Figure 5.4:</u> A second example of a cranial blunt/sharp force (chop wound) injury to the right portion of the frontal (as indicated in red). The injury is partially healed. The crania is Grave AS from Nordby (FHM 3970), male, 61-70 yrs.

The urban samples of Horsens Klosterkirke and Ole Worms Gade, each had one individual with cranial blunt force trauma. The individual in the Horsens sample was a male aged 71-80 years old and in Ole Worms Gade the individual was a female aged 41-50 years old.

Out of the observed crania in each sample (HK= 62; OW= 46), with only one individual exhibiting cranial blunt force injuries, that only accounts for 2% of the sample The rural samples of Tirup and Nordby both showed higher instances of cranial blunt force trauma, both having 3 individuals injured in this manner. The Tirup individuals were all male, two of which aged 31-40 yrs. and one aged 21-30 yrs. The Nordby individuals were also all male, two of which aged 21-30 yrs. and one aged 61-70 yrs. Out of the observed crania in each sample (Tirup= 101; NOR= 51), those individuals with cranial blunt force injuries accounts for 3% in Tirup and 6% in Nordby. Therefore the rural Nordby shows the highest frequency of cranial blunt force and sharp force injuries.

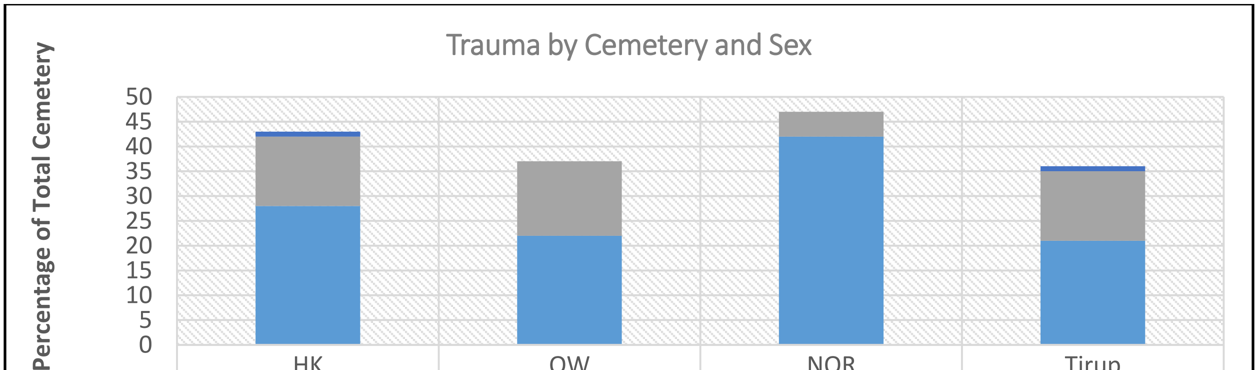
The number of fractures (present in a single individual) between the sexes was not statistically significant (χ^2= 19.52, df= 14, p= 0.146). The highest number of fractures observed in an individual was seven. The highest percentage of fractures however, were seen in those males and females with only one fracture (30%). The males are the only individuals that exhibit a total of more than four fractures (Table 5.9).

<u>Table 5.9:</u> Crosstabulation of the number of fractures present in a single individual for the sexes. Raw counts are provided with percentages of the total research sample (n= 345).

# of Frac-tures		**Sex**				**Percentage of the Total (n)**			
		Ind.	**M**	**F**	**Total**	**Ind.**	**M**	**F**	**Total**
0	Count	6	104	101	211	2%	30%	30%	61%
1	Count	1	46	24	71	0.5%	13%	7%	20.5%
2	Count	1	24	10	35	0.5%	7%	3%	10.5%
3	Count	0	9	1	10	0%	3%	0.5%	3.5%
4	Count	0	5	8	13	0%	1%	2%	3%
5	Count	0	3	0	3	0%	1%	0%	1%
6	Count	0	1	0	1	0%	0.5%	0%	0.5%
7	Count	0	1	0	1	0%	0.5%	0%	0.5%
TOTAL	**Count**	**8**	**193**	**144**	**345**	**2%**	**56%**	**42%**	

When examining comparisons of the cemeteries (Figure 5.5), the two earliest cemeteries (Nordby and Tirup) show a greater number of males with trauma (NOR= 28; Tirup= 23). The two later populations (Ole Worms Gade and Horsens Klosterkirke) show fewer injured males than the early sites (OW= 20; HK= 22), but the overall trauma count for males and females in the later sites are equal in total number (n= 34). Frequencies of trauma in both males (n= 93 with trauma) and females (n= 43 with trauma) out of the total sample (n= 345) would indicate that males account for 27% and females account for 13% of recorded trauma.

Figure 5.5: Bar graph illustrating the percentage of individuals with trauma in each of the cemetery samples, by sex.



	HK	OW	NOR	Tirup
Ind.	1	0	0	1
Females	14	15	5	14
Males	28	22	42	21

5.2.2 Age Groups

The presence of trauma in the combined cemetery sample, by age group is presented in Table 5.10. No significant differences were observed in the presence of trauma by age

(χ^2= 4.055, df= 6, p= 0.542). Those aged 31-40 yrs. showed the highest frequency of trauma presence in the total sample, accounting for 12%. The next highest frequency was 11% for those aged 21-30 yrs.

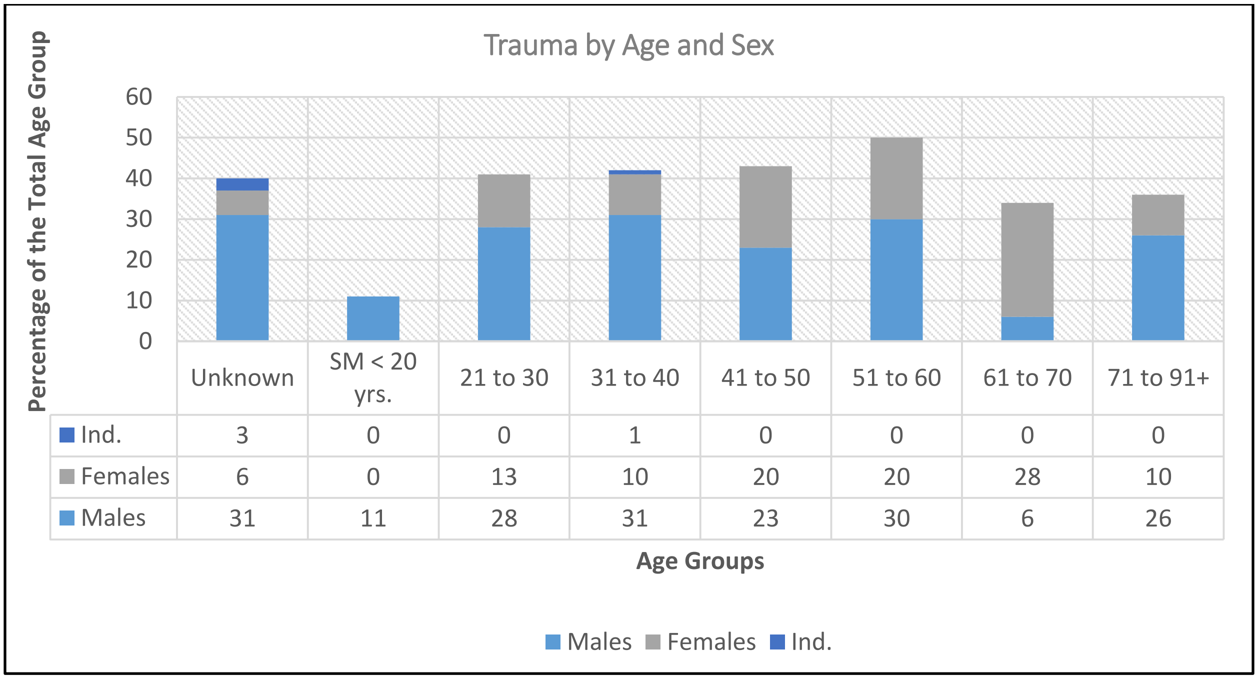
<u>Table 5.10:</u> Crosstabulation of the trauma present and absent in each age group (TA). Raw counts are provided with percentages of the total research sample (n= 345).

Age Group		**Trauma**			**Percentage of the Total (n)**		
		Absent	**Present**	**Total**	**Absent**	**Present**	**Total**
SM <20 yrs.	Count	8	1	9	2%	0.5%	2.5%
21-30 yrs.	Count	52	37	89	15%	11%	26%
31-40 yrs.	Count	57	42	99	17%	12%	29%
41-50 yrs.	Count	17	13	30	5%	4%	9%
51-60 yrs.	Count	5	5	10	1%	1%	2%
61-70 yrs.	Count	12	6	18	3%	2%	5%
71-91+ yrs.	Count	37	21	58	11%	6%	17%
TOTAL	**Count**	**207**	**138**	**345**	**60%**	**40%**	

Across samples from all four cemeteries (n= 345), females within the age group 21-30 years showed the most injuries, accounting for 3.5% (n= 12/345) of the population (Figure 5.6). When sex is not accounted for (Table 5.10), the combined sample of all individuals (n= 345) show 31-40 year olds (n= 42) with the greatest injuries, accounting for 12% of the population.

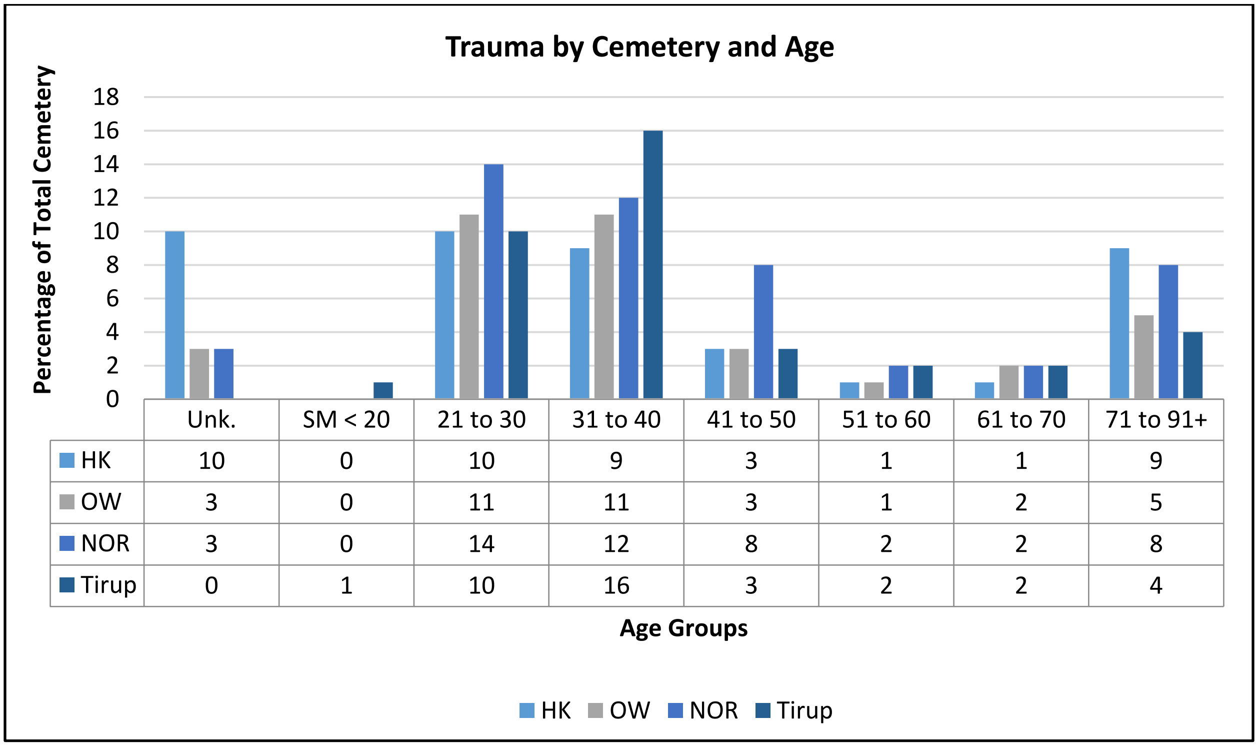
Within cemeteries (Figure 5.7), the urban Ole Worms Gade and rural Tirup showed the highest number of injury in the age group 21-30 years (n= 10). Rural Tirup showed the highest number of injury in the age group 31-40 years accounting for 16% of the total Tirup sample (n= 17/108) Within rural Nordby the most trauma appeared in the age group 21-30 years (14% of the cemetery), and the fewest injuries in the 51-60 and 61-70 year old individuals (2% of the cemetery). Lastly, rural Tirup showed the highest number of injury for 31-40 years (16%). This information is illustrated in Figures 5.6 and 5.7 below.

Figure 5.6: Bar graph illustrating the percentage of trauma presence in each of the age groups by sex.



	Unknown	SM < 20 yrs.	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 91+
Ind.	3	0	0	1	0	0	0	0
Females	6	0	13	10	20	20	28	10
Males	31	11	28	31	23	30	6	26

Figure 5.7: Bar graph illustrating the percentage of trauma presence for each cemetery by age group.



	Unk.	SM < 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 91+
HK	10	0	10	9	3	1	1	9
OW	3	0	11	11	3	1	2	5
NOR	3	0	14	12	8	2	2	8
Tirup	0	1	10	16	3	2	2	4

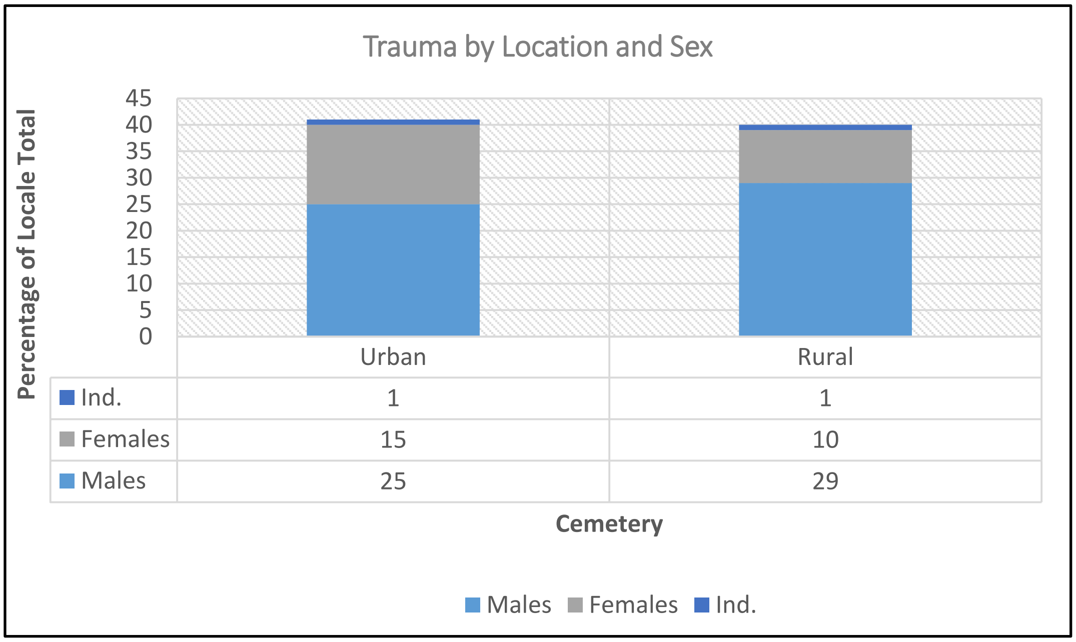
5.2.3 Geographical Location Patterns

When examining the urban and rural cemeteries, the occurrences of trauma were not statistically significant (χ^2= 0.001, df= 1, p= 0.982) as shown in Table 5.11. The raw observed counts show rural individuals with only slightly more trauma (Figure 5.8). These counts indicate that rural males (n= 51) had more injuries than the urban males (n= 42), which accounts for 15% of the total population (n= 345). In turn, urban females (n= 25) had more injuries than the rural females (n= 18), accounting for 7% of the total population (n= 345).

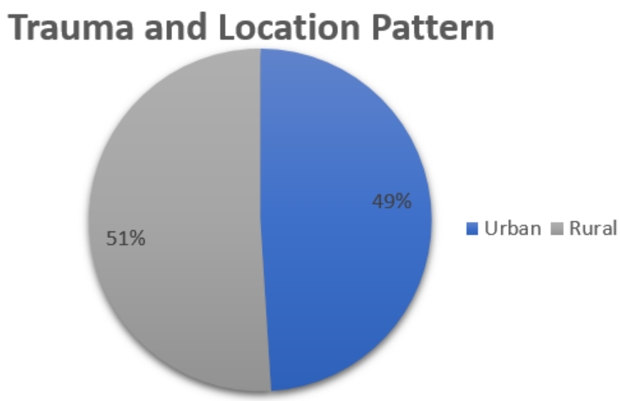
Table 5.11: Crosstabulation of trauma presence and absence by location (urban and rural). Raw counts are accompanied with percentages of the total research sample (n= 345).

Locale		Trauma			Percentage of the Total		
		Absent	Present	Total	Absent	Present	Total
Rural	Count	104	70	174	30%	20%	50%
Urban	Count	103	68	171	30%	20%	50%
TOTAL	**Count**	**207**	**138**	**345**	**60%**	**40%**	

Figure 5.8: Bar graph illustrating percentage of trauma presence by location (urban and rural) and sex.



<u>Figure 5.9:</u> Pie graph illustrating the percentage of trauma presence in urban and rural locations. Percentages are calculated from the total number of injured individuals (n= 138).



There were significant differences by sex among rural individuals with multiple traumatic lesions (χ^2= 9.403, df= 1, *p*= 0.002) (Table 5.12). A total of 35 rural individuals had multiple injuries, accounting for 20% of all rural individuals (n= 174). Of these 35 individuals, 6 (3%) were female and 29 (17%) were male. A total of 33 urban individuals had multiple injuries, 16 (9%) who were female and 17 (10%) who were male, accounting for a total of 19% of the total urban population (n= 171). When broken down into individual cemeteries, individuals from Nordby were driving this difference, as it is the only site in which there was a statistically significant difference between males and females (χ^2= 11.297, df=1, *p*= 0.001), as seen in Table 5.13.

<u>Table 5.12:</u> Crosstabulation of the presence of multiple trauma in rural and urban samples, by sex (no indeterminate individuals). Percentages are calculated from the total number of rural (n= 171) and urban (n=166) individuals.

Location	**Trauma**		**Sex**			**Percentage of the Total (n)**		
			F	**M**	**Total**	**F**	**M**	**Total**
Rural	≤1 Traumatic Lesion	Count	62	74	136	36%	43%	79%
	>1 Traumatic Lesion	Count	6	29	35	4%	17%	21%
TOTAL		**Count**	**68**	**103**	**171**	**40%**	**60%**	

Urban	≤1 Traumatic Lesion	Count	60	73	133	36%	44%	80%
	>1 Traumatic Lesion	Count	16	17	33	10%	10%	20%
TOTAL		**Count**	**76**	**90**	**166**	**40%**	**60%**	

Table 5.13: Crosstabulation of the presence of multiple trauma in the sexes (no indeterminate individuals) by each cemetery. Percentages of the total are calculated from the total number of injured individuals in each cemetery (n= 75/66/91/105).

Cemetery	**Trauma**		**Sex**			**Percentage of the Total (n)**		
			F	**M**	**Total**	**F**	**M**	**Total**
HK	≤1 Traumatic Lesion	Count	25	33	58	33%	44%	77%
	>1 Traumatic Lesion	Count	8	9	17	11%	12%	23%
	TOTAL	**Count**	**33**	**42**	**75**	**44%**	**56%**	
NOR	≤1 Traumatic Lesion	Count	23	27	50	35%	41%	76%
	>1 Traumatic Lesion	Count	0	16	16	0%	24%	24%
	TOTAL	**Count**	**23**	**43**	**66**	**35%**	**65%**	
OW	≤1 Traumatic Lesion	Count	35	40	75	38%	44%	82%
	>1 Traumatic Lesion	Count	8	8	16	9%	9%	18%
	TOTAL	**Count**	**43**	**48**	**91**	**47%**	**53%**	
Tirup	≤1 Traumatic Lesion	Count	39	47	86	37%	45%	82%
	>1 Traumatic Lesion	Count	6	13	19	6%	12%	18%
	TOTAL	**Count**	**45**	**60**	**105**	**43%**	**57%**	

The distribution of individuals with evidence of multiple trauma, greater than one traumatic lesion, for urban and rural locations by age groups is presented in Table 5.14. This comparison showed statistically significant differences (χ^2= 18.362, df= 6, *p*= 0.005) for the urban age groups when unknown and < 20 year olds were not accounted for in the sample. Despite this significance, the rural locales showed a greater number of individuals with multiple injuries (n = 35), which is 20% of the total rural individuals. The age group that had the most multiple injuries for the rural individuals was 31-40 year olds (n = 10), representing 6% of the total rural population.

Table 5.14: Crosstabulation of multiple trauma presence in the age groups by urban and rural location. Percentages of the total are calculated by total number of individuals for the location (n= 174/171).

Locale	Age Group		Multiple Trauma				Percentage of the Total (n)		
			No Lesion	1 Traumatic Lesion	>1 Traumatic Lesion	Total	0	≤1	>1
Rural	SM <20 yrs.	Count	3	1	0	4	2%	0.5%	0%
	21-30 yrs.	Count	25	11	9	45	14%	6%	5%
	31-40 yrs.	Count	31	14	10	55	18%	8%	6%
	41-50 yrs.	Count	6	4	4	14	3%	2%	2%
	51-60 yrs.	Count	4	1	2	7	2%	0.5%	1%
	61-70 yrs.	Count	10	1	2	13	6%	0.5%	1%
	71-91+ yrs.	Count	18	3	6	27	10%	2%	3%
	TOTAL	**Count**	**104**	**35**	**35**	**174**	**60%**	**20%**	**20%**
Urban	SM <20 yrs.	Count	5	0	0	5	3%	0%	0%
	21-30 yrs.	Count	26	9	9	44	15%	5%	5%
	31-40 yrs.	Count	27	13	4	44	16%	8%	2%
	41-50 yrs.	Count	11	1	4	16	6%	0.5%	2%
	51-60 yrs.	Count	1	1	1	3	0.5%	0.5%	0.5%
	61-70 yrs.	Count	2	2	1	5	1%	1%	0.5%
	71-91+ yrs.	Count	18	5	8	31	11%	3%	5%
	TOTAL	**Count**	**102**	**36**	**33**	**171**	**60%**	**21%**	**19%**

5.3 Injury and Fracture Analysis

5.3.1 Fracture Types and Other Lesions

Macroscopic examination of the fractures indicated that they were predominantly in the two stages of healed or partially healed. Only a few fractures observed were considered unhealed. A smooth callus in fully healed bones does not portray a fracture angle or margin; therefore, the type of fracture could not be classified with one hundred percent surety, without using Micro-CT or regular CT for each individual. In all, the types of fractures present in the 345 individuals do differ slightly (Table 5.15).

Table 5.15: Compilation of all of the observed fracture types and trauma types in the research sample. Percentages are calculated by the total population for that group (n) at the top of each column.

Fracture Type	Males (n= 193)	Females (n= 144)	Indet. (n= 8)	Males w/ Multiple Fractures (n= 46)	Females w/ Multiple Fractures (n= 22)	Total # of Individuals with Fractures (n= 345)
Transverse	20 (10.3%)	6 (4.2%)	0	2 (4.4%)	0	26 (8%)
Spiral	4 (2.1%)	2 (1.4%)	0	0	1 (4.5%)	6 (2%)
Oblique	9 (4.7%)	3 (2.1%)	0	0	0	12 (3.5%)
Segmental	1 (0.52%)	1 (0.69%)	0	1 (2.2%)	0	2 (0.58%)
Butterfly	0	2 (1.4%)	0	0	0	2 (0.58%)
Crush	5 (2.6%)	2 (1.4%)	0	0	1 (4.5%)	7 (2%)
Stress	7 (3.6%)	2 (1.4%)	0	1 (2.2%)	0	9 (3%)
Depression	8 (4.1%)	3 (2.1%)	0	3 (6.5%)	1 (4.5%)	11 (3%)
Vertebral Compression	45 (23%)	26 (18%)	2 (25.0%)	16 (34.8%)	10 (45.5%)	73 (21%)
Re-fracture of a Fusion	2 (1.0%)	0	0	1 (2.2%)	0	2 (0.58%)

Spondylolysis	7 (3.6%)	4 (3%)	0	0	0	11 (3%)
Avulsion	7 (3.6%)	1 (0.69%)	0	0	0	8 (2.3%)
Bennett	0	1 (0.69%)	0	0	0	1 (0.29%)
Colles'	1 (double Colles') (0.52%)	2 (1.4%)	0	1 (2.2%)	0	3 (0.87%)
Burst	1 (0.52%)	0	0	0	0	1 (0.29%)
Other Types of Conditions and Trauma Observed						
Traumatic Fusion	2 (1.0%)	3 (2.1%)	0	0	0	5 (1.4%)
Non-traumatic Fusion	46 (23.8%)	21 (14.6%)	1 (12.5%)	2 (4.3%)	2 (9.1%)	67 (19.4%)
Sharp Force	5 (2.6%)	0	0	2 (4.3%)	0	5 (1%)
Cranial Blunt-/Sharp-Force (Chop Wounds)	7 (4%)	1 (1%)	0	4 (8.7%)	0	8 (2%)
Joint Dislocations	10 (5%)	4 (3%)	0	1 (2.2%)	1 (4.5%)	14 (4%)
Os Acromiale	4 (2%)	4 (3%)	0	0	0	8 (2%)
Congenital Hip Dysplasia	0	1 (0.69%)	0	0	0	1 (0.29%)
Non-Functional Cleft	3 (1.6%)	1 (0.69%)	0	0	0	4 (1.2%)
Unclassifiable	16 (8.3%)	8 (5.6%)	0	3 (6.5%)	1 (4.5%)	24 (7%)

Types of fractures for long bones were either transverse, spiral, oblique, butterfly, segmental, crush, depression, Colles', or stress. Types of fractures observed in other bones were classified as compression, avulsion, and Bennett. When depression fractures occurred in the cranium, they were classified as cranial blunt force trauma. The most common type of fracture that appeared in the sample was compression fractures of the vertebrae. The presence of fused boney elements was also noted. These were either traumatic in nature, such as fusion due to a severe fracture at the joint, or a fusion with no clear or definite sign of a traumatic lesion, meaning other pathological conditions could be the causation. The differentiation of non-traumatic lesions, are those that could be equated to accidental causation and appeared in particular areas of the body, as described earlier in Section 3.4.1. Some of these fusions had re-fractured and were partially healed. The re-fractures were considered as another traumatic event, although the original fusion may not have been traumatic in nature (i.e., pathological or activity-related fusions). The breakdown of the compression fractures, rib fractures and spondylosis observed in the samples are presented below in Tables 5.16-5.18.

Table 5.16: Breakdown of all vertebral compression fractures present in the sexes by cemetery and age group. Percentages are calculated from the total number of individuals in the sub-sample.

Cemetery	Vertebral Compression Fractures	Sex				Percentage of the Total (n)			
		F	M	Ind.	Total	F	M	Ind.	Total
HK (n=79)	Count	9	10	1	20	11%	13%	1%	25%
OW (n=92)	Count	6	9	0	15	7%	10%	0%	17%
NOR (n=66)	Count	1	14	0	15	2%	21%	0%	23%
Tirup (n=108)	Count	10	12	1	23	10%	10%	1%	21%
TOTAL (n=345)		**26**	**45**	**2**	**73**	**8%**	**13%**	**1%**	**21%**
Age Group		**F**	**M**	**Ind.**	**Total**	**F**	**M**	**Ind.**	**Total**
Unk. (n=32)	Count	2	2	1	5	6%	6%	3%	15%
SM <20 yrs. (n=9)	Count	0	0	0	0	0%	0%	0%	0%
21-30 yrs. (n=89)	Count	7	10	0	17	8%	11%	0%	19%

31-40 yrs. (n=99)	Count	7	16	1	24	7%	16%	1%	24%
41-50 yrs. (n=30)	Count	4	5	0	9	13%	17%	0%	30%
51-60 yrs. (n=10)	Count	1	3	0	4	10%	30%	0%	40%
61-70 yrs. (n=18)	Count	2	1	0	3	11%	6%	0%	17%
71-91+ yrs. (n=58)	Count	3	8	0	11	5%	14%	0%	19%
TOTAL (n=345)		**26**	**45**	**2**	**73**	**8%**	**13%**	**1%**	**21%**

<u>Table 5.17:</u> Breakdown of all rib fractures present in the sexes, for each cemetery and age group. Percentages are calculated from the total number of individuals in the sub-sample.

Cemetery	**Rib Fractures**	**Sex**				**Percentage of the Total (n)**			
		F	**M**	**Ind.**	**Total**	**F**	**M**	**Ind.**	**Total**
HK (n=79)	Count	1	4	0	5	1%	5%	0%	6%
OW (n=92)	Count	3	3	0	6	3%	3%	0%	6%
NOR (n=66)	Count	0	1	0	1	0%	2%	0%	2%
Tirup (n=108)	Count	0	2	0	2	0%	2%	0%	2%
TOTAL (n=345)		**4**	**10**	**0**	**14**	**1%**	**3%**	**0%**	**4%**
Age Group		**F**	**M**	**Ind.**	**Total**	**F**	**M**	**Ind.**	**Total**
Unk. (n=32)	Count	0	2	0	2	0%	6%	0%	6%
SM <20 yrs. (n=9)	Count	0	0	0	0	0%	0%	0%	0%
21-30 yrs. (n=89)	Count	2	2	0	4	2%	2%	0%	4%
31-40 yrs. (n=99)	Count	1	3	0	4	1%	3%	0%	4%
41-50 yrs. (n=30)	Count	0	0	0	0	0%	0%	0%	0%
51-60 yrs. (n=10)	Count	1	0	0	1	10%	0%	0%	10%
61-70 yrs. (n=18)	Count	0	0	0	0	0%	0%	0%	0%

71-91+ yrs. (n=58)	Count	0	3	0	3	0%	5%	0%	5%
TOTAL (n=345)		**4**	**10**	**0**	**14**	**1%**	**3%**	**0%**	**4%**

Table 5.18: Breakdown of all spondylolysis present in the sexes, for each cemetery and age group. Percentages are calculated from the total number of individuals in the sub-sample.

Cemetery	**Spondylolysis**	**Sex**				**Percentage of the Total (n)**			
		F	**M**	**Ind.**	**Total**	**F**	**M**	**Ind.**	**Total**
HK (n=79)	Count	1	0	0	1	1%	0%	0%	1%
OW (n=92)	Count	2	2	0	4	2%	2%	0%	4%
NOR (n=66)	Count	0	3	0	3	0%	5%	0%	5%
Tirup (n=108)	Count	1	2	0	3	1%	2%	0%	3%
TOTAL (n=345)		**4**	**7**	**0**	**11**	**1%**	**2%**	**0%**	**3%**
Age Group		**F**	**M**	**Ind.**	**Total**	**F**	**M**	**Ind.**	**Total**
Unk. (n=32)	Count	0	0	0	0	0%	0%	0%	0%
SM <20 yrs. (n=9)	Count	0	0	0	0	0%	0%	0%	0%
21-30 yrs. (n=89)	Count	0	1	0	1	0%	1%	0%	1%
31-40 yrs. (n=99)	Count	3	3	0	6	3%	3%	%	6%
41-50 yrs. (n=30)	Count	0	0	0	0	0%	0%	0%	0%
51-60 yrs. (n=10)	Count	0	1	0	1	0%	10%	0%	10%
61-70 yrs. (n=18)	Count	1	0	0	1	6%	0%	0%	6%
71-91+ yrs. (n=58)	Count	0	2	0	2	0%	3%	0%	3%
TOTAL (n=345)		**4**	**7**	**0**	**11**	**1%**	**2%**	**0%**	**3%**

5.3.2 Fracture Frequencies

Fracture frequencies were calculated to aid in quantifying the amount of trauma in the samples. As described in Chapter 4, methods were employed to examine differential frequencies within and between groups of individuals following Judd (2002a). The resulting frequencies from these two types of count are only informative of which bones were affected by trauma and where in the body the most injuries occurred. For these counts, only segments that were 75% or more complete were included in the segment count, and only bones that were 100% complete are included in the bone count. Calculated frequencies can be found in Appendix C.

The trauma patterns exhibited in both the urban and rural populations were similar and did not show one portion of the body affected over another. The bones that were affected were variable throughout the body in both urban and rural samples (Appendix C). However, within the overall sample, individuals showed that the lumbar and the thoracic vertebrae were fractured the most. The proximal femora, especially those that were a dislocation with a fracture in the femoral head or neck, were also high in their count. Other heavily affected areas from the total sample showed the scapulae, metacarpals, carpals, and right ribs with higher bone and segment counts. When examining the individual cemeteries, Horsens Klosterkirke showed the right ischium with the highest bone count, with the right proximal femur, right clavicle, and phalanges following. Ole Worms Gade had three areas that were equal for their highest bone count: right ribs, right middle fibula, and the right ribs. Nordby were equal in bone counts for the right temporal and left middle tibia. Lastly, the highest bone count for Tirup was in the right carpals, with the sternum and right distal radius following. Therefore, the pattern of bones affected among and between the cemeteries were not very similar to one another, nor did they show distinct patterning. However, when the entirety of the sample is considered, those areas affected by trauma are clearer.

The most informative fracture frequencies at the population level were the individual mean trauma counts (fractures observed by the number of individuals in the sample), mean multiple injury counts (fractures observed by the number of only injured individuals in the sample), and individual counts (individuals with multiple fractures by the number of individuals in the sample). The total number of injured individuals in the samples, the total number of fractures observed, the total number of individuals with one or more injuries, and the total number of individuals in each sample are shown in Table 5.19 below. The counts represented in this table are only calculations of a ratio. Also, the fractures accounted for are only those found in the long bones. As Judd's (2002a) study shows, that completeness of these long bones plays a pivotal role in accounting for them. It is hard to assess completeness of groups of bones such as the vertebrae. When the entire sample was considered (n= 345), the fracture frequency indicated that there were 0.19 injuries per individual. However, when only considering the injured individuals in the entire sample (n= 138), there were 0.48 (mean multiple injury count = # of fractures observed ÷ # of injured individuals) injuries per individual in 40% (individual count = # of individuals with one or more injuries ÷ # of individuals in the sample) of the sample. When looking at individual cemeteries, 47% (individual count) of rural Nordby had 0.61 (mean multiple injury count) injuries per person. Urban Horsens Klosterkirke had the second highest injury occurrence with 43% (individual count) of the sample exhibiting 0.47 (mean multiple injury count) injuries per person.

Table 5.19: Fracture frequency calculations (as defined by Judd, 2002a) of long bone fractures present in each cemetery. Formulas are noted (*) below the table.

	Total # of Indivs.	Total # of Long Bone Fractures Observed	Total # of Indivs. w/ 1 or more injuries	Total # of Injured Indivs.	*Individual Count	*Individual Mean Trauma Count	*Mean Multiple Injury Count
HK	79	16	34	34	0.43	0.20	0.47
OW	92	22	34	34	0.37	0.24	0.65
NOR	66	19	31	31	0.47	0.29	0.61
Tirup	108	9	39	39	0.36	0.08	0.23
TOTAL	345	66	138	138	0.40	0.19	0.48

***Formulas for calculating frequencies:**

Individual Mean Trauma Count = # of fractures observed ÷ # of individuals in the sample
Mean Multiple Injury Count = # of fractures observed ÷ # of injured individuals
Individual Count = # of individuals with one or more injuries ÷ # of individuals in the sample

5.3.3 Sum Person-Years and Odds Ratio

The sum person-years was calculated for individuals with only long-bone fractures. Table 5.20 presents the calculations for the total population and each individual cemetery.

Table 5.20: Person-years calculations (as defined by Glencross & Sawchuck, 2003) for long bone fractures present, in the total population and each cemetery. Person-years calculations represent each individual age cohort, not those that suffered trauma.

Age Group	Cohort Mid-point	# of People	Person-Years (P-Y)	HK	P-Y	OW	P-Y	Tir	P-Y	NOR	P-Y
		Total Population		Cemetery Populations							
SM <20 yrs.	15	9	135	2	30	3	45	4	60	0	0
21-30 yrs.	25	89	2225	20	500	24	600	25	500	20	500
31-40 yrs.	35	99	3465	20	700	24	840	40	1400	15	525
41-50 yrs.	45	30	1350	8	360	8	360	5	225	9	405
51-60 yrs.	55	10	550	1	55	2	110	6	330	1	55
61-70 yrs.	65	18	1170	1	65	4	260	5	325	8	520

71-80 yrs.	75	44	3300	10	750	12	900	14	1050	8	600
81-90+ yrs.	85	14	1190	6	510	3	255	2	170	3	255
Sum Person -Years			**13,385**		**2,970**		**3,370**		**4,060**		**2,860**

Crude prevalence rates for only the long bones were calculated (Table 5.21). The "strength" of the odds ratio calculations (as described in Glencross, 2002), indicate that those between certain values show an amount of strength for the calculated outcome. The odds ratios were then computed using the below formula from Chapter 4. Each odds ratio is accompanied by its 95% Confidence Interval calculation.

$$(A \div C) \div (B \div D) = AD \div BC$$

<u>Table 5.21:</u> Calculated Crude Prevalence Rates (as defined by Glencross, 2002) for long bone fractures in different population groups. The strong positive odds ratio for males and females is significant at a 95% confidence interval (not crossing over 1).

Population	Long bone Fractures	Total # of Individuals in the Sample	*Crude Prevalence Rate	Odds Ratio
HK	16	79	0.20	N/A
OW	22	92	0.24	N/A
NOR	19	66	0.29	N/A
Tirup	9	108	0.08	N/A
Urban	38	171	0.22	1.39 (weak) **95% CI = 0.82-2.00
Rural	28	174	0.16	
Males	32	193	0.17	2.38 (strong positive) **95% CI = 1.19-4.77
Females	12	144	0.08	
Age ~30 yrs. (AG 1)	16	98	0.16	AG1/AG2 = 1.73 (moderate positive)
Age 31-60 yrs. (AG 2)	13	139	0.09	

Age > 60 yrs. (AG 3)	10	76	0.13	**95% CI = 0.80-3.76 AG2/AG3 = 0.71 (weak) **95% CI = 0.30-1.70 AG1/AG3 = 1.24 (weak) **95% CI = 0.53-2.89

*Crude Prevalence Rate = total # of long-bone fractures ÷ total # of individuals in the sample
**95% CI Upper = e^ [ln (OR) + 1.96√(1/a + 1/b + 1/c + 1/d)]
95% CI Lower = e^ [ln (OR) - 1.96√(1/a + 1/b + 1/c + 1/d)]

Table 5.22 shows crude prevalence rates of long bone fractures for each cemetery, urban and rural locations, males and females, and age groups. The corrected crude prevalence rates were calculated using the total number of long bone fractures divided by the total number of fractured long bones and complete long bones in the sample. The age groups were collapsed in order to have large enough sample sizes to calculate odds ratios. As such these collapsed age groups do not directly coincide with the other statistical comparisons by age group. Table 5.23 shows the use of person-years calculations to determine the fracture rate and the odds ratio.

<u>Table 5.22:</u> Corrected Crude Prevalence Rates (as defined by Glencross, 2002) of long bone fractures in the population groups. Moderate positive relationships are seen within sexes, location, and AG1/AG2, and are significant at a 95% confidence interval.

Population	Long bone Fractures	Total # of Complete Long Bones + Total # of Bones w/ Fractures	*Corrected Prevalence Rate (10^3)	Odds Ratio
HK	16	389	41.1	N/A
OW	22	390	56.4	N/A
NOR	19	447	42.5	N/A
Tirup	9	547	16.4	N/A
Urban	38	779	48.7	1.73 (moderate positive) **95% CI = 1.31-2.47
Rural	28	994	28.2	
Males	32	1079	29.7	1.72 (moderate positive) **95% CI = 1.33-2.65
Females	12	694	17.3	

Age ~30 yrs. (AG 1)	16	555	28.8	AG1/AG2 = 1.76 (moderate positive) **95% CI = 1.17-3.11 AG2/AG3 = 0.59 (moderate negative) **95% CI = 0.38-1.13 AG1/AG3 = 1.03 (no effect) **95% CI = 0.70-1.87
Age 31-60 yrs. (AG 2)	13	792	16.4	
Age > 60 yrs. (AG 3)	10	359	27.9	

* Corrected Prevalence Rate =
Total # of long-bone fractures ÷ (total # of bones with fractures + total number of complete long-bones)
**95% CI Upper = $e^{[\ln(OR) + 1.96\sqrt{(1/a + 1/b + 1/c + 1/d)}]}$
95% CI Lower = $e^{[\ln(OR) - 1.96\sqrt{(1/a + 1/b + 1/c + 1/d)}]}$

<u>Table 5.23:</u> Person-year rates of long bone fractures (as defined by Glencross & Sawchuck, 2003) in the population groups. The strong positive odds ratio values are for comparisons between AG1/AG2 and A1/A3, and are significant at a 95% confidence interval.

Population	**Long bone Fractures**	**Person-Years Total**	**Rate/10^3**	**Odds Ratio**
HK	16	2970	5.4	N/A
OW	22	3370	6.5	N/A
NOR	19	2860	6.6	N/A
Tirup	9	4060	2.2	N/A
Urban	38	6340	6.0	1.48 (weak) *95% CI = 0.91-2.41
Rural	28	6920	4.0	
Males	32	7680	4.2	1.23 (weak) *95% CI = 0.61-2.46
Females	12	6220	1.9	

*95% CI Upper = $e^{[\ln(OR) + 1.96\sqrt{(1/a + 1/b + 1/c + 1/d)}]}$
95% CI Lower = $e^{[\ln(OR) - 1.96\sqrt{(1/a + 1/b + 1/c + 1/d)}]}$

5.3.4 Observed Patterns in Cemetery Populations

Table 5.24 presents the distributions of trauma by sex for each cemetery. The presence of trauma was not statistically significant (χ^2= 2.962, df= 3, *p*= 0.389) between the cemeteries (Table 5.25). Furthermore, the presence of individuals with multiple traumas (>1 traumatic lesion present) was not statistically significant (χ^2= 1.639, df= 3, *p*= 0.651) between the cemetery samples (Table 5.26).

Table 5.24: Breakdown of sexes with trauma by individual cemetery. Percentages are calculated from the total number of injured individuals (n= 138).

					Percentage of the Total		
Cemetery	**Males**	**Females**	**Ind.**	**Total**	**M**	**F**	**Ind.**
HK	**22**	**11**	**1**	**34**	**16%**	**8%**	**1%**
OW	**20**	**14**	**0**	**34**	**14%**	**10%**	**0%**
NOR	**28**	**3**	**0**	**31**	**20%**	**2%**	**0%**
Tirup	**23**	**15**	**1**	**39**	**17%**	**11%**	**1%**
TOTAL	**93**	**43**	**2**	**138**	**67%**	**26%**	**2%**

Table 5.25: Crosstabulation of trauma presence by individual cemetery. Percentages are calculated from the total research sample (n= 345).

							Percentage of the Total			
Trauma		**HK**	**NOR**	**OW**	**Tirup**	**Total**	**HK**	**NOR**	**OW**	**Tirup**
Absent	Count	45	35	58	69	206	13%	10%	17%	20%
Present	Count	34	31	34	39	138	10%	9%	10%	28%
TOTAL	**Count**	**79**	**66**	**92**	**108**	**345**	**23%**	**19%**	**27%**	**31%**

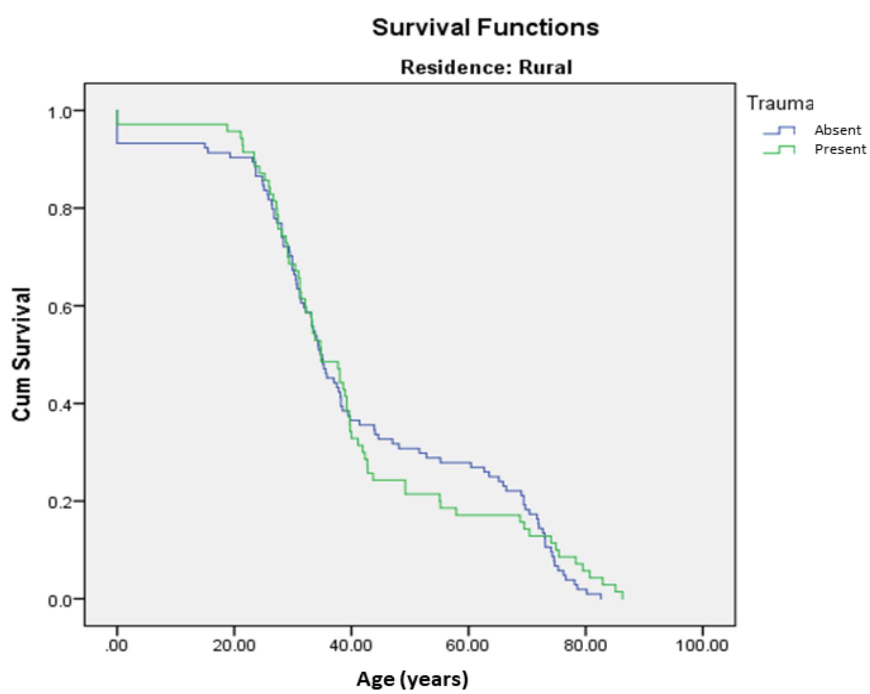
Table 5.26: Crosstabulation for individuals with multiple injuries by each cemetery. Percentages are calculated from the total research sample (n= 345).

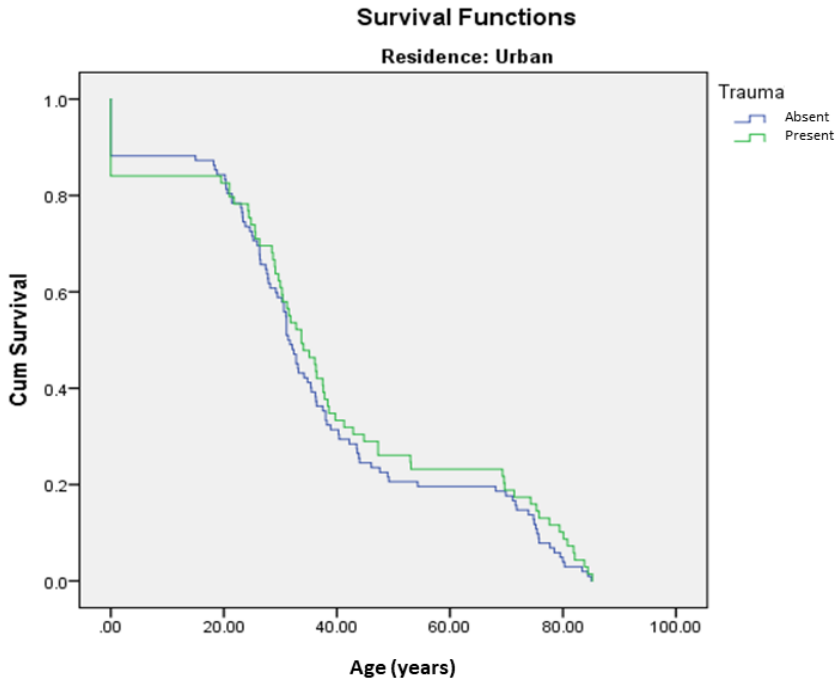
							Percentage of the Total			
Multiple Trauma		**HK**	**NOR**	**OW**	**Tirup**	**Total**	**HK**	**NOR**	**OW**	**Tirup**
≤1 Lesion	Count	62	50	76	89	277	18%	13%	22%	26%
>1 Lesion	Count	17	16	16	19	68	5%	5%	5%	6%
TOTAL	**Count**	**79**	**66**	**92**	**108**	**345**	**23%**	**19%**	**27%**	**31%**

5.4 Survival Analyses

Additional analyses were performed to test for differences in survivorship for those individuals that sustained fractures. Survival analysis was done using SPSS Kaplan-Meier tests. There was no significant difference (χ^2= 1.313, df= 1.000, p= 0.252) in survivorship for those individuals that experienced trauma compared to those individuals who did not. There was also no significant differences in survivorship for males (χ^2= 1.688, df= 1.000, *p*= 0.194) or females (χ^2= 0.011, df= 1.000, *p*=0.915), or for urban (χ^2= 1.016, df= 1.000, *p*= 0.313) and rural (χ^2= 0.191, df= 1.000, *p*= 0.662) individuals. Although not statistically significant, the survival analysis suggested that some individuals in urban and rural locales with trauma lived longer than those without trauma (Figure 5.10). The first graph in Figure 5.10 for rural locations, demonstrates that trauma in older adults tended to have reduced survivorship. For the urban locations individuals with or without trauma have similar survivorship curves, though those with trauma are slightly greater than those without. This is not to suggest that there was a tendency for individuals to live longer despite their traumatic injuries. As survival analyses tend to use grouped cohorts from the initial samples, interpretation of these survival functions should not be over-interpreted.

Figure 5.10: Kaplan-Meir survival analysis for trauma absence and presence in rural and urban locations. Individuals are represented by their age cohort which is the Transition Analysis point estimate.
*0 (blue) = presence of trauma, 1 (green) = absence of trauma





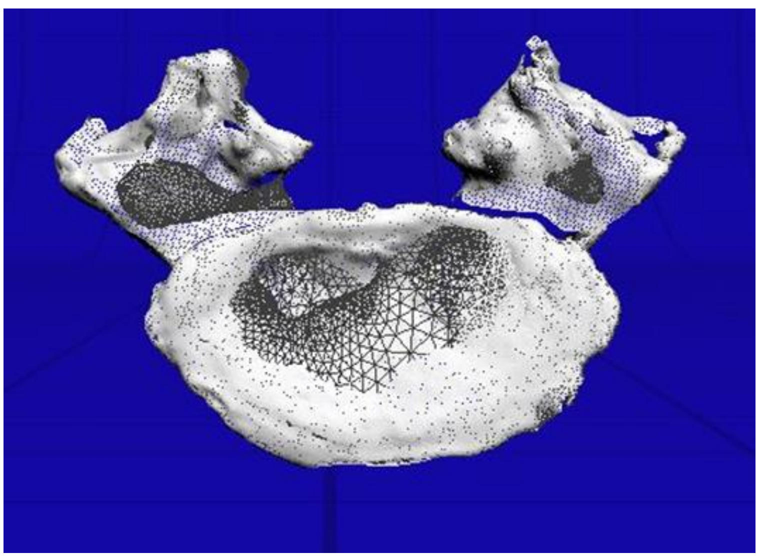
5.5 3D Imaging Results

After initial assessment of the skeletal remains, selected individuals from each cemetery were scanned using both CT and NextEngine 3D scanning. The goal was to scan the full range of lesions seen among the total sample of fracture and trauma variations as a pilot study to understand the potential role of 3D scanning technologies for the analysis of skeletal trauma in bioarchaeological samples

5.5.1 NextEngine Scans

The scans from the NextEngine were only informative for particular kinds of fractures. Predominantly, the depression fractures were easier to distinguish on the vertebral bodies and the cranium than other very well healed antemortem fractures. Other types of fracture, such as those observed in the long bones, were not easy to see in the NextEngine scans. Many of the long bone fractures were very well healed, and although a callus was present, the topographical surfaces captured by the scans were too uniform to determine any other informative data about the fracture. Long bone scans were also problematic because of their large size in relation to the small platform. Nonetheless, the range in fractures could be clearly seen in the scans. With the rendering process, fractures were more easily observed when the scan was placed in a latticework or pixelated image (Figure 5.11). In these types of images, the distance between the nodes changed across the bone. The nodes that show shorter distances between them are showing areas of more dense bone. However, within the fracture (depressed) portion of bone, there is less density, showing discrepancies in the cortical bone due to trauma (compression) to the vertebral body. The lattice work showed changes in angles and topography more clearly than the original scanned image. In particular, depressions were seen much more clearly, better clarifying whether a fracture was present or not. This will be demonstrated further in Chapter 6.

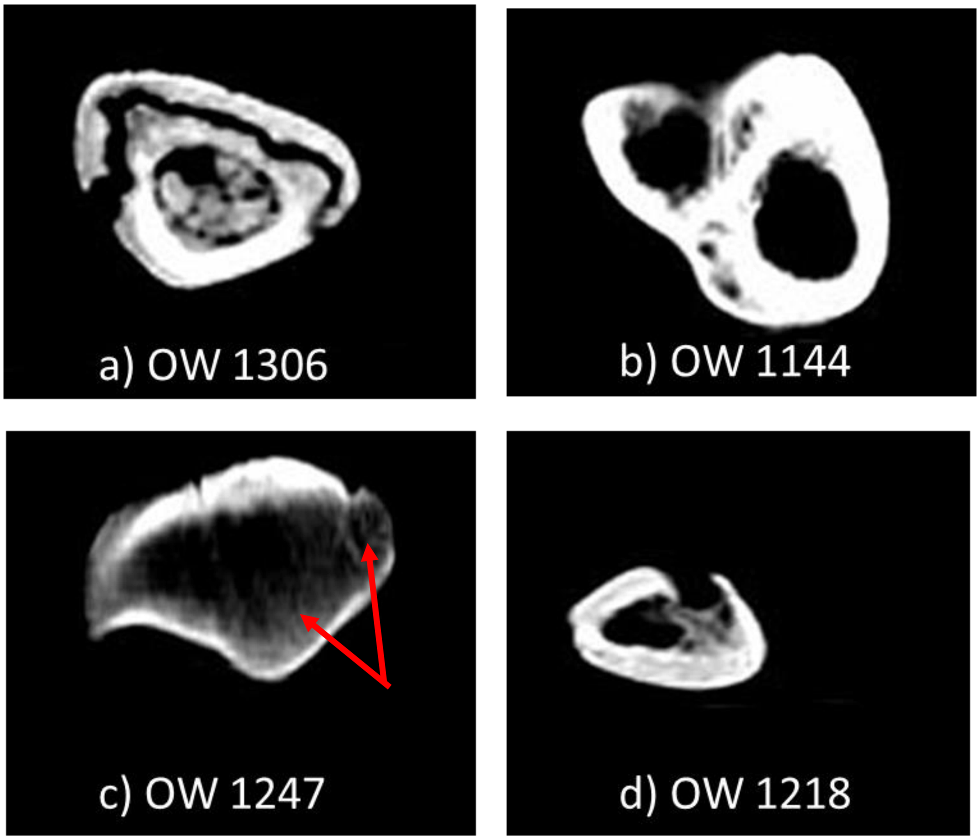
Figure 5.11: Image of the lattice or pixelated image during rendering for NextEngine. Image depicts a 5th lumbar (view is superior).



5.5.2 CT Scans

Images from the CT scans showed variation in many internal boney structures such as medullary cavities and excess bone growth (Figures 5.12a to 5.12d). In Figure 5.12a, this particular fractured bone was accompanied by extra bone growth in the medullary cavity. The extra bone growth was not considered to be dense cortical bone, due to its transparent appearance in the scan. Dense cortical bone would appear as non-transparent, essentially resulting in a stark white on the scan. Bones that tended to have less cortical and more trabecular boney structures appeared more transparent, but with more organized internal structure. Long bone fractures, especially those that were spiral, oblique, or compound, and improperly set at the time of injury, showed two portions of bone. For example, in Figure 5.12b, the individual had a severe compound fracture, causing the two portions of bone to overlap one another. The resulting CT shows two medullary cavities as a result of the bone not being re-set or by being immobilized long enough for the bone to set in the overlap position. The bones have fused back together during their healing process, which is indicated by the cortical bone surface between the two medullary cavities. In Figure 5.12c, the patella was scanned for an avulsion fracture. A lot of the internal structure was not captured in the scan due to the slice size (3 mm), but there is still evidence of the start of the trabecular structure as indicated by the red arrows in 5.12c. Lastly, Figure 5.12d shows a scan of a fractured fibula that was accompanied with severe infection. The infection was clear from the external examination (Figure 5.14), but is apparent by the presence of the woven bone in the medullary cavity. This may also be the origin of the woven bone in Figure 5.12a. The type of infection is not available from observations of the CT scan or other studies.

<u>Figures 5.12a to 5.12d:</u> Examples of raw CT scan results of fractures and lesions observed in the sample. The red arrows show trabecular structure in the patella (c).
*a) right tibia cross-section; b) right tibia cross-section; c) left patella cross-section ; d) left tibia cross-section

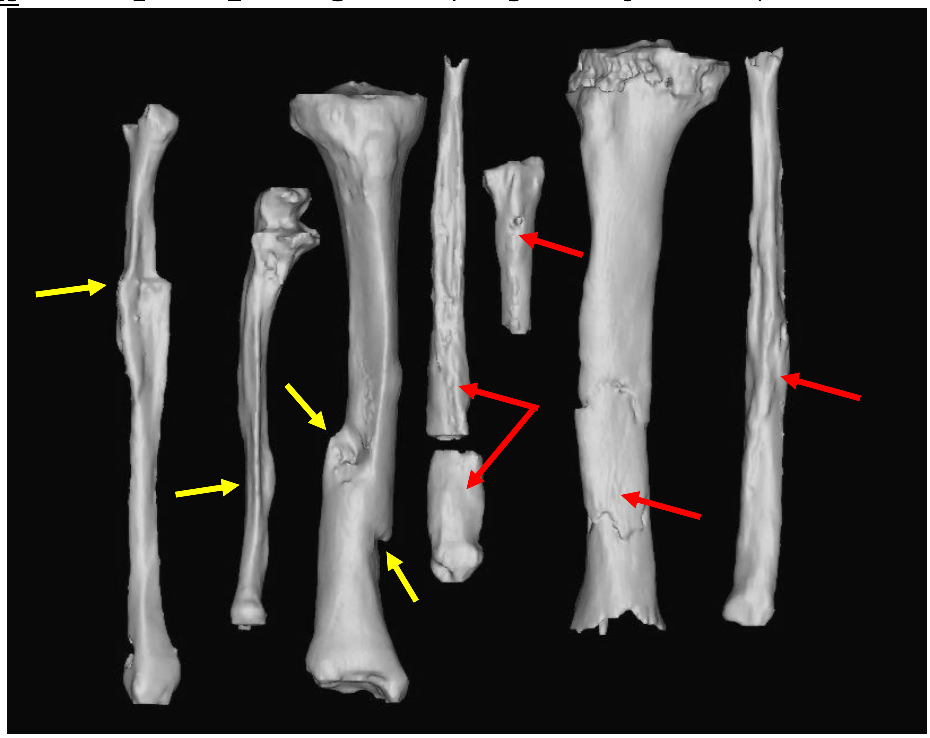


Rendered images were created in MIMICS from the original CT scans (Materialise NV, 2015). Examples of rendered 3D models can be seen in Figure 5.13, and are the same long bones as in the CT scans in Figures 5.12a to 5.12d, with the exception of 5.12c, the patella. The four far-right boney elements are those bones with severe infections from fractures, indicated by the red arrows. The malaligned fractures are pictured on the three far left boney elements and are further indicated by yellow arrows where the malalignment occurs. The bones can also be seen in Figure 5.14, in the real-life stills. Rendered images from the CT scans were not as successful for inferring information about trauma as hoped. Reasons for this are discussed further in Chapter 7.

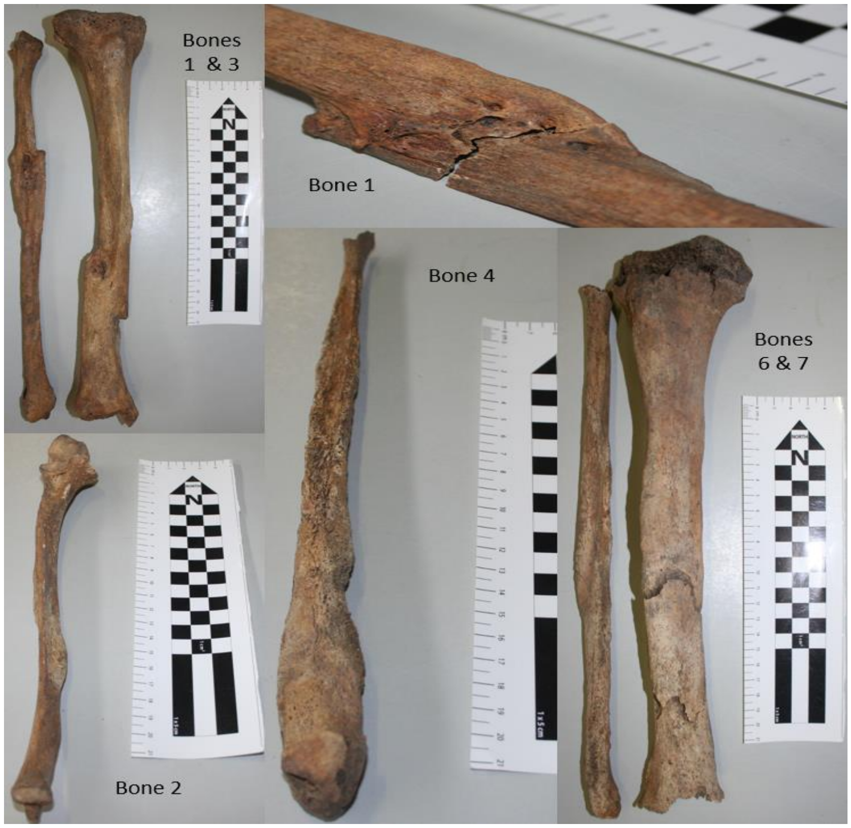
<u>Figure 5.13:</u> Image of a MIMICS 3D rendering for Ole Worms Gade individuals. The individuals are those depicted in Figures 5.12a to 5.12d. The red arrows show infected bone. The yellow arrows show malaligned or un-set bones.

*Bones 1 & 3 = right tibia and fibula; Bone 2 = right ulna; Bone 4 = left fibula; Bone 5 = left distal radius with a posterior view; Bones 6 & 7 = right tibia and fibula

<u>Bones</u> = 1 2 3 4 5 6 7



<u>Figure 5.14:</u> Collage of images showing the external appearance of the bones depicted in the scans for Figure 5.10.



Ultimately, fracture classification was based more directly on the macroscopic examination instead of the digital captures, as the digital imaging in this thesis project was a pilot study. Therefore, the statistical analyses described in this chapter are those involving macroscopic fracture classifications and not classifications resulting from studying the NextEngine or CT scans. The implications for the role of 3D imaging in analysis of skeletal trauma is discussed further in Chapter 7.

CHAPTER 6: DISCUSSION

6.1 Introduction

In this chapter, results of the observed patterns of trauma in the samples are discussed in a broader context, toward achieving a better understanding of Danish medieval urban and rural lifestyles. Following a detailed explanation of the observed patterns, the hypotheses proposed at the beginning of the thesis are revisited with respect to the observed results.

6.2 Population Patterns in Traumatic Lesions

6.2.1 Sex Patterns

Differences in the presence of trauma in males (27% of the total population), females (12%), and those of indeterminate sex (1%) were statistically significant (Table 5.6), with males exhibiting more trauma than females. This pattern of a greater frequency of trauma in males is consistent with those of other studies in medieval Europe (e.g., Grauer & Roberts, 1996; Judd & Roberts, 1999; Agnew & Justus, 2014; Agnew et al., 2015). The cemetery at which this difference was the greatest is rural Nordby, with only 3 females (5% of Nordby; n= 3/66) and 28 males (42% of Nordby; n= 28/66) exhibiting trauma (Figure 5.5). In this sample, the males were the only individuals with joint dislocations and sharp and blunt force traumas. The three other cemeteries (Tirup, Ole Worms Gade, and Horsens Klosterkirke) show a more equal distribution of injury between males and females (Figure 5.5 and Table 5.24). Like Nordby, findings from rural Tirup showed that only males exhibit joint dislocations (Table 5.7) and blunt- and sharp-force injuries (Table 5.8), but almost the same proportion of females were injured in the population when other types of fractures are considered. The earlier urban cemetery of Ole Worms Gade, showed evidence that both males and females had dislocations, but only one female exhibited evidence of cranial blunt-force trauma. The later urban cemetery of Horsens

Klosterkirke had both males and females with joint dislocations, but one older male was the victim of cranial blunt-force and sharp-force traumas and one female had sharp-force trauma. Males in this population showed more rib fractures, which is the opposite compared to Ole Worms Gade.

The presence of cranial blunt- and sharp- force traumas is not surprising for these cemetery samples due to the time periods they represent. In particular some of the cranial blunt-force traumas represented in these samples are distinctly 'chop wounds'. These wounds possess BOTH blunt- and sharp- forces (Wittschieber et al., 2016). As sharp-force wounds are actually considered a sub-category of blunt-force trauma, it is not surprising to see the evidence of sharp weapons in blunt-force injuries (Blau, 2017). Sharp-force has often been referred to as a blunt force action to the body, but is provided by a sharpened object (Smith et al., 2003). The result of these forces in chop wounds, are caused by a large weapon with a sharpened edge being exerted with a slow load to a small surface area. Even though other wounds that are only seen as blunt-force to the cranium may have other possible aetiologies such as a fall or an object dropped from above (Scott & Buckley, 2010), these 'chop wounds' are seen strictly as violent in nature as it is unlikely an individual would have fallen directly on a sharpened edge of a large, heavy weapon. Boyd (1996) suggests that these findings may therefore be direct evidence of physically 'aggressive behaviours'. Furthermore, the fact that these lesions are present in the cranium suggests intentional and violent trauma (Boyd, 1996). Injuries located at the front and top of the cranial vault can further indicate that there is more intragroup than intergroup conflict amongst the individuals (Steadman, 2008). All violence is interpersonal, but injury patterns can differ depending on whether that person is a next door neighbour (e.g. intragroup) versus a random individual from another country (e.g. intergroup). Some kinds of injury may result from distinct warfare, whereas other instances of injury may not be as severe as you would see in warfare-like combat. Although this would assume warfare-like combat to be strictly between those individuals from different countries, this is not only the case. There are instances of warfare combat within an individual country, such as the Civil War of the United States or the Saxon wars in Britain. But warfare or combat, even massacres tend to produce much more intense injuries than those resulting from neighbouring skirmishes. As such, injuries that are more dispersed throughout the cranium may indicate that an individual employed a defensive behaviour rather than being involved in actual warfare (Paine et al., 2007). Warfare, from the past, follows the aim to strike down or kill the opponent, causing injuries to be more direct and area focused. Modern warfare follows a much different pattern and aim. However, a person trying to flee an attack may cause the trauma to be more 'off target' as they try to protect themselves from glancing blows.

A lot of the cranial trauma observed in this research (Table 5.8; n= 8 individuals, mostly males, with 12 separate injuries or impacts; total observed crania= 260) was present on the frontal or parietal regions (n=8), but it cannot be said with certainty that this was due to conflict originating in their own population. The rural individuals had more instances of cranial trauma (n= 6), but they also were the only individuals that had more than one impact site. Looking at the cranial trauma in particular could suggest that males were taking part in more dangerous activities, since they make up seven of the eight individuals that show these injuries. More so that they were more involved in this possible violent interactions, more so than the females. Although research has suggested cranial trauma can be considered to be violent behaviour, cranial trauma can result from accidents such as falling or having something fall from above (Scott & Buckley, 2010). Similar to findings for the rural individuals, defining the causation for the cranial injuries in the urban centres is presumptive at best. Research has suggested that urbanisation and the proximity of living spaces can lead individuals to take part in more violent behaviour than would be seen in the rural countryside where individuals have more complications in fractures (Judd & Roberts, 1999). Since the rural individuals have more cranial injuries than the urban individuals in this sample, this does not apply to the current study. In their study of an urban medieval Italian site, Boccone and colleagues (2011) found females had more injuries than males. This contradicts many of the urban/rural bioarchaeological studies on injuries which show that rural females tend to have more injuries than urban females. As a result, the Boccone et al. (2011) study suggested that the urban lifestyle was comparable to the hardened lives of the rural individuals, meaning that urban life was just as hardened and dangerous as that in the rural communities.

The most common form of fractures observed, were compression fractures in the spinal column (Table 5.16). Surprisingly, the males of all four cemeteries showed greater presence of compression fractures in the vertebrae than females. Females also showed this traumatic condition, but to a lesser extent than their male counterparts. Researchers have suggested that compression fractures are more related with osteoporotic processes and a reduction in bone mass (Cooper, 1993). In fact, compression fractures are a common fragility fracture for any individuals with osteoporosis. Therefore, compression fractures would be more expected in older females. In their study of Wharram Percy (Yorkshire, UK), Agarwal and colleagues (2004) supported this hypothesis by observing only female individuals with compression fractures in their skeletal sample. Studies of medieval Poland showed that the greatest number of fractures was compression fractures in the vertebrae; the urban sample showed these in both males and females but, they were more frequent in the males (Agnew & Justus, 2014; Agnew et al., 2015). Additionally, compression fractures were present in younger as well as the older adults. Agnew et al. (2015) concluded that compression fractures are seen in those individuals that likely performed labour-heavy activities because of the variation in the distribution of these fractures by sex and age. For the cemetery samples of this research, compression fractures follow that of Agnew and Justus (2014) more closely in their overall pattern. These vertebral fractures were seen throughout the age groups (both young and old), and males tended to acquire them more often. Labour intensive activities that could possibly be attributed to the compression injuries in the Danish sample had a lot to do with agricultural practices. The mouldboard plow was introduced to Denmark from AD 1000-1100 and was used to do very deep plowing (Lauring, 1960). Other agricultural technologies used, included the harrow which is pulled behind horses to help break up the earth, iron sickle in harvesting, and even the grain mill. The grain mill however, was not introduced until 1100 (Lauring, 1960). Although there was seasonal work much like other crop rotation practices, once the mill was introduced, grain processing became a year round activity. Although the urban landscape at the time, was focused more on trade, there were occupations such as blacksmiths and farriers that would be hard at work and could have obtained compression trauma in the spine.

6.2.2 Sex and Gender Associations through the Life-Course

When patterns of fractures differ markedly between males and females, it is worth examining the idea of developing gender roles and sex-based divisions of labour (Šlaus et al., 2012). The best way to examine this idea is to use the life-course as a theoretical foundation. All samples in the Danish population showed that males had more injuries than females. Although this follows the observations made by many other researchers, it is important to understand these findings in the Danish context. Many bioarchaeological studies show there is an expected traditional gender role where males are more active in the society than the females, but this is not to say that females were not active to some extent (Gilmour et al., 2015). Historians note that Danish women were active in the rural household and helped in caring for the animals (Lauring 1960; Hybel & Poulsen, 2007). The injuries sustained by females in the household may not have been as severe compared to those sustained by the males; therefore, the two sexes may show injuries affecting different areas of the body. When the population shows an increase in the number of females with injuries in general, such as our two later samples (Ole Worms Gade and Horsens Klosterkirke), the female individuals show a prevalence of injuries that is closer to the number of males that were injured in the population. Because of this almost equal prevalence between urban males and females, the males were likely performing different duties in these trade centres, than those seen in the early and rural samples. In the medieval period, we see fewer restrictions on the work that women could perform in such trade centres (Gilchrist, 2012). Although many of the activities were still confined to the home, women were taking part in other work outside of the home, which may have led to greater exposure to injury-prone activities and thus increased the frequency of them showing skeletal injuries.

One such study, specific to medieval Denmark showed how cranial trauma may be attributable to differences in sexual divisions of labour. Milner and colleagues (2015) found males were more injured than the females from the cemetery samples from Tirup, St. Mikkel, and Sortebrødre. However, closer examination of the type and location of the trauma showed that females suffered just as extensive trauma as the males. Females and males were therefore, both taking part in a hardened lifestyle (Milner et al., 2015). However, in that study, the males were much more likely to show cranial fractures, whereas the females were more likely to incur fractures in the radius and tibia. Therefore, different areas were affected by trauma in the two sexes. This would further be suggestive as to the kinds of activities each sex was performing. The trauma exhibited in the Milner et al. (2015) study, showed high occurrence in rural locations. In this case, one may be able to assume that females were performing tasks that could have caused more falls (radial fractures) or more interaction with farm animals (tibial fractures). The males on the other hand were performing those tasks that caused more head injuries, possibly handling heavy machinery, as well as the larger livestock, not to mention falls that could have been more concentrated in the head rather than the radial region. Falls may also be incurred due to poorer terrain in the rural countryside for both the males and females.

Another study conducted on Danish samples specifically linked sexual dimorphism with gendered roles in fracture patterns, with sexual dimorphism measured as the total size difference in the pelvis between male and female individuals (Nielson, 2011). The skeletal samples in the Nielson study were both urban centres in medieval Denmark, Odense and Ribe. Ribe was an important urban centre established in Denmark and can be arguably seen as one of the oldest towns in Denmark (Crabtree, 2001). Nielson (2011) found that in Odense, males and females had the same fracture frequency, with 5 males and 5 females exhibiting fractures out of a total of 91 individuals. However, the comparative sample from Ribe showed more males (9) with fractures than the females (2) out of 95 individuals. Nielson (2011) noted that Odense had less sexual dimorphism with equal fracture prevalence. The town of Ribe however, had greater levels of sexual dimorphism that would lead to a greater difference in the prevalence of fractures between sexes. Within the Odense population, the females were much closer in size to the males than in the Ribe samples. As a result, females likely took part in the activities that were presumed to be assigned to or taken by the males; this was considered to explain the appearance of a less well-defined division in labour and result in females and males experiencing more similar opportunities for injury (Nielson, 2011). The opposite can be assumed of the Ribe sample, where the females were much smaller than the males; therefore, the smaller females were unable to take part in activities primarily taken by males and this created a greater division in labour by the population at that site. Divisions in labour are seen as the likely cause of the types of injury examined in the present and these referenced studies, rather than originating from violence, as the fractures were distributed throughout the body, and considered to mean that the injuries were likely due to activity (Nielson, 2011).

A factor for size difference between the sexes may depend on relationship status (Nielson, 2011). This is yet another component of a population that can be revealed by taking a life-course approach to research findings on skeletal injury. The life-course includes considering social and cultural factors throughout ones' life, and sexual preferences would fall under either one or both of these constraints. For example, females who are in a more monogamous society are typically closer in size to their male counterparts (Nielson, 2011). However, "serial monogamy" is reported in both the urban populations at both Ribe and Odense, as males or females who had lost a partner tended to re-marry quite frequently in their lifetime (Benedictow, 2003; Nielson, 2011). Although the Nielson study presents interesting factors to consider for gendered differences in fracture patterns, the conclusions drawn are presumptive. Size inequities due to biological differences between the sexes would be an interesting component to consider in future studies of gender roles, fracture patterns, and divisions of labour.

As discussed earlier in the thesis, bone strength and quality are inherently important when examining fractures and their differences among individuals. Over time, bone strength decreases due to a number of factors, ultimately leaving individuals at risk for fractures. Therefore, one must consider that "gender differences in skeletal structure and strength play a powerful role in determining gender differences in fracture risk" (Lang, 2011:1). The mass and strength of muscle tissue has a direct effect on bone strength, and muscle can also differ markedly between males and females. The differences are initiated at adolescence as differentiation between testosterone and estrogen levels begin. After adolescence, in adulthood, both males and females start to lose bone strength due to changes in hormone levels. However, for females the loss is greater due to decreasing production of estrogen as well as general aging processes (Lang, 2011). Not to mention, females may also lose bone mass with episodes of lactation and child rearing. Therefore, Lang concludes that the relationship between bone strength and muscle mass "is more preserved in males than in females" (Lang, 2011:2).

Although gender is strictly a sociocultural concept, bone biology may support theses sociocultural nuances. For instance, losses in bone strength and muscle mass may have differential and detrimental effects on the activities each sex may be able to perform. In turn, major activity differences in a particular culture and location can create greater discrepancies in the patterns of division of labour for those injured individuals of a population.

6.2.3 Age Patterns

Trauma did not differ statistically by age group when all of the samples were combined (Table 5.10 and Figure 5.7). However, the general trend suggested that individuals between 31-40 years of age showed evidence of incurring more trauma than individuals in other age groups by representing 12% of the total population (n = 42/345). Those aged 21-30 years were second for the highest number of trauma at 11% of the total population (n=37/345). The oldest-old individuals aged 71-90+ years showed the third highest level of trauma at 6% of the population (n=21/345). Of all individuals in the oldest-old age group alone (n=58), those with trauma made up 36% (n= 21/58). Looking more closely at the individual cemeteries (Figure 5.7), Tirup showed the highest raw count of trauma lesions in the middle adult age group (31-40 years). Individuals in this age group accounted for 16% of the total population. Nordby had the highest percentage for those aged 21-30 years accounting for 14% of the total population. When examining the oldest-old age groups (71-91+ years old), Horsens Klosterkirke showed the highest frequency (9%) of individuals with fractures, slightly above the other cemetery populations (OW= 5%; NOR= 8%; Tirup= 4%). However, Horsens Klosterkirke accounted for 12% of all individuals in that age group alone (n= 7/58). Compression fractures were present in all of the age groups. However, joint dislocations did appear more frequently in individuals who were older than 51 years of age. The proportion of individuals with multiple traumas (Table 5.12; n= 68; 20% of the total; 49% of those with trauma), including those with rib fractures, varied in their distribution in the body, although such an injury pattern was represented in all age groups.

Trauma research associated with age is made extremely difficult due to the healing process and inability to pinpoint the exact age at which the trauma occurred (Judd & Roberts, 1999). In fact, many trauma studies do not consider age controls or factors because trauma is just too unpredictable (Glencross & Sawchuck, 2003). Trauma lesions are a cumulative phenomenon. Specifically, older individuals would have a higher risk of possessing trauma because they have experienced more years of possible exposure to trauma (Glencross & Sawchuck, 2003). Therefore, the age structure of the population will affect the prevalence rates of trauma lesions (Glencross & Sawchuck, 2003). For the Danish samples, although we might expect the highest rates of trauma to be seen in the oldest-old groups due to the cumulative effect, the populations may not have had very many oldest-old individuals present in the burial sample. Reasons for this may be due to skeletal preservation, but more likely the burial sample is biased. Moreover, selective mortality may have occurred where those injured died at a much younger age. If this were the case, the Danish samples should show more instances of perimortem trauma, especially if the individuals had little time to fully heal after incurring the trauma. Yet, selective mortality would explain the large portion of the cemetery population falling below the age of 50 years. Other researchers have seen the cumulative results of increased trauma with age, such as that seen in medieval urban and rural Poland (Agnew & Justus, 2014). That does not mean, however, that younger individuals do not show their fair share of traumatic lesions, just the same.

Some research has shown, regardless of the cumulative effect, that middle age and young adults can exhibit high rates of fractures (Brickley, 2006). It has been suggested further that individuals who are more prominent in the economic class of a population (20-40 years) would show high rates of trauma (Judd, 2004). As part of the economically contributing portion of the population, these individuals would be hard working, exposing them to the risks of experiencing trauma. Younger individuals typically show fractures in the long bones, which is ultimately occurring more in males than in females (Cooper, 1993). Older individuals would demonstrate fractures more in the proximal femur, vertebral bodies and the distal forearms, more so in females than males (Cooper, 1993). This would support the conclusion that there were inconsistent levels of cancellous bone due to osteoporosis (Cooper, 1993). This suggests that there is some level of heterogeneity in the types of trauma and bone fragility between age groups. Although aging is associated with increased bone loss, bone loss is not a uniform process throughout the skeleton. When examining differences in age-related fractures, this factor must be kept in mind when drawing conclusions from such patterns (Djuric et al., 2010). Likewise, aging processes do not uniformly affect the same bone in all its parts, nor affect every bone in the same degree. Therefore, each bone must be individually considered and not assumed to be inclusive to what is going on in the entire body at the same time.

Despite the inconsistencies due to preservation and methodological errors in age-related trauma data, the use of transition analysis in this study allowed for more precise age estimation of those older individuals, which has not been possible in other trauma research. Those oldest-old individuals may represent an important portion of the injured population. By using this age estimation method, error in trauma frequencies can be reduced since the old adults can be further broken down into other age groups (Glencross & Sawchuck, 2003). The use of this more concise methodology allows for a more accurate representation of the trauma in each population. However, there is the possibility that some individuals may appear on the higher and lower cut-offs of the age groups, causing them to be aged too young or be aged too old. Regardless, the oldest-old individuals of a population are possible to more accurately age and categorize using transition analysis than other age estimation methods that exist thus far for biological anthropology. Where the old transition analysis (Boldsen et al., 2002) would fall short would be in age estimating individuals in poor preservation. Although the statistical analysis uses a software program to combat missing variables, sometimes a whole structure (i.e., pubic symphysis, auricular surface, cranial sutures) cannot be scored at all if it is missing. However, the transition analysis of today (Boldsen et al. circa 2020) will use more skeletal areas (i.e., knee joint) to be examined, hopefully making up the lack of completely missing portions.

Following a life-course approach to interpretations, it is suggested that the young adults (20-40 yrs.) and middle adults (40-60 yrs.) were the more active portion of the population. These were the individuals who were more physically capable than the really young and the elder and more infirm adult of the community, and were able to take greater roles in trade, commerce, and agricultural activities (Judd & Roberts, 1998). They would be exposed to instances that could cause more injuries due to their active lifestyles. In other contexts, researchers have proposed that this age group were the individuals most often involved with population level conflicts such as warfare because they are the most physically able (Knüsel, 2000; Rhodes & Knüsel, 2005). The Danish historic timeline shows that, although more peaceful than other areas, there were still times of violence, famine, and economic hardships. However, no specific patterns seen in these populations would suggest warfare as the predominant cause and manner of trauma. The cemetery of Nordby would be the exception to this as the cranial wounds were chop wounds. If this was otherwise anticipated, other populations would need to be examined throughout Denmark. In particular those populations more geographically close to the borders would need to be the focus, as the majority of warfare taken place in Denmark was due to changing leaderships and conflicts with neighbouring countries such as Germany (Lauring, 1960)

6.2.4 Geographical Location Patterns

Trauma patterns in the urban and rural cemeteries were not significantly different (Figure 5.8). The rural individuals had only slightly more individuals with trauma than their urban counterparts, however it did not change the prevalence of those injured out of the total population (R= 20% (70/345); U= 20% (68/345)). The trend typically expected for other European medieval populations, is rural communities suffering more trauma due to differences in activities and the level of activity (Judd, 2002b; Šlaus et al., 2012). The Danish rural males (n= 51; 29%) sustained more trauma than urban males (n= 42; 25%), but the urban females (n= 25; 15%) had more injuries than rural females (n= 18; 10%). The pattern in the female groups does not follow that seen by other researchers, where rural females are expected to have higher rates of trauma due to a more hardened lifestyle (Boccone et al., 2011). When the sample is broken down by individual cemeteries, differences in trauma in the sexes was statistically significant for the rural population. Rural individuals showed that they sustained more instances of multiple injuries (Table 5.12), which could be attributed to the difference in the prevalence of trauma seen in the sexes between urban and rural locations. This significance is driven more by the Nordby cemetery, as more males were injured regardless of the accounted for females.

When the presence of injuries is broken down into individuals with multiple injuries versus no trauma the statistical significance is in relation to the urban age groups (Tables 5.13 and 5.14). Of the two urban samples, the greatest injury recidivism (reoccurring injuries) is present in Horsens Klosterkirke (n= 17) accounting for 12% of Horsens Klosterkirke, although not much more than that of Ole Worms Gade (n= 16; 9%). Many factors may contribute to this trend. Horsens Klosterkirke spans the Early Modern period in Denmark; therefore, other factors such as advanced technologies and exposure to higher risks in trauma may be present here, but not for the earlier samples. A number of things could contribute to this conclusion. Other research on injury recidivism by Judd (2002b) looked specifically at the differences for urban and rural communities from the Bronze Age in Sudan. In the Judd (2002b) study, middle aged rural adults did not sustain multiple injuries as much as those in the younger age groups. However, urban middle aged adults suffered more multiple injuries than younger individuals. In addition, the study showed that the urban older individuals did not suffer multiple injuries as much as their rural counterparts. Judd (2002b) suggests that high rates of injuries are expected for urban middle age adults and more bi-modally distributed for rural young adults and older adults. The pattern observed by Judd (2002b) was similarly observed for the age groups in both urban and rural populations for the Danish sample, with both young and middle age adults experiencing more multiple traumas.

The stress and strains that are experienced by individuals in urban centres, due to tighter living quarters and unsanitary conditions, would suggest that urban peoples take part in more interpersonal violence (Judd & Roberts, 1998; Betsinger, 2007). Injuries are suspected to occur in the facial, head, rib, and hand regions for urban individuals because of the nature of violence, as discussed earlier in sub-section 6.2.1 (Brickley & Smith, 2006). Accidental trauma, however, is expected more in rural individuals and injuries occur more in distal portions of the forearms, with variability throughout the entire body with more appendicular areas affected (Judd & Roberts, 1999; Standen & Arriaza, 2000; Scott & Buckley, 2010; Lessa, 2011). Peaks of accidental injuries should be more commonly seen in the adolescent, young adult, and old adult age groups (Lovejoy & Heiple, 1981). The young adults have a higher ability to take part in such activities that cause accidents and the old adults have lowered mobility and greater tendency to fall. Accidental traumas are more revealing about the lifestyle of that population because of their variable nature (Betsinger, 2007). This could be due to the fact that many accidental traumas coincide with daily activity, occupations, and even geographical terrain. More importantly "different lifestyles will affect the prevalence of skeletal injuries by element types as well as regional patterns" (Agnew & Justus, 2014:190). Although body regions may be indicative of lifestyle or violent and non-violent interactions, the Danish populations did not differentiate greatly in their injured body regions in reference to fractures. However, rural individuals suffered more violent indicators of injuries such as sharp-force and cranial blunt-force than the urban individuals. Regions of the body that were fractured were extremely variable among all cemetery samples, but it can be said with some certainty that the right side of the body was more injured. The lack of differences in injury patterns between the urban and rural Danish populations suggest there may be more continuity between the Danish urban and rural centres than is seen in other parts of medieval Europe.

6.2.5 Geographical Location Patterns and the Life-Course

Rural communities are equated with individuals who perform agricultural activities, where working roles between ages and sexes are less restricted. Farming or agricultural activities are considered some of the most dangerous occupations for many nations (Judd & Roberts, 1998). Farming is extremely unique because of the differences between types of rural landscapes, where a multitude of activities are performed and settings of the activities can differ greatly (Judd & Roberts, 1998). Many researchers expect greater risks of trauma to occur in rural populations due to the extreme activities involved with farming and agriculture (Šlaus et al., 2012). The differences in patterns of trauma seen in rural countrysides have often related to the differentiation in activities. For instance, adolescents showed low levels of trauma in rural communities. Beyond the biological evidence that children often present less trauma due to fast healing processes, the lack of trauma could be attributed to their roles on the farm. In a medieval Serbian sample, male adolescents were typically involved in guarding pastures, foraging, and milling cereal grains (Djuric et al., 2010). These activities would present them with fewer risks of trauma. Much of the harder labour activities, such as taking care of large livestock and plowing the land, were left for males that were older than 25 years of age (Djuric et al., 2010). Thus, adult males and adult females were expected to take on a much greater role in the rural household and farm. Colles' fractures are common in male and females in adulthood. Although these patterns are true for the Serbian sample presented by Djuric et al. (2010), farming practices cannot with certainty be assumed to be universal. The study done by Mays and colleagues

(2006b) on medieval Norway, a population much more similar to Denmark in culture and society, suggests that these types of fractures were less common in rural communities. He hypothesised that the physical environment of less pavement and more soft grounds with grass may have allowed for less severe falls to take place. The physical environment for rural individuals did entail less developed landscape with no cobble street pavement. However, other rural environmental studies have suggested that hills, loose rock, and uneven ground could have presented more opportunity for falls (Alvrus, 1999). Falls may also affect the oldest-old age groups. When disparities occur between the urban and rural locations, Judd and Roberts (1999) suggest urban and rural lifestyles may not have differed as much as previously thought and an urban lifestyle was just as taxing and grueling as a rural lifestyle.

The rural Danish countryside saw a lot of settlements of rural individuals near the arable lands, rather than the pastures (Hybel & Poulsen, 2007). Arable lands would have accounted for cleared landscapes, but would have presented a more dangerous activity of working with large animals for plowing. For example, Tirup as the main rural population in this research saw a higher mortality for females than males before the age of 40 (Hybel & Poulsen, 2007). Boldsen (2002) concluded that this would be attributable to females dying around their reproductive ages. However, there may be other causes for this disparity, because accidental trauma and disease were a common occurrence in rural Denmark. The diseases observed most often in Middle Age Denmark are leprosy, tuberculosis, DISH, syphilis, focal osteolytic disease (an ADBOU specific condition), dental enamel hypoplasia and the plague (Boldsen, 1997; Crabtree, 2001; Boldsen, 2005; Boldsen, 2007; DeWitte, 2006; ADBOU, 2015; Scott & Hoppa, 2018). Female labour often took place in the household, although they did interact with some smaller livestock. Males, on the other hand, performed more diverse activities but focused more on hardened labour working with machinery and large livestock (Hybel & Poulsen, 2007). The nature of more accidents occurring in the rural landscapes would show concentrations of injuries in the extremities (Judd & Roberts, 1999). However, this pattern was not clear-cut in the research sample; instead injuries showed greater diversity throughout the body.

The process of urbanisation has long been investigated by bioarchaeologists. Urbanisation can be a result of social or economic processes, but is often equated to a large increase of people in a sedentary population (Betsinger, 2007). However, urbanisation is heavily dependent on the economic and social complexities that are not present in their rural counterparts (Lewis, 2002). Those problems that exist in rural agriculturalists would be expected to increase in the urban population (Betsinger, 2007). The more complex social, political, and economic systems present in urban centres create group inequalities. These differences would often lead to greater disparities between rich and poor individuals, leaving poor individuals to experience greater hardship and poverty (Lewis, 2010). Urban centres were more attractive to the poor, as there were more options for housing, trade, and labour (Walter & DeWitte, 2017). Furthermore, in the late medieval periods, urban centres relied greatly on rural to urban migration, where rural individuals would replace those urban poor and untrained labourers (Lewis, 2013). As a result skeletal markers, not just traumatic lesions, were more prominent and tended to increase due to the stressful process of urbanisation (Lewis, 2002). The addition of the more prominent skeletal markers would support intensification of the levels of activity in urban centres.

Contemporary patterns still show distinct differences in trauma patterns between urban and rural populations. Rural agriculture has become more technologically advanced with bigger machinery, but additionally rural areas now encompass mining activities, still leaving rural occupations as the most dangerous today. Although urban centres see an increased level of violence related death and injuries, accidental trauma is the main cause of trauma in both rural and urban communities (Batista et al., 2012). This accidental trauma is far more extensive in urban centres than the rural counterparts. Accidents in the urban centres are equated with traffic accidents, sports, and occupational hazards, whereas accidents in rural countrysides involve large livestock and machinery accidents. Rural females exhibit the least amount of trauma (Batista et al., 2012). Urban injuries are more frequent, specifically in male children and for individuals of lower socioeconomic status (Gilbride et al., 2006). Compared to past population studies, changes have drastically altered the affected age groups for trauma, but the sex differentials have stayed the same. Contemporary studies indicate that "traumatic injuries largely affect young people, which increases the societal burden of trauma" (Kristiansen et al., 2014:23). Injuries are the leading cause of death for people aged one to 45 years of age (Peek-Asa et al., 2004). Although more injuries may occur in urban centres, the injuries that occur in the rural communities lead to greater mortality (Peek-Asa et al., 2004). The extensiveness of the injuries incurred in the countryside are often fatal as they are farther removed from health services for treatment, leaving many people unable to be treated fast enough before succumbing to their injuries. However, the number of people that reside in both types of populations makes more contemporary patterns of injuries and trauma more distinct.

Although differential patterns are informative of the relationships between urban and rural communities, we must recognize that "the relationship between town and country are inherently complex," due to the movement or migration of people (Walter & DeWitte, 2017:345). Another concept to become aware of is the levels of urbanisation and 'ruralness' of specific regional contexts. Denmark is a small country and during its history has changed its borders several times due to the shifts in the political and royal environments. Through the changes in territory, much of Denmark was still considered a rural landscape. The rural villages would surround the urban town centres and the towns were very dependent upon the rural villages for resources (Lauring, 1960). Due to the dependence on these rural resources, the urban towns never expanded out or to the size of other European cities like Amsterdam or London (Lauring, 1960). Regardless of size, the towns were essential for a successful Baltic trade route and would often reside close to the outer borders of the country on the harbours. The levels of development for the rural and urban centres may have been less pronounced than other major cities, because of the overly rural nature of Denmark. With this progression of the rural landscape becoming a smaller township, differences in socioeconomics and the family unit were not as great, leading to less differences between trauma occurrence.

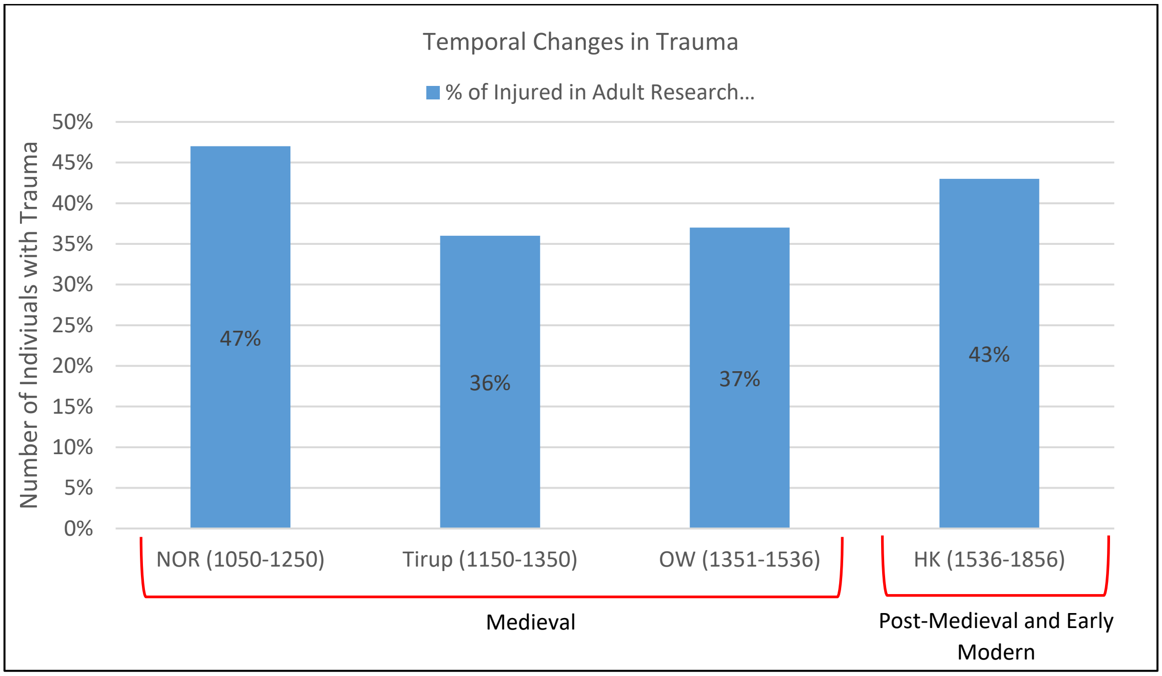
Many factors may ultimately contribute to this continuity between the Danish urban and rural centres. When determining levels of urbanisation, many think of population size as the deciding factor for differentiating between urban and rural areas. That is a modern concept. On the contrary, for Denmark, it was trade and commerce that determined whether a town or village was seen as urban or rural (Petersen et al., 2006). Furthermore, researchers trying to reconstruct the size of populations from the past have suggested that the urban centres and their size were dependent on 'social interactions' (Cesaretti et al., 2016). The majority of urban individuals tended to live where they worked, especially when specialized craftsmanship became more ideal for trade. Therefore, their interactions did not span much further than their household, leaving the 'urban economy' dependent on trade and commerce in more centralised and dense areas. Cesaretti and colleagues (2016:27) go on to say, "the social and economic life of most individuals was strongly constrained by the household, which formed the social and spatial context for work and life." However, this interaction could be restricted by physical spatial constraints, where the medieval European cities were unable to expand as it was rare that they would take down and rebuild the city walls (Cesaretti et al., 2016). Other cities that were able to expand without the impediment of defensive walls were able to accommodate more and more people and their growth became exponential.

The major differences presented here can be further supported by other osteobiographical data found in medieval Denmark. For instance, Petersen and colleagues (2006) found that males have greater survivorship than females. This may account for the under- or over-representation of one group or the other in some of the cemetery samples. Survivorship was important in medieval Denmark as individuals constantly faced the grim reality of famine and epidemics. Other differences noted between societal groups was the increased stature and craniometric measurements in migrants (Petersen et al., 2006). Although the urban centres may not have been of a substantial magnitude as those found in other parts of Europe, there are still osteological differences that can attest to the divisions between urban and rural individuals (Petersen et al., 2006); urban and rural differences will still exist with relatively minor levels of urbanisation.

6.2.6 Site Patterns

Differences in the presence of trauma in the Danish populations does not change drastically from one time period to the next or from one site to the next (Figure 6.1). Researchers have suggested that later time periods would see an increase in injuries, primarily due to technological advances in weaponry and an increase in more ‘sedentary and complex’ societies as individuals abandoned the rural countryside (Boyd, 1996; Šlaus et al., 2012). However, this is not observed here in the Danish samples.

<u>Figure 6.1:</u> Bar graph illustrates the percentage of individuals with trauma for the cemetery and their corresponding time period.



6.2.7 Site Patterns and the Life-Course

In addition to the social environment of the human experience, the life-course theory considers the individuals' physical environment. As the physical environment (i.e., farm lands and trade commodities) changed drastically from one time period to the next through medieval Europe, climate becomes an important factor to examine for the life-course. Taking this into consideration, researchers have suggested that violence or skeletal trauma may coincide with changes in the climate or physical environment. Larsen (2002) has long proposed that the context of trauma may be environmental, where reduced food resources (i.e., famine) due to a severe climate change will ultimately lead to stress between populations and individuals, leading to violence. He further suggested that the increase in population size within a sedentary environment will lead to the increased stress due to shortages in food resources. The climate is an important consideration when examining trauma because climate changes had a much greater impact on societal life in the past than they do today (Hybel & Poulsen, 2007). The Danish historic timeline indicates two major changes in the climate: The Medieval Warm Period (AD 1100-1400) and The Little Ice Age (AD 1400-1800). The Medieval Warm Period in Denmark was when agricultural activities turned to deforesting the landscape to make available land for planting large quantities of cereal grains (Hybel & Poulsen, 2007). It was during this same period that Denmark suffered famine and outbreaks of the plague, killing off much of its population. The greatest famine to take place was AD 1315-1317, where extreme rainfall caused devastating crop failures (Hybel & Poulsen, 2007). The Little Ice Age occurred directly after The Medieval Warm Period, where the climate saw a decline in temperatures, and it was during this time that many agricultural activities started to focus on animal husbandry (Hybel & Poulsen, 2007). The evidence of these two major changes in climate for Denmark may have coincided greatly with changes in population dynamics and stress placed on past individuals, leading to increased instances of trauma.

As the life-course takes on many sociocultural components for consideration, it is worth noting them here in relation to climatic phenomenon. Sociocultural researchers have suggested that deforestation and annihilation of the physical environment causes disengagement between the people and their environment, leading to further societal problems and stressors (Harrod & Martin, 2014). Furthermore, times of famine and resource shortages not only cause direct stress on the people, but the simple observed threat of a destitution due to the shortages increases acts of violence between individuals (Harrod & Martin, 2014). Although times of hardship from resulting changes in climate may occur, people throughout history have adapted behaviourally and culturally to help combat some of these issues. Some of these adaptations may be beneficial or harmful, depending on the interactions with the physical environment. Largely, climate change and violence, create a feedback loop (Harrod & Martin, 2014). In essence, changes in the physical environment will eventually lead to changes in peoples' cultures, societies, politics, and economic landscapes. Although Denmark experienced great changes in climates throughout the medieval period, the temporal changes in the cemeteries did not indicate that more trauma occurred during these devastating times. For instance, if this were to be the case, there should be more instances of trauma seen in Tirup, Ole Worms Gade, and Horsens Klosterkirke, which is not illustrated in this research. These cemeteries would have higher rates as they were in use during the great famine of AD 1315-1317and the Great Warming Period (AD 1100-1400) and Little Ice Age (AD 1400-1800).

6.3 Fracture and Lesion Interpretation

Many of the difficulties in trauma studies for bioarcheology lie in the fact that there are variable ways in defining and categorizing the types of fractures in populations (Djuric et al., 2006). These issues can further lead to difficulties in trying to decipher the patterns of the trauma and interpreting its cause or relevance. The preservation and fragmentary nature of the remains are the cause for many of these misinterpretations, leaving it difficult to detect all possible fractures that may be present in the sample (Grauer & Roberts, 1996). The goal of this research was to use methods that would reduce the possibility of underrepresentation and misinterpretation of fractures in medieval Danish adult remains.

The traumatic lesions that were assessed for these samples ranged in their type, placement, and degree of healing. Although fractures are the most common form of trauma in the archaeological record, other instances of trauma such as joint dislocations, blunt force and sharp force wounds were observed in the Danish samples. These different types of injuries in addition to the fractures can provide further insight into various activities these individuals took part in.

6.3.1 Type, Placement, and Healing of Fractures

This research observed great variety in fractures. However, the specific type of fracture (i.e., oblique, transverse, spiral, etc.) was difficult to determine with absolute certainty. This was due to the level of healing for many of the fractures. The majority of fractures in the samples were fully healed, meaning there was no evidence of a fracture margin to aid in determining the type. The hard callus had been fully formed, all but erasing the evidence needed to characterize the fracture further. There were only a few instances where type could be determined, due to the angulation at which the bone healed or ultimately the placement of the fracture. For instance, an oblique fracture could be identified as the type because the fractured ends of the bones had healed at that angle and were not fully set at or around the time of injury. The placement of fractures such as these, was also detrimental in assessing forearm fractures. The best example to reiterate this is the classification of a Parry fracture.

This study observed the presence of several ulnar fractures that occurred either in the midshaft or distal portion of the bones. Predominantly these were found in Nordby and Ole Worms Gade. However, they were not classified as a Parry fracture, as not all of the definitive characteristics of a Parry fracture could be ascertained due to the level of healing (i.e., they could not be defined as a transverse fracture). However, Parry fractures provide an example of why deciphering placement of fractures is so important for interpretation. A Parry fracture is typically used in bioarchaeological studies to help identify interpersonal violence in populations. It is thought that the Parry fracture can only occur when a victim is defending themselves from an overhead attack, in which they raise their forearm to stave the blow. However, its etiology is poorly understood by many researchers and can be controversial (Judd, 2008). According to Judd (2008) there are four criterion for an ulnar fracture to occur and be considered a Parry fracture: an absence of a radial fracture, a transverse fracture margin, the fracture must be located below the midshaft of the ulna, and minor malalignment of the fracture margins. If all of these criteria do not occur in accordance with one another, it cannot be classified as a Parry fracture, but simply as an ulnar fracture. Therefore, placement can be very important when determining type of fracture.

As the hard boney callus had been formed in many of these fractures, the timing of fracture, or the age at which the individual received the injury could not be determined (Grauer & Roberts, 1996). Although more current research has implemented histological and radiological methods for determining the 'age' of a fracture callus (i.e., Capella et al., 2013; De Boer et al., 2015; Capella et al., 2019; Naqvi et al., 2019). These methods suggest that presence or absence of particular histomorphological characteristics in a boney callus may be able to provide a better timeline of injury. Unfortunately, histological analysis is beyond the scope of this dissertation, but the usefulness of such methodologies would be extremely helpful for future research in trauma analyses. The presence of healing in a fracture is the basis of researchers' classifications of perimortem and antemortem. The distinction between the two can mean all the difference in a population level study, as a researcher could determine whether the individual died as a result of the trauma with the absence of healing. The pilot study of this research was to help in determining the discrete characteristics needed to classify a fracture as perimortem or antemortem. However, the lack of viability in that study is discussed in the next chapter. The biological process of healing has been covered in Chapter 3 in great detail, but its importance is reiterated here.

The presence of healed fractures can be helpful in analysing sociocultural aspects of trauma. The treatment and care for an individual can be seen in healed fractures. Those fractures that have little to no malalignment due to the injury being properly set, would have allowed the person greater mobility after the injury and is further suggestive of greater care. Fractures that are accompanied by malalignment and evidence of infection may show less care, however issues surrounding access and personal disregard of injury must be taken into account as well. When orthopedic intervention occurred in the archaeological record, we often see the limbs were reduced (Tilley, 2015). When determining care in the archaeological record, it is often difficult when material evidence (i.e., splints, bandages, etc.) of care is often perishable over time. But with reduced limb fractures, we may interpret that there was some form of technology used, in order to set the bone (Tilley, 2015). Does this mean there was more care taken with these individuals, versus those that had malaligned fractures? Does this also contribute to the knowledge of how 'disability' was approached in a society? These are difficult questions to answer, however care and/or the lack there of, should be considered further.

Another sociocultural aspect is human interaction. Differential levels of healing in one individual may indicate abuse (Gowland, 2016). Research has shown that not just young individuals are abused, but it can occur in the elderly. Gowland (2016) proposed that the awareness of old age in the past, depended greatly on the overall impairment of the individual and their social status. However, multiple levels of healing can be difficult to ascertain as many of the remodelling processes are at the microstructure level, leaving it hard to determine just with macroscopic examination. The greatest contribution of healing can be seen in its involvement in understanding the life-course. The healing process changes over the life-course and is dependent on "the differences in the victim's mobility, ability to self-defend, social identity, and age-related physical changes" (Gowland, 2016:515). The methods surrounding deciphering the exact timing when the trauma occurred are not well researched. It is often difficult to hone in on when and at what age the individual suffered the trauma, when lesions are often so well healed. Due to this, it cannot be discounted that the injuries or fractures we observe in the adults, may have occurred at a much younger age.

Evidence of elder abuse does not seem to be present for the Danish samples, although it cannot be completely discounted. There were 14 individuals that had multiple trauma for the oldest-old (71-91+ years). When these individuals are examined separately they do not exhibit traumatic lesions that would constitute abuse. Rather their injuries are more consistent with accidental or activity related trauma such as Colles' or compression fractures. There is also presence of dislocations in the joints. These are common fractures also associated with osteoporosis. However, we must still present the caveat that although a Colles' fracture is common in the elderly due to falls on outstretched hands, the fact that they may have been pushed instead, cannot be fully discounted. And in that case, these would be fractures due to abuse or violence. Researchers may never be able to decipher between the two with absolute certainty.

6.3.2 Vertebral Lesions

The most common type of fracture that was observed for the samples was compression or depression fractures throughout the vertebral column (n= 73; 21% of the total population; Table 5.16). These fractures are a type of direct trauma that involve one (depression or compression) or both with the sides of the bone being crushed and deformed and are more common in bones with more cancellous structures (Lovell, 1997). These types of fractures are most commonly associated with the vertebral bodies, where the forces have caused a reduction in height, particularly in the anterior, posterior, or lateral portions. An indirect form of this compression of the vertebral body is the burst fracture, where the force occurred in a different area and not at the impact site (Lovell, 1997). In the vertebral column a burst fracture occurs when the cartilage between the bodies has been vertically compressed forcing it through the vertebral plate on the vertebral body (Lovell, 1997). There was only one such instance of this specific form of fracture seen in an elderly male in the rural Nordby sample (Figure 6.2). The burst fracture was severe, but fully healed and located in the lumbar vertebrae.

Figure 6.2: Lateral view of a burst fracture in the lumbar vertebrae. Grave CC is from Nordby (FHM 3730) and is a male, aged 71-91+ years.

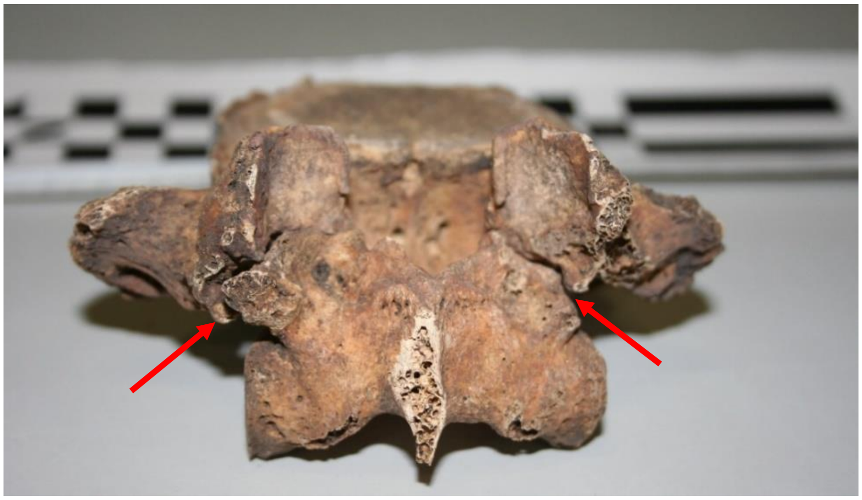
Compression fractures that exist in the axial skeleton were extremely common in medieval samples and are informative of the extent and level of activity that the individuals preformed (Agnew et al., 2015). However, one main issue in compression fractures is determining their cause as they can be differentially diagnosed and may be caused by many factors including pathology, activity, and age-related changes (Roberts, 2000). Research suggests that agricultural activities common in this time period, such as bending and lifting heavy objects, were a common cause of these injuries (Agnew et al., 2015). Modern samples tend to see many vertebral compression fractures in elderly individuals or individuals who have existing pathologies (Cho & Chang, 2011). In fact, the U.S. alone sees 25% of these fractures in post-menopausal females; the intensity and frequency of the fractures increase greatly with advancing age, seeing 80% of females with compression fractures up into their 80's (Old & Calvert, 2004). Most of these fractures are caused by habitual activity, but they can occur spontaneously. Compression fractures are a trademark fracture of osteoporosis, especially in females, but they have been further linked to Caucasian ancestry and individuals that have greater histories of fractures (Old & Calvert, 2004).

The compression fractures that were exhibited in the Danish samples were predominantly located in the lumbar vertebrae (Figure 6.3). This makes sense as these are the main load-bearing vertebrae of the spinal column which leads to the pressures that can cause the compression to the vertebral body (Junno et al, 2009). As mentioned previously, the bending and lifting of heavy loads is what causes many of these fractures. Junno and colleagues (2009) investigated how a temporal shift in the size and shape of the lumbar vertebrae may have led to increased occurrences of compression fractures in individuals. They hypothesized that vertebral size, such as width and height, are an additional risk factor for individuals with fractures in the spine. Their study found that size in the fourth lumbar vertebra had changed drastically from the medieval period to modern day. Specifically, the vertebral height had increased, whereas the vertebral width had decreased in both males and females. They associated these differences with stature increase for the increased height, but a more genetic factor for the decrease in width. The greater widths seen in the medieval period could have been physiologically supported, as individuals during this time had more physically demanding lifestyles versus those of modern individuals. This study goes to show that indeed when examining fractures in the axial skeleton, these can be easily attributable to levels of activities in individuals (Agnew et al., 2015).

<u>Figure 6.3:</u> Anterior view of a compression fracture in the lumbar vertebrae. Grave 2391 is from Horsens Klosterkirke (HOM 1272), and is a male aged 31-40 years.

Another vertebral condition that became evident in the samples was the presence of spondylolysis (Figure 6.4). A total of 11 spondylolysis fractures were observed in the sample, with seven males and four females exhibiting the condition (Table 5.18). The fracture etiology for spondylolysis is either a unilateral or bilateral fracture of the lamina or *pars interarticularis* on the posterior aspect of the vertebrae (D'Angelo del Campo et al., 2017). The fracture in this region often leads to the spinous process area and the inferior articular facets to become detached from the rest of the vertebral body. The cause and manner of these fractures is typically repetitive, habitual activity in bending or loading (Agnew et al., 2015). Other factors have been suggested for the likelihood of these fractures. Their cause can be multifaceted in nature, because of being linked to congenital weakness in the spinal region (D'Angelo del Campo et al, 2017). The condition is most often seen in the two lower lumbar vertebrae and it can be witnessed in all ages from children to adults, but likelihood increases with advanced aging (D'Angelo del Campo et al., 2017). Mays (2006), found that the condition formed in the final period of growth and into young adulthood. Therefore, it would be more informative of examining the lifestyle of younger people than for those in adulthood (Mays, 2006). The condition of spondylolysis appeared in all four cemeteries (n= 11; 3% of the total population) in this research though most occurred in the rural samples. Within the seven males and four females that exhibited this condition, most of the individuals belonged within the age group that was most active, from 31-40 years of age (n= 6; 2% of the total population). The urban Ole Worms Gade showed the opposite with individuals in the older age groups from 51-80 years affected most. These trends show that indeed the more active agricultural groups and young adult individuals possessed this defect. It can safely be assumed then that repetitive loading efforts during activity likely contributed to this condition in the rural individuals. Males and females were nearly equally affected by this condition and enough information does not exist to discern further causation for the fracture.

<u>Figure 6.4:</u> Posterior view of lumbar vertebra 5, exhibiting partially healed fractures of the *pars interarticularis* (red arrows), consistent with spondylolysis. Grave 1040 is from Ole Worms Gade (HOM 1649), and is a male, 71-91+ years.



6.3.3 Other Fractures Observed

Fractures in the appendages, trunk area, and pelvic girdle varied greatly in their appearance and type. Most of these fractures occurred in the long bones, more specifically the femur. Long bone fractures are extremely important for trauma analysis in bioarchaeological studies. These types of fractures are more indicative of the surrounding environments, even more so when occupation and activities can be further discerned (Judd, 2002a; Gilmour et al., 2015).

The types of long bone fractures observed in this study varied greatly. The type of fracture is difficult to determine for fully or partially healed breaks due to the callus formation. By analyzing the angles of the broken portion of bones that had healed together, some types of fractures were easier to determine than others. The two most common types of fractures observed for all individuals in this research were oblique (n= 12) and transverse fractures (n= 26; Table 5.15). However, there was no clear pattern to these types of fractures in the samples.

Pelvic girdle fractures occurred most often in association with severe dislocations of the hip joints. In these cases, the dislocations were severe subluxations causing the superior rim of the acetabulum to fracture out of place allowing the head of the femur to break free of the acetabular socket. One very unique pelvic fracture was a transverse fracture to the ischiopubic ramus in a young adult male individual from urban Horsens Klosterkirke (Figure 6.5). Fractures in this area are often found in horseback riders but in bioarchaeology are considered rare (Hofmann et al., 2010; Andelinović et al., 2015). This specific activity would be more expected in an agricultural or rural based setting; however, this individual was from the Early Modern period and is urban. Although urban individuals from the past were less equated with horses due to their more urbanised surroundings, they did provide a form of transportation for goods making it possible for individuals to encounter horses or engage in horseback riding (Andelinović et al., 2015). Pelvic fractures, although very rare in the archaeological record, can pose great risk to the individual and mortality is high for these individuals due to the inability to stabilize and treat such a difficult area of the body (Hofmann et al., 2010). Therefore, this could have been associated with his cause of death; however, the person lived for some time after the break occurred as there is partial healing present. It is unlikely the individual sustained the injury during a riding accident as there was no evidence of trauma anywhere else in the body. Studies that have empirical evidence of horseback riding accidents, show a considerable variation in the fractures. The study by Ki and colleagues (2018) show that the individuals in horse riding accidents sustained their injuries mostly in the limbs. The next area to be injured the most was the trunk area, followed by the head (Ki et al., 2018). Many of the victims of such accidents also exhibit multiple fractures in several areas of the body. A common occurrence also to be found in modern clinical literature is severe trauma to the torso resulting in soft-tissue injuries to the organs (Ki et al., 2018). As the soft-tissue is absent in this medieval case, it could have been a possibility, but cannot be further supported. It is more likely that for this individual, the trauma could have been the result of a fall, where this area was the indirect area of impact, especially if the direct impact occurred at the ischial tuberosity.

Fractures in the ischiopubic rami are considered in the clinical literature as an occult fracture. This means that they are not easily identified with modern technologies such as x-rays and CT scans. As a result, many of these may go undiagnosed. They can often be accompanied by a proximal femoral fracture, but not always. Those clinicians that have witnessed these types of fractures in modern populations predominantly see them associated with falls or accidents and may be associated with groin pain (Suzuki, 2013). Although the fractures can also occur from non-traumatic causes, such as osteoporosis, they tend to appear most often in the superior portion of the ramus as this is the area that bears the most weight (Suzuki, 2013). In the study by Suzuki (2013), the patients that suffered from such a break were elderly individuals that fell. The individual in this medieval sample was not elderly, but rather a young adult aged 21-30 years old. This was also the only fracture for this individual. Although a fall cannot be ruled out for this individual, he does not fit the modern archetype and the injury could therefore have been caused by other means not yet considered.

<u>Figure 6.5:</u> Inferior view of a right os coxae, with a transverse fracture to the ischiopubic ramus. Grave 3026 is from Horsens Klosterkirke (HOM 1272), and is a male, 21-30 years old.

Fractures that occurred in the ribs were only somewhat common (n=14) throughout the sample (Table 5.17). Rib fractures are often associated with violent and intentional traumas (Lambert, 2002; Krakowka, 2017). However, rib fractures can be extremely common in accidental injuries and can be associated with activity patterns although they are under-reported in archaeological samples (Lessa, 2011; Agnew et al., 2015). Previous studies have shown that rib fractures can be useful in looking at activities and social class in past populations. For those individuals that are part of late urbanisation, healed rib fractures and upper limb fractures were quite common (Betsinger, 2007). These fractures seen in other medieval samples, that did occur in this area were often displayed in the middle section of ribs (ribs 4-9) and appeared in the younger adult and middle adult age groups (Brickley, 2006). Injuries to the ribs occurred in all the cemetery samples for this research. Rib fractures were most common on the right side of the body and were seen most in the urban samples. There were three rural individuals with rib fractures who were either young adult males or oldest-old adult males, with no rib fractures observed in female individuals. For the urban individuals the fractures occurred in both males and females of differing age groups. In Horsens Klosterkirke, there were four males injured in the ribs, one oldest-old and two young adults, and only one young-adult female. In Ole Worms Gade, three females, one old adult and two young adults, and three young adult males were injured. The patterns seen in this research follow closely with previous studies. Urban craftsman and females have just as high a risk of obtaining rib fractures due to falls as rural agriculturalists from working with large livestock. Although the fractures were most common in the adult age groups mostly in young adults, as suggested by Brickley (2006), some oldest-old adults had rib fractures. These much older individuals with rib fractures could have been due to other underlying pathologies, such as osteoporosis. Not to mention, elderly individuals are more susceptible to falls and these may cause rib fractures.

An often common and easily identifiable fracture in skeletal remains is the Colles' fracture (Figure 6.6). This fracture occurs in the distal radius and is caused by an indirect force where a fall on an outstretched hand can cause a fracture in the forearm bones (Judd, 2008; Gilmour et al., 2015). The distal radius is usually displaced posteriorly while the anterior portion is under tension forces, causing a transverse fracture to occur (Judd, 2008). When the distal portion of the radius is displaced anteriorly, it is a reverse Colles' or a Smiths' fracture. Displacement of the distal portion of the radius is easily discerned as many of these fractures tend to heal in the position they were displaced in, due to poor stabilization of the fracture and movement of the limb before healing can occur (Gilmour et al., 2015). As this fracture occurs at the wrist joint, movement before healing can commence, seems a more likely scenario. Although Colles' fractures were only present in two (rural Nordby and Tirup) of the four cemetery samples for this research (n= 3; 0.87% of the total population), all three individuals were from a rural cemetery and were in the young adult (21-30 yrs.; one female from Tirup) or old adult age ranges (61-80 yrs.; One female from Tirup; one male from Nordby). As falls tend to be common in the elderly, researchers have suggested that Colles' breaks in the radii could be due to loss of bone mass as a result of osteoporosis (McEwan et al., 2004). This would suggest we see more of these occurring in females that are post-menopausal, but this was not the case for this research. The loss in bone mass is the likely cause for such specific fracturing of the radii.

<u>Figure 6.6:</u> Anterior view of a left radius, exhibiting a partially healed Colles' fracture. Grave CC is from Nordby (FHM 3970), and is male, aged 71-91+ years. This is the same individual with the only vertebral burst fracture.

Another form of indirect trauma seen in the cemetery samples was the avulsion fracture (n= 8; 2.3% of the total population). Prevalence of these injuries did not differ between age groups, locations, or sexes (HK= 2; OW= 2; NOR= 3; Tirup= 1). These types of fractures are not as common, but they typically occur in those bones that are in the joint and surrounded by ligaments and tendons (Lovell, 1997). When the tendon or ligament is overstrained and pulls away from the bone in the joint, a piece of bone fractures at the junction pulling away from the main bone. Examples of an avulsion fracture are the clay-shoveler's fracture and patellar fractures. The clay-shoveler's fracture occurs when tendons are overstrained in the spine causing a fracture in the spinous process of the vertebrae (Lewis, 2016). No such instances of a clay-shoveler's fracture were seen in this research. However, the avulsions that did happen occurred in the metacarpals, lower limb long bones, and the patella. Avulsion fractures in the patella (Figure 6.7) are quite common in modern populations, and tend to appear as transverse fractures through the patella, where the portion of avulsed bone may differ in size depending on the age of the injured individual and the force of the injury (Grogan et al., 1990). The patellar avulsion fractures that were observed in the cemeteries can be classified as a lateral or medial patellar avulsion fracture. In this case, the lateral margin of the patella was avulsed by the pull of the ligament resulting in a "bipartite patella", a condition caused by a repetitive stress lesion in the knee joint (Grogan et al., 1990). A medial avulsion fracture of the patella results as a partial or full dislocation of the patella when the knee is over extended (Grogan et al., 1990). In her study of the *Mary Rose*, Stirland found nine examples of avulsion fractures in the lower portions of the bodies of sailors aboard the ship (Stirland, 2003; Mays, 2008). Since the sailors were on a deck in rough seas, their lower limbs indicated overstrained muscle ligaments and tendons. Therefore, the avulsions appeared on the tibial tuberosity and on the fifth metatarsal (Mays, 2008). Due to their specific mechanism of injury, avulsion fractures are difficult to discern from other fractures unless well studied by the observer. Their pattern can be so distinct, that many would mistake them for malformed or unfused portions of bone as they show no evidence in other surrounding bones. Often the pulled portion of bone is well healed and may only resemble a small portion of new bone formation on the surface of the larger bone.

<u>Figure 6.7:</u> Medial view of a left patella, exhibiting a well healed medial avulsion fracture. Grave 1247 is from Ole Worms Gade (HOM 1649), and is male, 31-40 years old.

One Bennett's fracture was observed in the sample. As stated earlier, this fracture occurs at the inter-articular surface in metacarpal one. The fracture was observed for one oldest-old female individual from Horsens Klosterkirke. This was also the only fracture she possessed and it was very well healed. The causality of such fractures are not well recorded, so it cannot be said with certainty how this individual obtained the fracture.

Lastly, fractures that were not able to be classified, were those that were too obscured by the healing process, or that suffered severe postmortem damage to decipher fracture type.

6.3.4 Unique Types of Lesions

Several lesions were recorded that were outside of those typical fractures mentioned above. These lesions are caused by trauma, but there are still debates today as to their causality.

Joint dislocations are injuries to the skeletal joints involving consistent displacement of the articular surfaces of the bones making up the joint (Aufderheide et al., 1998). Dislocations can either be complete or incomplete and can involve luxation (complete separation of the bones in the joint) or subluxation (partial separation of the bones in the joint) of the bones. These types of injuries to the skeleton can be commonly accompanied with a severe fracture of the bones in and around the joint such as the acetabular fracture in Figure 6.8 (Lovell, 1997). An extremely obvious and common condition that is the result of a dislocation is osteoarthritis of the joint surfaces. This is often how we can diagnose these issues in bioarchaeological samples. Although dislocations can involve a considerable amount of soft tissue involvement such as tendons and muscles, those dislocations that are discernable in boney elements are dislocations that have persisted for a significant amount of time to cause a severe enough boney reaction. Reactions, such as the development of traumatic arthritis resulting from a persistent dislocation, can cause excessive osteophyte formation, compression or narrowing of the joint surfaces, or eburnation where cartilage has become degraded and can no longer protect the joint (Aufderheide et al., 1998). Severity of the dislocation depends on its location, such as in the knee, hip, or shoulder. The most common joints to be affected the most are those of the lower limbs (i.e., knee, hip, or ankle). There was a total of 18 dislocations found in the research sample, accounting for 5% of the total population (Table 5.7). Of the four cemetery samples, Horsens Klosterkirke (n= 79) had the most dislocations in the joints including four right hips, one left hip, one double hip and one right shoulder (n= 8; 2% of the total population; 10% of Horsens Klosterkirke; 44% of those with dislocations). The individuals exhibiting more instances of dislocations were males 31-40 years of age (n= 5; 1% of the total population; 28% of those with dislocations). The double hip dislocation was interestingly in an adult female aged approximately 31-40 years of age. The next cemetery with the most dislocations was Nordby (n= 6; 2% of the total population; 9% of Nordby; 33% of those with dislocations) to include two right elbow, one left hip, two right hips, and one left knee. Ole Worms Gade and Tirup both had two individuals with dislocations (n= 2; 1% of the total population; 2% of Ole Worms Gade; 11% of those with dislocations). Ole Worms Gade included a female aged 41-50years and one unaged male. The Tirup individuals were two males aged 31-40 and 41-50 years respectively. Dislocations were predominantly in males that were aged approximately 31-40 years of age. Overall, males accounted for 83% of those with dislocations, only 4% of the total population, and 8% of the male population.

<u>Figure 6.8:</u> Lateral view of a right os coxae with a well healed fracture of the acetabular rim due to a hip dislocation. Grave 2848 is from Horsens Klosterkirke (HOM 1272), and is a male, aged 51-60 years.

Hip dislocations, especially those that are accompanied by a severe fracture, are considered a common occurrence for older individuals due to osteoporotic processes (Lewiecki, 2006). It cannot be determined for certain whether the older individuals in Horsens Klosterkirke had osteoporosis unless the bone mineral density of these individuals are much lower than those others in the population (Mays et al., 2006b). In addition, hip fractures are relatively uncommon in the bioarchaeological record; that is not to say that they did not happen, but when they do, they likely occurred in much older individuals (Brickley, 2002; Mays et al., 2006b). The rarity of hip fractures is often associated with the fact that many people could not survive to old age due to differences in mortality rates in adults (Ives et al., 2017). For many of the earlier populations of Denmark, mortality was high and individuals were not expected to live much longer than 20 years at best (Benedictow, 2003). Therefore the rarity of elderly individuals appearing in a sample, let alone with a hip fracture, is understandable. The study done by Ives and colleagues (2017) found that older males exhibited more hip fractures than females in medieval Britain. Young males would show hip fractures, but rarely did younger females ever exhibit the injury. In addition, Brickley (2002) suggests that femoral neck fractures, as a result of osteoporosis, are rare in the archaeological record because of their lack of healing. However, this is not the case for the Danish samples. These results suggested that the cause and manner for hip fractures can differ markedly between subgroups such as males and females in a population. A common result of the hip fractures in Ives et al. (2017) saw compaction of the femoral head, inferiorly into the intertrochanteric region. This same type of hip fracture was seen within the Danish sample and is evidenced further in Figure 6.9 below.

<u>Figure 6.9:</u> Inferior view of a very well healed, displaced femoral head compression fracture, due to a hip dislocation. Grave BM is from Nordby (FHM 3970), and is a male, aged 21-30 years.

It is important to note that joint fractures tend to persist well into later life, but fractures that appear in the shafts of the long bones are typically not associated with osteoporosis or other pathologies (Riggs, 1991). Studies of British medieval sites, such as Wharram Percy, show no instances of hip, wrist, and compression or fragility fractures in the oldest aged individuals (Agarwal et al., 2004). Therefore Agarwal et al. (2004) conclude that because of this, there might be differences in tissue responses, different levels of bone loss, heterogeneity, or mortality bias. Therefore, when examining instances of joint changes, traumatic arthritis, or joint dislocations there are many causative factors to consider further. One major factor is bone quality in the individuals (Agarwal et al., 2004). The environment, genetics, and presence of a pathology are all factors that may affect a person's susceptibility to joint dislocations.

More severe cases of a dislocation may result in the creation of a pseudojoint. A pseudojoint is the development of a new joint surface that develops near or around the original joint surface (Roberts & Manchester, 2007). These can appear as a false acetabulum or depression in the femoral neck or proximal femoral shaft. Pseudojoints are not as well researched, but they do occur in some severe cases, as the one shown below in Figure 6.10.

<u>Figure 6.10:</u> Medial view of a right femur with the presence of a pseudojoint, likely the result of a hip dislocation. There is also presence of metabolic bone formation throughout the femoral head and neck. Grave 2220 is from Horsens Klosterkirke (HOM 1272), and is a male, 31-40 years.

6.3.5 Non-Traumatic Lesions

Although not included in the analysis of trauma patterns in this research, a number of additional non-traumatic lesions were observed in the samples, and are extremely important to note. Many researchers that have no knowledge of skeletal trauma can often times confuse these as being related to a traumatic event, when in reality they are more likely congenital in nature. Because of this often times confusing etiology, these lesions are discussed separately here.

A somewhat common joint condition, specific to the shoulder, is *os acromiale* (Figure 6.11). There are two hypotheses that are proposed for its causality: the bone failed to fuse congenitally or stress to the shoulder joint did not allow for the acromion process to form properly (Case et al., 2006). As the cause of *os acromiale* is not inherently known, it was not included in the trauma counts or statistical analyses for this research. It is deemed to be a condition more common in younger individuals as the acromion process does not fully fuse until 17 or 18 years of age, leaving it a more unexpected condition for the adults in this study (Case et al., 2006). Researchers have ruled out fracture being a cause of *os acromiale* as edges of fracture margins do not resemble the regular margins seen in *os acromiale* (Case et al., 2006). In her study of the *Mary Rose*, Stirland (1996) suggested *os acromiale* as a condition caused by stress to the shoulder joint in young adolescence. Her examination of archers aboard the ship showed a high degree of this condition, suggesting the stress and strains presented through the movements of archery are sufficient enough to cause a disruption in the fusion of the acromion process.

Case and colleagues (2006) examined *os acromiale* in both Tirup and Nordby cemeteries from medieval Denmark, suggesting that Tirup had a 6.1% *acromiale* frequency and Nordby a 9.1% frequency. The frequencies for this research differed from those reported in the Case et al. (2006) study. Tirup (n= 108) and Nordby (n= 66) both had an occurrence of 3% for *os acromiale* (Tirup= 3/108; NOR= 2/66). The Tirup individuals were two males and one female all aged 31-40 years. The Nordby individuals consisted of one male aged 31-40 years and one female aged 41-50 years. Although not included in the Case et al. (2006) study, another one of the cemeteries from this study showed instances of *os acromiale*. Ole Worms Gade (n= 92) was the only urban cemetery to show this condition at 3% of the population (OW= 3/92). The individuals however were younger than the other cemeteries of Tirup and Nordby. Two females exhibited the condition, one aged < 20 years and one aged 31-40 years. The remaining third individual was a male aged 21-30 years.

With comparison to more contemporary South African populations, Case et al. (2006) concluded that the *os acromiale* was a genetic condition as other such studies have observed a higher occurrence of the condition in individuals with African ancestry. As the three individuals from Ole Worms Gade were slightly younger than those seen in the other two cemeteries, delay in fusion of the joint could be a more likely cause due to the presence of distinct epiphyseal surfaces. For the individuals from Tirup and Nordby the condition in this instance may be more conducive to a stress-related cause for the *os acromiale*. Especially since these two cemeteries are rural and would have conducted activities of a high stress nature. The etiology of this condition is questionable, but worth mentioning.

Figure 6.11: Posterior view of a left acromian process, exhibiting well healed *os acromiale.* Grave 1360 is from Ole Worms Gade (HOM 1649), and is a male, 21-30 years old.

A congenital condition that is not at all considered abnormal, as it is quite common in populations, is the failure of the neural arch to join in vertebrae, at the posterior spinous process (Barnes, 1994). These are called cleft neural arches and occur most in the lumbosacral region of the spine. It occasionally can be associated with spina bifida if the condition is serious. Those that do not occur with spina bifida present no serious damage to the spinal canal as the cleft is normally pushed outwards, widening the canal without compacting the neural tube (Barnes, 1994). These clefts were observed in the four cemetery samples (HK= 1; OW= 2; NOR= 1;

Tirup= 4). Almost all of the cases occurred in the fifth lumbar or first sacral vertebrae; however, there was one case of non-fusion of a cervical neural arch (Tirup; Male, 31-40 years). Overall the condition accounts for 2% of the total population, but Tirup shows the greatest prevalence out of the four cemeteries (HK= 1/79; OW= 2/92; NOR= 1/66; Tirup= 4/108) at 4%. Five of the eight cases of the condition were aged 31-40 years (62% of those with cleft arches), two were aged 21-30 years (25%) and one from 10-20 years (13%). The fact that this condition is of a congenital nature, seeing it younger individuals is not uncommon, and those that were in their 30's are still young enough to maintain this condition from a younger age. Grave 1086 shows a cleft neural arch, but it shows incomplete sacralization as the first sacral segment has not fully fused to the rest of the sacral column (Figure 6.12). Evidence of cleft neural arches have been found in the archaeological record, however scientists either misinterpret them as traumatic rather than a congenital defect or they group them with instances of spina bifida occulta. An individual excavated from the Franklin Expedition in Canada had presence of a cleft neural arch in the lumbar vertebrae (Stenton et al., 2015). Researchers confirmed it was a congenital malformation that was likely an asymptomatic condition since fibrous tissue still protects the neural tissues. Another study found the condition in a Peruvian burial, dated AD 400-700 (Titelbaum & Castillo, 2015). This individual had presence of many other conditions considered anomalies. Although the cleft appeared in a fifth lumbar, there were additional partial clefts seen in two lower cervical vertebrae. When the cleft occurs in the cervical this is more an indication of a delay in the development of the notochord itself, making the vertebral body look as a butterfly shape (Titelbaum & Castillo, 2015). The conditions seen in the Danish cemeteries did not show such severe cases of cleft neural arch malformation and were typical in their formation (Figure 6.13).

<u>Figure 6.12:</u> Posterior view of a sacrum, exhibiting an S1 cleft neural arch. Grave 1086 is from Ole Worms Gade (HOM 1649), and is a male, aged 31-40 years.

<u>Figure 6.13:</u> Posterior view of a 5th lumbar vertebrae with a cleft neural arch. Grave 146 is from Tirup (VKH 1201), and is a male, 21-30 years old.

6.4 Rates and Patterns of Trauma

While trauma is observed at the individual level and can inform our understanding of individual life events, methods for understanding population level patterns are desirable. The best way to construct this population level analysis is by using the calculated frequencies of the conditions to assess prevalence and common patterns. Approaches to constructing these frequencies are numerous and variable. Issues still exist in how different methodologies deal with poor skeletal preservation. When the condition of the bones is considered, fracture classification becomes difficult and the question becomes more about how much bone must be present (i.e., preservation) to include that bone and individual in the frequency calculation (Judd, 2002a). When skeletal samples are poorly preserved, fractures and trauma counts in general may be underrepresented due to fragmentary bones. Saddest of all, we will truly never be able to completely observe all of the injuries people of the past endured, as we do not have the ability to observe the soft tissues. Still to move forward in research of skeletal remains, researchers must focus more on the quantitative data rather than the qualitative, as this will allow for greater objectivity when deciphering injuries rather than submit to the verbal description (Judd, 2008). All quantified data recorded for this study can be seen in Appendices A-D, providing the reader with an overview of the total sample of individuals, the categorized trauma, calculated fracture frequencies, and transition analysis scores.

6.4.1 Quantifying Fractures

Approaches to quantifying trauma lesions occur at both the individual and population levels, but both use frequency data to do so. Frequencies allow for researchers to observe changes in rates of trauma over time and many have adapted a biocultural perspective for interpreting them (Grauer & Roberts, 1996). By looking beyond the mere occurrence of the trauma, such as fracture type, considerations must be made as to the healing and complication patterns to help decipher the complete etiology (Grauer & Roberts, 1996). Frequency calculations by Judd (2002a) were implemented to properly quantify the fractures observed in the study sample. Specifically, the bone count, segment count, individual mean trauma count, mean multiple injury count, and individual counts were calculated (cf Chapter 4, Table 4.2).

When simple prevalence rates of the total population (n= 345) are considered, Tirup shows the highest trauma frequency (n= 39/345) accounting for 11% of the population. Furthermore, by element, vertebrae show the most evidence of fractures followed by the right proximal femur. There was a total of 73 vertebral compression fractures (HK= 20/79; OW= 15/92; NOR= 20/66; Tirup= 23/108) which accounted for 21% of the total sample population (n= 73/345). However, when other types of fractures in the vertebrae are included, the fractures comprise 94 total, making up 27% of the total population (n= 94/345). This pattern matches closely with other studies of skeletal samples in medieval Europe, with high frequencies of vertebral fractures (e.g., Roberts, 2000; Junno et al., 2009; Agnew & Justus, 2014; Agnew et al., 2015).

Without consideration of the prevalence rates as stated above, and focusing only those fracture frequency calculations (Table. 5.19, Chapter 5) as provided by Judd (2002a), the individual count and mean multiple injury count were more informative of the smaller cemetery populations and what portion of the population showed more fractures. The frequencies themselves differ greatly in value from the percentages provided by the crude prevalence rates, as the denominator is much smaller for the individual count and mean multiple injury count. For these counts, only the injured individuals comprise the denominator, instead of the full sample size (all individuals). The issue with these fracture frequencies is that they do not include other forms of injury beyond long bone fractures, such as dislocations (unless a fracture occurred in the dislocation of course) as this is a criteria set by Judd (2002a) in calculating and using the formulae provided within the study. Also, many of these counts only include those long bones that are 75% or 100% complete. Per this stipulation, it makes sense that only long bone fractures are accounted for when these counts are calculated. Percentages of completeness when assessing groups of bones (i.e. C1-C7, T1-T12, or L1-L5) is difficult to define when multiple bones make up the larger group. Therefore, the counts as presented by Judd (2002a), still do not truly represent the total number of trauma seen in the populations, as Judd fully concludes in her study. Therefore, fracture frequency calculations still present a problem. Four key areas of concern are: the numerator (fracture classification), the denominator (choosing a denominator), causation of the fracture (too many mechanisms of injury), and multiplicity (individuals that have multiple events of trauma) (Aitken et al., 2014). Determining the numerators and categorization of trauma is difficult in that there are so many types and causations. Does the researcher include any and all fractures despite their cause, such as fatigue fractures or pathological fractures? When deciphering the denominators, the researcher must consider what portions of the population they want to include. Is the research about adults or children or both? These issues surrounding numerators and denominators are those best recognized in population studies or better known as epidemiological studies.

Paleoepidemiological studies, although helpful and informative, recognize the same issues as Aitken and colleagues (2014) do about numerators and denominators. These studies when applied to past populations are biased because the skeletal sample is only a small portion (those that died) of the once living population (Milner & Boldsen, 2017). Due to this, the sample will reflect selective mortality. This is to say that the cemetery population will only show those individuals from that population that experienced a much greater risk of dying than the other portion of the population that was living (Wood et al., 1992; Milner & Boldsen, 2017). Hence, those individuals with fractures that are much older had a longer time to be exposed to events that may have caused them trauma; they have had more time to accumulate more fractures. To avoid this bias and to better assess risk for fractures in groups of people, Milner and Boldsen (2017) suggest that the numerators and denominators only consider all observable bones of interest. For example, if an individual does not have both left and right radii, they cannot be a part of either the numerator or the denominator. If the person just has one of these radii and it shows a fracture, it cannot be part of the fracture frequency numerator because it will inflate the frequency of individuals that have fractures (Milner & Boldsen, 2017). Therefore, fracture frequencies of past populations may never really show the exact picture of the true trauma experiences. Due to excavation, preservation methods, and selective mortality and mortality bias, this may never be fully resolved.

Despite the issues for population level studies and fracture frequencies, paleoepidemiological studies are the most helpful for bioarchaeological research of past populations. These types of studies help examine life experiences of past peoples, morbidity and mortality rates, differential risks for groups of individuals, but perhaps most importantly they help us see the change of societies over time (Milner & Boldsen, 2017). Population level studies help researchers have a diverse understanding of the causes and circumstances that surround the different forms of injuries (Aitken et al., 2014). Clinical research looking at fractures in modern populations use epidemiological studies to help with the prevention and care of fractures, rather than just recording the data as quantitative research. Clinical research in particular tends to report statistics for these living populations, but by using more nuanced epidemiological studies they can focus their efforts of prevention on specific demographics of the population.

Although there are issues with methodology and the recording of fractures, calculation of fracture frequencies can aide paleoepidemiological studies by highlighting those groups of people or parts of the body that were injured most. As a result, researchers can draw conclusions as to the activities and lifestyles of these injured portions of the population. The goal of paleoepidemiological studies is to determine rates and patterns of different conditions that may have been present in the once living population. What were these individuals ultimately doing differently to cause their condition, and why? Population studies reveal more about the people, because the raw frequencies (such as bone and segment counts), do not tell us much about the life experiences of those groups (Milner & Boldsen, 2017). Rather, there are better frequencies that would be more informative for the population level.

6.4.2 The Person-Years Construct

The issues that continue to plague trauma studies of skeletal populations, is a never-ending battle. By calculating raw counts and prevalence rates for trauma frequencies there become two major issues. One issue is the cumulative impact of trauma in an individual's lifetime. The second issue is the population age structure is only representative of a portion of the whole, resulting in a skewed sample. The two issues become related when older aged individuals are expected to show the highest numbers of fracture counts due to having a longer time of exposure to trauma (Glencross & Sawchuck, 2003). However, if this study can attest to anything, it is the fact that this is not always the case; there are other factors to consider. A method for combating these major issues is by using the Person-Years Construct. The concept is not new, as it was described by Lovejoy and Heiple (1981). As noted in Chapter 3, Lovejoy and

Heiple (1981) acknowledged that age structure of the population would ultimately skew the prevalence rates of trauma. Lovejoy and Heiple (1981) solved the issue by trying to create life tables for the population. In contrast, the Person-Years Construct uses the Poisson distribution and the Z-statistic, which accounts for very rare life events. Trauma can be considered rare and not an everyday occurrence. However, it must be stated that the numerator for person-years is only calculated using six types of long bones: the humerus, radius, ulna, femur, tibia, and fibula (Glencross, 2002). Therefore this does not encompass all of the types of trauma seen in the Danish sample.

The sum person-years is calculated by using "the midpoint of each age cohort and multiplying by the absolute number of individuals in that age class, and then adding together the person-years from all age grades that are represented" (Glencross & Sawchuck, 2003:371). These calculations were done using the Danish sample. For the total number of individuals in the sample (n=345), the sum person-years was calculated to be 13,385. Each cemetery possessed their own count separate from the total population. This is discussed in more detail back in Chapter 5 (see Section 5.3.3). The Person-Years Construct allows for researchers to calculate fracture frequency, supposedly providing more idealistic rates of trauma. For example, the crude prevalence rate in Horsens Klosterkirke would tell us that 20% of the population have long bone fractures. In contrast, the person-years calculation tells us that the rate is actually much smaller at 0.0054, when age cohorts and exposure to trauma are further considered. As one can see, there are drastic differences in these numbers.

Traditional studies of trauma quantify fractures in a population by using the crude prevalence rate (CPR). Crude prevalence rates were calculated for the Danish sample. The highest rates for long bone fractures can be seen in the Nordby cemetery, urban locations, males, and AG1 (10-30 yrs.). The rates account for the total number of long bone fractures and the complete long bones in the sample as a total. When rates using person-years is examined, the highest fracture rates are still seen in the Nordby cemetery, urban locations, males, and AG1 (10-30 yrs.).

After calculating and comparing the long bone fracture rates, an odds ratio was calculated. Odds ratio counts in addition to person-years calculations, are best used in instances of rare life events. Odds ratios measure the probability of “an exposure and an outcome” (Szumilas, 2010:227) or in this particular case one group experiencing an event (trauma) over another. When comparing odds ratios, those instances where the value is equal to 1, the exposure produces no effect on the outcome. For values greater than one, the exposure has a higher odds of effecting the outcome. Values less than one, there is lesser odds of effecting the outcome (Szumilas, 2010). Furthermore, the larger the confidence interval, the lower the precision and the smaller the interval the higher the precision of these outcomes (Collier & Primeau, 2019). Those confidence intervals that do not cross the null value of 1, are considered significant (Szumilas, 2010).

For some bioarchaeologists, this is used to examine whether or not certain events caused a greater risk of a person dying and entering the skeletal assemblage (mortality). For example, DeWitte and Hughes-Morey (2012) used the odds ratio to determine risk of mortality for Black Death victims in England. They looked at stature and its correlation to health (i.e., stunting) to see if shorter or stunted individuals had greater odds of dying from the Black Death. For the present research, the odds ratios is used to compare differences in the risk of experiencing trauma.

In this study, the odds ratios from the crude prevalence rates show only moderate positive (1.73), strong positive (2.38), and weak (1.39, 0.71, 1.24) relationships (Sahai & Khurshid, 1996). Long bone fractures between urban and rural location, AG1 (~30 yrs.)/AG3 (> 60 yrs.), and AG2 (31-60 yrs.)/AG3 are weak with one another. The moderate positive value was represented for AG1 (~30 yrs.)/AG2 (31-60 yrs.) at 1.73. The weak relationship indicates that these groups would have lesser odds in attaining a long bone fracture. The strong positive relationship for males and females (2.38) however, would provide greater odds in attaining long bone fractures. Simply, all of these values with the exception of one (AG2/AG3 = 0.71), indicate that between location, sex, AG1/AG2 and AG1/AG3 there is slightly higher odds of effecting the outcome or acquiring trauma in their lifetime. For individuals between AG2/AG3 there is no effect on the outcome of trauma.

Using person-years calculations for the odds ratios have only slightly reversed the previous results. The relationships seen between urban/rural, males/females, and AG2 (~30 yrs.)/AG3 (> 60 yrs.) are seen as weak. Individuals in these groups have lower odds of being affected by the presence of long bone fractures. The groups with greater odds are in the relationships between AG1 (~30 yrs.)/AG2 (31-60 yrs.), and AG1 (~30 yrs.)/AG3 (> 60 yrs.). The strong positive correlation between these groupings suggest that differences in age have a greater odds in acquiring a long bone fracture. Perhaps the biggest issue with person-years calculations of fracture frequencies, is that it does not account for preservation in the sample (Cahn, 2019). By not allowing for different levels of preservation and not accounting for how much of the bones are represented in the sample, all individuals and all of their skeletal elements are represented in all of the categories, which is not true (Cahn, 2019).

When examining the level of precision for these correlations, the confidence intervals are considered. The Crude Prevalence Rate showed high precision of the odds ratio for urban and rural (CI= 0.82-2.00) and AG1/AG3 (CI= 0.30-1.70) outcomes. If a confidence interval does not cross the null value of one, the relationship is significant. The odds ratios for CPR only showed the male/female category as significant. The Corrected Crude Prevalence Rate showed high precision for AG2/AG3 (CI= 0.38-1.13), urban and rural (CI= 1.31-2.47) and AG1/AG3 (CI= 0.70-1.87). The Corrected CPR for urban and rural, males and females, and AG1/AG2 relationships were all significant as the confidence interval did not reach one. Lastly, the Pearson-Years odds ratios showed high precision for the urban and rural and the male and female relationships. Those relationships that were deemed significant were AG1/AG2 and AG1/AG3 with confidence intervals greater than one. However, the Person-Years confidence intervals showed less precision overall among all of the odds ratios calculations as the intervals were much wider than those that were calculated for the CPR and Corrected CPR.

6.4.3 Survival Analysis

Survival analyses were implemented in order to shed further light on mortality bias and heterogeneity in the cemetery samples. These issues stem from the previously mentioned Osteological Paradox, which is further discussed in this section. An early model to help alleviate these issues proposed by the Paradox, was Usher's four-state hazard model (Usher, 2000; DeWitte, 2006). The idea behind a hazard model is that there may be different sub-groups within the larger population (i.e., adult, child) that have different 'age specific' hazard rates causing a false pattern of mortality (Vaupel & Yashin, 1985). Furthermore, "each individual in the population could have his/her own unique hazard," causing even more difficulties in determining a concrete mortality pattern of a population (DeWitte, 2006:72). Usher's model assumes that each individual of a population are in one of four different states at one time. State 1 is individuals with no skeletal lesion, State 2 is individuals with active lesions, State 3 is individuals with fully healed lesions, and State 4 is death (Usher, 2000; DeWitte, 2006). Even though an individual can only be in one state at a given time, there is tendency for them to transition and move to the next state; Usher's model considers these rates of transition as a hazard rate (Usher, 2000; DeWitte, 2006). Overall, the hazard rate is extremely informative as it is "dependent upon an individual's age and level of frailty" (DeWitte, 2006:75). The calculation of these states and rates according to Usher's model results in life curve tables, or essentially a survival curve.

An important study by DeWitte (2014), looked at survival of individuals in an English population by using the Kaplan-Meier analysis. The survival analysis is used to determine whether the presence or absence of a condition increases the likelihood of individuals surviving in a population. DeWitte's (2014) study examined skeletal samples for presence of healed or unhealed periosteal boney reactions. The individuals with evidence of remodelled bone were the individuals that had a greater chance at surviving. The presence of a remodelling process was reflective of better health in the individuals. This same concept can be used for individuals that sustained fractures in the archaeological record. A Kaplan Meier survival analysis for the Danish samples did not detect significant differences in survivorship in between those with and without observed trauma. However, the analysis did suggest for rural individuals that those that had skeletal trauma had slightly higher survivorship than those without skeletal trauma, possibly due to levels of frailty or other unknown environmental factors. Yet, it must be kept in mind that these survival analyses only portray hard-tissue trauma lesions. Much of the trauma that individuals suffer from may only affect the soft-tissues and would therefore be undetectable in the bone (Baker et al., 1984; Judd & Redfern, 2012). Therefore, injuries that can often times be fatal, may never be recorded and survival of particular individuals in a population must be interpreted and approached with some caution.

When revisiting the study by DeWitte (2014), she found that the individuals that had healed or remodelled bone survived much longer than those that had no lesion or had no remodelled bone present. Researchers in bioarchaeology would assume that the individuals with no lesions should survive longer than those with fully healed lesions. The 'non-afflicted' individuals should be healthier in retrospect. When studying populations of the past, this may not be a clear assumption to make due to the Osteological Paradox which was briefly mentioned the earlier chapters (Wood et al., 1992). The presence or the absence of a particular lesion cannot in essence speak to overall health of that individual. Individuals with healed lesions may in all actuality be healthier as they lived long enough to acquire the disease, live with it, and ultimately heal from it. Those without any lesions may not be healthier, but frailer (DeWitte, 2014). The individuals without lesions could have been affected by the disease, but they could not live long enough to develop any physical manifestations in the bones due to being frailer.

The Osteological Paradox affects our overall interpretations of what is happening in the past, whether health or trauma related (Wood et al., 1992). The survival analysis was a step towards trying to understand this concept and how it affected the trauma in these Danish samples. Did the individuals with trauma actually live longer than those without trauma? Is there a selective mortality for those that had trauma and those that did not? It is still inherently hard to answer these questions directly. One caveat to contend with is distinguishing between fully healed, slightly healed, or non-healed traumatic lesions. For individuals with fully healed and even partially healed lesions, we can with some certainty suggest that these individuals lived sometime after their initial injury. Those with no healing did not live very long after the injury. If the survival analysis distinguished this, we may be able to get a much clearer picture of survival. By taking into account levels of healing, the Osteological Paradox is grappled with again, because “death is the ultimate state of poor health” and those that died from their traumatic injuries would indeed be considered as the unhealthy portion of the society due to not surviving the affliction (DeWitte & Stojanowski, 2015:399). The problem persists when the exact timing of trauma cannot be determined, therefore linking “survivorship with lesion-manifestation timing” is continuously problematic for bioarchaeological studies (DeWitte & Stojanowski, 2015:400). The Danish samples show an overarching conclusion that the young and middle adults (21-50 yrs.) and those older adults (61-70 yrs.) represented the most traumatic injuries. Although, those individuals between 51-60 years of age showed less trauma, due to sample sizes for the age cohorts, it could suggest that the trauma was nearly evenly distributed.

In addition, the ideal of frailty comes to mind as well when considering the Paradox further. In their early paper, Wood et al. (1992) suggested that there is hidden heterogeneity in frailty. In other words, every individual has a different susceptibility to disease, trauma, and other environmental stressors (Wood et al., 1992; DeWitte & Stojanowski, 2015). If this is the case, how can we exact these population level studies if we become used to defining and using groups of individuals. Individuals that have fractures in the population, are combined together for group analyses, without further taking into consideration the issue of frailty. In fact, frequency-based methods, which use portions of the whole population to interpret patterns, are often the victims of the Osteological Paradox (DeWitte & Stojanowski, 2015). Trauma studies would indeed fall in this category. If trauma analyses did not use frequency based methods, how could these injuries ultimately be recorded and reported? Some would suggest, taking the ‘forensic perspective’ to trauma, in that it is reporting on more recent humans and they are usually burial contexts that have been used over a short period of time (DeWitte & Stojanowski, 2015). But as bioarchaeologists, we cannot simply ignore the past. As trauma research progresses the underlying factor of *when*, at what exact age, did the trauma actually occur, would help alleviate some of the issues of the Osteological Paradox. By assessing this, perhaps levels of actual health and overall frailty can be deduced further.

Additionally, although we may not be able to pinpoint exactly when the trauma took place, we can now use better age estimation techniques (i.e., transition analysis) to more accurately assess age estimations. Age estimation is a pillar for demographic studies of populations, therefore they need to be as accurate as possible (Wright & Yoder, 2003). From this study alone, the evidence that transition analysis can indeed provide us with ages above our previous cut-off points, is extremely promising for population level studies. Most importantly, the oldest-old aged individuals are no longer part of an arbitrary group. What is most helpful in regards to transition analysis, is that the data is based on a wide and variable range of skeletal populations around the globe which would help avoid sample mimicry and sample bias (Boldsen et al., circa 2020). It has been well recognized that age estimations that use particular methods, may fall victim to sample mimicry. This is where the estimations of the sample tend to reflect those individuals of the reference sample used for the estimation methods (Bocquet-Appel & Masset, 1982; Konigsberg & Hens, 1998; Wright & Yoder, 2003). The sample population and the structure of that population, would be further ‘reflected’ in the studied population (Bocquet-Appel & Masset, 1982). Traditional methods of age estimation in paleodemography often describe a mortality profile that shows individuals with high mortality between 15-50 years, with little of these individuals surviving into old age (Milner et al., 2000). This often times does not match up with historical records. So why is the archaeological data and the historical records not matching one another when it comes to mortality profiles? It is more than sample mimicry; it is also caused by errors in age estimation methods thus far employed for these types of population level studies. Therefore, in order to obtain a more accurate mortality profile, the age estimation methods themselves must improve and transition analysis has done just this. Transition analysis avoids sample mimicry by assessing age indicators throughout the body and deciding simply if these indicators are present or absent. Also and most importantly, because transition analysis uses wide global distribution and a varied and wide range of individuals (i.e., age groups, males and females, etc.) for their sample populations in their program, mimicry and bias are lessened. The vast range in populations and even individuals that are in the program, are what make transition analysis unique. It is the hope here that by using fewer traits (making for less error as well), the more informative the analysis can be.

The Osteological Paradox still continues to inform studies of skeletal assemblages of the past. It may never be as clear-cut as we would like it. Future research that revolves around population level analyses and health must be ever diligent as they move forward.

6.5 Bioarchaeological Context

The Danish populations in this research have their own unique context, history, and bioarchaeological information. This study encompasses only a small portion of the timeline and geographic region in medieval Denmark and medieval Europe alone. Therefore, it is important to place the results of the research in a much broader context.

6.5.1 Medieval Denmark

The Tirup sample is perhaps one of the more well studied populations in Danish skeletal research. Boldsen and Milner (2015) focused on male cranial trauma lesions in Tirup, as well as two other cemetery samples. Cranial blunt force trauma was found to be well represented in the Tirup sample and those individuals that did show evidence of cranial blunt force or cranial sharp force trauma were all male individuals. The males come from the middle adult and young adult age groups and all the lesions have been partially healed. Boldsen and Milner (2015) also showed that distal radial fractures were more common in females than they were in males. Colles' fractures recorded in this research were female specific for Tirup. Although Colles' fractures did appear more often in female individuals, they did occur in males and tended to occur in the oldest-old age group.

Collier and Primeau (2019) examined two Danish Medieval cemeteries from Randers (urban) and Tjærby (rural) during 1050-1536 CE. The researchers did not find any difference in trauma between urban and rural individuals, nor did they find any significant difference between males and females. The lack of difference between urban and rural trauma matches well with the results of this study where trauma was nearly evenly split. However, there was a great difference in males and females in this study that is not reflected in Collier and Primeau (2019). It appeared that Randers (urban) had a high frequency of vertebral trauma, whereas Tjærby (rural) had trauma more evenly throughout the body. The high frequency of vertebral trauma matches well with this study, although these were observed in all cemeteries. In fact one rural and one urban cemetery from the 4 possible, had the highest amounts of these vertebral fractures. Odds ratios and risk calculations were also performed by Collier and Primeau (2019). They found that Randers was 1.13 times more likely to suffer trauma than Tjærby, although there was no prevalence difference between the two. The risk calculations suggested that males did have a higher risk for both of the assemblages, but only for the lower limb and young adults in Randers had a higher risk than young adults in Tjærby (Collier & Primeau, 2019). Although there were no risk calculations for the current study, odds ratios (for Crude Prevalence Rates) calculations show that urban individuals were 1.39 times more likely to acquire trauma. This is not much higher than that found between the urban and rural samples in Collier and Primeau (2019).

Sex differences in trauma patterns were examined closely by Nielson (2011), who examined urban Denmark samples from Ribe and Odense. Specifically, Nielson (2011) showed that fractures in the radii, tibiae, and the hands were seen more common in females. The males showed more variable fracture placements. These fractures appeared in the clavicles, hands, and ribs. In addition, males were overly represented for joint dislocations, although this was not statistically significant.

Arcini (1999) in her dissertation work, focused on the urban centre of Lund. The fractures seen in Lund were variable in both males and females. Arcini (1999) observed cranial trauma in males and radial trauma in the females. This pattern is similar to what was found in the previously mentioned studies, including this thesis study. Although she only recorded trauma lesions on an urban sample, the areas of the body affected were very similar where vertebral fractures outnumbered any other types of fractures. The trauma seen in both this study and the study done by Arcini (1999), shows that many of the injuries were due to accidents or activity related injuries.

6.5.2 Medieval Europe

Recent studies of injury patterns in medieval Poland show that trauma occurred more often in rural than urban centres (Agnew & Justus, 2014; Agnew et al., 2015). Of those injuries found in rural individuals, the ribs and the vertebrae were the most injured portions of the body. Compression fractures were found to be extremely common. The compression fractures in the spine, showed that heavy loads were being carried and that this was suggestive of a high instance of labourious activities (Agnew & Justus, 2014). Along with compression fractures in the spine there was significant evidence of spondylolysis in the lumbar vertebrae. The types of fractures and the number of fractures seen between the urban and rural Polish centres show that activity related injuries were more common than fractures related to violence. This conclusion supports that this sample was part of a hardened and stressful lifestyle in medieval Poland. Betsinger (2007) in her dissertation research supports this further by showing low injury prevalence in medieval urban Poland samples. Males again showed more injuries than females, but few of these were compression fractures (Agnew & Justus 2014; Agnew et al., 2015). These patterns were activity related injuries, indicating a strenuous lifestyle for those individuals.

Trauma in medieval Britain has been extensively researched and many comparisons between urban and rural locations have been undertaken. In a very early, but precedent setting study, Judd and Roberts (1999) showed that equal instances of trauma in both male and female groups suggested an agricultural (rural) way of life. Urban centres that relied on crafts, showed less trauma, due to the intensity of the activities that were being performed. In the rural households, areas of injuries in males were variable, while females had injuries mostly in the forearms. Multiple injuries during life, referred to as injury recidivism, was examined in British rural and urban populations by Judd (2002b). In her study, urban individuals did not exhibit as much trauma as their rural counterparts. In addition, rural individuals were more likely to sustain more than one injury. Males were injured more often than the females. Multiple injuries were observed to be greater in the rural young age groups. Many of the urban older adults showed very few instances of injury, let alone multiple injuries. In St. Helen-on-the-Walls, Grauer and Roberts (1996) observed that the urban British centre individuals had more injuries in the forearms and those that displayed the most fractures were in the middle adult age range of 35-44 years of age. Regardless, long bone fractures were not very common in this sample.

These studies demonstrate several similarities to the observations from this dissertation research, although the difference between urban and rural locations were not as clear-cut. There was no difference in the number of individuals with trauma for the Danish urban and rural centres in this research (Urban n= 68, Rural n= 70). Males were consistently injured more than females, which is a pattern that coincides with those trauma patterns observed in other European countries. Differences between the sexes seems to be a seemingly common trend in many medieval archaeological sites. Forearm injuries in both males and females were a common trend. Injuries of this nature would suggest more use of the hands and upper limbs. Unfortunately, machinery and technologies had not advanced far enough yet as to reduce the impact of manual labour. Falls were common but could occur in or out of the household environment. Although certain portions of the body were more injured in the Danish samples than other portions, there were no distinct differences between the axial or appendicular elements to suggest specific activities were the causation. All portions of the body were seen as susceptible to trauma. The injuries just occurred more equally than the trends witnessed in the other medieval samples.

6.6 Revisiting the Hypotheses

At the beginning of this dissertation, there were five hypotheses proposed. They were as follows:

1. Rural populations will possess trauma lesions in the trunk region and the upper and lower limbs, while urban populations will possess trauma lesions in the forearms, cranium, and facial regions.

2. Urban populations will have a higher proportion of trauma than rural populations.

3. Males will have a higher proportion of trauma than females in the lower or younger/middle adult age ranges.

4. Females will have a higher proportion of trauma than males in the higher or oldest-old adult age range.

5. Trauma in the oldest-old age group will be consistent with osteoporotic fragility fractures in the trabecular portions of the long bones (i.e. distal radius and femoral neck) and compression fractures in the vertebral bodies as compared to younger adults.

Hypothesis-1

The trauma patterns exhibited in both the urban and rural populations were similar and did not show one portion of the body affected over another. Although within the whole sample, there was more of a pattern of which portions of the body were affected more (vertebrae), there are no distinct differences between specifically the urban and rural individuals. The bones that were affected were variable throughout the body in both urban and rural samples (Appendix C). Research has showed that rural activities show a variable range in the areas of body affected by fractures, which is less typical of an urban population (Grauer & Roberts, 1996; Judd & Roberts, 1999). The Danish urban populations showed the opposite of what has been observed in previous studies. Long bone fractures are said to be rarer in urban individuals (Grauer & Roberts, 1996), but this was not the case for the Danish samples. The lower limbs were the second most affected area for the urban individuals. The rural populations followed a similar pattern where the lower limbs were heavily affected in addition to the ribs and hands. **Hypothesis-1 is not supported by the data** because the patterns were not apparent in the urban and rural populations.

Hypothesis-2

Although rural populations present individuals with a dangerous occupational environment and a more hardened lifestyle, urban populations are thought to possess greater amounts of trauma among individuals (Judd & Roberts, 1998; Judd & Roberts, 1999; Djuric et al., 2006). The urban Danish populations in this sample did not experience more trauma than their rural counterparts. Therefore, **Hypothesis-2 is not supported by the data**. The rural population showed only slightly higher amounts of trauma than the urban. The difference between the two were almost indistinguishable and rates of trauma were practically equal to one another.

Hypotheses-3 and -4

Studies of past populations have shown a nearly universal phenomenon of males being injured more often than females (e.g., Judd, 2002b; Brickley, 2006; Betsinger, 2007). Another part of this hypothesis suggested that males in the young and middle adult age groups would incur more injuries than females in that same group. The patterns seen in the Danish samples showed that males have more injuries than females and the representative age groups for these injured males were 21-40 years and 70-90+ years. **This data supports Hypothesis-3.** The more males in the young and middle adult age groups was expected, as these were likely the males that were involved with the harder labour and their risk of injury was higher. The oldest-old males with more injuries was atypical for other studies of medieval Europe. Females in the oldest-old groups are said to possess more fractures than the males of the same age group because they have greater loss of bone mineral density due to menopause and osteoporosis (Riggs, 1991; Brickley, 2002; Mays et al., 2006b). This is not to say that males do not suffer from osteoporosis, but they usually possess more bone mineral density in general, than their female counterparts, leaving them less susceptible to fractures. The appearance of the oldest-old males being more injured than females in this group was interesting for this research and **did not**

support Hypothesis-4. The difference could be due to sample size and the fact that most of the skeletal samples did not have many individuals that reached these old ages.

Hypothesis-5

Individuals with hip fractures and dislocation of the hip joints were consistently observed in middle adult and older individuals. Out of a total of 13 individuals with hip dislocations, three were unaged, one was under 30 years old, five were 31-50 years old, and four were 50+ years old. Colles' fractures were present in the sample in the older females. Another osteoporotic fracture is vertebral compression fractures. These types of fractures did not just occur in the older individuals, but they occurred throughout the age groups of both males and females. The over-abundance of these types of fractures suggested that the populations led an extremely active lifestyle. Therefore, the injuries seen in the oldest-old groups were consistent with osteoporotic fractures in addition to other accidental fractures. Thus, **the data supported Hypothesis-5**.

CHAPTER 7: THE PILOT STUDY

7.1 3D Imaging Techniques

The capture and rendering of traumatic lesions using 3D imaging techniques was undertaken as a pilot study to determine if images could better classify traumatic lesions in past populations. Many of the issues in trauma analyses is that fracture classification is hindered by not being able to see minute changes in the fractures, or to determine original placement before callus formation. Although many of the fractures seen in the Danish sample are antemortem and have a healed callus, internal imaging, such as CT data, was implemented to help discern the original fracture pattern from the internal structures of bone. By non-invasively examining these healed calluses through CT, researchers may be able to determine original placement, but also how stabilised the bone is and how much compact bone has developed after healing (Augat et al., 2014). Other benefits of using imaging techniques for trauma is examining topographical changes in the bone surface.

7.1.1 NextEngine Scanning and Scan Studio Software

The NextEngine 3D scanner captured the texture and topography of fractured bones. The Scan Studio program that accompanies the scanner meshed together multiple scans into one image (White, 2015). Each individual scan showed that this type of 3D imaging was best utilized in capturing whether depression fractures were present. Since it captures topography or surfaces of the bones, the depressions became more apparent in the scanned image than they were in the macroscopic examination (Figure7.1). As a majority of the fractures in the Danish samples were located in the vertebral column, the NextEngine scans were key in deciphering the etiology of those spinal fractures. Degrees of compression in the vertebral bodies could be seen in the macroscopic examination. Therefore, those vertebrae that were only slightly depressed or compressed received further confirmation from the scanned image as to their classification. Depression fractures in the cranium were not abundant in the samples. Those that were identified were captured via the NextEngine, even though little evidence could be gleaned from the macroscopic examination. Some of the blunt force fractures in the cranium were so well healed that whether or not a depression was present was questionable. However, the 3D scans AND the macro-lens of the handheld camera captured angles much better than the naked-eye.

Research shows that the use of the NextEngine scanner can be useful in retaining the bones original sharpness and morphologies (Urbanová et al., 2017), which is a capability that may not be possible in other digital imaging techniques. The NextEngine scanner is more accurate at capturing smaller objects of bone with small details (Urbanová et al., 2017). This research unfortunately cannot attest to this capability. Smaller surfaces of the fractures that needed to be captured were hindered by the lighting capabilities. As a result, it was near impossible to use the NextEngine to help determine perimortem and postmortem fractures. A very important detail in determining this timing of fractures is present in fracture margins. The minute changes in margin texture and colouration was unable to be captured with the 3D scanner. Antemortem fractures may not retain fracture margins due to callus formation and the capturing of the small margin details is not necessary. Therefore, the usefulness of the 3D scans centre on their ability to detect depressions on uniform surfaces. The scans can also capture changes in angulation which can attest to direction of the force.

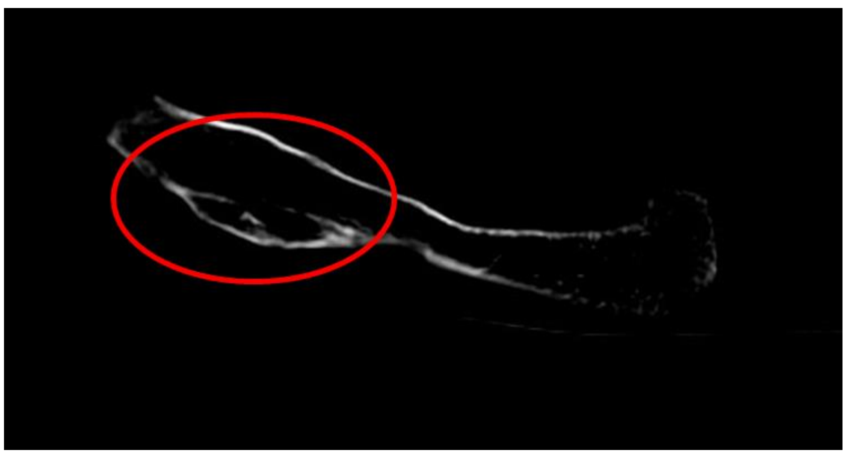
Although helpful in many aspects, the NextEngine is not without its issues. The issues with this scanner lie with its post-processing capabilities. The Scan Studio program, which helps with the editing of the NextEngine scans, is not capable of performing simple fine-edging editing (Urbanová et al., 2017). In the editing phase of the scan, the final result was incomplete or lacking portions of the bone that the laser was unable to reach due to lighting or positioning. The bone was sometimes too big for the scanner platform, causing almost an entire portion of the posterior aspect to be completely missed by the laser, even though the rotation was 360^{o}. In this instance, using multiple scans from multiple angles were spliced together to make one image. A far more time-consuming endeavor than it would be for the entire 360^{o} scan.

Figure 7.1: Collage of images with an example of a depression fracture in a 5^{th} lumbar vertebrae. Photos show the original bone (top), the NextEngine raw image (bottom left), and the pixelated or lattice rendered image (bottom right).

7.1.2 CT Scanning and MIMICS Software

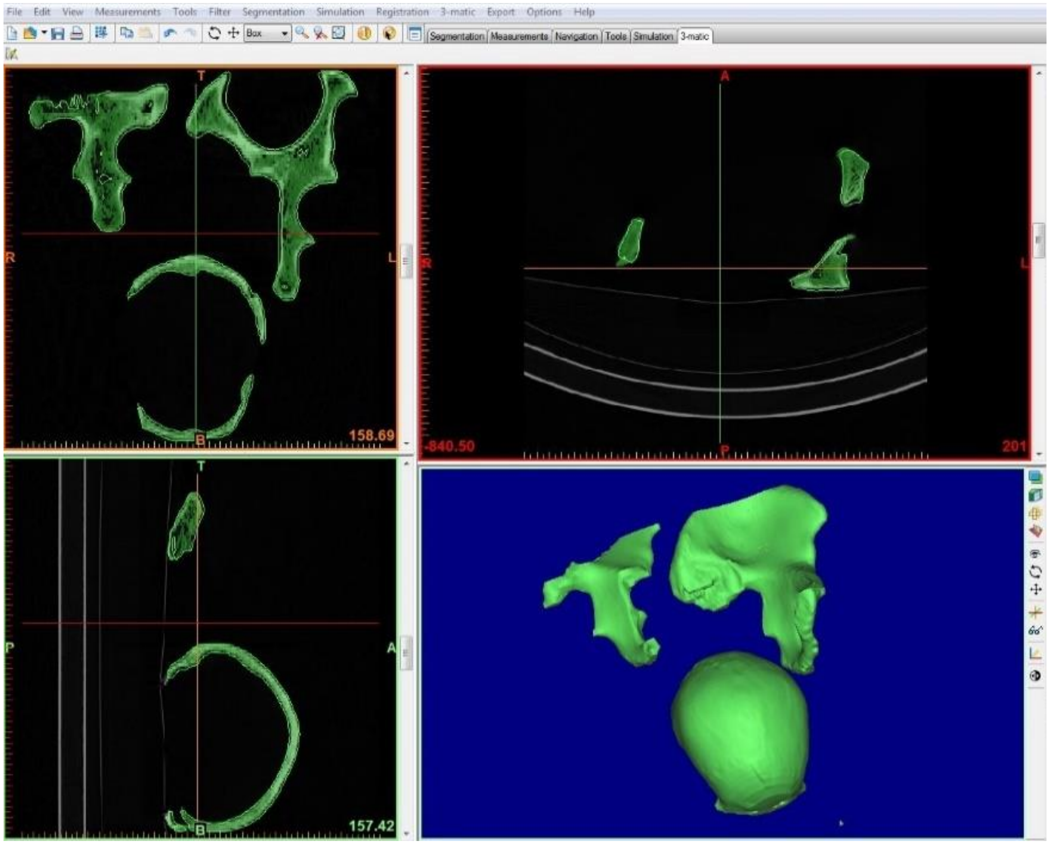
Additional scans using computed tomography techniques were gathered to compare to the NextEngine. One major capability between the two is that internal structures of bone become more apparent in the CT data; internal structures cannot be gathered in the NextEngine scans. The use of CT data in trauma classification can help determine fracture healing and morphology. This specific capability is important in examining antemortem trauma as the hard bone callus erases the fracture margins. Therefore, the CT imaging will capture the internal structures of these calluses (Figure 7.2). Structures that may become more apparent in the CT scans may be additional bone flakes at the edge of fractures, additional formation of cortical bone, and callus formation stages. The stages of a healed callus are informative of the timing of trauma or when it occurred originally, something that still evades many researchers in bioarchaeology (Messina et al., 2013). Researchers have found that CT's can show the difference between perimortem and postmortem fracture responses, such as plastic response, fracture outline and textures, and the presence of hinging (Messina et al., 2013). CT images may also be helpful for determining the difference between trauma and pseudotrauma.

Figure 7.2: Raw CT image of the formation of a boney callus in the ischiopubic ramus of Grave 3026 from Horsens Klosterkirke (HOM 1272; male, 21-30 yrs. old).



The MIMICS software program used the original CT scanning data to render and create a final 3D image. MIMICS allows the user to edit the scans (Figure 7.3) of foreign objects, measure the density of the bone, and measure angles in the bone surfaces. The 3D images seen in MIMICS were of a better quality than the ones that were seen in the Studio Scan program with the NextEngine. The contouring and filling were easier to see in the final MIMICS 3D images; the contour is a feature needed for a more precise 3D print or reconstruction.

<u>Figure 7.3:</u> Screen capture of the editing process of a CT scan in the MIMICS software.



Although some fracture characteristics were better ascertained with the 3D technologies used in this pilot study, such as depressions and angulations, there were still some characteristics that were not captured. The characteristics that reside on the fracture margin are of particular interest. Unfortunately, the 3D rendering programs were not useful in capturing these minute details. The use of a micro-CT would have been better utilized for this type of research, as it would have captured smaller details and more exact changes in fracture margin characteristics. Additional issues were the researcher and rendering programs. The original placement of the bones on the CT mat were not ideal for rendering even though it was more conducive for time management. Placing more bones on the scanning platform mat cut down on the amount of scans needed. However, more bones on the platform mat made the rendering process more difficult in MIMICS. Bones were overlapped and in the way of another bone from a different view (Figure 7.3), even though the image could be rotated. Placing more bones on the platform made the editing of the x-ray image more difficult. As bones were different shapes and sizes, editing the 'noise' in one layer of the scan could sometimes erase portions of bone in another layer. In retrospect, taking the time to scan the bones individually would have provided better results. Therefore, the imaging techniques used in this pilot study were only slightly helpful in making more accurate fracture classifications. Other such methods were therefore utilized in order to exact the classification for data and statistical purposes. Ultimately, the pilot study did help provide a more permanent record of trauma lesions that can be used in future research.

7.2 Further Considerations

At the beginning of the research development, the capabilities of the NextEngine scanner were highly overestimated. Although it captures topographical changes in bone, it is not meant to be used for high precision scans to capture small or minute fracture characteristics. Rather, it should only be used for a more generalized and macroscopic examination of the bone. This conclusion may also be hindered further by the fact that much of the trauma present was antemortem with callus development, leaving little to no evidence of original fracture margins. Fracture margins is where researchers examine the minute fracture characteristics such as stepping. Therefore if there were no distinct margins to scan, that capability could not be explored further. For future use of any NextEngine scans for trauma, there should be more variability in the fractures examined. More so, presence of perimortem trauma would be more helpful in determining whether fracture margins can be accurately captured.

Once it was observed that changes in fractures could not be accurately recorded using the NextEngine scanner, research development lead to implementing computed tomography (CT). As much of the trauma was antemortem, it was the hope that fracture classifications may be more accurate using CT for examining the internal structures. Unfortunately, time did not permit the level of analysis necessary. However, the CT scan results may provide additional information, although perhaps not specific for fracture classifications per se. Specifically the CT scans were informative of the healing process in general. For example, scans that showed well set bones, exhibited more continuity in their callus formation, with denser boney internal structure. In this case, the scans were able to show which fractures were likely more stable than those that had less dense internal structures (Augat et al., 2014). Also, the CT scans were helpful in deciphering whether those with less dense structure in the callus were a result of infection, or if it was simply poorly set to begin with. Fractured bones that were able to heal completely and become biomechanically stable exhibited denser formations. In some instances the bone, although not well set, was still able to be more stable because of the dense internal structure and the redevelopment of a medullary canal (Marsell & Einhorn, 2011).

Although the pilot study did not reach all of its expectations towards better classifying fractures, it was helpful in other respects, specifically in examining the extent of healing and callus formations. The use of micro-CT technology will be better utilized in future studies of this nature, as this technology has precision capabilities for capturing fracture margin characteristics.

CHAPTER 8: CONCLUSION

The main objective of this research was to examine trauma patterns in age and sex groups, of rural and urban populations in medieval Denmark. This research process set out to determine more precise age ranges and examine the use of three-dimensional means of classification of trauma lesions. The pilot study of using 3D technologies were not in and of themselves more informative, but it still contributed to a better understanding of trauma lesions overall and presents researchers with another avenue to consider when undertaking trauma analysis in the future. This research exemplified that if better age estimation techniques are utilized, patterns of trauma lesions can be more accurate and may allow for more precise interpretations of behaviours and activities of people in the past.

This research is unique because very few studies focus on the analysis of trauma lesions specific for elderly individuals. From this evidence researchers can move forward with examining the reasons as to why these oldest age groups are affected by trauma. Thus, this research can complement clinical studies of osteoporosis, other pathologies, and activities and behaviours of the elderly.

8.1 Research Outcomes

The foremost objective of this research was to understand the different observable patterns of skeletal trauma in adults, particularly older adults. This is important because many studies have typically left these older age groups 'open-ended' because of limitations of age estimation techniques. The method of transition analysis developed by Boldsen et al. (2002) showed that these age categories could be more precise by using a combination of age specific characteristics. The examination of these age specific characteristics and how they transition from one stage to the next was represented by the statistical regression model and the transition probability. As a result, the age-specific differences in frequency, type, and location of the trauma became clearer within and between samples of individuals. The mere presence of trauma in old age groups showed the importance of more precise age estimations. Without these 50+ years broken down further, older adult trauma would be presumptive at best.

Another objective was to understand the patterns of trauma between urban and rural populations and whether there were changes in patterns of trauma over time. Although major differences between locations did not exist for this Danish sample, these results are still informative. These results suggest that the differences in urban and rural lifestyles for Denmark were not as significant as they likely were for other parts of medieval Europe. In other words, further research would need to consider similarities and differences in the levels of activity performed in each location. Migration processes and the movement of rural individuals to more urban centres throughout the medieval period may have caused a continuum effect in their activity patterns resulting in little differences between the two. A further consideration as to the lack of any major differences between the urban and rural samples, may be due to their time frame. The urban samples were both much later than the two rural populations. This could account for the nearly identical prevalence rates.

This research examined differences in traumatic lesions between males and females. Differences in skeletal markers between males and females are a major component of assessing activities in past populations; therefore, this analysis considered sex differences in those that express trauma. The evidence of trauma between the males and females of medieval Denmark showed that males were more involved with those activities that may have put them at greater risk of being injured. The early rural populations showed a greater difference between males and females than the urban centres. The later years of medieval Denmark saw female labour as less restrictive in the urban centres; therefore, the females performed activities and tasks that were just as risky to injury as that of their urban males. It may suggest that the urban environment presented both the males and females with greater risk of injury. Portions of the physical environment, such as living quarters, places of occupation, or even cobbled streets, could have been hazardous. Urban centres were part of the main thoroughfare of trade, commerce, and political movements; these components of the environment could present more avenues where people could be injured.

Ultimately it was the objective to tie all of the research together through the theoretical approach of the life-course. However, limitations were presented to where this could not be done fully. The life-course approach is helpful in many respects, but it emphasizes evaluating the social, political, and environmental circumstances of a person's life over the entirety of their lifespan. As mentioned in previous chapters, the age at which a fracture occurred in a person cannot be accurately assessed with current available methods. Therefore, trauma events are equated to their age-at-death versus years during their lifespan for when the injury may have occurred. Due to this limitation, this research in particular may be better described as looking at a biocultural approach more so than the life-course.

In summary.

- Trauma did not differ greatly between urban and rural populations.
- Trauma did significantly differ between males and females, with males being injured more often than females.
- The use of Transition Analysis aging techniques allowed for individuals to be aged into categories rather than just 55+ years. Individuals appeared in the age groups 51-60, 61-70 and 71-91+ years.

- These old and oldest-old individuals did show traumatic injuries.
- The age group with the highest traumatic injuries were those aged 31-40 years. This age group would also have represented the more economically active portion of the sample.
- The age group that exhibited the highest number of multiple injuries, were those aged 31-40 and 41-50 years.
- Trauma did not differ from one time period to the next. Although this may also be reflected in the trends reflected for rural (early) and urban (later) differences.
- The types of fractures to appear the most in the total sample were compression fractures in the thoracic and lumbar vertebrae. Suggesting activity related trauma was more common than violence-related trauma.
- The pilot study showed that the NextEngine is good for capturing topographical changes for fractures that could be initially missed by macroscopic examination. This helped the most with deciphering the presence of depression fractures.
- The pilot study research should be continued, but with using micro-CT imaging rather than basic CT and NextEngine scans.

8.2 Future Research

The observation and calculation of fractures and other traumatic lesions in the skeleton is a well-established area of focus for bioarchaeological studies. In addition to this type of research, other studies have compared diets, activity, health, mortality, and occupational differences between urban and rural locations. The continuous study of both areas in bioarchaeology presents researchers with the ability to re-test and improve upon the methods and theories they use to draw conclusions about the patterns observed in past populations. The ability for this research to comprise a large sample size of adults, process individuals of more concise age ranges, and ultimately use three-dimensional techniques to capture the trauma presents the field of bioarchaeology with new avenues to continue to improve upon.

Future research concerning three-dimensional techniques of trauma lesions must consider their access to equipment. In this study, the CT data was captured in 3mm slices. However, the use of 1mm slices would have possibly created an improved rendered image of the fractured bones. The better images would have displayed more minute characteristics that would have been more beneficial for fracture determination. In addition, access to a micro-CT scanner would prove to be best for acquiring better quality images. Quantifying fractures is still a constant debate today, as paleoepidemiologists would prefer a more collective way of creating a concise numerator and denominator. These researchers would like to see trauma studies account for individuals that have full representation of their bones; therefore, fracture occurrence is neither over- or under- estimated (Milner & Boldsen, 2017). This makes the segment and bone count methods useless and a more accurate count of fractures must be considered. The use of the individual mean trauma count, mean multiple injury count, and the individual count used in this study are more apt at quantifying fractures for poorly preserved remains (Judd, 2002a). Bioarchaeological remains are often incomplete; these counts serve a greater purpose in still including even those more incomplete bones. Populations that are in greater condition should see more precise bone counts and elemental counts making these methods more appropriate for a population level study (Milner & Boldsen, 2017).

Although this research accounted for only adult remains, the inclusion of younger remains would have provided a more complete picture of the whole population. Even though, the research must keep in mind that traumatic processes and remodelling in sub-adults versus adults are not comparable to one another. In fact they are two separate processes all together. If future studies were to consider all possible age groups that are represented in the sample, the research would need to employ transition analysis as its age estimation method. The use of this scoring and regression model was a significant accomplishment for this research since individuals well above 50+ years were able to be represented in the samples. Researchers have thought that many individuals during these time periods did not live to grow that old and that oldest-old individuals were rare in the bioarchaeological record (Mays et al., 2006a). This research can help disprove this inaccurate assumption. Even with smaller numbers in the younger individuals, oldest-old individuals did exist and did take part in the activities of urban and rural Danish settlements. The evidence of this is supported by the more accurate age estimations.

The research would be a perfect sample to test for histomorphological characteristics as there were different levels of healing throughout the trauma lesions. The presence or absence of such characteristics would help in deciphering more concrete timing of the trauma lesions. However, a less invasive form of this research (hopefully forthcoming in future research) would be better implemented.

It is essential that researchers adopt a biocultural theoretical approach to their analysis when closely examining the lifestyles and activities of past peoples. The use of life-course theory is essential to do this properly. Rather than only accounting for the raw observations of patterns in the skeletal remains, this theoretical approach considers the life time. As a result, researchers can ask questions as to what was going on politically, culturally, socially, and physically for these individuals to represent specific patterns. To properly apply this type of theory to trauma research in general though, timing of fractures should be investigated further.

Histomorphological methods have started to delve into the timing of fractures, but there is still a ways to go in this research. Deciphering the timing of fractures in the skeleton would go a long ways to help apply a *true* life-course approach to trauma research.

<u>**REFERENCES CITED**</u>

ADBOU. (2015). Human Osteological Methods – Age Estimation. pp. 9-11. Odense, Denmark: ADBOU.

ADBOU. (2016). ADBOU Version 2.1.046: Age Estimation Software. Odense, Denmark: ADBOU.

Agarwal, S.C., Dumitriu, M., Tomlinson, G.A., & Grynpas, M.D. (2004). Medieval trabecular bone architecture: the influence of age, sex, and lifestyle. *American Journal of Physical Anthropology*, *124*(1), 33–44. http://doi.org/10.1002/ajpa.10335

Agarwal, S. (2012). The past of sex, gender, and health: Bioarchaeology of the aging skeleton. *American Anthropologist, 114*(2), 322-335. DOI: 10.1111/j.1548-1433.2012.01428.x

Agnew, A.M., Betsinger, T.K. & Justus, H.M. (2015). Post-cranial traumatic injury patterns in two medieval Polish populations: The effects of lifestyle differences. *PLoS ONE, 10*(6), 1–19. https://doi.org/10.1371/journal.pone.0129458

Agnew, A.M. & Justus, H.M. (2014). Preliminary investigations of the bioarchaeology of medieval Giecz (XI-XII C.): Examples of trauma and stress. *Anthropological Review*, *77*(2), 189–203. https://doi.org/10.2478/anre-2014-0015

Aitken, S.A., Hutchison, J.D., McQueen, M.M., & Court-Brown, C.M. (2014). The importance of epidemiological fracture data: Injury epidemiology for the non-epidemiologist. *Bone and Joint Journal, 96-B*(7), 863–867. https://doi.org/10.1302/0301-620X.96B7

Alghnam, S., Tinkoff, G.H., & Castillo, R. (2016). Longitudinal assessment of injury recidivism among adults in the United States: findings from a population-based sample. *Injury Epidemiology, 3*(5), 1-10.

Alvrus, A. (1999). Fracture patterns among the Nubians of Semna South, Sudanese Nubia. *International Journal of Osteoarchaeology*, *9*(6), 417–429. https://doi.org/10.1002/(SICI)1099-1212(199911/12)9:6<417::AID-OA509>3.0.CO;2-4

Andelinović, S., Anterić, I., Škorić, E. & Bašić, Z. (2015). Skeleton changes induced by horse riding on medieval skeletal remains from Croatia. *International Journal of the History of Sport*, *32*(5), 708–721. https://doi.org/10.1080/09523367.2015.1038251

Andersen, T.B., Jensen, P.S., & Skovsgaard, C.V. (2016). The heavy plow and the agricultural revolution in medieval Europe. *Journal of Development Economics, 118,* 133-149.

Andrén, A. (1989). State and towns in the Middle Ages: The Scandinavian experience. *Theory and Society, 18*(5), 585-609.

Angel, J.L. (1974). Patterns of fractures from Neolithic to Modern times. *Anthropology Kozlemenyek, 18,* 9-18.

Antrop, M. (2004). Landscape change and the urbanization process in Europe. *Landscape and Urban Planning*, *67*(1–4), 9–26. https://doi.org/10.1016/S0169-2046(03)00026-4

Arcini, C. (1999). Health and disease in early Lund: Osteo-pathologic studies of 3,305 individuals buried in the cemetery area of Lund 990-1536. Dissertation: Lund University.

Aufderheide, A.C., Rodriquez-Martin, C., & Langsjoen, O. (1998). The Cambridge Encyclopedia of Human Paleopathology. London, UK: Cambridge University Press.

Augat, P., Morgan, E.F., Lujan, T.J., MacGillivray, T.J., & Cheung, W.H. (2014). Imaging techniques for the assessment of fracture repair. *Injury, 455,* S16-S22.

Baker, S.P., O'Neill, B., & Karpf, R.S. (1984). The Injury Fact Book. Lexington, Massachusetts: Lexington Books.

Barnes, E. (1994). Chapter 3: Developmental Field Defects of the Vertebral Column, Ribs, and Part I: Notochord Field Defects. *In* Barnes, E. (ed.), *Developmental Defects of the Axial Skeleton in Paleopathology,* (pp. 35–133). Niwot, Colorado: University Press of Colorado.

Basener, C.J., Mehlman, C.T. & DiPasquale, T.G. (2009). Growth disturbance after distal femoral growth plate fractures in children: A meta-analysis. *Journal of Orthopedic Trauma*, *23*(9), 663–667. https://doi.org/10.1097/BOT.0b013e3181a4f25b

Batista, A.M., Marques, L.S., Batista, A.E., Falci, S.G.M. & Ramos-Jorge, M.L. (2012). Urban-rural differences in oral and maxillofacial trauma. *Brazilian Oral Research*, *26*(2), 132–138. https://doi.org/10.1590/S1806-83242012000200008

Batsevich, V.A., Yasina, O.V. & Kobyliansky, E.D. (2013). Age-related skeletal changes in adult populations under various social and geographical conditions: An anthropo-ecological study. *Archaeology, Ethnology and Anthropology of Eurasia*, *41*(4), 146–154. https://doi.org/10.1016/j.aeae.2014.07.016

Becker, S.O., Pfaff, S., & Rubin, J. (2016). Causes and consequences of the Protestant Reformation. *Explorations in Economic History, 62,* 1-25. http://dx.doi.org/10.1016/j.eeh.2016.07.007

Benedictow, O. (2003). Chapter 9: Demographic conditions. *In* Helle, K. (ed.), *The Cambridge History of Scandinavia* (pp. 235-249). Cambridge, UK: Cambridge University Press. doi:10.1017/CHOL9780521472999.015

Bennell, K., Matheson, G., Meeuwisse, W. & Brukner, P. (1999). Risk factors for stress fractures. *Sports Medicine (Auckland, N.Z.)*, *28*(2), 91–122. https://doi.org/10.2165/00007256-199928020-00004

Bennike, P., Bro-Rasmussen, F., & Bro-Rasmussen, P. (1987). Dislocation and/or congenital malformation of the shoulder joint. Observation on a medieval skeleton from Denmark. *Anthropologischer Anzeiger*, *45*(H.2), 117-129. http://www.jstor.org/stable/29539776.

Bennike, P. (2008). Chapter 14: Trauma. *In* Pinhasi, R. & Mays, S. (eds.) *Advances in Human Paleopathology* (pp. 309-328). London, UK: John Wiley & Sons.

Betsinger, T.K. (2007). The Biological Consequences of Urbanization. Dissertation: The Ohio State University.

Billing, L. & Gedda, K.O. (1952). Roentgen examination of Bennett's fracture. *Acta Radiologica, os-38*(6), 471-476. https://doi.org/10.1177%2F028418515203800605

Blau, S. (2017). How traumatic: a review of the role of the forensic anthropologist in the examination and interpretation of skeletal trauma. *Australian Journal of Forensic Sciences*, *49*(3), 261-280. DOI: 10.1080/00450618.2016.1153715

Boccone, S., Chilleri, F., Pacciani, E., Cecchi, J.M., & Salvini, M. (2011). The skeleton of a medieval male with multiple traumatic fractures from Piazza della Signoria, Florence, Italy. *International Journal of Osteoarchaeology*, *21*(5), 602–612. https://doi.org/10.1002/oa.1167

Bocquet-Appel, J.P. & Masset, C. (1982). Farewell to paleodemography. *Journal of Human Evolution, 11*, 321–333.

Boldsen, J.L. (1997) Estimating patterns of disease and mortality in a medieval Danish village. *In* R.R. Paine (ed.) *Integrating Archaeological Demography: Multidisciplinary approaches* (pp. 229-241). Carbondale, IL: Occasional Papers of the Centre of Archaeological Investigation, Southern Illinois University, Vol. 24.

Boldsen, J.L. (1998). Body proportions in a medieval village population: Effects of early childhood episodes of ill health. *Annals of Human Biology*, *25*(4), 309-317.

Boldsen, J.L. (2000). Demografisk struktur i landsbyen Tirup. *In* Hikun 27: Arkæologi og antropologi – indsigt og udsyn. Middelalderens kirkegårde (pp. 233–244) (in Danish).

Boldsen, J.L. (2001). Epidemiological approach to the paleopathological diagnosis of leprosy. *American Journal of Physical Anthropology*, *115,* 380-387.

Boldsen, J.L. (2005). Leprosy and mortality in the medieval Danish village of Tirup. *American Journal of Physical Anthropology*, *126,* 159-168.

Boldsen, J.L. (2007) Early childhood stress and adult age mortality – a study of dental enamel hypoplasia in the medieval Danish village of Tirup. *American Journal of Physical Anthropology, 132,* 59-66.

Boldsen, J.L. (2008). Leprosy in the medieval Lauchheim community. *American Journal of Physical Anthropology, 135*(3), 301-310.

Boldsen, J.L. (2009). Leprosy in medieval Denmark osteological and epidemiological analyses. *Anthropologischer Anzeiger, 67*(4), 407-425.

Boldsen, J.L., Milner, G.R., Konigsberg, L.W., & Wood, J.W. (2002). Transition analysis: a new method for estimating age from skeletons. *In* Hoppa, R.D. & Vaupel, J.W. (eds.) *Paleodemography: Age Distributions from Skeletal Samples* (pp. 73–106). New York, NY: Cambridge University Press.

Boldsen, J.L., Milner, G. R., & Weise, S. (2015). Cranial vault trauma and selective mortality in medieval to early modern Denmark. *Proceedings of the National Academy of Sciences, 112*(6), 1721–1726. https://doi.org/10.1073/pnas.1412511112

Boldsen, J.L. & Mollerup, L. (2006). Outside St. Jorgen: leprosy in the medieval Danish city of Odense. *American Journal of Physical Anthropology, 130*(3), 344-351.

Boldsen et al. circa 2020 – resource is in preparation

Boonen, S., Cheng, X.G., Nijs, J., Nicholson, P.H.F., Verbeke, G., Lesaffre, E., Aerssens, J., & Dequeker, J. (1997). Factors associated with cortical and trabecular bone loss as quantified by peripheral computed tomography at the ultradistal radius in aging females. *Calcified Tissue International, 60*, 164–170.

Boschin, F. & Crezzini, J. (2012). Morphometrical analysis on cut marks using a 3D digital microscope. *International Journal of Osteoarchaeology*, *22*(5), 549–562. https://doi.org/10.1002/oa.1272

Boucherie, A., Jørkov, M.L.S., & Smith, M. (2017). Wounded to the bone: Digital microscopic analysis of traumas in a medieval mass grave assemblage (Sandbjerget, Denmark, AD 1300-1350). *International Journal of Paleopathology, 19*, 66-79.

Boyd, D.C. (1996) Skeletal correlates of human behavior in the Americas. *Journal of Archaeological Method and Theory*, *3*(3), 189–251. http://www.jstor.org/stable/20177348.

Brickley, M.B. (2002). An investigation of historical and archaeological evidence for age-related bone loss and osteoporosis. *International Journal of Osteoarchaeology*, *12*(5), 364–371. https://doi.org/10.1002/oa.635

Brickley, M.B. (2006). Rib fractures in the archaeological record: A useful source of sociocultural information? *International Journal of Osteoarchaeology*, *16*(1), 61–75. https://doi.org/10.1002/oa.809

Brickley, M.B. & Ives, R. (2008). Chapter 3: Background to bone biology and mineral metabolism. *In* Brickley, M.B. & Ives, R. (eds.) *The Bioarchaeology of Metabolic Bone Disease*, (pp. 21-40). Oxford, UK: Elsevier Ltd.

Brickley, M.B., Moffat, T., & Watamaniuk, L. (2014). Biocultural perspectives of vitamin D deficiency in the past. *Journal of Anthropological Archaeology*, *36*(1), 48–59. https://doi.org/10.1016/j.jaa.2014.08.002

Brickley, M. & Smith, M. (2006). Culturally determined patterns of violence. *American Anthropologist*, *108*(1), 163–177. DOI 10.1002/ajpa.10259

Buckley, H.R. & Tayles, N. (2003). Skeletal pathology in a prehistoric pacific island sample: Issue in lesion recording, quantification, and interpretation. *American Journal of Physical Anthropology, 122,* 303-324.

Budnik, A. & Liczbińska, G. (2006). Urban and rural differences in mortality and causes of death in historical Poland. *American Journal of Physical Anthropology*, *129*(2), 294–304. https://doi.org/10.1002/ajpa.20288

Buikstra, J.E. & Ubelaker, D.H. (1994) Standards for data collection from human skeletal remains. Fayetteville, Arkansas: Arkansas Archaeological Survey.

Buhr, A.J. & Cooke, A.M. (1959) Fracture Patterns. *The Lancet*, *273*, 531-536.

Butt, W.D. (1962) Fractures of the Hand. I. Description. *Canadian Medical Association Journal 86*, 731-735.

Cahn, J. (2019). Beyond Compare: Investigating the effects of compositional characteristics and method selection on the results of skeletal analyses. Dissertation. University of Toronto: Toronto, Ontario.

Capella, A., Amadasi, A., Gaudio, D., Gibelli, D., Borgonovo, S., Di Giancamillo, M., and Cattaneo, C. (2013). The application of cone-beam CT in the aging of bone calluses: a new perspective? *International Journal of Legal Medicine, 127*(6), 1139-1144.

Capella, A., de Boer, H.H., Cammilli, P., De Angelis, D., Messina, C., Sconfienza, L.M., Sardanelli, F., Sforza, C., and Cattaneo, C. (2019). Histological and radiological analysis on bone fractures: Estimation of posttraumatic survival time in skeletal trauma. *Forensic Science International, 302*, 1-9.

Case, D.T., Burnett, S.E. & Nielsen, T. (2006). Os acromiale: Population differences and their etiological significance. *HOMO- Journal of Comparative Human Biology, 57*(1), 1–18. https://doi.org/10.1016/j.jchb.2005.11.001

Cesaretti, R., Lobo, J., Bettencourt, L.M.A., Ortman, S.G., & Smith, M.E. (2016). Population-area relationship for medieval European cities. *PLoS One, 11*(10), 1-27. Doi:10.1371/journal.pone.0162678

Cho, W.I. & Chang, U.K. (2011). Comparison of MR imaging and FDG-PET/CT in the differential diagnosis of benign and malignant vertebral compression fractures. *Journal of Neurosurgery: Spine*, *14*(2), 177–83. https://doi.org/10.3171/2010.10.SPINE10175

Christensen, S.B. & Mikkelsen, J. (2006). The Danish urban system pre-1800: A survey of recent research results. *Urban History*, *33*(3), 484–510. https://doi.org/10.1017/S0963926806004081

Christensen, T. & Bennike, P. (2011). Introduction: A brief history and the current state of physical anthropology in Denmark. *In* Marquex-Grant, N & Fibiger, L. (eds.) *The Routledge Handbook of Archaeological Human Remains and Legislation: An international guide to laws and practice in the excavation and treatment of archaeological human remains*, (pp. 131-136). London, UK: Routledge.

Collier, L. & Primeau, C. (2019). A tale of two cities: A comparison of urban and rural trauma in medieval Denmark. *International Journal of Paleopathology, 24,* 175-184. https://doi.org/10.1016/j.ijpp.2018.10.002

Cooper, C. (1993). The epidemiology of fragility fractures: Is there a role for bone quality? *Calcified Tissue International*, *53*(1 Supplement), 4–7. https://doi.org/10.1007/BF01673397

Crabtree, P. (ed.) (2001). Medieval Archaeology an Encyclopedia. New York, New York: Garland Publishing, Inc.

Cunha, E., & Pinheiro, J. (2009). Chapter 21: Antemortem trauma. *In* Blau, S. & Ubelaker, D.H. (eds.) *Handbook of Forensic Anthropology and Archaeology*, (pp. 246-262). Walnut Creek, CA: Left Coast Press.

Curry, J.D. & Butler, G. (1975). The mechanical properties of bone tissue in children. *The Journal of Bone and Joint Surgery, 57-A* (6), 810-814.

d-maps.com (2007-2020). Blank map of Denmark. https://dmaps.com/carte.php?num_ car=2179&lang=en. Accessed, March 18, 2020.

D'Angelo del Campo, M., Suby, J.A., García-Laborde, P. & Guichón, R.A. (2017). Spondylolysis in the past: A case study of hunter-gatherers from Southern Patagonia. *International Journal of Paleopathology*, *19*(July), 1–17. https://doi.org/10.1016/j.ijpp.2017.07.001

De Boer, H., Van der Merwe, A., Hammer, S., Steyn, M., and Maat, G. (2015). Assessing post-traumatic time interval in human dry bone. *International Journal of Osteoarchaeology*, *25*(1), 98-109.

De Vore, W.E., Jacobi, K.P., & Dye, D.H. (2018). Rethinking Massacres: A bioarchaeological and forensic investigation of Prehistoric multiple burials in the Tennessee River Valley. *In* Anderson, C.P. & Martin, D.L., *Massacres: Bioarchaeology and Forensic Anthropology Approaches* (pp. 12-22). Gainesville, Florida: University of Florida Press.

DeWitte, S.N. (2006). The paleodemography of the Black Death 1347-1351. Dissertation. Pennsylvania State University.

DeWitte, S.N. (2014). Differential survival among individuals with active and healed periosteal new bone formation. *International Journal of Paleopathology, 7,* 38-44. http://dx.doi.org/10.1016/j.ijpp.2014.06.001

DeWitte, S. & Hughes-Morey, G. (2012). Stature and frailty during the Black Death: The effect of stature on risks of epidemic mortality in London A.D. 1348-1350. *Journal of Archaeological Science*, *39*, 1412-1419.

DeWitte, S. & Stojanowski, C.M. (2015). The osteological paradox 20 years later: Past perspectives, future directions. *Journal of Archaeological Research, 23*(4), 397-450. DOI:10.1007/s10814-015-9084-1

Djuric, M.P., Roberts, C.A., Rakocevic, Z.B., Djonic, D.D., & Lesic, A.R. (2006). Fractures in late medieval skeletal populations from Serbia. *Endocrinology*, *76*(December), 989–993. https://doi.org/10.1002/ajpa

Djuric, M., Djonic, D., Milovanovic, P., Nikolic, S., Marshall, R., Marinkovic, J. & Hahn, M. (2010). Region-specific sex-dependent pattern of age-related changes of proximal femoral cancellous bone and its implications on differential bone fragility. *Calcified Tissue International*, *86*(3), 192–201. https://doi.org/10.1007/s00223-009-9325-8

Domett, K.M. & Tayles, N. (2006). Adult fracture patterns in prehistoric Thailand: A biocultural interpretation. *International Journal of Osteoarchaeology*, *16*(3), 185–199. https://doi.org/10.1002/oa.815

Donaldson, L., Reckless, I., Scholes, S., Mindell, J., & Shelton, N. (2008). The epidemiology of fractures in England. *Journal of Epidemiological Community Health, 62*, 174–180. http://doi.org/10.1136/jech.2006.056622

Duday, H. & Guillon, M. (2006). Chapter 6: Understanding the circumstances of decomposition when the body is skeletonized. *In* Schmitt, A., Cunha, E., & Pinheiro, J. (eds.) *Forensic Anthropology and Medicine: Complementary Sciences from Recovery to Cause of Death*, (pp. 117-157). Totowa, New Jersey: Humana Press Inc.

Ekenman, I., Eriksson, S.A.V., & Lindgren, J.U. (1995). Bone density in medieval skeletons. *Calcified Tissue International*, *56*(5), 355–358. https://doi.org/10.1007/BF00301601

Elder, G.H. Jr. (1994). Time, human agency, and social change: Perspectives on the life course. *Social Psychology Quarterly*, *57*(1), 4–15.

Farr, J.N. & Khosla, S. (2015). Skeletal changes through the lifespan - From growth to senescence. *Nature Reviews Endocrinology*, *11*(9), 513–521. https://doi.org/10.1038/nrendo.2015.89

Fausto-Sterling, A. (2005). The bare bones of sex: Part 1- sex and gender. *Journal of Females in Culture and Society, 30*(2), 1491-1527. DOI 132.174.250.038

Fibiger, L., Ahlström, T., Bennike, P. & Schulting, R.J. (2013). Patterns of violence-related skull trauma in Neolithic southern Scandinavia. *American Journal of Physical Anthropology*, *150*(2), 190–202. https://doi.org/10.1002/ajpa.22192

Fleming-Farrell, D., Michailidis, K., Karantanas, A., Roberts, N. & Kranioti, E.F. (2013). Virtual assessment of perimortem and postmortem blunt force cranial trauma. *Forensic Science International*, *229*(1–3), 162.e1-162.e6. https://doi.org/10.1016/j.forsciint.2013.03.032

Friedl, L. (2011). Confounding factors in interpreting fracture frequencies in skeletal populations. *AnthroWebzin, 7*(2), 91-96.

Fulminante, F. (2016). Infant feeding practices in Europe and the Mediterranean from prehistory to the Middle Ages: A comparison between historical sources and bioarchaeology. *Childhood in the Past, 8*(1), 24-47.

Gaither, C.M. & Murphy, M.S. (2012). Consequences of conquest? The analysis and interpretation of subadult trauma at Puruchuco-Huaquerones, Peru. *Journal of Archaeological Science, 39*(2), 467–478. https://doi.org/10.1016/j.jas.2011.10.002

Galloway, A. (1999). Broken bones: anthropological analysis of blunt force trauma. Illinois: Charles C Thomas Publisher.

Gilbride, S.J., Wild, C., Wilson, D R., Svenson, L.W. & Spady, D.W. (2006). Socio-economic status and types of childhood injury in Alberta: a population based study. *BMC Pediatrics*, *6*(30), 1-10. https://doi.org/10.1186/1471-2431-6-30

Gilchrist, R. (2000). Archaeological biographies: Realizing human lifecycles, -courses and -histories. *World Archaeology*, *31*(3), 325-328.

Gilchrist, R. (2004). Archaeology and the life course: A time and age for gender. *In* Meskell, L. & Preucel, R. (eds.) *A Companion to Social Archaeology* (pp. 142-160). Oxford, UK: Blackwell.

Gilchrist, R. (2012). Medieval Life: Archaeology and the Life Course. Woodbridge, Suffolk, UK: Boydell Press.

Gilmour, R.J., Gowland, R., Roberts, C., Bernert, Z., Kiss, K.K. & Lassányi, G. (2015). Gendered differences in accidental trauma to upper and lower limb bones at Aquincum, Roman Hungary. *International Journal of Paleopathology*, *11*, 75–91. https://doi.org/10.1016/j.ijpp.2015.08.004

Glencross, B. (2002). An approach to the paleoepidemiology of bone fractures: methods and techniques applied to long bones from the Indian Knoll skeletal sample, Kentucky. Dissertation. University of Toronto.

Glencross, B.A. (2011). Chapter 14: Skeletal injury across the life course: Towards understanding social agency. *In* Agarwal, S.C. & Glencross, B.A. (eds.), *Social Bioarchaeology* (pp. 390-409). Malden, MA: Blackwell Publishing Ltd.

Glencross, B. & Agarwal, S.C. (2011). An investigation of cortical bone loss and fracture patterns in the Neolithic community of Catalhoyuk, Turkey using metacarpal radiogrammetry. *Journal of Archaeological Science*, *38*(3), 513–521. http://doi.org/10.1016/j.jas.2010.10.004

Glencross, B. & Sawchuk, L. (2003). The person-years construct: Ageing and the prevalence of health-related phenomena from skeletal samples. *International Journal of Osteoarchaeology*, *13*(6), 369–374. https://doi.org/10.1002/oa.698

Glencross, B. & Stuart-Macadam, P. (2000). Childhood trauma in the archaeological record. *International Journal of Osteoarchaeology*, *10*(3), 198–209. https://doi.org/10.1002/1099-1212(200005/06)10:3<198::AID-OA522>3.0.CO;2-B

Gorecki, P. (1983). Viator to Ascriptitius: Rural economy, lordship, and the origins of serfdom in medieval Poland. *Slavic Review, 42*(1), 14–35.

Gowland, R.L. (2016). Elder abuse: Evaluating the potentials and problems of diagnosis in the archaeological record. *International Journal of Osteoarchaeology, 25,* 514-523. DOI: 10.1002/oa.2442

Graham-Campbell, J. (2007). Introduction. *In* Graham-Campbell, J. & Magdalena, V. (eds.), *The Archaeology of Medieval Europe Vol. 1*: *Eighth to Twelfth Centuries AD*, (pp. 13–19). Aarhus, Denmark: Aarhus University Press.

Grauer, A.L. & Roberts, C.A. (1996). Paleoepidemiology, healing, and possible treatment of trauma in the medieval cemetery population of St. Helen-on-the-Walls, York, England. *American Journal of Physical Anthropology, 100,* 531-544. https://doi.org/10.1002/(SICI)1096-8644(199608)100:4<531::AID-AJPA7>3.0.CO;2-T

Grogan, D.P., Carey, T.P., Leffers, D., & Ogden, J.A. (1990). Avulsion fractures of the patella. *Journal of Pediatric Orthopedics*, *10*, 721-730.

Hamblen, D.L. & Simpson, H. (2007). Chapter 2: Pathology of fractures and fracture healing. *In* Hamblen, D.L. & Simpson, H. (eds.), *Adam's Outline of Fractures (12th Edition).* Edinburgh and London, UK: Churchill Livingstone.

Hansen, J., Petersen, H.C., Frei, K.M., Courtaud, P., Tillier, A., Fischer, A., & Allentoft, M.E. (2017). The Maglemosian skeleton from Koelbjerg, Denmark revisited: identifying sex and provenance. *Danish Journal of Archaeology, 6*(1), 50-66.

Harrod, R.P. & Martin, D.L. (2014). Bioarchaeology of Climate Change and Violence: Ethical Considerations. New York, NY: Springer.

Henderson, J. (1987). Factors Determining the State of Preservation of Human Remains. *In* Boddington, A., Garland A. N. & Janaway, R. C. (eds.) *Death Decay and Reconstruction: Approaches to Archaeology and Forensic Science* (pp. 43-54). Manchester University Press, Manchester.

Hofmann, M.I., Papageorgopoulou, C., Boni, T. & Ruhli, F.J. (2010). Two case examples of pelvic fractures in medieval populations from central Europe. *Journal of Anthropological Science, 88,* 179–188. http://www.ncbi.nlm.nih.gov/pubmed/20834057

Hybel, N. & Poulsen, B. (2007). The Danish Resources c. 1000-1550: Growth and Recession. The Netherlands: Hotei Publishing, IDC Publishers, Martinus Nijhoff Publishers and VSP.

IBM Corp. (2013). IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.

Ives, R. & Brickley, M. (2005). Metacarpal radiogrammetry: a useful indicator of bone loss throughout the skeleton. *Journal of Archaeological Science, 32*(10), 1552-1559.

Ives, R., Mant, M., de la Cova, C., & Brickley, M. (2017). A large-scale palaeopathological study of hip fractures from post-medieval urban England. *International Journal of Osteoarchaeology, 27*(2), 261–275. https://doi.org/10.1002/oa.2536

Jantzen, C., Kieffer-Olsen, J., & Madsen, P.K. (1994). De sma brodres hus i Ribe. *In* Gelius W, Guldberg M, Stoumann I. (eds). *Mark og Montre Årbog for kunst- og kulturhistorie. Vol. 30.* (pp. 26–36) Ribe: Ribe Amts Museumsråd (in Danish).

Johnson, E. (1985). Current developments in bone technology. *Advances in Archaeological Method and Theory, 8*, 157–235. http://www.jstor.org/stable/20170189

Jørkov, M.L.S., Jørgensen, L. & Lynnerup, N. (2010). Uniform diet in a diverse society. Revealing new dietary evidence of the Danish Roman Iron Age based on stable isotope analysis. *American Journal of Physical Anthropology, 143*(4), 523–533. https://doi.org/10.1002/ajpa.21346

Judd, M.A. (2002a). Comparison of long bone trauma recording methods. *Journal of Archaeological Science, 29*(11), 1255–1265. https://doi.org/10.1006/jasc.2001.0763

Judd, M.A. (2002b). Ancient injury recidivism: An example from the Kerma period of ancient Nubia. *International Journal of Osteoarchaeology*, *12,* 89-116. https://doi.org/10.1002/oa.587

Judd, M.A. (2004). Trauma in the city of Kerma: Ancient versus modern injury patterns. *International Journal of Osteoarchaeology*, *14*(1), 34–51. https://doi.org/10.1002/oa.711

Judd, M. A. (2008). The parry problem. *Journal of Archaeological Science*, *35,* 1658-1666. http://doi.org/10.1016/j.jas.2007.11.005

Judd, M.A. & Redfern, R. (2012). Chapter 20: Trauma. *In* Grauer, A.L. (ed.) *A Companion to Paleopathology.* (pp. 359-379). Chichester: Blackwell Publishing Ltd.

Judd, M.A. & Roberts, C.A. (1998). Fracture patterns at the medieval leper hospital in Chichester. *American Journal of Physical Anthropology*, *105*(1), 43–55. https://doi.org/10.1002/(SICI)1096-8644(199801)105:1<43::AID-AJPA5>3.0.CO;2-E

Judd, M. A., & Roberts, C. A. (1999). Fracture trauma in a medieval British farming village. *American Journal of Physical Anthropology*, *109*, 229-243.

Junno, J.A., Niskanen, M., Nieminen, M.T., Maijanen, H., Niinimaki, J., Bloigu, R. & Tuukkanen, J. (2009). Temporal trends in vertebral size and shape from medieval to modern-day. *PLoS ONE*, *4*(3), 4–8. https://doi.org/10.1371/journal.pone.0004836

Jurmain, R. (1999). Stories from the Skeleton: Behavioral Reconstruction in Human Osteology. Amsterdam, Netherlands: Gordon and Breach Publishers.

Karim, L. & Vashishth, D. (2013) Chapter 4: Bone microdamage and its contributions to fracture. *In* Silva, M.J. (ed.) *Skeletal Aging and Osteoporosis: Biomechanics and Mechanobiology* (pp. 87-104). Heidelberg, Germany: Springer-Verlag.

Ki, H.C., Shin, E-K., Woo, E.J., Lee, E., Hong, J.H., & Shin, D.H. (2018). Horse-riding accidents and injuries in historical records of Joseon Dynasty, Korea. *International Journal of Paleopathology*, *20*, 20-25. doi:https://doi.org/10.1016/j.ijpp.2017.12.001

Kieffer-Olsen, J., Boldsen, J.L., & Pentz, P. (1986). A newly found church at Bygholm. *Vejle Amts Årbog 1986,* 24-51 (in Danish).

Kieffer-Olsen, J. (1993). Grave and burial custom in medieval Denmark - 8 cemetery excavations Dissertation: Department of Medieval Archaeology*:* Moesgaard, Århus (in Danish).

Knüsel, C.J. (2000). Activity-related changes in casualties from the medieval battle of Towton, AD 1461. *In* Fiorato, V., Boylston, A. & Knüsel, C.J. (eds.) *Blood Red Roses: The Archeology of a Mass Grave from Towton, AD 1461*. (pp. 103-118). Oxford, UK: Oxbow Books.

Knüsel, C.J. (2010). Bioarchaeology: a synthetic approach. *Bulletins et memoires de la Societe d'anthropologie de Paris, 22*(1-2), 62-73.

Konigsberg, L.W. & Hens, S.M. (1998). Use of ordinal categorical variables in skeletal assessment of sex from the cranium. *American Journal of Physical Anthropology, 107*: 97–112.

Krakowka, K. (2017). Patterns and prevalence of violence-related skull trauma in medieval London. *American Journal of Physical Anthropology*, *164*(3), 488–504. https://doi.org/10.1002/ajpa.23288

Kristiansen, T., Lossius, H. M., Rehn, M., Kristensen, P., Gravseth, H. M., Røislien, J., & Søreide, K. (2014). Epidemiology of trauma: A population-based study of geographical risk factors for injury deaths in the working-age population of Norway. *Injury*, *45*(1), 23–30. http://doi.org/10.1016/j.injury.2013.07.007

Kuckelman, K.A., Lightfoot, R.R. & Martin, D.L. (2002). The bioarchaeology and taphonomy of violence at Castle Rock and Sand Canyon Pueblos, Southwestern Colorado. *American Antiquity, 67*(3), 486–513. https://doi.org/10.2307/1593823

Lambert, P.M. (2002). The archaeology of war: A North American perspective. *Journal of Archaeological Research*, *10*(3), 207–242. https://doi.org/10.1023/A:1016063710831

Lang, T. (2011). Review Article: The bone-muscle relationship in men and females. *Journal of Osteoporosis*, *2011*, Article ID 702735, 1-4. Doi:10.4061/2011/702735

Larsen, C.S. (1997). Chapter 4: Injury and violent death. *In* Larsen, C.S. (ed.) *Bioarchaeology: Interpreting behaviors from the human skeleton*, (pp. 109-160). Cambridge, UK: Cambridge University Press.

Larsen, C.S. (2002). Bioarchaeology: The lives and lifestyles of past people. *Journal of Archaeological Research*, *10*(2), 119–166. https://doi.org/10.1023/A:1015267705803

Lascombes, P. & Metaizeau, J.D. (2010). Femoral fracture. *In* Lascombes, P. (ed.) *Flexible Intramedullary Nailing in Children* (pp. 197-230). Berlin, Germany: Springer.

Lauring, P. (1960). A History of Denmark. (Translated by David Hohnen). Copenhagen, Denmark: Host & Sons Forlag and Dorset Press.

Le, V.H. & Lebwohl, N.H. (2015). Spondylolisthesis: A historical perspective on etiology, diagnosis, and treatment. *In* Wollowick, A.L. & Sarwahi, V. (eds.) *Spondylolisthesis: Diagnosis, Non-Surgical Management, and Surgical Techniques*, (pp. 3-15). Boston, MA: Springer. https://doi.org/10.1007/978-1-4899-7575-1

Lenz, K. & Hybel, N. (2016). The Black Death. *Scandinavian Journal of History*, *41*(1), 54-70. DOI: 10.1080/03468722.2015.1110533

Lessa, A. (2011). Daily risks: A biocultural approach to acute trauma in pre-colonial coastal populations from Brazil. *International Journal of Osteoarchaeology, 21*(2), 159–172. https://doi.org/10.1002/oa.1118

Lewiecki, E.M. (2006). Prevention of osteoporotic fractures. *Aging Health, 2.4,* 649+.

Lewis, M.E. (2002). Impact of industrialization: Comparative study of child health in four sites from medieval and post-medieval England (A.D. 850-1859). *American Journal of Physical Anthropology, 119,* 211-223.

Lewis, M. E. (2010). Life and death in a civitas capital: Metabolic disease and trauma in the children from late roman Dorchester, Dorset. *American Journal of Physical Anthropology, 142*(3), 405–416. http://doi.org/10.1002/ajpa.21239

Lewis, M. E. (2013). Children of the Golden Minster: St. Oswald's Priory and the impact of industrialization on child health. *Journal of Anthropology, 2013,* 1–11. https://doi.org/10.1155/2013/959472

Lewis, M.E. (2016). Work and the adolescent in medieval England A.D. 900–1550: The osteological evidence. *Medieval Archaeology*, *60*(1), 138–171. https://doi.org/10.1080/00766097.2016.1147787

Lovejoy, C.O. & Heiple, K.G. (1981). The analysis of fractures in skeletal populations with an example from the Libben site, Ottowa County, Ohio. *American Journal of Physical Anthropology, 55*, 529-541.

Lovell, N. (1997). Trauma analysis in paleopathology. *American Journal of Physical Anthropology*, *40*, 139–170. https://doi.org/10.1002/(SICI)1096-8644(1997)25+<139::AID-AJPA6>3.0.CO;2-#

Lynnerup, N. (1998). The Greenland Norse: a biological-anthropological study. Greenland & Coppenhagen: Meddelelser om Grønland, Man & Society, and The Commission for Scientific Research in Greenland.

Lynnerup, N. & Søren Nørdby, (2004). The Greenland Norse: bones, graves, computers, and DNA. *Polar Record*, *40*(213), 107-111. DOI: 10.1017/S0032247402002875.

Mant, M. (2019). Time after time: individuals with multiple fractures and injury recidivists in long eighteenth-century (c. 1666-1837) Londong. *International Journal of Paleopathology, 24,* 7-18.

Marklein, K.E., Leahy, R.E., & Crews, D.E. (2016). In sickness and in death: Assessing frailty in human skeletal remains. *American Journal of Physical Anthropology, 161*(2), 208-225.

Marieb, E.N. & Hoehn, K. (2006). Human Anatomy and Physiology, 8th Edition. Pearson Education Publishing: New York, New York.

Marsell, R. & Einhorn, T.A. (2011). The biology of fracture healing. *Injury, 42,* 551-555.

Martin, D.L. (1998). Chapter 3: Violence against females in the La Plata River Valley (A.D. 1000-1300). *In* Martin, D.L. & Frayer, D.W. (eds.) *Troubled Times: Violence and Warfare in the Past; War and Society Volume 3* (pp. 45-75). Amsterdam, Netherlands: Gordon & Breach Publishers.

Martin, D.L., & Harrod, R.P. (2015). Bioarchaeological contributions to the study of violence. *American Journal of Physical Anthropology*, *156*, 116–145. https://doi.org/10.1002/ajpa.22662

Materialise NV (2015). MIMICS 3D Programming Version 19.0. Belgium.

Mays, S.A. (1998). Osteoporosis in earlier human populations. *Journal of Clinical Densitometry, 2*(1), 71-78. doi: 0169-4194/99/2:71-78/$12.00

Mays, S.A. (2006). Spondylolysis, spondylolisthesis, and lumbo-sacral morphology in a medieval English skeletal population. *American Journal of Physical Anthropology, 131,* 352-362. DOI 10.1002/ajpa.20447

Mays, S. (2008). Human remains in marine archaeology. *Environmental Archaeology*, *13*(2), 123–133. https://doi.org/10.1179/174963108X343245

Mays, S. (2010). Chapter 9: Traces of injury on the skeleton. *In* Mays, S. (ed.), *The Archaeology of Human Bones (2nd Edition),* (pp. 236-264). Abingdon, Oxon, UK: Routledge.

Mays, S., Brickley, M., & Ives, R. (2006a). Skeletal manifestation of rickets in infants and young children in a historic population from England. *American Journal of Physical Anthropology*, *129*(3), 362–374. https://doi.org/10.1002/ajpa.20292

Mays, S., Turner-Walker, G., & Syversen, U. (2006b). Osteoporosis in a population from medieval Norway. *American Journal of Physical Anthropology*, *131,* 343-351.

Mays, S., Ives, R., & Brickley, M. (2009). The effects of socioeconomic status on endochondral and appositional bone growth, and acquisition of cortical bone in children from 19th century Birmingham, England. *American Journal of Physical Anthropology*, *140*(3), 410–416. https://doi.org/10.1002/ajpa.21076

McEwan, J.M., Mays, S., & Blake, G.M. (2004). Measurements of bone mineral density of the radius in a medieval population. *Calcified Tissue International*, *74*(2), 157–161. https://doi.org/10.1007/s00223-002-1047-0

McGee, A., Qureshi, A., & Porter, K. (2004). Review of the biomechanics and patterns of limb fractures. *Trauma*, *6*(1), 29–40. https://doi.org/10.1191/1460408604ta295oa

Meindl, R.S. & Lovejoy, C.O. (1985). Ectocranial suture closure: A revised method for the determination of skeletal age at death based on the lateral-anterior sutures. *American Journal of Physical Anthropology, 68*(1), 57-66.

Melbye, J. & Fairgrieve, S.I. (1994). A massacre and possible cannibalism in the Canadian arctic: New evidence from the Saunaktuk site (NgTn-1). *Artic Anthropology, 31*(2), 57-77. http://www.jstor.org/stable/40316364

Messina, A.D., Carotenuto, G., Micciche, R. & Sineo, L. (2013). Fatal cranial injury in an individual from Messina (Sicily) during the times of the Roman Empire. *Journal of Forensic and Legal Medicine*, *20*(8), 1018–1023. https://doi.org/10.1016/j.jflm.2013.09.023

Micozzi, M.S. (1991). Postmortem Change in Human and Animal Remains: A Systemic Approach. Indiana, US: C.C. Thomas.

Milner, G.R., Wood, J.W., & Boldsen, J.L. (2000). Chapter 18: Paleodemography: Problems, progress, and potential. *In* Saunders, S.R. & Katzenburg, M. (eds.). *Biological Anthropology of the Human Skeleton*, (pp. 467-497). New York, New York: Wiley & Sons.

Milner, G.R. & Boldsen, J.L. (2012). Transition analysis: A validation study with known-age modern American skeletons. *American Journal of Physical Anthropology*, *148*(1), 98–110. https://doi.org/10.1002/ajpa.22047

Milner, G.R. & Boldsen, J.L. (2016). Transition analysis age estimation: Skeletal scoring manual. Fordisc Version 1.02. Odense, Denmark: ADBOU.

Milner, G.R. & Boldsen, J.L. (2017). Life not death: Epidemiology from skeletons. *International Journal of Paleopathology, 17*, 26–39. https://doi.org/10.1016/j.ijpp.2017.03.007

Milner, G.R., Boldsen, J.L., Weise, S., Lauritsen, J.M., & Freund, U.H. (2015). Sex-related risks of trauma in medieval to early modern Denmark, and its relationship to change in interpersonal violence over time. *International Journal of Paleopathology*, *9*, 59–68. https://doi.org/10.1016/j.ijpp.2015.02.002

Mitchell, P.D. & Redfern, R.C. (2010). Brief communication: Developmental dysplasia of the hip in medieval London. *American Journal of Physical Anthropology, 144*(3), 479-484. https://doi.org/10.1002/ajpa.21448

Møller-Christensen, V. (1953). Location and Excavation of the First Danish Leper Graveyard from the Middle Ages – St. Jørgen's Farm, Naestved. *Bulletin of the History of Medicine 27*, 112.

Mollerup, L. (1996). Nordby kirkegard: Skeletfundene fra Viby Tommerhandel: FHM 3970. ADBOU: Syddansk Universitet (in Danish).

Mollerup, L. & Boldsen, J. (2010). The temporal distribution of syphilis and syphilis like lesions in the Black Friars in Odense, Denmark: A likelihood based approach to cemetery analysis. *In* ADBOU 1992-2009: Forskningsresultater. Odense, Denmark: University of Southern Denmark.

Moraitis, K., & Spiliopoulou, C. (2006). Identification and differential diagnosis of perimortem blunt force trauma in tubular long bones. *Forensic Science, Medicine, and Pathology, 2*(4): 221-229. DOI: 10.1385/Forensic Sci. Med. Pathol.:2:4:221.

Müller, M., Nazarian, S., Koch, P., & Schatzker, J. (1990). The Comprehensive Classification of Fractures of Long Bones. New York, New York: Springer-Verlag.

Naqvi, A., Raynor, E., and Freemont, A.J. (2019). Histological aging of fractures in infants: a practical algorithm for assessing infants suspected of accidental or non-accidental injury. *Histopathology, 75*(1), 74-80.

Nelson, D.A. & Villa, M.L. (2003). Ethnic differences in bone mass and bone architecture. *In* Agarwal, S. & Stout, S.D. (eds.), *Bone Loss and Osteoporosis: An Anthropological Perspective*, (p. 47-62). New York, NY: Plenum Press.

Neri, R. & Lancellotti, L. (2004). Fractures of the lower limbs and their secondary skeletal adaptions: A 20th century example of pre-modern healing. *International Journal of Osteoarchaeology*, *14*(1), 60–66. https://doi.org/10.1002/oa.686

Nielson, J. (2011). Does human sexual dimorphism influence fracture frequency, types and distribution? *Anthropological Review*, *74*(1), 13–23. https://doi.org/10.2478/v10044-010-0002-3

Old, J.L. & Calvert, M. (2004). Vertebral compression fractures in the elderly. *American Family Physician, 69*, 111-116.

Olivier, G. & Bressac, F. (1980). Chapter 7: The anthropology of a capital city and considerations of urbanization. *In* Schwidetzky, I., Chiarelli, B., & Necrasov, O. (eds), *Physical Anthropology of European Populations*, (pp. 129-144). Paris, France: Mouton Publishers.

Paine, R.R., Mancinelli, D., Ruggieri, M., & Coppa, A. (2007). Cranial trauma in Iron Age Samnite agriculturalists, Alfedena, Italy: Implications for biocultural and economic stress. *American Journal of Physical Anthropology, 132*, 48-58.

Parfitt, M. (2003). New concepts of bone remodeling: A unified spatial and temporal model with physiologic and pathophysiologic implications. *In* S. Agarwal & S.D. Stout (eds.), *Bone Loss and Osteoporosis: An Anthropological Perspective*, (p. 1-24). New York, NY: Plenum Press.

Pederson, D.D. (2010). Antropologisk rapport: HOM 1649, Ole Worms Gade. ADBOU, Syddansk Universitet (in Danish).

Peek-Asa, C., Zwerling, C., & Stallones, L. (2004). Acute traumatic injuries in rural populations. *American Journal of Public Health*, *94*(10), 1689–1693. http://doi.org/10.2105/AJPH.94.10.1689

Perry, M. (2007). Is bioarchaeology a handmaiden to history? Developing a historical bioarchaeology. *Journal of Anthropological Archaeology*, *26*(3), 486-515.

Petersen, H.C., Boldsen, J.L., Paine, R.R., & Storey, G.R. (2006). Chapter 5: Population relationships in and around medieval Danish towns. *In* Storey, G.R. (ed.) *Urbanism in the Preindustrial World*, (pp. 110-120). Tuscaloosa, AL: University of Alabama Press.

Peterson, L. (1991). Pedological research in Denmark. *In* Møberg, J.P. & Madsen, H.B. (eds.) *Soil Research in Denmark* (pp. 9-49). København C. A. Reitzels forlag Rosendahls bogtrykkeri Esbjerg.

Phenice, T.W. (1969). A newly developed visual method of sexing the os pubis. *American Journal of Physical Anthropology, 30,* 297-302.

Price, T.D. & Petersen, E.B. (1987). A Mesolithic camp in Denmark. *Scientific American, 245*(2), 112–121. http://doi.org/10.1038/scientificamerican0881-120

Redin, L. (1976). *Lagmanshejdan*. Dissertation. Lund: Lunds Universitet (in Danish).

Reilly, D.T. & Burstein, A.H. (1974). The mechanical properties of cortical bone. *The Journal of Bone & Joint Surgery, 56,* 1001–1022.

Reiner, D.S., Pastena, J.A., Swan, K.G., Lindenthal, J.J., & Tischler, C.D. (1990). Trauma recidivism. *The American Surgeon, 56*(9), 556-560.

Rhodes, J.A. & Knüsel, C.J. (2005). Activity-related skeletal change in medieval humeri: Cross-sectional and architectural alterations. *American Journal of Physical Anthropology*, *128*(3), 536–546. https://doi.org/10.1002/ajpa.20147

Riggs, B. L. (1991). Overview of osteoporosis. *Western Journal of Medicine, 154,* 63-77.

Riggs, B.L., Melton, L.J., Robb, R.A., Camp, J.J., Atkinson, E J., Peterson, J.M., Khosla, S. (2004). Population-based study of age and sex differences in bone volumetric density, size, geometry, and structure at different skeletal sites. *Journal of Bone and Mineral Research, 19*(12), 1945–1954. https://doi.org/10.1359/JBMR.040916

Robb, J. (1994). Chapter 5: Violence and gender in early Italy. *In* Martin, D.L. & Frayer, D.W. (eds.) *Troubled Times: Violence and Warfare in the Past*, (pp.111-144). Amsterdam: Gordon & Breach. doi:10.1006/jasc.2001.0763

Roberts, C. (2000). Chapter 21: Trauma in biocultural perspective: Past, present and future work in Britain. *In* Cox, M. & Mays, S. (eds.) *Human Osteology in Archaeology and Forensic Science*, (pp. 337-356). London, UK: Greenwich Medical Media Ltd. http://dro.dur.ac.uk/7002/1/7002.pdf

Roberts, C. & Manchester, K. (2007). The Archaeology of Disease (Third Edition). Ithaca, NY: Cornell University Press.

Rogers, A., Horst, M., Rittenhouse, K., To, T., Gibson, S., Schwab, C.W., & Rogers, F. (2014). Urban versus rural trauma recidivism: is there a difference? *European Journal of Trauma Emergency Surgery, 40*, 701-706.

Ryan, T.M. & Shaw, C.N. (2015). Gracility of the modern *Homo sapiens* skeleton is the result of decreased biomechanical loading. *Proceedings of the National Academy of Sciences*, *112*(2), 372–377. https://doi.org/10.1073/pnas.1418646112

Sahai, H. & Khurshid, A. (1996). Formulas and tables for the determination of sample sizes and power in clinical trials for testing differences in proportions for the matched pair design: a review. *Fundamentals of Clinical Pharmacology, 10*, 554-563.

Saul, F.P. & Saul, J.M. (1989). Chapter 15: Osteobiography: A Maya example. *In* Iscan, M.Y. & Kennedy, K.A.R. (eds.) *Reconstruction of Life from the Skeleton* (pp. 287-302). New York, NY: Wiley-Liss, Inc.

Schoenau, E. & Fricke, O. (2008). Mechanical influences on bone development in children. *European Journal of Endocrinology*, *159*(Supplement 1), 27–31. https://doi.org/10.1530/EJE-08-0312

Scott, R.M. & Buckley, H.R. (2010). Biocultural interpretations of trauma in two prehistoric Pacific Island populations from Papua New Guinea and the Solomon Islands. *American Journal of Physical Anthropology*, *142*(4), 509–518. https://doi.org/10.1002/ajpa.21250

Scott, A.B. & Hoppa, R.D. (2018). The ice age with little effect? Exploring stress in the Danish Black Friars cemetery before and after the turn of the 14th century. *International Journal of Paleopathology*, Online-December 27th. https://doi.org/10.1016/j.ijpp.2018.12.004

Shattuck, R.E. (2010). Perimortem fracture patterns in South-Central Texas: A preliminary investigation into the perimortem interval. Master's Thesis: Texas State University-San Marcos.

Silva, M.J. & Jepsen, K.J. (2013). Chapter 1: Age-related changes in whole-bone structure and strength. *In* Silva, M.J. (ed.) *Skeletal Aging and Osteoporosis: Biomechanics and Mechanobiology*, (pp.1-30). Verlag, Berlin, & Heidelberg, Germany: Springer.

Singer, B.R., McLauchlan, G.R., Robinson, C.M., & Christie, J. (1998). Epidemiology of fractures in 15,000 adults: The influence of age and gender. *The Journal of Bone and Joint Surgery, 80-B*, 243-248.

Skovgaard-Petersen, I. (2003). Chapter 8(b): The making of the Danish kingdom. *In* Helle, K. (ed.), *The Cambridge History of Scandinavia* (pp. 235-249). Cambridge: Cambridge University Press. doi:10.1017/CHOL9780521472999.015

Šlaus, M., Novak, M., Bedić, Ž. & Strinović, D. (2012). Bone fractures as indicators of intentional violence in the eastern Adriatic from the antique to the late medieval period (2nd-16th century AD). *American Journal of Physical Anthropology, 149*(1), 26–38. https://doi.org/10.1002/ajpa.22083

Smith, G.E. & Wood-Jones, F. (1910). The Archaeological Survey of Nubia. *Report for 1907-1908. Volume 2: Report on the Human Remains*. Cairo, Egypt: National Printing Department.

Smith, O.C., Pope, E.J., & Symes, S.A. (2003). Chapter 15: Look until you see: Identification of trauma in skeletal material. *In* Steadman, D.W. (ed.) *Hard evidence: Case studies in forensic anthropology,* (pp. 138–154). Upper Saddle River: Pearson Education Inc.

Sofaer, J. (2006). The Body as Material Culture: A Theoretical Osteoarchaeology. Cambridge, UK: Cambridge University Press.

Sorg, M.H. & Haglund, W.D. (2002). Chapter 1: Advancing forensic taphonomy: Purpose, theory and practice. *In* Haglund, W.D. & Sorg, M.H., *Advances in Forensic Taphonomy: Method, Theory, and Archaeological Perspectives,* (pp. 3-30). Boca Raton, Florida: CRC Press.

Spencer, S.D. (2012). Detecting violence in the archaeological record: Clarifying the timing of trauma and manner of death in cases of cranial blunt force trauma among pre-Columbian Amerindians of West-Central Illinois. *International Journal of Paleopathology, 2,* 112-122.

Standen, V.G. & Arriaza, B.T. (2000). Trauma in the preceramic coastal populations of northern Chile: Violence or occupational hazards? *American Journal of Physical Anthropology, 112*(2), 239–249. https://doi.org/10.1002/(SICI)1096-8644(2000)112:2<239::AID-AJPA9>3.0.CO;2-3

Steadman, D.W. (2008). Warfare related trauma at Orendorf, a middle Mississippian site in west-central Illinois. *American Journal of Physical Anthropology, 136*(1), 51–64. https://doi.org/10.1002/ajpa.20778

Steckel, R.H. (2005). Health and nutrition in Pre-Columbian America: The skeletal evidence. *Journal of Interdisciplinary History, 36*(1), 1-32.

Stenton, D.R., Keenleyside, A.B & Park, R.W. (2015). The ”Boat Place” burial: New skeletal evidence from the 1845 Franklin expedition. *Arctic*, *68*(1), 32–44. https://doi.org/10.14430/arctic4454

Stewart, T.D. (1979). Essential of Forensic Anthropology – Especially as Developed in the United States. Springfield, IL: Charles C. Thomas.

Steyn, M., Iscan, M.Y., De Kock, M., Kranioti, E.F., Michalodimitrakis, M., & L'Abbe, E. N. (2010). Analysis of ante mortem trauma in three modern skeletal populations. *International Journal of Osteoarchaeology*, *20*(5), 561–571. https://doi.org/10.1002/oa.1096

Stini, W.A. (2003). Chapter 5: Bone loss, fracture histories, and body composition characteristic of older males. *In* Agarwal, S. & Stout, S.D. (eds.), *Bone Loss and Osteoporosis: An Anthropological Perspective*, (p. 63-89). New York, NY: Plenum Press.

Stirland, A. (1996). Patterns of trauma in a unique medieval parish cemetery. *International Journal of Osteoarchaeology*, *6*(July 1995), 92–100. https://doi.org/10.1002/(SICI)1099-1212(199601)6:1<92::AID-OA260>3.3.CO;2-C

Stirland, A. (2005). Human remains. *In* Gardiner, J. & Allen, M. J. (eds.) *Before the Mast: Life and Death Aboard the Mary Rose (The Archaeology of the Mary Rose, Volume 4),* (pp. 516–44). Portsmouth, UK: Mary Rose Trust.

Stodder, A.L.W. & Palkovich, A.M. (2012). Chapter 1: Osteobiography and bioarchaeology. *In* Palkovich, A.L.W. & Palkovich, A.M. (eds.) *The Bioarchaeology of Individuals* (pp. 1-8). Tallahassee, FL: University Press of Florida. Stojanowski, C.M., Seidemann, R.M, & Doran, G.H. (2002). Differential skeletal preservation at Windover Pond: Causes and consequences. *American Journal of Physical Anthropology, 119,* 15-26.

Suzuki, K. (2013). Diagnosis of occult fractures of the ischiopubic rami. *Journal of Biomedical Science and Engineering, 6,* 391-394. http://dx.doi.org/10.4236/jbise.2013.63A049

Szumilas, M. (2010). Information management for the busy practitioner: Explaining Odds Ratios. *Journal of the Canadian Academy of Child & Adolescent Psychiatry, 19*(3), 227-229.

Tarp, P. (2010). Antropologisk rapport: HOM 1272- Horsens Klosterkirke. ADBOU: Syddansk Universitet (in Danish).

Tilley, L. (2015). Theory and Practice in the Bioarchaeology of Care. Springer International Publishing: Switzerland.

Titelbaum, A.R. & Castillo, S.U. (2015). A rare case of os odontoideum from an Early Intermediate period tomb at the Huacas de Moche, Peru. *International Journal of Paleopathology*, *11*, 23–29. https://doi.org/10.1016/j.ijpp.2015.08.001

Todd, T.W. (1921). Age changes in the pubic bone. *American Journal of Physical Anthropology, 4*(1), 1-70.

Ubelaker, D.H. & Adams, B.J. (1995). Differentiation of perimortem and postmortem trauma using taphonomic indicators. *Journal of Forensic Science, 40,* 509-512.

Urbanová, P., Ross, A.H., Jurda, M., & Šplíchalová, I. (2017). The virtual approach to the assessment of skeletal injuries in human skeletal remains of forensic importance. *Journal of Forensic and Legal Medicine*, *49*, 59–75. https://doi.org/10.1016/j.jflm.2017.05.015

Usher, B.M. (2000). A multistate model of health and mortality for paleodemography. Dissertation. Pennsylvania State University.

Vaupel, J.W. & Yashin, A.I. (1985). Heterogeneity's ruses: some surprising effects of selection on population dynamics. *The American Statistician, 39,* 176-185.

Verlinden, P. & Lewis, M.E. (2015). Childhood trauma: Methods for the identification of physeal fractures in nonadult skeletal remains. *American Journal of Physical Anthropology*, *157*(3), 411–420. https://doi.org/10.1002/ajpa.22732

Vieira, A.E., Repeke, C.E., Ferreira Jr., S.B., Colavite, P.M., Biguetti, C.C., et al. (2015) Intramembranous bone healing process subsequent to tooth extraction in mice: Micro-computed tomography, histomorphometric and molecular characterization. *PLoS One, 10*(5), 1-22. doi:10.1371/journal.pone.0128021

Villotte, S., Churchill, S.E., Dutour, O.J., & Henry-Gambier. (2010). Subsistence activities and the sexual division of labor in the European Upper Paleolithic and Mesolithic: Evidence from upper limb enthesopathies. *Journal of Human Evolution, 59*, 35-43.

Von Endt, D.W. & Ortner, D.J. (1984). Experimental effects of bone size and temperature on bone diagenesis. *Journal of Archaeological Science*, *11*, 247–253.

Walker, P.L. (1997). Chapter 6: Wife beating, boxing, and broken noses: skeletal evidence for the cultural patterning of interpersonal violence. *In* Martin, D.L & Frayer, D.W. (eds.) *Troubled Times: Violence and Warfare in the Past* (pp. 145– 75). Portland, OR: Psychology Press.

Walker, P. (2001). A bioarchaeological perspective on the history of violence. *Annual Review of Anthropology*, *30*, 573–596.

Wall, E.J. & May, M.M. (2012). Growth plate fractures of the distal femur. *Journal of Pediatric Orthopaedics*, *32*(Supplement 1), 40–46. https://doi.org/10.1097/BPO.0b013e3182587086

Walter, B.S. & DeWitte, S.N. (2017). Urban and rural mortality and survival in medieval England. *Annals of Human Biology*, *44*(4), 338–348. https://doi.org/10.1080/03014460.2016.1275792

Wanek, J., Papageorgopoulou, C., & Ruehli, F. (2012). Chapter 18: Fundamentals of paleoimaging techniques: bridging the gap between physicists and paleopathologists. *In* Grauer, A.L. (ed.), *A Companion to Paleopathology*, (pp. 324-338). Oxford, UK: Blackwell Publishing Ltd.

Washburn, S.L. (1951). The New Physical Anthropology. *Transactions of the New York Academy of Science Series II, 13,* 298-304.

Wedel, V.L. & Galloway, A. (2014). Broken Bones: Anthropological Analysis of Blunt Force Trauma, Second Edition. Charles C. Thomas Publisher: Springfield, IL.

Wheatley, B.P. (2008). Perimortem and postmortem bone fractures? An experimental study of fracture patterns in deer femora. *Journal of Forensic Sciences, 53*(1), 69-72. doi: 10.1111/j.1556-4029.2008.00593.

White, S. (2015). Virtual archaeology: The NextEngine desktop laser scanner. *Archaeology International*, *18*, 41-44. https://doi.org/10.5334/ai.1804

White, T. (1992). Chapter 3: Cannibalism in the Prehistoric Southwest: Mancos 5MTUMR–2346 and Its Context. *In* White, T. (ed.) *Prehistoric Cannibalism at Mancos 5MTUMR-2346* (pp. 31-64). Princeton, New Jersey: Princeton University Press. http://www.jstor.org/stable/j.ctt7ztk6d.9

White, T.D., Black, M.T., & Folkens, P.A. (2012). Human Osteology (Third Edition). Oxford, UK: Elsevier Inc.

Wieberg, D.A.M. & Wescott, D.J. (2008). Estimating the timing of long bone fractures: Correlation between the postmortem interval, bone moisture content, and blunt force trauma fracture characteristics. *Journal of Forensic Sciences*, *53*(5), 1028-1034. doi: 10.1111/j.1556-4029.2008.00801.

Wittschieber, D., Beck, L., Vieth, V., & Hahnemann, M.L. (2016). The role of 3DCT for the evaluation of chop injuries in clinical forensic medicine. *Forensic Science International,* 266, e59-e63. http://dx.doi.org/10.1016/j.forsciint.2016.05.025

Wood, J.W., Milner, G.R., Harpending, H.C., Weiss, K.M., Cohen, N., Eisenberg, L.E., & Wilkinson, R.G. (1992). The Osteological Paradox. *Current Anthropology*, *33*(4), 343–370. https://doi.org/papers2://publication/uuid/3AD1960D-AE51-4550-BE94-EBED5FB00559

Wright, L.E. & Yoder, C.J. (2003). Recent progress in bioarchaeology: Approaches to the Osteological Paradox. *Journal of Archaeological Research*, *11*(1), 43-70.

Yamashita, J., Li, X., Furman, B.R., Ralph Rawls, H., Wang, X. & Mauli Agrawal, C. (2001). Collagen and bone viscoelasticity: A dynamic mechanical analysis. *Journal of Biomedical Materials Research*, *63*(1), 31–36. https://doi.org/10.1002/jbm.10086

Yoder, C. (2006). The Late Medieval Agrarian Crisis and Black Death Plagues epidemic in medieval Denmark: A paleopathological and paleodietary perspective. Dissertation: Texas A & M University.

Yoder, C. (2010). Diet in medieval Denmark: a regional and temporal comparison. *Journal of Archaeological Science*, *37*, 2224-2236. doi:10.1016/j.jas.2010.03.020

Appendix A

Description:

Master table of all individuals scored, to include cemetery, grave identification, sex, Transition Analysis (TA) point estimates, TA age range, TA age group category, observed age ranges, observed age group category, and lesion presence and specifics.

Legend:

Column Title	Variables and Definitions
Cemetery (Cem.)	HK – Horsens Klosterkirke; OW – Ole Worms Gade; NOR – Nordby; Tirup
Grave	Grave number assigned during excavation.
Sex	M – Male; F – Female; I - Indeterminate
Age Group Category	1 (adolescent) – 10-20 yrs.; 2 (young adult) – 21-30 yrs.; 3 (adult) – 31-50 yrs.; 4 (old adult) – 51-70 yrs.; 5 (oldest-old adult) – 71-91+ yrs.
TA Point Estimate	Point estimate calculated using Transition Analysis program, ADBOU 2.0.
TA Age Range	Age range calculated using Transition Analysis program, ADBOU 2.0. Calculated at the 95% Confidence Interval.
Observed Age Category (Obs. Age Categ.)	1 (10-20 yrs.); 2 (21-30 yrs.); 3 (31-40 yrs.); 4 (41-50 yrs.); 5 (51-60 yrs.); 6 (61-70 yrs.); 7 (71-80 yrs.); 8 (81-90 yrs.); 9 (91-100 yrs.)
Observed Age (Obs. Age)	Age range observed by macroscopic and metric analysis of skeletal features as referenced in Buikstra & Ubelaker, 1994.
Defects Present (Def. Pres.)	Number of all defects to include trauma, fusions, dislocations, spondylolysis, *os acromiale* and possible pathologies observed in the individual.
Trauma (Tra.)	0 – Trauma Not Present; 1 – Only Trauma Present; 2 – Only Non-Trauma Present; 3 – Both Trauma and Non-Trauma Present
Multiple Trauma (Mult. Tra.)	0 – No trauma; 1 - ≤ 1 Trauma Lesion; 2 - > 1 Trauma Lesion
Cranial Blunt-force (CBT)	0 – Absent; 1 – Present
Sharp-force (SFT)	0 – Absent; 1 – Present
Fractures Present (Fract. Pres.)	Number of fractures present in the remains.
Dislocations (Discloc.)	Number of dislocations present in the remains.

Cem.	Grave	Sex	Age Gr.	TA P.Est.	TA Age	Obs. Age Gr.	Obs. Age	Def. Pres.	Tra.	Mult. Tra.	CBF	SFT	Fract. Pres.	Disloc.
HK	2594	F	2	24.6	24.6-39.3	2	30-39	1	2	0	0	0	0	0
HK	2598	F	1	20.3	15.7-25.2	2	25-29	0	0	0	0	0	0	0
HK	2628	M	2	25.2	20.5-30.8	2	30-44	0	0	0	0	0	0	0
HK	2651	M	3	0	0	0	25-39	1	3	2	0	0	2	0
HK	2654	F	1	19.5	19.5-24.1	2	25-34	1	3	1	0	0	1	0
HK	2680	M	3	32.4	25.2-44.1	3	35-44	0	0	0	0	0	0	0
HK	2693	F	4	0	0	0	39-60+	1	1	1	0	0	1	0
HK	2694	M	3	40.4	29.3-62.2	4	30-50	0	0	0	0	0	0	0
HK	2763	M	5	79.4	60.6-92	7	35-39	1	3	2	1	2	7	1
HK	2768	F	2	23	19.7-27.3	2	25-34	1	2	0	0	0	0	0
HK	2770	M	2	25	19.1-33.9	2	0	0	0	0	0	0	0	0
HK	2782	M	5	71.4	25-90.4	7	0	1	3	2	0	1	1	0
HK	2821	M	5	78.5	57.2-91.7	7	35-44	1	2	0	0	0	0	0
HK	2830	F	5	82.1	63.5-93.9	8	60+	1	1	1	0	0	1	0
HK	2831	F	4	0	0	0	50-59	1	3	2	0	0	1	0
HK	2848	M	4	53.1	34.3-79	5	39-59	1	3	2	0	0	3	1
HK	2858	F	2	23.4	17.5-32.4	2	30-34	0	0	0	0	0	0	0
HK	2865	M	3	0	0	0	35-49	1	1	2	0	0	3	0
HK	2867	M	5	83.8	68.2-94.5	8	44-50+	1	3	1	0	0	1	0
HK	2876	Ind.	2	27.4	19.7-37.8	2	30-34	0	0	0	0	0	0	0
HK	2878	M	3	0	0	0	0	0	0	0	0	0	0	0
HK	2883	M	2	26.3	21.9-31.6	2	39-50	0	0	0	0	0	0	0
HK	2884	M	5	77.6	47.9-91.9	7	0	1	3	1	0	0	1	0
HK	2905	M	3	31.1	16.7-53.3	3	22-39	0	0	0	0	0	0	0
HK	2907	F	5	75.7	56.4-89.5	7	30-44	0	0	0	0	0	0	0
HK	2914	F	2	30	30-67.2	2	0	1	1	2	0	0	2	0
HK	2915	M	5	74.9	44.2-90.3	7	60+	0	0	0	0	0	0	0
HK	2945	M	3	35.4	27.2-48.1	3	39-60+	0	0	0	0	0	0	0
HK	2947	M	5	85.2	70.7-110	8	40-60+	1	1	2	0	0	5	1
HK	2958	F	5	71.6	30.2-89.3	7	0	0	0	0	0	0	0	0
HK	3000	M	2	26.4	20.2-35.4	2	30-44	0	0	0	0	0	0	0
HK	3001	F	3	30.6	30.6-57.3	3	0	1	2	0	0	0	0	0
HK	3016	M	3	42.9	30.8-65.2	4	35-60+	1	1	1	0	0	1	0
HK	3024	M	3	38.6	21-68.6	3	30-34	1	1	1	0	0	1	0
HK	3026	M	2	25.5	21.2-30.4	2	25-39	1	1	1	0	0	1	0
HK	3028	F	3	37.8	21.1-65.3	3	50-59	1	1	1	0	0	1	0

Cem.	Grave	Sex	Age Group	TA Point Es	TA Age Ra	Obs. Age Categ.	Obs. Age	Def. Pres.	Tra.	Mult. Tra.	CBF	SFT	Fract. Pres.	Disloc.
HK	2005	F	1	15	15-83.3	1	35-39	0	0	0	0	0	0	0
HK	2014	F	3	32.8	20.7-50.9	3	44-55	1	1	2	0	0	2	0
HK	2059	M	2	21	16.4-26.5	2	35-44	1	3	1	0	0	1	0
HK	2060	F	3	44.8	29.7-71.2	4	44-60+	1	3	2	0	0	2	0
HK	2146	M	5	74.3	49-89.5	7	35-39	1	1	2	0	0	1	0
HK	2167	M	2	0	0	0	30-35	0	0	0	0	0	0	0
HK	2203	F	3	40.3	24.4-65.3	4	50-60+	0	0	0	0	0	0	0
HK	2216	F	3	49.2	33.8-71	4	30-60+	0	0	0	0	0	0	0
HK	2220	M	3	31.8	20.6-48.5	3	60+	1	1	2	0	0	3	0
HK	2252	Ind.	0	0	0	0	0	1	1	1	0	0	1	0
HK	2256	F	4	69.6	69.6-90	6	0	1	3	2	0	0	2	0
HK	2306	M	3	47.6	28.4-78.6	4	30-39	0	0	0	0	0	0	0
HK	2315	M	3	38.2	30.7-49.7	3	50-59	0	0	0	0	0	0	0
HK	2338	M	3	38	30-51.1	3	44-60+	1	2	0	0	0	0	0
HK	2339	F	1	18.4	18.4-25.3	1	0	0	0	0	0	0	0	0
HK	2351	F	5	73.9	50.2-89.1	7	60+	1	2	0	0	0	0	0
HK	2391	M	3	35.1	28.5-44.6	3	39-60+	1	3	1	0	0	1	0
HK	2392	M	2	21.4	16.8-27.3	2	39-59	1	2	0	0	0	0	0
HK	2397	M	2	23.8	19.3-29	2	30-44	0	0	0	0	0	0	0
HK	2409	M	2	28.7	23.8-34.8	2	27-59	1	1	2	0	0	2	0
HK	2411	M	3	0	0	0	0	1	1	1	0	0	1	0
HK	2427	M	4	0	0	0	50-59	1	1	1	0	0	1	0
HK	2442	F	3	43.9	30.5-65.7	4	39-60+	0	0	0	0	0	0	0
HK	2452	M	3	32.8	32.8-80.8	3	0	1	2	0	0	0	0	0
HK	2459	Ind.	3	38	24.3-78	3	35-39	0	0	0	0	0	0	0
HK	2468	M	4	0	0	0	55+	1	1	1	0	0	0	1
HK	2475	F	3	36.4	19.5-67.4	3	60+	0	0	0	0	0	0	0
HK	2489	M	3	36.3	28.4-48.5	3	39-49	0	0	0	0	0	0	0
HK	2499	M	2	25.6	20-33.3	2	0	1	3	1	0	0	1	0
HK	2544	F	3	30.6	23.3-42.4	3	39-59	1	2	0	0	0	0	0
HK	2570	F	2	24.4	19.4-31.2	2	25-35	1	1	2	0	0	2	0
HK	2573	F	5	85	69.3-110	8	0	0	0	0	0	0	0	0
HK	2583	M	3	37.6	28.9-53.3	3	35-50	1	3	1	0	0	0	1
HK	2587	M	3	31	24-41.2	3	30-44	0	0	0	0	0	0	0
HK	2593	F	2	21.8	18.1-26.7	2	50-59	1	3	2	0	0	4	1

Cem.	Grave	Sex	Age Gr.	TA P.Est.	TA Age	Obs. Age Gr.	Obs. Age	Def. Pres.	Tra.	Mult. Tra.	CBF	SFT	Fract. Pres.	Disloc.
HK	3029	F	2	25.9	25.9-63.2	2	0	0	0	0	0	0	0	0
HK	3066	F	5	80	62.6-92.2	7	44-60+	0	0	0	0	0	0	0
HK	3081	M	5	80.8	59.7-9.3	8	50-59	1	3	1	0	0	1	0
HK	3096	Ind.	3	0	0	0	0	0	0	0	0	0	0	0
HK	3097	F	3	42.2	15.4-89.3	4	0	0	0	0	0	0	0	0
HK	3105	F	3	31.7	17.7-52.9	3	0	0	0	0	0	0	0	0
HK	3106	F	5	83.4	68.3-94.1	8	39-60+	0	0	0	0	0	0	0
HK	3138	F	3	33.7	18.2-58.5	3	60+	1	1	2	0	0	4	2
TOTAL								**44**	**35**	**17**	**1**	**3**	**62**	**8**
OW	1003	F	1	20.2	15.4-25.1	2	30-39	0	0	0	0	0	0	0
OW	1004	M	2	23.2	19.5-27.8	2	30-44	1	2	0	0	0	0	0
OW	1006	M	2	29.5	24-36.7	2	30-49	1	2	0	0	0	0	0
OW	1013	F	3	35.5	17.5-69.5	3	50-59	0	0	0	0	0	0	0
OW	1014	F	3	32.8	25.9-43.5	3	27-39	0	0	0	0	0	0	0
OW	1020	F	4	53	29.9-80	5	0	1	1	1	0	0	1	0
OW	1024	F	3	36.2	26-55.4	3	30-39	0	0	0	0	0	0	0
OW	1026	M	3	38.9	29.3-55.5	3	30-39	0	0	0	0	0	0	0
OW	1027	F	1	18.2	18.2-45.8	1	0	0	0	0	0	0	0	0
OW	1029	F	2	24.3	19-32	2	30-44	1	1	2	0	0	2	0
OW	1032	F	4	69.9	46.4-86.6	6	0	0	0	0	0	0	0	0
OW	1040	M	5	80.1	62.8-92.1	7	30-39	1	3	2	0	0	5	0
OW	1044	F	3	34.1	25.2-49.4	3	30-39	1	1	1	0	0	1	0
OW	1063	F	2	0	0	0	0	0	0	0	0	0	0	0
OW	1067	M	3	37.5	24.4-62.4	3	0	1	1	1	0	0	1	0
OW	1074	M	3	31.1	24.7-39.9	3	30-44	0	0	0	0	0	0	0
OW	1075	M	3	0	0	0	0	0	0	0	0	0	0	0
OW	1085	M	3	31.1	24.7-39.9	3	30-60+	0	0	0	0	0	0	0
OW	1086	M	3	39.7	30.6-55	3	30-39	1	3	1	0	0	1	0
OW	1088	M	2	26.5	22.4-31.3	2	25-44	0	0	0	0	0	0	0
OW	1105	F	2	27.8	15.6-46.8	2	0	0	0	0	0	0	0	0
OW	1114	M	3	31.4	16.7-63.4	3	0	0	0	0	0	0	0	0
OW	1132	F	3	43.6	28-72.7	4	35-50	0	0	0	0	0	0	0
OW	1144	F	2	29.7	22.6-41	2	35-44	1	1	2	0	0	4	0
OW	1161	M	2	24.8	19.9-30.6	2	30-35	1	1	1	0	0	1	0
OW	1177	M	5	84.4	68.8-110	8	35-44	1	1	1	0	0	1	0
OW	1180	F	4	68.1	40.9-86.4	6	35-49	0	0	0	0	0	0	0

Cem.	Grave	Sex	Age Gr.	TA P.Est.	TA Age	Obs. Age Gr.	Obs. Age	Def. Pres.	Tra.	Mult. Tra.	CBF	SFT	Fract. Pres.	Disloc.
OW	1186	F	3	47.3	33.6-66	4	39-49	1	3	2	0	0	4	0
OW	1196	F	4	69.7	46.8-86.3	6	40-59	1	1	1	0	0	0	0
OW	1212	F	2	26.3	20.8-33.8	2	30-39	1	2	0	0	0	0	0
OW	1214	M	3	36.4	24-57.1	3	30-39	1	3	1	0	0	1	0
OW	1218	F	5	81.9	65-93.4	8	30-39	1	1	2	0	0	3	0
OW	1235	M	4	0	0	0	0	1	1	2	0	0	2	0
OW	1247	M	3	33.7	27.9-42.2	3	30-39	1	3	1	0	0	1	0
OW	1258	M	3	0	0	0	0	0	0	0	0	0	0	0
OW	1269	F	3	34.2	20.6-56	3	25-29	0	0	0	0	0	0	0
OW	1276	F	2	27.9	21.6-37.1	2	30-35	0	0	0	0	0	0	0
OW	1282	F	2	20.6	20.6-32.5	2	30-34	0	0	0	0	0	0	0
OW	1292	F	1	20.4	20.4-53.5	1	0	1	2	0	0	0	0	0
OW	1306	M	3	0	0	0	0	1	1	2	0	0	2	0
OW	1340	M	2	29.2	17.7-43.8	2	35-39	0	0	0	0	0	0	0
OW	1355	F	4	69.3	40.8-87.5	6	30-34	1	3	1	0	0	1	0
OW	1360	M	2	30.4	24.7-38.3	2	30-35	1	3	2	0	0	3	0
OW	1376	F	3	36.1	21.2-64.8	3	0	1	1	1	0	0	1	0
OW	1381	M	2	27.6	27.6-45.2	2	45-49	0	0	0	0	0	0	0
OW	1383	M	3	31.5	23.4-44.1	3	30-39	1	1	1	0	0	1	0
OW	1387	M	1	18.8	18.8-34.7	1	30-39	0	0	0	0	0	0	0
OW	1388	M	3	0	0	0	0	0	0	0	0	0	0	0
OW	1389	F	5	84.4	70.3-94.7	8	39-60+	1	2	0	0	0	0	0
OW	1401	M	3	47.3	33.9-72.7	4	35-44	1	1	2	0	0	2	0
OW	1402	M	4	0	0	0	39-44	1	3	2	0	0	4	1
OW	1416	M	5	74.8	25.2-91.5	7	30-39	0	0	0	0	0	0	0
OW	1423	Ind.	3	0	0	0	0	0	0	0	0	0	0	0
OW	1427	M	3	43.5	24.8-75.3	4	35-39	0	0	0	0	0	0	0
OW	1434	F	3	32.1	32.1-74.7	3	0	0	0	0	0	0	0	0
OW	1439	M	2	26.3	21.8-31.9	2	30-39	1	1	1	0	0	1	0
OW	1447	M	3	44	32.2-68.2	4	35-44	0	0	0	0	0	0	0
OW	1448	M	3	0	0	0	0	0	0	0	0	0	0	0
OW	1455	F	3	31.2	23.5-44.4	3	44-60+	1	3	2	0	0	2	0
OW	1478	F	3	46.1	28-74.1	4	30-44	0	0	0	0	0	0	0
OW	1485	F	2	21	21-45.5	2	0	1	1	1	0	0	1	0
OW	1498	F	2	30.3	23.6-41.2	2	30-60+	0	0	0	0	0	0	0
OW	1511	M	5	75.2	45.7-90.4	7	50-59	0	0	0	0	0	0	0

Cem.	Grave	Sex	Age Gr.	TA P.Est.	TA Age	Obs. Age Gr.	Obs. Age	Def. Pres.	Tra.	Mult. Tra.	CBF	SFT	Fract. Pres.	Disloc.
OW	1518	M	5	77.7	31.6-110	7	0	0	0	0	0	0	0	0
OW	1519	F	3	41.3	23.1-72.6	4	0	1	1	2	1	0	4	1
OW	1520	F	2	21.4	16-27.9	2	30-39	0	0	0	0	0	0	0
OW	1521	M	3	38.4	16-79.6	3	30-34	1	3	1	0	0	1	0
OW	1524	F	5	71.1	39.9-88.5	7	0	0	0	0	0	0	0	0
OW	1526	M	2	29.1	23.2-36.9	2	35-44	1	1	1	0	0	1	0
OW	1527	F	5	79.5	60.9-92	7	40-60+	0	0	0	0	0	0	0
OW	1540	F	2	28.2	22-37.8	2	50-60+	0	0	0	0	0	0	0
OW	1543	M	2	23.3	23.3-39.7	2	50-60+	1	2	0	0	0	0	0
OW	1547	M	3	37.5	28.5-52.3	3	40-59	0	0	0	0	0	0	0
OW	1550	F	3	31.1	24.7-41.1	3	35-60+	0	0	0	0	0	0	0
OW	1552	M	2	29	23.6-36.7	2	39-59	1	3	1	0	0	1	0
OW	1553	M	3	36.3	28-50.1	3	30-60+	1	3	1	0	0	1	0
OW	1570	F	5	80.3	64.2-92.1	7	35-44	0	0	0	0	0	0	0
OW	1574	F	5	75.3	48.1-90.5	7	0	1	3	2	0	1	4	0
OW	1575	F	5	75.8	51.3-90.4	7	50-60+	1	1	2	0	0	4	0
OW	1591	F	3	49	29.8-76.3	4	44-60+	0	0	0	0	0	0	0
OW	1596	M	3	33.2	26.5-44.1	3	39-59	0	0	0	0	0	0	0
OW	1602	F	3	0	0	0	0	0	0	0	0	0	0	0
OW	1620	M	4	54.3	34.8-80.5	5	39-60+	1	2	0	0	0	0	0
OW	1627	M	3	33.1	26.4-42.4	3	30-44	0	0	0	0	0	0	0
OW	1632	M	2	28.5	22.6-36.9	2	35-44	1	1	2	0	0	2	0
OW	1634	M	3	0	0	0	0	0	0	0	0	0	0	0
OW	1638	F	5	75.8	47.3-90.9	7	0	0	0	0	0	0	0	0
OW	1639	M	2	30.3	24.9-37.5	2	30-44	1	3	2	0	0	2	0
OW	1640	M	3	34.8	26.8-46.7	3	35-44	0	0	0	0	0	0	0
OW	1642	M	5	75.4	55.6-89.1	7	39-60+	1	2	0	0	0	0	0
OW	1643	M	5	71.8	17.7-90.7	7	0	0	0	0	0	0	0	0
OW	1649	F	3	0	0	0	0	0	0	0	0	0	0	0
TOTAL								**42**	**35**	**16**	**1**	**1**	**66**	**2**
NOR	AD	F	3	38.2	23.5-60.1	3	27-39	1	2	0	0	0	0	0
NOR	AE	M	3	39.2	31.1-52.2	3	35-50	1	1	1	0	0	0	1
NOR	AH	M	3	39.6	30.5-55.1	3	30-44	1	1	1	0	0	1	0
NOR	AJ	F	2	28.1	16.9-43.6	2	35-44	0	0	0	0	0	0	0
NOR	AN	M	3	31.2	25.0-40.3	3	0	1	1	1	0	0	1	0
NOR	AS	M	4	68.8	36.1-88.3	6	50-59	1	1	2	1	1	2	0

Cem.	Grave	Sex	Age Gr.	TA P.Est.	TA Age	Obs. Age Gr.	Obs. Age	Def. Pres.	Tra.	Mult. Tra.	CBF	SFT	Fract. Pres.	Disloc.
NOR	AU	F	2	26.8	26.8-43.5	2	30-44	0	0	0	0	0	0	0
NOR	AW	F	2	29.3	17.4-47.2	2	30-34	1	1	1	0	0	1	0
NOR	BA	M	2	27.5	21.2-36.4	2	35-44	1	3	2	0	0	4	0
NOR	BB	M	3	0	0	0	0	1	3	2	0	0	4	0
NOR	BC	F	3	44	29.9-66.6	4	45-50+	0	0	0	0	0	0	0
NOR	BD-BC	M	3	31.9	25.4-42.3	3	30-39	0	0	0	0	0	0	0
NOR	BE	F	5	80.7	57.7-93.4	8	50-60+	1	1	1	0	0	1	0
NOR	BF	M	2	29.9	24.9-36.4	2	30-39	0	0	0	0	0	0	0
NOR	BG	M	5	78.1	49.8-92.2	7	39-60+	0	0	0	0	0	0	0
NOR	BH	M	4	66.4	29.8-87.6	6	40-44	0	0	0	0	0	0	0
NOR	BL	F	3	39.8	28-58	3	44-60+	1	2	0	0	0	0	0
NOR	BM	M	2	27.5	22.9-33.2	2	30-59	1	3	2	0	0	5	1
NOR	BN	M	2	28.1	22.8-35	2	30-44	1	1	2	2	0	2	0
NOR	BO	M	2	29.9	24.1-38.1	2	30-44	0	0	0	0	0	0	0
NOR	BP	F	2	26.8	22-33.1	2	30-44	0	0	0	0	0	0	0
NOR	BQ	M	4	55.2	27.7-85.2	5	35-44	1	1	2	0	0	4	0
NOR	BS	M	3	34.8	28.5-43.3	3	35-59	1	1	1	0	0	2	0
NOR	BU	F	3	35.3	20.3-61.8	3	0	0	0	0	0	0	0	0
NOR	CA	F	4	65.2	39.1-84.5	6	60+	0	0	0	0	0	0	0
NOR	CC	M	5	75.4	53.1-89.6	7	35-44	1	1	2	0	0	6	0
NOR	CF	M	3	31.2	25.4-39.2	3	35-59	1	1	2	0	0	1	1
NOR	CH	M	2	24.8	20-30.6	2	30-39	0	0	0	0	0	0	0
NOR	CM	F	2	24.9	19.7-32.2	2	0	0	0	0	0	0	0	0
NOR	CQ	M	2	23.5	18.9-29.4	2	25-35	1	1	1	0	0	1	0
NOR	CU	M	3	31	25.4-38.5	3	39-59	1	3	1	0	0	1	0
NOR	CV	F	2	28.4	23.3-35.3	2	30-59	1	2	0	0	0	0	0
NOR	CX	F	2	25.1	20.4-31.2	2	35-59	0	0	0	0	0	0	0
NOR	CY	M	3	41.1	31-59.6	4	35-59	1	3	2	0	0	2	1
NOR	CZ	M	2	26.1	21.2-32	2	25-35	1	1	2	2	2	0	0
NOR	DA	M	2	30.2	24.3-38.5	2	35-44	0	0	0	0	0	0	0
NOR	DC	M	3	32.2	26.3-40.6	3	27-35	0	0	0	0	0	0	0
NOR	DF	F	3	37.8	28.1-53.3	3	45-59	0	0	0	0	0	0	0
NOR	DG	M	3	41.9	32-59.8	4	39-59	1	3	2	0	0	2	1
NOR	DJ	M	5	85.1	69.1-110	8	0	1	1	2	0	0	2	0
NOR	DK	M	3	37.5	29.4-50.5	3	30-44	1	2	0	0	0	0	0
NOR	DM	M	5	74.1	45-89.7	7	35-39	1	3	1	0	0	1	0

Cem.	Grave	Sex	Age Gr.	TA P.Est.	TA Age	Obs. Age Gr.	Obs. Age	Def. Pres.	Tra.	Mult. Tra.	CBF	SFT	Fract. Pres.	Disloc.
NOR	DN	M	3	27.3	22.4-33.5	2	25-35	1	1	1	0	0	1	0
NOR	DR	M	3	33.3	26.7-42.9	3	30-44	1	1	1	0	0	1	0
NOR	DS	M	4	69.4	44.6-86.3	6	35-59	0	0	0	0	0	0	0
NOR	DZ	M	2	0	0	0	0	1	1	2	0	0	2	1
NOR	EB	F	4	65.9	41.9-84.6	6	25-39	0	0	0	0	0	0	0
NOR	EM	M	2	30.4	23.9-41.1	2	30-39	1	1	1	0	0	1	0
NOR	EQ	F	4	69.7	27.8-87.9	6	35-39	0	0	0	0	0	0	0
NOR	ES	M	3	42.3	31.6-63.3	4	0	1	3	2	0	0	4	0
NOR	EV	F	5	74.6	54.2-88.9	7	35-50	0	0	0	0	0	0	0
NOR	EX	M	5	86.3	72.3-110	8	60+	1	3	2	0	0	3	0
NOR	EZ	F	3	43.9	29.9-66.7	4	0	0	0	0	0	0	0	0
NOR	FC	F	5	74.3	51.5-89.1	7	60+	1	2	0	0	0	0	0
NOR	FE	F	3	42.8	28.6-65.3	4	35-44	1	3	1	0	0	1	0
NOR	FF	M	3	49.2	32.9-76.5	4	30-44	1	1	1	0	0	1	0
NOR	FN	M	3	38.1	29.3-52.6	3	25-44	0	0	0	0	0	0	0
NOR	GR	F	5	78.6	58.6-91.6	7	35-39	0	0	0	0	0	0	0
NOR	Q	F	4	70.4	494-86.4	6	30-39	0	0	0	0	0	0	0
NOR	R	M	2	21.4	17.7-25.9	2	0	1	3	2	0	0	2	0
NOR	U	F	3	47	27.8-74.3	4	35-44	0	0	0	0	0	0	0
NOR	V	M	5	74.1	38.6-90.5	7	0	0	0	0	0	0	0	0
NOR	W	M	3	41.4	24.8-76.4	4	0	0	0	0	0	0	0	0
NOR	X	M	4	69.4	37.9-87.7	6	34-39	0	0	0	0	0	0	0
NOR	Y	M	2	26.7	26.7-45	2	35-44	1	3	1	0	0	1	0
NOR	Z	M	5	76.6	54.4-90.6	7	40-44	0	0	0	0	0	0	0
TOTAL								**36**	**31**	**16**	**3**	**3**	**60**	**6**
TIRUP	10	F	3	0	0	0	50+	0	0	0	0	0	0	0
TIRUP	14	M	4	0	0	0	50+	0	0	0	0	0	0	0
TIRUP	15	F	3	0	0	0	35+	0	0	0	0	0	0	0
TIRUP	37	M	3	43.7	30.2-72.3	4	30-47	1	1	1	0	0	1	0
TIRUP	39	F	3	35	19.9-58.6	3	17-30	0	0	0	0	0	0	0
TIRUP	40	F	4	52.8	19.5-87.9	5	45-55	0	0	0	0	0	0	0
TIRUP	41	F	4	69	37.9-87.1	6	40-55	0	0	0	0	0	0	0
TIRUP	46	Ind.	3	0	0	0	0	0	0	0	0	0	0	0
TIRUP	75	M	3	31.4	20.5-47.1	3	0	0	0	0	0	0	0	0
TIRUP	76	M	3	38	19.5-70.6	3	35-47	1	1	1	0	0	1	0
TIRUP	77	F	3	49.2	32.4-73.3	4	30-55	1	1	2	0	0	1	0

Cem.	Grave	Sex	Age Gr.	TA P.Est.	TA Age	Obs. Age Gr.	Obs. Age	Def. Pres.	Tra.	Mult. Tra.	CBF	SFT	Fract. Pres.	Disloc.
TIRUP	79	F	3	38	16.9-77	3	0	1	1	2	0	0	4	0
TIRUP	86	F	3	32.1	24.6-43.7	3	44-55	1	1	1	0	0	1	0
TIRUP	89	M	2	29.9	24.2-37.3	2	39-55	0	0	0	0	0	0	0
TIRUP	91	Ind.	3	31.2	24.4-41.5	3	27-47	0	0	0	0	0	0	0
TIRUP	94	F	2	28.1	21.5-38.4	2	35-44	0	0	0	0	0	0	0
TIRUP	95	M	2	23.7	23.7-35.4	2	0	0	0	0	0	0	0	0
TIRUP	96	F	2	26.5	15.7-40.5	2	0	0	0	0	0	0	0	0
TIRUP	113	F	3	33.8	19.2-56.9	3	55+	0	0	0	0	0	0	0
TIRUP	129	M	3	33.1	26.5-42.3	3	30-60+	0	0	0	0	0	0	0
TIRUP	130	F	3	31.2	17.9-52.5	3	0	0	0	0	0	0	0	0
TIRUP	142	F	4	55.1	31.5-80.1	5	60+	1	3	1	0	0	1	0
TIRUP	143	M	3	34.8	19.6-58.4	3	0	1	1	1	0	0	1	0
TIRUP	146	M	2	25.2	20-31.8	2	45-55	1	3	2	0	0	1	0
TIRUP	155	M	5	73	35.6-89.9	7	40+	0	0	0	0	0	0	0
TIRUP	168	M	2	27.3	17.6-38.3	2	40-59	0	0	0	0	0	0	0
TIRUP	187	F	2	29.1	21.7-39.9	2	30-44	1	1	1	0	0	2	0
TIRUP	188	F	2	25.9	20.6-33	2	30-35	1	1	2	0	0	1	0
TIRUP	189	Ind.	3	38.9	27.4-58	3	44-60	1	3	1	0	0	2	0
TIRUP	196	M	3	30.5	18.8-47	3	26-40	0	0	0	0	0	0	0
TIRUP	197	F	2	29.1	17.9-44.9	2	30-44	1	1	2	0	0	1	0
TIRUP	198	M	3	34.4	25.7-47.4	3	50-60+	0	0	0	0	0	0	0
TIRUP	200	M	3	30.7	17.7-48.9	3	50-60+	0	0	0	0	0	0	0
TIRUP	201	M	3	44.6	22.4-83.1	4	30-50	0	0	0	0	0	0	0
TIRUP	205	M	5	82.9	67-93.9	8	50+	1	3	1	0	0	2	0
TIRUP	206	M	2	21.1	21.1-31.9	2	40-59	1	3	1	0	0	1	0
TIRUP	207	M	1	18.8	18.8-28.8	1	30-39	1	3	1	0	0	1	0
TIRUP	221	F	4	69.5	36.8-88.1	6	50+	1	1	1	0	0	1	0
TIRUP	223	M	5	73.1	73.1-91.1	7	50-60+	0	0	0	0	0	0	0
TIRUP	226	M	2	26.4	16.2-37.4	2	40-49	0	0	0	0	0	0	0
TIRUP	227	M	2	21.5	21.5-31.8	2	30-44	1	1	1	0	0	1	0
TIRUP	228	F	2	23.4	18.8-29.7	2	39-60+	1	1	1	0	0	1	0
TIRUP	230	F	2	24.3	19.4-31	2	25-30	1	3	1	0	0	1	0
TIRUP	236	M	5	76.2	49.3-90.9	7	55-60+	0	0	0	0	0	0	0
TIRUP	245	M	3	34.1	27.6-43.1	3	30-44	0	0	0	0	0	0	0
TIRUP	249	M	2	23.6	17.9-31.2	2	30-34	0	0	0	0	0	0	0
TIRUP	251	M	3	0	0	0	35-45	0	0	0	0	0	0	0

Cem.	Grave	Sex	Age Gr.	TA P.Est.	TA Age	Obs. Age Gr.	Obs. Age	Def. Pres.	Tra.	Mult. Tra.	CBF	SFT	Fract. Pres.	Disloc.
TIRUP	263	F	5	72.7	34.2-89.9	7	50-52	0	0	0	0	0	0	0
TIRUP	264	M	5	73.1	73.1-91.1	7	30+	0	0	0	0	0	0	0
TIRUP	267	F	3	40	25.3-62.8	3	39-59	1	3	1	0	0	1	0
TIRUP	269	M	2	23.1	23.1-33.8	2	25-34	0	0	0	0	0	0	0
TIRUP	270	M	3	39.7	29.6-57.5	3	44-60+	1	3	2	0	0	2	0
TIRUP	272	F	1	19.3	19.3-46.1	1	30-40	0	0	0	0	0	0	0
TIRUP	274	M	1	15.5	15.5-26.8	1	30-50	0	0	0	0	0	0	0
TIRUP	275	M	3	33.2	22.6-49	3	45-50+	0	0	0	0	0	0	0
TIRUP	276	M	5	75.3	46.8-90.5	7	0	0	0	0	0	0	0	0
TIRUP	280	M	3	32.2	21-48.8	3	40-49	1	1	1	0	0	1	0
TIRUP	281	M	4	57.9	37.1-80.6	5	39-59	1	3	2	0	0	3	0
TIRUP	287	M	3	39.2	30.1-55.2	3	39-50	1	1	2	0	0	2	0
TIRUP	295	M	3	35.8	16.7-70.7	3	35-45	0	0	0	0	0	0	0
TIRUP	299	F	5	74.7	53.4-89.1	7	50+	0	0	0	0	0	0	0
TIRUP	300	F	3	38.5	22.5-65.5	3	35-44	0	0	0	0	0	0	0
TIRUP	301	F	2	0	0	0	25-35	0	0	0	0	0	0	0
TIRUP	303	M	1	15	15-53.9	1	35-40	0	0	0	0	0	0	0
TIRUP	307	M	2	28.1	18.1-39.9	2	40-44	0	0	0	0	0	0	0
TIRUP	316	M	3	34.7	21-55.7	3	50-55	0	0	0	0	0	0	0
TIRUP	317	F	2	25.7	25.7-41.6	2	35-44	0	0	0	0	0	0	0
TIRUP	318	M	3	37.7	29.1-51.5	3	30-44	1	1	2	0	0	2	0
TIRUP	321	M	3	30.6	25.1-38	3	35-44	0	0	0	0	0	0	0
TIRUP	323	M	3	31.4	24.9-41.4	3	25-39	1	3	2	0	0	2	1
TIRUP	325	F	4	60.4	40.5-80.2	5	44-60+	0	0	0	0	0	0	0
TIRUP	326	F	0	0	0	0	0	0	0	0	0	0	0	0
TIRUP	348	M	3	38.6	29.3-54.3	3	30-60+	1	1	2	2	1	2	0
TIRUP	349	M	3	33.5	22.2-51.7	3	39-49	0	0	0	0	0	0	0
TIRUP	352	F	4	55.2	27.6-84.1	5	45-49	0	0	0	0	0	0	0
TIRUP	365	M	3	48.1	26.4-81.2	4	40-45	0	0	0	0	0	0	0
TIRUP	369	F	5	72	41.6-89.1	7	60+	0	0	0	0	0	0	0
TIRUP	370	M	3	37	18.8-68.4	3	50-55	1	2	0	0	0	0	0
TIRUP	372	F	2	23.7	23.7-50.1	2	35-50	0	0	0	0	0	0	0
TIRUP	373	M	3	33.8	26.5-46.1	3	35-59	1	1	2	0	0	3	0
TIRUP	394	M	5	78.3	57.6-91.5	7	50-60+	1	1	2	0	0	3	0
TIRUP	400	F	3	35.1	19.6-59.4	3	25-35	0	0	0	0	0	0	0
TIRUP	402	M	3	33.2	24.6-46.6	3	35-44	1	1	1	0	0	1	0

Cem.	Grave	Sex	Age Gr.	TA P.Est.	TA Age	Obs. Age Gr.	Obs. Age	Def. Pres.	Tra.	Mult. Tra.	CBF	SFT	Fract. Pres.	Disloc.
TIRUP	404	M	3	39.8	31.4-53.8	3	39-59	1	1	2	0	0	2	2
TIRUP	408	F	3	33.4	19.3-54.5	3	50-55	1	1	1	0	0	1	0
TIRUP	409	M	2	27.2	21.5-34.3	2	55-65	1	1	2	1	0	3	0
TIRUP	410	M	3	35.6	27.4-48.1	3	35-59	0	0	0	0	0	0	0
TIRUP	414	F	3	34.3	19.6-60	3	60+	0	0	0	0	0	0	0
TIRUP	446	M	5	82.6	65.3-94	8	60+	1	2	0	0	0	0	0
TIRUP	448	F	3	42.7	25-72.7	4	40-45	1	1	1	0	0	1	0
TIRUP	454	F	2	28.4	28.4-48.7	2	30-45	0	0	0	0	0	0	0
TIRUP	456	M	5	71.7	31..7-89.6	7	25-29	0	0	0	0	0	0	0
TIRUP	457	M	3	34.7	22.4-57.2	3	30-40	1	1	2	2	0	2	0
TIRUP	469	F	5	80.2	64-92	7	39-60+	0	0	0	0	0	0	0
TIRUP	470	M	4	62.7	29.8-86.5	6	40-45	0	0	0	0	0	0	0
TIRUP	473	F	4	63.5	27.4-87.1	6	35-45	0	0	0	0	0	0	0
TIRUP	477	M	2	28.8	15.6-44.9	2	35-40	1	1	1	0	0	1	0
TIRUP	479	M	3	39.4	30.2-55.2	3	50-60	0	0	0	0	0	0	0
TIRUP	514	F	5	79.5	63.6-91.4	7	60-70	1	1	2	0	0	2	0
TIRUP	516	F	5	71.9	39.4-89.3	7	35-44	0	0	0	0	0	0	0
TIRUP	522	F	2	29.4	15.5-53	2	30-40	0	0	0	0	0	0	0
TIRUP	534	M	5	74.9	16.4-91.5	7	30-50	1	1	2	0	0	2	0
TIRUP	538	M	3	38.2	20.3-70.5	3	45-59	0	0	0	0	0	0	0
TIRUP	544	M	2	25.8	25.8-41.7	2	30+	0	0	0	0	0	0	0
TIRUP	553	F	4	51.6	24.2-83.5	5	40-44	0	0	0	0	0	0	0
TIRUP	557	F	2	29.5	18..1-45.6	2	35-40	0	0	0	0	0	0	0
TIRUP	570	F	4	70.4	46.4-87.3	6	30-59	1	1	2	0	0	2	0
TIRUP	587	F	3	33.2	19.7-56.5	3	30-40	0	0	0	0	0	0	0
TOTAL								**41**	**38**	**19**	**5**	**1**	**63**	**3**

Appendix B

Description:

Compilation table of the observed trauma, anomalies, dislocations, fusions, spondylolysis, and *os acromiale* data for each cemetery.

Legend:

Variable	Definition
Sex	M – Male; F – Female
Transition Analysis (TA) Age Group	0 – Ind.; 1 – 10-20 yrs.; 2 – 21-30 yrs.; 3 – 31-40 yrs.; 4 – 41-50 yrs.; 5 – 51-60 yrs.; 6 – 61-70 yrs.; 7 – 71-80 yrs.; 8 – 81-90 yrs.; 9 – 90+ yrs.
Lesion Type	T – Trauma; D – Dislocation; A – Anomaly
Fracture & Trauma Type	Possibilities are abbreviated: Transverse, Oblique, Compression, SFT – Sharp-force Trauma, Spiral, Crush, Butterfly, FF – Fractured Fusion; UC – Unclassified, Stress, Depression, Segmental, Avulsion, and Subluxation (for dislocations only).
Elements	The bones that were fractured or the joints that were dislocated.
Portion	Portion of the bone where the injury occurred, when assessable.
% of Portion Present	Percentages represent: 25% - partial present, 50% - half is present, 75% - most, but not all is present, and 100% all of the portion is present.
Pathologies and Anomalies	Variable possibilities in this category. Assessed macroscopically or by historical or anthropological reports. (TB – Tuberculosis)
Spondo. or *Os Acromiale*	One or both may be present. (Spondo. – Spondylolysis and occurs in L5)
Fusions	Elements that were fused but no causation could be determined. However, those that appeared to result from a traumatic event were specified as so.

HORSENS KLOSTERKIRKE

Sex	TA Age Gr.	Les. Ty.	Frac. & Tra. Ty.	Bones Involved	Port.	% of Port. Pres.	Pathology and Anomalies	SP or *OA*	Fusions
F	3	T	Comp.	T5-T11		100		SP	
M	2	T	Obl.	L. Rad.	Dist.	100			L5-S1 Sacrum to L & R Os Cox.
F	4	T	Comp.	T1-T12 L1-L2		100 100	DISH		L5-S1
M	7	T D	Comp.	T7-T11 R. Hip		100 75			
M	3	T	Tran. Comp.	R. Fem. Neck R. Ribs 11-12 L2-L3	Prox. Mid.	75 100 100			
Ind.	0	T	Comp.	L2-L4		75			
F	6	T	Tran. Comp.	R. Clavicle C6	Lat.	100 100			C7-T1
M	3	—							Manubrium to R & L Rib 1
F	7	—					Osteoarthritis		Unordered Thor. Verts
M	3	T	Comp.	L4-L5		75			Unordered Thor. Verts
M	2	—							L5 to Sacral Alae
M	2	T	Obl. Tran.	R. Radius R. Ribs 5-8	Dist. Mid.	100 100			
M	0	T	Tran.	L. MT 1	Dist.	100			
M	0	T	Tran.	R. Fem. Neck	Prox.	50			
M	3	—							C3-C7 Unordered

									Thoracic
M	0	T D	UC	R. Femur R. Hip	Mid.	100	Pseudojoint		
M	2	T	Comp.	T12		75	Possibly DISH		T7-T13
F	3	___					Tuberculosis		L5-S1
F	2	T	UC UC	R. Tibia R. Fibula	Mid. Mid.	100 100	Periostitis at Fracture Site		
M	3	D		L. Sacroiliac			Periostitis L5 Non-Funct. Cleft		L5-S1
F	2	T D	Comp.	T1-T12 L-L5 R. Hip		75 75			2 Unordered Thor. Verts
F	2	A		L. Hip			Congenital Hip Dysplasia		
M	0	T	Comp.	C7 T1		75 100			L5-S1
F	2	T	Tran.	R. Transverse Process of C7		50			L5-S1
F	0	T	Comp.	L1-L5		100	TB		
M	7	T	Dep. SFT Crush Tran. Obl. Comp. Stress	L. Parietal L. Parietal R. Tibia R. Scapula Unordered Rib L. MC 5 R. Fibula R. Tibia	Post. Post. Mid. Lat. Stern. Mid. Mid. Mid.	100 100 100 75 50 50 100 100			L. Middle & Dist. Phalange ('Claw Pinky')
F	2								L5-S1

M	7	T	SFT	L. Prox. & Med. Phala.	Prox.	25			L. Prox. & Middle Phalanges
M	7	____							T4-T5
F	8	T	Bennett's	L. MC 1	Prox.	100			
F	0	T	SFT Comp.	Unid. Bone L2-L3		 100	Possible Syphilis or Tuberculosis		R. Rib to T8 All Vert Bodies Sternum to Ribs
M	5	T D	Comp. Sublux.	L1-L3 R. Hip		75			Partial L3-L4
M	0	T	Spiral Seg.	R. Tibia R. Fibula	Prox. Mid.	100 100			
M	8	T	Crush	L. Cuboid & Navicular		100			Traumatic Fusion of Cuboid/Navic. R. Rib 1 to Manub.
M	7	T	Comp.	L1-L5		75	DISH		Thoracic Verts
F	2	T	Comp.	T8-T10 L4-L5		75 100			
M	8	T D	Comp. Avul.	L. Fem. Head L2 R. Patella L. Hip	Prox. Lat.	100 100 100	6th Lumbar	SP	
F	3	____							Thoracic Verts 2 Cervical Verts
M	4	T	Comp.	T7-T11		75	Periostitis		
M	3	T	Comp.	L1		100			
M	2	T	Tran.	R. Ischiopubic Ramus		75	6th Lumbar		
F	3	T	Comp.	L5		100			
M	8	T	Avul.	L. Humerus	Mid.	100			L5-S1
F	3	T	Comp. Crush	L3-L5 L. Fem. Neck R. MC 1	 Prox. Prox.	50 75 100			

		D		R. Scaphoid L. & R. Hips					

OLE WORMS GADE

Sex	TA Age Gr.	Les. Ty.	Frac. & Tra. Ty.	Bones Involved	Port.	% of Port. Pres.	Pathology and Anomalies	SP or *OA*	Fusions
M	2						6th Lumbar		L6-S1
M							DISH or Tuberculosis		L5-S1 Several Thoracic Verts
F	5	T	Tran.	R. Ribs 7-10	Stern.	75			
F	2	T	Comp. Dep.	T6-T9 R. Ribs 2-6	 Stern.	50 75			
M	7	T	Comp. Avul.	C1-C7 T1-T12 L1-L5 L. Patella	 Ant.	50 75 100	Leprosy	SP	Vert. bodies L. & R. Rib 1 to Sternum
F	3	T	Comp.	T9-T12		75			
M	3	T	Tran.	Unseri. Rib	Vert.				
M	3	T	Crush	T9 Spino. Proc.		100	L5 Non-Funct. Cleft		L5-S1
F	2	T	Tran. Stress Spiral	R. Ulna L. Fibula R. Tibia R. Fibula	Dist. Mid. Mid. Mid.	100 100 100 100	Periostitis		
M	2	T	Comp.	L2		75			
M	8	T	UC	L. Ulna	Mid.	100			
F	4	T	Comp. Tran.	T2-T5&10-11 L2-L3 L5 Spino.Proc		100 100 100		SP	Vert. Bodies
F	2						Congenital Non-Fusion of the Sternum		L. & R. Rib 1 to Sternum

F	6	T	UC	R. & L. Nasal		100			Traumatic Fusion of Nasals
M	3	T	Comp.	T3-T8		75			
F	8	T	UC Seg. Obl.	L. Fibula L. Ulna L. Radius	Mid. Mid. Mid.	100 100 100	Periostitis		
M	0	T	Comp. Tran.	L1-L2 R. Rib 2-6	 Stern.	75 50			
M	3	T	Avul.	R. Patella	Lat.	75			R. Ribs 6-7
F	1	______		R. Scapula		50		*OA*	
M	0	T	Butterfly Spiral	R. Tibia R. Fibula	Mid. Mid.	100 75	Periostitis		
F	6	______				100	6th Lumbar		L6-S1
M	2	T	Crush Tran. Hairline	R. MC 1 Phal. R. Fibula L. Tibia	Prox. /Med. Mid. Mid.	100 100 100		*OA*	C1 to Occipital C3-C4 C7-T2
F	3	T	Comp.	L5		50			
M	3	T	Tran.	L. Ribs 7-10		75			Unseri. Rib Head to T10 Transverse Proc.
F	8	______							L5-S1
M	4	T	Crush Obl.	R. MC 3 L. Humerus	Prox. Dist.	100 100	Infection w/ Persiostitis		
M	0	T D	Comp.	C3-C7 T1-T12 L1-L5 L. Hip		25 50 50			Thoracic Verts

M	2	T	Comp.	T9-T11		100			
F	3	T A	Tran.	R. Ribs 7-10 L5 R. Scapula	Vert.	100	S1 Non-Funct. Cleft	*OA* SP	
F	2	T	UC	L. Fibula	Mid.	100	Periostitis		
F	4	T D	Dep. Comp. Sublux.	Frontal L. Unseri.Rib L2 R. Hip	Mid. Stern.	100 100			
M	3	T	Obl.	R. Tibia	Mid.	100			Dist. R. Tibia & Fibula
M	2	T	Comp.	S1		75			
M	2	____					DISH		Vert. Bodies
M	2	T	Comp.	L4-L5		100			L5-S1
M	3	T	Tran.	L. Radius	Mid.	100			T9-T10
F	7	T	SFT Comp. Butterfly Obl.	L. Radius T8-T9 L3-L4 L. Ulna L. Radius	Mid. Mid.	50 50	Periostitis		
F	7	T	UC Obl. Crush UC	L. Scapula L. Radius R. MC 4 Phal. L. Femur	Spine Mid. Prox. /Med. Mid.	25 50 100 100			
M	5	____							L5-S1
M	2	T	UC	R. Tibia R. Fibula	Mid. Mid.	100 100	Periostitis		

M	2	T	UC Tran.	L. Clavicle L. Ribs 2-6	Mid. Mid.	100 75	Periostitis		C3-C4
M	7	____							L1-L2 L. & R. Rib 1 to Manubrium

NORDBY

Sex	TA Age Gr.	Les. Ty.	Frac. & Tra. Ty.	Bones Involved	Port.	% of Port. Pres.	Pathology and Anomalies	SP or *OA*	Fusions
F	3	___							L5-S1
M	3	D		R. Elbow					
M	3	T	UC	R. Ulna	Mid.	100			
M	3					50		SP	
M	6	T	Chop Wound UC Comp.	R. Frontal L. Fibula T12	Post. Mid. 	100 100 100			
F	2	T	Stress	R. MT4	Prox.	100			
M	2	T	Comp. UC Stress Tran.	L2-L3 L. Fibula L. Tibia R. Fem. Neck	 Mid. L.Mid. Prox.	100 75 100 50			C3-C4
M	0	T	Stress Stress Crush FF	R. Femur L. Femur C6-T1 Spino. Proc. L1-L2	Prox. Prox. 	75 100 75 100	Severe Infection Possible Scoliosis		
F	8	T	Comp.	L1-L5		100			
F	3	___							C3-T1 L5-S1
M	2	T	Obl. UC Comp.	L. Clavicle L. Scapula T6-T9	Mid. Spine 	100 50 100	Possible DISH or TB		L1-L2

			FF	L5 L. Fem. Head L5-S1	Prox.	100 100			
M	2	T	Dep.	Frontal L. Parietal	Mid. Ant.	100 100	Periostitis		
M	5	T	Comp. Stress Avul.	L1-L3 L. Tibia R. Femur	Mid. Mid.	100 100 100	Infection	SP	
M	3	T	FF	L5 & Sacrum	Sacroil.	100			
M	7	T	Burst Crush UC Colles’ UC	L1 L. MC 5 Med. Dist. Phal. L. MT 2 L. & R. Radius L. Ulna	Mid. Dist. Dist.	100 100 100 75 25	TB		
M	3	T D	Comp.	T1-T12 R. Hip		100	Osteoarthritic Lipping & Periostitis		
M	3	T	Comp.	L2-L5		100			Partial Left Sacroiliac Joint
M	2	——		L5				SP	
F	2	A					S1 Non-Funct. Cleft		
M	4	T D	Comp. Obl. UC	T11-T12 L. Tibia L. Fibula R. Elbow	Dist. Dist.	100 100 100			C2-C5
M	2	T	Chop Wound	Frontal R. Parietal	Mid. Post.	100 100			

M	4	T D	Comp. Dep. L. Knee	L1-L5 L. Patella	 Lat.	100 100	Possible TB		L5-S1
M	8	T	Tran. Tran.	R. Ribs 7-10 R. Ribs 11-12	Mid. Mid.	75 50			
M	3	___		R. Scapula				*OA*	
M	7	T	Comp.	T11-T12		100	TB		L1-L5
M	2	T	Stress	L. Tibia	Mid.	100			
M	3	T	Comp.	L4-L5		100			
M	0	T D	Avul. Crush Sublux.	R. Ischium R. MC 5 Phala. R. Hip	 Med./ Dist.	75 75			Traumatic Fusion of R. MC 5 Phala.
M	2	T	UC	R. Tibia	Mid.	75			
M	4	T	Comp. UC	T11-T12 L1-L5 L. Tibia L. Fibula	 Mid. Mid.	75 100 100 100	Osteomyelitis		Partial R. Sacroiliac Joint Traumatic Fusion of L. Tib./Fib.
M	8	T	Comp.	C3-C7 T1-T12 L1-L5		100 75 100	TB		Vert Bodies L & R. Sacroiliac Joints R. Ribs 7-10
F	7	___							Unseri. Lumbar & Thor. Verts
F	4	T	Avul.	L. Patella	Lat.	100		*OA*	R. Sacroiliac Joint
M	4	T	Comp.	L1-L4		100			
M	2	T	Dep. Comp.	Mandible L3-L5	Med.	100 100	Deep Enthesophyte (Prox R. Hum)		Partial L5-S1
M	2	T	Tran.	Sternum	Lat.	75			L5-S1

TIRUP

Sex	TA Age Gr.	Les. Ty.	Frac. & Tra. Ty.	Bones Involved	Port.	% of Port. Pres.	Pathology and Anomalies	SP or *OA*	Fusions
M	4	T	Avul.	R. Tibia	Prox.	50			
M	3	____				100		SP	
F	4	T	Crush Comp.	R. Medial Cuneiform & MT 1 L1-L2	Prox.	100 100	Leprosy or TB		Traumatic Fusion of R. Med. Cunei. & MT 1
F	3	T	UC Comp.	R. Carpals R. MC 2-4 C3-C7 T1-T12 L1-L5	Dist. Prox.	75 50 50 25 25			Traumatic Fusion of R. Carpals & MC's 2-4
F	3	____				100		SP	
F	5	T	Comp.	T10		100			L5-S1
M	3	____				100		SP	
M	2	T A	Tran. Stress	Stern. Body Unsided MT	 Prox.	75	L5 Non-Funct. Cleft		
F	2	T	Comp.	L2		100	Path of Unk. Origin		
F	2	T	Comp. UC	T11 R. Ulna	 Mid.	100 100			
Ind.	3	T	Comp.	C6		100	Possible Leprosy or TB		C6-C7
F	2	T	Comp. UC	L5 T-T6 Spino. Proc.		100 100			

M	8	T	Comp.	L2-L5		50			Lumbar Verts L. & R. Sacroiliac Joints L. & R. Rib 1 to Manubrium
M	2	T	Tran.	L. Manubrium		100			L2-L4
M	1	T A	Spiral	L. Femur	Mid.	100	6th Lumbar L6 Non-Funct. Cleft		
F	6	T	Colle's	R. Radius	Dist.	100			
M	2	T	Obl.	R. Clavicle	Mid.	75			
F	2	T	Colle's	R. Radius	Dist.	100			
F	2	T	Comp.	L5		100			Partial L5-S1
F	3	T	Comp.	T7-T10		100			L5-S1
M	3	T	Comp.	T6-T8 L2-L3		100 100			R. Rib 1 to Manubrium Partial R. Clavicle to Manubrium
M	3	T	Comp.	L3-L4		100			
M	5	T	Comp. Obl.	T7-T11 L2-L5 R. Fibula	 Dist.	75 100 100			C3-C6 Partial L5-S1 R. Dist. Tibia & Fibula
M	3	T	Comp.	T6-T8 L5		100 100			
M	3	T	Comp. UC	C6-C7 L. Clavicle	 Mid.	100 75	Osteochondritis Dessicans (Dist. R. Fem.)		
M	3	T D	Comp.	T6-T7 & 9-10 L5 R. Hip		75 100			Partials throughout Verts

M	3	T A	UC Dep. SFT	L. Clavicle Medial R./L. Parietals L. Frontal L. Frontal	Stern. Lat. Orb. Marg.	100 100 100 100	C1 Non-Funct. Cleft		
M	3	A					L5 Non-Funct. Cleft		
M	3	T	Comp. Tran.	T-T9 L. Ribs 7-10 R. Rib 2	 Mid. Mid.	100 75 75			
M	7	T	Comp. UC	T11-T12 L1-L5 R. Ribs 7-10	 Vert.	100 100 75	Possible Schmorl's Nodes		
M	3	T	Comp.	L1		100			
M	3	T D	Tran. Comp.	L. Femur L4-L5 L. Hip R. Shoulder	Prox.	75 75			
F	3	T	Dep.	Mandible	Inf. & Ant.	100			
M	2	T	Comp. Dep.	T10-T12 L1-L4 Left Parietal	 Post.	100 100 100			
M	8	___							R. Os Coxa to S1
F	4	T	Spiral	R. Femur	Dist.	75			
M	3	T	Dep.	Frontal Frontal	Med. Med.	100 100	Button Osteoma		
M	2	T	Spiral	R. Fibula	Dist.	100			
F	7	T	Comp.	T5-T7 &10-11 L2-L5		75 100	Possible Leprosy or TB		

M	7	T	Dep. Pos. Crush	Mandible L. Wrist Joint w/ Dist. Ulna & Radius	Inf. & Ant.	100	Possible Leprosy or Tuberculosis		Traumatic Fusion of L. Wrist Joint w/ Dist. Ulna & Radius
F	6	T	Comp.	T4-T5 L4-L5		100 100			

Appendix C

Description:

Tables of cemeteries and the fractured bones and their calculated bone count and segment count frequencies.

Legend:

Variable	Definition
Bone Count	= # of lesions observed ÷ total # of bones *Bone counts can only be calculated for bones that are 100% present.
Segment Count	= (segments w/ fractures ÷ segments observed) X 100% *Segment counts can only be calculated for segments of bone that are ≥ 75% present.
L.	Left side
R.	Right side
P (bone abbr.)	Proximal portion
M (bone abbr.)	Middle portion
D (bone abbr.)	Distal portion

*Note:

The bones reflected in the tables are the bones that exhibited fractures. If bones are not listed in the table, they had no frequency to report and were not a portion of the fractures seen in the sample. Therefore the bones in the tables will differ between cemeteries.

HORSENS KLOSTERKIRKE

	L. MHum	R. MHum	L. DRad	L. PFem	R. PFem	R. MTib	R. MFib	R. Clav	L. Ilium	L. Isch	R. Isch	R. Patella
Bone Count	0.02	0.02	0.06	0.03	0.02	0.06	0.09	0.11	0.08	0.06	0.43	0.02
Segment Count	0.02	0.02	0.04	0.04	0.01	0.06	0.07	0.04	0.03	0.04	0.15	0.02
	Sacrum	R. Carpals	L. Tarsals	L. MT's	L. MC's	R. MC's	Phala	R. MTib	R. Ribs	C1-C7	T1-T12	L1-L5
Bone Count	0.1	0.02	0.02	0.02	0.06	0.03	0.02	0.06	0.09	0.11	0.08	0.06
Segment Count	0.04	0.02	0.02	0.02	0.04	0.04	0.01	0.06	0.07	0.04	0.03	0.04

	L. Parietal
Bone Count	0.05
Segment Count	0.04

OLE WORMS GADE

	L. DHum	R. MRad	L. MUlna	R. DUlna	L. PFem.	L. MTib	R. MTib	L. MFib	R. MFib	L. Clav.	L. Scap
Bone Count	0.02	0.07	0.05	0.03	0.05	0.02	0.1	0.1	0.13	0.04	0.13
Segment Count	0.02	0.07	0.05	0.03	0.04	0.02	0.09	0.07	0.1	0.02	0.05
	L. Isch	R. Isch	L. Patella	R. Patella	Sacrum	R. MC's	L. Ribs	R. Ribs	C1-C7	T1-T12	L1-L5
Bone Count	0.04	0.05	0.03	0.03	0.04	0.09	0.05	0.13	0.02	0.77	0.36
Segment Count	0.02	0.02	0.03	0.03	0.03	0.07	0.03	0.06	0.02	0.26	0.25

	L. Frontal
Bone Count	0.02
Segment Count	0.03

	R. Frontal	L. Parietal	R. Parietal	R. Mandible
Bone Count	0.09	0.03	0.03	0.02
Segment Count	0.08	0.02	0.02	0.02

	R. PHum	L. DRad	R. DRad	L. DUlna	R. MUlna	L. PFem	R. PFem	R. MFem	L. MTib	L. DTib	R. MTib
Bone Count	0.04	0.03	0.04	0.02	0.02	0.06	0.06	0.02	0.09	0.03	0.02
Segment Count	0.03	0.02	0.02	0.02	0.02	0.04	0.04	0.02	0.08	0.02	0.02
	L. MFib	L. DFib	L. Clav	L. Scap	Stern	R. Isch	L.	L. MT's	R. MT's	L. MC's	R. MC's
Bone Count	0.07	0.02	0.04	0.17	0.07	0.03	0.04	0.05	0.04	0.03	0.03
Segment Count	0.06	0.02	0.02	0.04	0.05	0.02	0.04	0.03	0.03	0.02	0.02
	R. Ribs	C1-C7	T1-T12	L1-L5							
Bone Count	0.03	0.02	0.27	0.43							
Segment Count	0.02	0.02	0.017	0.31							

TIRUP

	L. Frontal	R. Frontal	R. Parietal	R. Mandible	L. Mandible
Bone Count	0.03	0.03	0.03	0.01	0.02
Segment Count	0.03	0.03	0.02	0.01	0.01

	R. DRad	R. MUlna	L. Clav	R. Clav	Manub	Stern.	R. Tarsals	L. PFem	L. MFem	R. DFem
Bone Count	0.05	0.02	0.05	0.03	0.04	0.1	0.02	0.03	0.02	0.04
Segment Count	0.03	0.01	0.03	0.01	0.03	0.04	0.02	0.02	0.01	0.02
	R. PTib	R. DFib	R. Carpals	L. MC’s	R. MC’s	L. Ribs	R. Ribs	C1-C7	T1-T12	L1-L5
Bone Count	0.04	0.03	0.12	0.04	0.04	0.04	0.08	0.02	0.39	0.43
Segment Count	0.01	0.03	0.06	0.02	0.02	0.01	0.03	0.01	0.25	0.35

TOTAL

	L. Frontal	R. Frontal	L. Parietal	R. Parietal	R. Mandible
Bone Count	0.01	0.04	0.02	0.005	0.004
Segment Count	0.01	0.03	0.02	0.004	0.004

	L. Tarsals	R. Tarsals	Phalan.	L. Ribs	R. Ribs	T1-T12	L1-L5
Bone Count	0.006	0.006	0.03	0.02	0.07	0.41	0.41
Segment Count	0.005	0.005	0.01	0.01	0.04	0.21	0.29

	L. Scap	R. Scap	Manub.	Sternum	L. Ilium	R. Isch	L. Patella	R. Patella	Sacrum
Bone Count	0.04	0.006	0.05	0.01	0.02	0.05	0.03	0.03	0.03
Segment Count	0.03	0.005	0.03	0.01	0.01	0.03	0.02	0.02	0.01

	L. MHum	L. DHum	R. PHum	R. MHum	L. MRad	R. DRad	L. MUlna	L. DUlna	R. MUlna
Bone Count	0.005	0.007	0.02	0.005	0.02	0.024	0.01	0.006	0.01
Segment Count	0.004	0.005	0.01	0.004	0.02	0.02	0.01	0.006	0.009

	R. DUlna	L. PFem	L. MFem	R. PFem	R. MFem	L. MTib	L. DTib	R. PTib	R. MTib
Bone Count	0.008	0.05	0.004	0.08	0.009	0.02	0.007	0.01	0.04
Segment Count	0.007	0.03	0.004	0.04	0.008	0.02	0.004	0.005	0.04

	L. MFib	L. DFib	R. MFib	R. DFib	L. MT's	R. Carpals	L. MC's	L. Clav	R. Clav
Bone Count	0.04	0.006	0.05	0.01	0.02	0.05	0.03	0.03	0.03
Segment Count	0.03	0.005	0.03	0.01	0.01	0.03	0.02	0.02	0.01

Appendix D

Description:

Tables of all individuals and their corresponding scores for Transition Analysis. For a more detailed definition please see Milner & Boldsen (2011). Numbers are presented as left and right (L, R). Dashes indicate an unscored trait for the left or the right when only one side was observable. Empty columns indicate that those landmarks were not available for scoring.

Legend:

Variable	Description
Individual (Ind.)	The grave number or burial for the individual.
Symphyseal Relief (SR)	1) sharp billowing 2) soft, deep billowing 3) soft, shallow billowing 4) residual billowing 5) flat 6) irregular
Symphyseal Texture (ST)	1) smooth (fine grained) 2) coarse grained 3) microporosity 4) macroporosity
Superior Apex (SA)	1) no protuberance 2) early protuberance 3) late protuberance 4) integrated
Ventral Symphyseal Margin (VSM)	1) serrated 2) beveling 3) rampart formation 4) rampart completion I 5) rampart completion II 6) rim 7) breakdown
Dorsal Symphyseal Margin (DSM)	1) serrated 2) flattening incomplete 3) flattening complete 4) rim 5) breakdown
Superior Demiface Topography (SDT)	1) undulating 2) median elevation 3) flat to irregular
Inferior Demiface Topography (IDT)	1) undulating 2) median elevation 3) flat to irregular
Superior Surface Morphology (SSM)	1) >2/3 covered by billows 2) 1/3-2/3 covered by billows 3) <1/3 covered by billows 4) flat 5) bumps
Apical Surface Morphology (ASM)	1) >2/3 covered by billows 2) 1/3-2/3 covered by billows 3) <1/3 covered by billows 4) flat 5) bumps
Inferior Surface Morphology (ISM)	1) >2/3 covered by billows 2) 1/3-2/3 covered by billows 3) <1/3 covered by billows 4) flat 5) bumps
Inferior Surface Texture	1) smooth 2) microporosity 3) macroporosity
Superior Posterior Iliac Exostoses (SPIE)	1) smooth 2) rounded bony elevations 3) pointed exostoses 4) jagged exostoses 5) touching exostoses 6) fusion
Inferior Posterior Iliac Exostoses (IPIE)	1) smooth 2) rounded bony elevations 3) pointed exostoses 4) jagged exostoses 5) touching exostoses 6) fusion
Posterior Exostoses (PE)	1) smooth 2) rounded exostoses 3) pointed exostoses
Coronal Pterica (C)	1) open 2) juxtaposed 3) partially obliterated 4) punctuated 5) obliterated

Sagittal Obelica (S)	1) open 2) juxtaposed 3) partially obliterated 4) punctuated 5) obliterated
Lambdoidal Asterica (L)	1) open 2) juxtaposed 3) partially obliterated 4) punctuated 5) obliterated
Zygomaticomaxillary Suture (Z)	1) open 2) juxtaposed 3) partially obliterated 4) punctuated 5) obliterated
Interpalatine (IP)	1) open 2) juxtaposed 3) partially obliterated 4) punctuated 5) obliterated

HORSONS KLOSTERKIRKE

Ind.	Pubic Symphysis (L, R)					Iliac Auricular Surface (L, R)									Cranial Sutures (L, R)					AGE
	SR	ST	SA	VSM	DSM	SDT	IDT	SSM	ASM	ISM	IST	SPIE	IPIE	PE	*C*	*S*	*L*	*Z*	*IP*	Years
2005									3, -								1,-			N/A
2014						3,1	2,2	3,4	4,3	4,2	2,1	2,3			-, 4	4	1,1	2,2		32.8
2059	3,-	2,-	1,-	2,-	1,-	3,3	2,2	3,4	3,3	2,4	-,2	6,6				5	1,1	2,-		21
2060	4,-	3,-	3,-	5,-	3,-	-, 3	-, 3	-, 5	-,4	-, 5	-, 3	-, 4			2,-	3	1,-			44.8
2146						2,3	3,2	5,4	3,4	4,5	2,2	2,2	2,-	2,-		5	-,1			74.3
2167																				N/A
2203						3,3	3,3	4,4	3,3	4,4	2,2	2,2	4,2	1,1		5	2,1	2,-	2	40.3
2216	4,4	3,3	4,1	4,5	4,4	2,2	3,3	5,5	3,5	3,2	2,2	3,3	3,3	1,1	5,5	5	4,4	3,2	3	49.2
2220						3,3	3,-	2,3	3,4		2,2	2,3			5,5	4	1,1		1	31.8
2252																				N/A
2256																5	2,2	3,2	3	69.6
2306						3,3	2,3	4,3	3,3	4,3	1,3	2,2		2,-	3,3	5	3,2	3,2		47.6
2315	4,4	2,2		5,6	3,4	2,3	2,2	3,2	3,2	5,4	2,1	2,3	3,3	3,3	5,5	4	1,1	3,-	5	38.2
2338	5,6	2,2	3,3	4,3	3,3	3,3	3,3	5,5	5,3	5,5	2,2	2,-	2,3	2,-	3,3	2	1,1	3,3	3	38
2339	2,2			2,2											-,2	1	1,1	2,2	1	18.4
2351						2,3	2,2	3,5	3,4	4,5	2,3	4,2	4,4	3,3				2,2		73.9
2391	5,5	3,3	-,4	6,4	3,4	-,3	-,2	-,4	-,4	-,5	-,3	-,3			2,3	4	1,1			35.1
2392	-,4	-,3	-,1	-,3	-,1	2,-	1,-	2,-	2,-	2,-	1,-	1,-								21.4
2397	4,4	4,1	1,2	2,2	2,2	3,3	1,2	3,3	3,2	4,3	2,2	2,2	2,2	1,2	2,4	4	1,1	-,2	1	23.8
2409	4,4	3,2	2,1	4,4	2,3	2,3	3,3	2,4	2,4	3,4	3,3	2,2	3,-	2,2	5,4	4	2,1	2,2	3	28.7
2411																				N/A
2427																				N/A
2442	5,4	4,4	4,3	4,4	4,4	3,3	2,2	4,3	3,3	3,3	2,3	-,4			4,-	5		2,2	4	43.9
2452						-,3		-,2	-,2							5		4,5		32.8
2459	-,5	-,2	-,3	-,4																38
2468																				N/A
2475						2,2	2,2	3,3	2,2	2,3	2,3	4,4	3,-	3,-						36.4
2489	4,-	3,-	3,-	5,-	4,-	1,1	2,2	3,4	3,4	4,3	1,2	2,2	2,2	1,1	3,3	4,	1,1	4,-		36.3
2499	4,-	2,-		2,-	2,-	3,-			3,-						-,3	2	,-1	2,-		25.6
2544	4,-	2,-		4,-	2,-	2,3	2,2	3,3	3,2	5,3	2,2	5,2	5,5	1,2						30.6
2570	3,-	2,-	1,-	3,-	2,-	2,2		4,4	3,3			3,3			1,1	2	1,1	2,2		24.4
2573						3,-	3,-	5,-	5,-	5,-	3,-	4,-	5,-	3,-		5				85
2583	5,5	3,3	3,4	6,6	3,3	-,3	-,1	-,4	-,4	-,4	-,2				3,-	5	2,2	2,4		37.6
2587	5,4	3,3		-,6	3,2															31
2593	4,4	3,3	2,1	2,2	1,2	2,2		3,4	3,3			2,-			3,3	5	1,1	-,4	3	21.8
2594						3,2		4,2	4,3			1,-			2,-	2		2,2	1	24.6
2598	-,3	-,2		-,2	-,1	3,3	2,1	2,3	3,5	2,2	2,1	2,2	1,3	1,1				2,2		20.3
2628	-,3	-,2	-,2	-,3	-,2	3,2		4,3	3,3						2,2	4	2,2	3,-	3	25.2
2651																				N/A
2654	-,2	-,2		-,2	-,1	1,2	2,2	3,3	2,3	3,-	1,1	2,2	2,1	1,1						19.5
2680	-,4	-,3	-,3	-,4	-,2	2,3	3,3	3,4	3,3	2,3	3,2	2,3	-,2	-,2						32.4
2693																				N/A
2694	-,5	-,2		-,5	-,4	3,3	3,3	4,3	5,5	5,2	2,2	2,3								40.4
2763	-,5	-,2	-,4	-,6	-,4	3,-	3,-	4,-	3,-	4,-	2,-	4,-	5,-	3,-	5,3	4	4,-	-,2	4	79.4
2768	4,3	2,2	3,2	5,2	2,1	3,1	1,1	3,3	2,2	3,4	1,2	2,2	4,4	1,1	1,1	4	4,4	2,2		23
2770	-,2	-,3		-,4	-,1	3,3	3,3	4,4	4,4	3,4	3,3	3,4	4,-	3,-						25
2782															5,5	4	1,2	4,2	3	71.4
2821						3,2	3,2	4,4	3,4	3,3	2,3	4,2	5,-	3,-		4	-,2	-,5		78.5
2830						2,3	2,-	5,5	5,5	5,-	3,-									82.1
2831																				N/A
2848	4,5	2,2	4,4	4,4	4,4	3,3	3,2	4,4	4,4	4,4	3,3	2,4	-,2	1,2						53.1
2858	4,-				1,-	2,3	2,2	3,3	2,2	3,2	1,2	3,4	3,3	1,3						23.4
2865																				N/A

Ind.	Pubic Symphysis (L, R)					Iliac Auricular Surface (L, R)									Cranial Sutures (L, R)					AGE
	SR	ST	SA	VSM	DSM	SDT	IDT	SSM	ASM	ISM	IST	SPIE	IPIE	PE	*C*	*S*	*L*	*Z*	*IP*	Years
2867	5,5	3,4	4,4	7,7	4,4	-,3		-,5	-,5			6,-			5,5	5		5,-		83.8
2876	4,4		2,2			1,1	2,3	3,4	2,2	4,3	1,3	3,3			1,1	2	1,1	2,-		27.4
2878																				N/A
2883	3,4	2,2	2,2	3,3	3,2	1,1	2,1	3,2	4,2	3,3	2,3	2,2	2,2	1,2	4,3	5	1	2,2	3	26.3
2884						2,-	2,-	4,-	4,-	5,-	3,-	6,-								77.6
2905						2,2	2,-	3,3	4,4	2,-	2,-					4	2,-			31.1
2907	-,6	-,4	-,4	-,7	-,5	3,3	2,3	3,3	3,5	3,3	3,2	3,4	4,2	3,3				2,2		75.7
2914															4,4	4	2,2	2,2	1	30
2915						3,3	-,3	-,4	4,4	-,5	-,3		-,3		4,-	5	4,-	2,-		74.9
2945	5,5	3,2	4,4	4,4	5,5	2,2		3,3	3,3								1,-	2,-		35.4
2947						3,3	3,3	5,5	4,5	5,4	3,2	3,2	3,4	-,3						85.2
2958						3,3		4,4	4,3							4				71.6
3000	-,4	-,2		-,4	-,1	3,3	1,1	4,4	3,3	3,3	1,2	2,2	2,3	1,1						26.4
3001						3,3		4,3	3,5						5,5	5	2,1		1	30.6
3016	-,5	-,3		-,6	-,4	3,3	3,1	4,3	3,2	3,4	3,2	2,-	3,-	2,-		5	1,1			42.9
3024						2,2	2,2	4,3	5,2	3,3	2,3	2,3				5			3	38.6
3026	3,3	3,3	3,2	4,3	2,2	1,1	2,1	3,3	2,2	2,-	2,2	2,-	2,-	1,-						25.5
3028						2,2	2,2	3.3	2.3	4.3	3,2	3,4	4,-	1,-						38.2
3039															2,2	4	1,1			25.9
3066	-,6	-,4	-,4	-,7	-,4	2,3	2,2	4,4	3,3	5,4	3,3	-,4	-,4							80
3081						3,-	3,-	4,-	4,-	4,-	2,-	6,-	3,-	3,-		5	-,2			80.8
3096																				N/A
3097						3,3									-,3	4	2,1	2,-		42
3105						3,3		4,4	4,4			2,3			2,2	2	1,1	2,2		31.7
3106	5,5	4,4	4,-	7,7	5,5	2,3	2,-	4,5	5,5	3,5	3,3	4,4								83.4
3138						2,-	2,-	4,-	3,-	4,-	2,-	2,-	3,-	1,-	2,5		2,-	2,2		33.7

OLE WORMS GADE

Ind.	Pubic Symphysis (L, R)					Iliac Auricular Surface (L, R)									Cranial Sutures (L, R)					AGE
	SR	ST	SA	VSM	DSM	SDT	IDT	SSM	ASM	ISM	IST	SPIE	IPIE	PE	*C*	*S*	*L*	*Z*	*IP*	Years
1003	-,2	-,3	-,1	-,2	-,1	3,3	3,3	3,3	3,3	3,2	2,2	2,2	3,4	1,1						20.2
1004	3,3	3,2	2,2	3,2	2,1	3,3	1,3	3,4	3,4	3,4	3,2	1,2	2,3	1,2						23.2
1006	4,4	2,3	2,2	4,4	2,3	2,3	3,3	4,4	3,2	3,2	2,3	2,3	2,4	2,3				2,2		29.5
1013						-,1	-,2	-,4	-,4	-,4	-2,	-,2	-,4	-,2						35.5
1014	4,4	3,3	4,3	5,3	3,2	2,3	2,2	4,3	4,4	4,3	3,3	4,2	5,4	3,3						32.8
1020	-,4	-,3			-,2	3,3	3,3	5,5	5,5	5,5	3,3	5,2	2,2	2,2						53
1024	5,4	2,3			4,3	1,2		4,4	3,4											36.2
1026	4,5	3,2		-,6	3,-	2,2	2,-	4,4	3,4	4,-	3,-	2,2	1,-	1,-		5				38.9
1027																2	1,1	-,2		18.2
1029	-,4	-,3	-,3	-,3	-,1	-,3		-,4	-,4			-,2								24.3
1032	5,-	3,-	4,-		3,-	3,3	3,2	4,4	3,4	4,3	2,2	3,4	-,4	-,3						69.9
1040	-,5	-,3		-,7	-,4	-,3	-,3	-,4	-,4	-,4	-,3	-,4	-,4	-,3	5,5	5	2,2	4,-	3	80.1
1044	4,4	3,2		-,4	2,2	2,3	2,3	3,2	3,3	3,3	2,2	2,2	4,5	3,3						34.1
1063																		-,4		N/A
1067						2,2	2,2	3,3	2,2	2,3	2,3	4,4	3,-	3,-	5,5	4	2,1			37.5
1074	3,3	3,3	3,-	4,4	3,3	3,3	3,3	3,4	2,3	3,3	2,2	3,2	4,2	2,2				2,2		31.1
1075															-,5			-,2	1	N/A
1085	3,4	2,2	2,3	3,3	2,3	1,1	3,1	3,3	3,3	4,3	2,2	2,6	-,2	-,2						31.1
1086	5,4	3,3	3,3	5,4	4,4	3,3	3,3	4,4	3,3	3,3	2,1	5,2	2,5	2,3		5		2,2		39.7
1088	4,3	2,2	3,2	5,2	2,2	3,2	2,3	4,4	4,4	4,4	2,2	1,-	4,4	1,1	1,-	5	1,1	2,2		26.5
1105						2,3	3,-	3,3	3,3		2,-				4,-			2,2	1	27.8
1114															3,3	4	1,1	2,2		31.4
1132	4,-	3,-		5,-	5,-	3,-	2,-	3,-	3,-	2,-	2,-	3,-	2,-	1,-						43.6
1144	3,-	3,-	3,-	4,-	2,-	2,2		4,4	3,3			3,3	-,4	-,3						29.7
1161	-,3	-,3	-,2	-,3	-,2	3,1	3,2	4,3	3,3	2,3	2,2	2,2	2,2	1,2						24.8
1177	6,6	4,4	4,4	7,7	4,4	3,-	3,-	5,-	5,-		2,-									84.4
1180						3,3	3,3	4,4	4,4	4,3	2,2	2,3	3,4	3,3		2	-,2	-,2		68.1
1186	5,5	3,2	4,4	5,6	4,4	3,3	3,3	4,3	3,3	4,3	2,2	2,3	4,4	2,3	5,5	4	2,1	2,2	1	47.3
1196						2,3	3,3	4,4	4,3	4,4	2,2	2,3	3,4	2,3	5,5	4	2,3	2,2		69.7
1212	3,-	3,-	2,-	3,-	2,-	3,2	3,3	4,4	3,3	3,2	1,2	2,2	3,-	1,-						26.3
1214						2,2	3,1	3,2	2,3	2,3	2,2	2,3	2,3	2,2	5,-	5	4,3	2,-		36.4
1218						3,3	3,2	5,4	4,5	4,4	3,3	4,4	4,4	3,3						81.9
1235																				N/A
1247	5,4	3,3	4,3	7,4	4,2	1,1	3,3	4,3	3,3	3,3	1,2	2,2	4,4	1,1	3,2	3		-,2	1	33.7
1258																4				N/A
1269						2,2	2,-	4,3	4,3			1,3		1,-	5,5	4	2,2		3	34.2
1276	-,3	-,3		-,5	-,3	2,2		4,3	3,4						3,2	3	1,1	2,2	1	27.9
1282						2,2	-,2	3,3	3,3	-,2	-,2	-,3			1,1	1	1,1	2,2	1	20.6
1292															-,2	2		2,2		20.4
1306																				N/A
1340						3,3	3,-	4,4	4,4	5,-	3,-				1,-	1				29.2
1355						3,3	2,2	4,3	4,3	5,4	3,3	4,3	4,4	3,3						69.3
1360	4,4	2,4	2,2	3,3	3,3	3,1	2,2	3,4	3,3	3,3	1,2	2,2	4,3	3,3	4,5	4	1,2		3	30.4
1376						3,2	2,2	3,4	3,3	3,3	2,3	3,3				2		2,-		36.1
1381						1,1	2,3	3,3	3,2	4,3	2,2	2,2	3,3	2,1						27.6
1383	-,4	-,3		-,4	-,2	3,-	3,-	4,-	3,-	3,-	2,-	2,-	3,-	1,-						31.5
1387						2,1	3,2	2,2	1,1	1,2	2,2	2,2	3,3	1,2						18.8
1388																				N/A
1389	4,-	3,-		7,-	5,-	3,3	3,3	5,4	5,5	5,5	3,3	3,-	3,4	3,-						84.4
1401	4,5	3,2	3,3	6,5	4,4	2,3	3,3	3,4	3,5	5,5	3,3	2,2								47.3
1402																5	2,2			N/A
1416	-,3	-,2		-,5		3,3	3,2	4,3	3,3	-,3	-,3	-,3	-,4	-,3	5,5	4	2,2	-,2		74.8
1423																				N/A

Ind.	Pubic Symphysis (L, R)					Iliac Auricular Surface (L, R)									Cranial Sutures (L, R)					AGE
	SR	ST	SA	VSM	DSM	SDT	IDT	SSM	ASM	ISM	IST	SPIE	IPIE	PE	*C*	*S*	*L*	*Z*	*IP*	Years
1427						2,3	2,2	4,3	3,4	3,3	2,2	2,2	3,4	2,2						43.5
1434															5,5	4	2,2	2,2	1	32.1
1439	3,3	3,2	2,2	3,2	2,2	2,3	3,2	3,2	3,3	3,3	2,2	3,3	2,3	2,2	5,5	3	1,2	3,2		26.3
1447	4,4	3,3	4,4	6,7	4,4	2,2	3,2	3,3	3,3	3,2	2,2	2,2	3,3	1,1						44
1448																			3	N/A
1455	-,4	-,3	-,3	-,4	-,2	-,3	-,3	-,3	-,3	-,3	-,2	-,3		-,1						31.2
1478		4,-			5,-	2,3	2,2	2,3	3,3	3,4	3,2	3,3	4,3	1,2						46.1
1485															4,-	2	1,-	-,3	1	21
1498	3,4	3,3	3,3	4,4	2,2	3,-	3,-	4,-	3,-	3,-	3,-	3,-	3,-	2,-						30.3
1511						-,3	-,3	-,4	-,4	-,3	-,2	-,3	-,3	-,2						75.2
1518															5,5		4,2			77.7
1519						-,3	-,3	-,4	-,4	-,3	-,3	-,3	-,4	-,1	3,2	4	1,1	-,2	1	41.3
1520	2,3	3,3	2,-		2,2															21.4
1521						-,3	-,2	-,4	-,2	-,2	-,1	-,2	-,3	-,2						38.4
1524						3,3	3,3	5,4	5,5	5,-	3,3	3,3		-,1	2,2	3	1,1			71.1
1526	3,4	2,2		-,4	2,3	2,2	3,2	3,4	3,3	3,3	2,2		2,2	2,-						29.1
1527						3,3	3,3	4,5	5,4	5,3	3,2	3,3	3,2	2,2						79.5
1540	3,3	3,3	3,-	2,2	3,-	3,3	3,2	4,4	3,3	2,2	2,2	3,3	3,3	1,1						28.2
1543						1,1	3,3	2,3	2,2	4,3	2,2	3,2	3,3	2,2					3	23.3
1547	6,-	4,-		7,-	4,-	2,2	2,2	4,3	3,3	3,3	3,2	2,3	-,3	-,2	1,2	2				37.5
1550	4,4	3,3	3,3	4,3	4,2	3,3	3,2	3,3	5,3	3,3	2,2	3,3	3,3	1,1						31.1
1552	4,4	3,3	2,2	4,3	2,2	3,3	2,3	4,4	4,3	3,3	2,3	3,3	2,3	1,2						29
1553	4,4	3,3	3,3	3,3	3,3	3,2	3,3	3,4	3,3	3,2	2,3	5,3	2,2	1,2	5,5		2,1		4	36.3
1570	5,5	4,4	4,4	7,7	5,5	3,3	3,3	4,4	3,3	4,3	2,2	3,5	3,4	2,2	5,-	5		3,3		80.3
1574						3,3	3,3	5,3	5,5	5,5	3,3	3,3	-,4	-,2						75.3
1575						3,2	2,2	5,4	5,5	5,5	3,3	3,2	4,4	1,1						75.8
1591	-,4	-,3		-,6	-,2	3,3	3,3	4,5	2,5	5,5	3,3	3,3	-,3	1,1						49
1596	4,4	3,3	4,3	3,4	2,2	3,3	3,3	4,4	4,3	3,3	2,2	3,4	3,2	2,2`						33.2
1602																				N/A
1620	5,5	3,2	4,3	6,6	4,4	3,3	3,3	4,3	3,3	5,3	3,3	2,5	3,3	1,1						54.3
1627	5,5	3,3	3,3	5,4	3,-	3,3	3,3	4,3	3,3	3,3	2,2	3,3	3,3	2,2						33.1
1632	4,-	3,-	2,-	4,-	2,-	3,-	3,-	4,-	4,-	5,-	2,-	2,-	2,-	1,-						28.6
1634																				N/A
1638						3,-	3,2	4,-	4,4	4,5	2,3		-,2		-,3	4				75.8
1639	4,4	2,4	2,2	4,4	3,2	3,3	1,2	4,5	2,3	2,2	2,2	2,2	4,3	3,3	4,4	4	1,1			30.3
1640	4,4	3,3	-,3	6,6	3,3	3,3	2,3	4,3	3,2	2,2	2,2	2,2	3,3	2,2						34.8
1642	4,5	3,3	4,4	6,6	4,4	3,3	3,2	4,4	4,4	5,5	3,3	3,3	5,5	2,3						75.4
1643															5,5	5	1,1			71.8
1649																				N/A

NORDBY

Ind.	Pubic Symphysis (L, R)					Iliac Auricular Surface (L, R)									Cranial Sutures (L, R)					AGE
	SR	ST	SA	VSM	DSM	SDT	IDT	SSM	ASM	ISM	IST	SPIE	IPIE	PE	*C*	*S*	*L*	*Z*	*IP*	Years
AD						3,3	2,2	4,4	3,3	3,2	2,2	3,2	3,3	1,2	3,2	4	1,2	2,3	1	38.2
AE	4,4	2,3		4,6	3,4	3,3	3,3	4,4	3,4	3,3	2,2	3,3	3,3	2,2	3,3	5	2,2			39.2
AH	4,4	4,4	3,4	5,6	4,4	2,2	3,2	3,3	3,3	3,4	2,2	3,3	2,4	2,2						39.6
AJ						2,2	2,2	3,4	3,3	3,3	1,2	3,-	2,-	1,-	1,1	2	2,1	2,2	1	28.1
AN	4,4	3,3	3,3	4,4	2,2	3,3	3,3	2,2	3,3	3,4	2,2	3,2	3,2	2,1	3,5	4	2,2	2		31.2
AS						2,3	3,3	4,3	3,3	5,5	3,3	2,2	4,2	3,3	5,3	4	1,1			68.8
AU						-,3	-,3	-,4	-,4	-,4	-,2	-,2	-,2	-,1	2,2	1	1,1		1	26.8
AW						3,3	3,3	4,3	3,2	2,2	2,2	2,-	3,-	1,-		4		1,2	1	29.3
BA	-,4	-,2		-,4	-,2	-,3	-,3	-,2	-,3	-,3	-,2	-,2	-,2	-,1		2	1,1	1,1	1	27.5
BB																				N/A
BC	-,5	-,3	-,3	-,7	-,4	-,3	-,3	-,3	-,3	-,3	-,2	-,2	-,4	-,1	3,2	4	1,1	2,-		44
BD	5,4	3,3	4,-	5,5	2,2	2,3	3,3	3,3	3,3	3,3	2,2	2,3	3,3	1,2		3				31.9
BE						3,-	3,-	5,-	4,-	5,-	3,-									80.7
BF	4,3	3,2	3,3	5,6	2,2	2,1	3,3	4,3	3,3	3,3	2,2	3,3	3,3	1,1	3,4	4	2,2	2,2	1	29.9
BG						3,-	3,-	4,-	4,-	4,-	2,-	3,-								78.1
BH						2,2	3,3	3,4	3,3	3,4	2,2	-,2	-,3	-,1						66.4
BL	6,-	3,-		4,-	2,-	3,3	3,-	4,4	3,3	3,-	3,-	2,3	4,3	1,1	5,5	3	1,2	3,-	3	39.8
BM	3,4	2,3	1,2	3,5	1,4	3,3	3,3	4,5	3,3	4,5	2,3	3,5	2,3	1,2						27.5
BN	4,4	2,2	3,3	4,4	2,2	3,3	3,3	3,3	3,3	3,4	2,2	2,2	3,3	1,1	2,2	2	1,1	2		28.1
BO	4,4	3,3	4,4	4,4	2,-	3,3	3,3	4,4	3,3	3,3	2,2	2,2	2,2	1,1	2,-	2	1,-	-,2		29.9
BP	4,3	4,4	3,-	2,7	2,2	3,2	2,2	4,3	3,3	3,3	2,2	2,2	3,3	1,1		2	1,1	2,3	1	26.8
BQ						3,3	2,2	4,4	3,3	3,3	2,2	3,3	3,4	1,1		3		2,-		55.2
BS	5,5	2,3	4,4	6,5	3,4	3,3	2,3	3,4	3,3	3,4	2,2	2,2	3,3	2,1	2,-		3,-	2,-	1	34.8
BU						3,2		4,3	3,3			3,3		1,1	4,4	3	2,2			35.3
CA						3,3	3,3	4,4	4,3	4,4	3,3	2,3	3,3	2,3		3	1,2	2,-		65.2
CC	5,-	4,-		7,-	4,-	3,3	-,3	4,4	3,3	-,3	-,2	3,-	3,-	1,-	5,5	3	2,2	-,2	3	75.4
CF	4,4	3,3	3,3	5,5	3,2	3,3	3,3	2,3	3,3	3,5	3,3	4,4	2,-	1,1	5,5	4	2,2		3	31.2
CH	-,3	-,2	-,2	-,2	-,2	-,3	-,3	-,3	-,3	-,3	-,2	-,3	-,2	-,1	5,5	3	2,2	-,2		24.8
CM	3,-	2,-	3,-	2,-	2,-	3,-	3,-	4,-	3,-	2,-	1,-	2,-	3,-	1,-						24.9
CQ	3,-	3,-		3,-	2,-	2,2	2,2	2,3	3,2	3,2	2,2	2,2	3,3	1,1	2,3	2	1,1	3,2	1	23.5
CU	4,4	3,3	3,3	6,5	3,2	3,3	3,3	3,3	3,3	3,3	2,2	3,4	3,3	2,2	-,3	4	2,2	2,2	1	31
CV	4,3	3,2	2,3	4,5	2,2	-,3	-,3	-,3	-,2	-,3	-,2	-,2	-,2	-,1	3,3	3	2,1	3		28.4
CX	4,4	3,3	3,2	4,4	2,2	1,2	1,1	2,3	2,3	3,3	2,2	2,2	3,3	1,1	2,2	4	2,2	3,2	1	25.1
CY	5,5	2,4	4,-	6,6	3,3	2,2	2,2	4,4	4,3	3,3	2,2	-,3			3,3	3	1,2	3,3		41.1
CZ	-,3	-,2	-,2	-,3	-,2	3,3	3,3	3,3	3,2	3,3	2,2	2,2	2,2	2,1	5,5	4	2,2		1	26.1
DA	4,4	3,3	3,3	4,4	2,2	3,3	3,2	2,2	2,2	2,3	2,2	3,2	3,3	2,2	3,3	4	2,1	2,2	3	30.2
DC	5,4	3,3	4,4	7,7	4,2	3,3	2,2	4,3	3,3	3,3	2,2	3,2	3,3	2,1	2,2	2	1,1	2,1		32.2
DF	6,6	4,3	3,3	7,3	2,2	3,3	3,2	3,4	3,3	3,3	3,2	3,3	4,3	3,3	2,3	3	1,1	2,2		37.8
DG	5,5	2,2	4,4	6,5	3,3	3,2	3,3	3,4	5,5	4,4	3,3	2,3	2,3	2,2	5,5	5	3,3	3,2		41.9
DJ						3,-	3,-	5,-	5,5	5,-	3,-	4,3	3,3	3,3						85.1
DK	4,5	2,2	3,3	5,5	3,4	3,3	3,3	4,4	2,2	3,4	2,3	3,3	3,3	1,2						37.5
DM	5,-	3,-		7,-	4,-	3,-	3,-	3,-	3,-	3,-	2,-	3,-	3,-	1,-						74.1
DN	4,4	3,3	3,2	3,3	2,2	3,3	2,2	3,3	3,2	2,2	2,3	2,3	3,3	1,1		4				27.3
DR	4,4	3,3	3,3	5,6	2,2	3,3	3,3	3,3	4,3	3,3	2,2	2,3	3,3	1,1	5,3	5	2,2			33.3
DS	4,4	3,4	4,3	6,5	4,4	3,3	3,3	5,5	5,5	5,5	2,2	3,2	3,3	1,2						69.4
DZ																				N/A
EB	5,4	3,3	3,-	6,7	4,4	3,-	3,-	3,-	3,-	3,-	2,-	3,-	4,-	1,-						65.9
EM	4,-	3,-	3,-	3,-	2,-	3,2	3,3	4,3	3,3	3,3	3,3	3,3	3,2	2,2						30.4

Ind.	Pubic Symphysis (L, R)					Iliac Auricular Surface (L, R)									Cranial Sutures (L, R)					AGE
	SR	ST	SA	VSM	DSM	SDT	IDT	SSM	ASM	ISM	IST	SPIE	IPIE	PE	*C*	*S*	*L*	*Z*	*IP*	Years
EQ						3,3	3,2	4,4	3,3	4,3	2,2	3,3	3,3	1,1						69.7
ES	5,4	2,2		6,6	4,3	3,3	3,3	4,3	3,3	3,4	3,3	5,6	3,3	3,3						42.3
EV	-,6	-,3		-,7	-,4	3,3	3,3	4,4	3,3	3,4	3,2	2,3	3,3	2,2						74.6
EX						3,3	3,3	5,5	5,5	5,5	3,3	6,5	3,3	3,1				-,2		86.3
EZ	5,-	4,-	4,-	6,-	4,-	3,2		4,4	-,3			3,3			3,-	2	2,1	2,2	1	43.9
FC						3,3	3,3	5,4	4,5	5,4	3,3	3,2	2,2	1,2						74.3
FE	4,-	2,-		5,-	3,-	3,3	3,3	4,3	4,4	3,5	2,2	3,3	3,3	2,3				2,-		42.8
FF	6,-	2,-	3,-	5,-	4,-	3,3	3,3	3,4	3,3	3,3	1,2	3,3	3,3	2,3						49.2
FN	4,5	3,2	3,3	6,6	4,4	3,2	2,2	3,3	3,2	2,2	2,2	2,2	2,2	1,1		4	2,2			38.1
GR						2,2	3,3	4,4	5,3	4,3	2,3	3,3	3,4	3,3						78.6
Q	6,-	4,-	4,-	7,-	5,-	3,3	3,2	4,3	4,4	4,4	2,2	5,2	3,3	2,2	5,5	4	2,2	2,2		70.4
R	2,2	3,3	1,-	2,2	1,2	1,3	3,3	4,3	3,2	3,2	2,2	2,2	3,3	1,2	3,2	3	2,1			21.4
U						3,2	3,3	4,3	4,3	4,4	4,2	3,-	3,3	3,3	3,-	2	2,2	3,-		47
V						2,-	2,-	4,-	3,-	3,-	2,-	3,-	3,-	3,-						74.1
W						-,3	-,3	-,3	-,4	-,4	-,2	-,2	-,3	-,1	3,-	3	2,2		3	41.4
X						3,2	3,3	4,4	4,4	4,3	2,2	2,2	-,2	1,1				2,-	5	69.4
Y						3,3	3,3	2,3	3,3	2,2	2,2	2,3	3,4	1,1				2,-		26.7
Z						3,3	3,3	4,4	4,3	4,3	2,3	3,2	3,3	3,2						76.6

TIRUP

Ind.	Pubic Symphysis (L, R)					Iliac Auricular Surface (L, R)									Cranial Sutures (L, R)					AGE
	SR	ST	SA	VSM	DSM	SDT	IDT	SSM	ASM	ISM	IST	SPIE	IPIE	PE	*C*	*S*	*L*	*Z*	*IP*	Years
10																				N/A
14																				N/A
15																				N/A
37	-,5	-,3		-,6	-,4	-,3	-,2	-,3	-,3	-,3	-,2		-,3	-,2		4				43.7
39						3,3		4,4	4,4			2,3	-,3	1,1	1,1	2	1,1			35
40						3,-	2,-	4,-	2,-	2,-	2,-		3,-							52.8
41						3,3	2,2	4,4	3,3	3,3	2,2	2,2	3,3	2,3						69
46																				N/A
75						3,3	3,3	3,4	3,3	2,3	2,2	2,2	3,2	1,1	2,2	4	1,1	-,2		31.4
76						3,3	3,3	3,3	3,3	3,3	2,2	3,2	3,3	2,2						38
77	4,5	3,3	4,4	6,6	4,4	3,-	2,-	4,-	3,-	3,-	2,-	3,-	3,-	2,-	2,3	3	1,1			49.2
79						3,-		4,-	3,-			2,-			5,5	5	1,2	2		38
86	4,-	4,-	4,-	6,-	2,-	2,2	2,3	3,3	3,3	3,3	3,2	3,3	4,3	2,2	2,2	3	1,1	-,2	1	32.1
89	3,4	3,3		5,5	3,2	3,3	3,3	4,3	3,3	4,3	2,2		3,2	2,2	4,-	5	2,3			29.9
91	4,4	3,3	3,3	2,5	4,4	3,3	3,3	4,3	3,2	3,3	2,2	3,3	2,2	2,2	5,3	4	2,1	2,-	1	31.2
94	-,4	-,3		-,3	-,2	3,3	3,3	3,3	4,3	3,3	2,2			3,-						28.1
95						-,2	-,2	-,3	-,3	-,3	-,2	-,3	-,2	-,1	2,2	4		2,-	1	23.7
96						3,3	3,-	4,3	3,-	4,-	2,-	2,3	2,3	1,1	2,2	1	1,2	-,2	1	26.5
113						2,2	3,3	3,3	3,4	3,4	2,2	2,2	3,2	2,1						33.8
129	4,4	3,2	3,-	5,5	3,3	3,3	3,2	3,3	3,3	-,3	-,2	-,3	-,3	-,2	3,2	3	1,1	2,2	3	33.1
130						2,-	2,-	2,-	3,-	3,-	2,-	3,-	4,-	1,-	2,2	3	2,1			31.2
142						3,3	3,3	4,5	4,4	4,4	3,2	2,3	3,3	1,2	2,2	2	2,2	-,2		55.1
143						2,3	3,2	3,3	2,3	3,3	2,2	3,2	3,3	1,2						34.8
146	3,3	3,3		3,3	2,2	3,3	3,3	3,3	3,2	3,2	2,2	2,2	3,3	1,2	2,-	3		2,-		25.2
155						-,3	-,3	-,4	-,3	-,3	-,2	-,2	-,2	-,1		4	2,-			73
168						2,3	2,2	3,3	4,3	-,3	-,2	3,-	3,-	1,-	2,2	2	2,2	3,2	1	27.3
187	-,4	-,3			-,2	2,2	3,2	4,3	2,2	3,3	2,2	3,3	3,4	2,2	3,2	2	2,1	2,-	1	29.1
188	3,-	3,-	2,-	3,-	2,-	3,3	3,3	3,3	3,3	2,3	2,2	3,3	3,3	2,1	3,5	4	1,1			25.9
189	5,5	3,3		6,6	4,-	3,3	2,3	3,3	2,2	3,3	2,2	2,2	3,3	2,2	-,5	4	1,1	2,3		38.9
196						3,-		3,-	2,-						3,3	3	1,1	2,2	1	30.5
197						3,3	3,3	3,4	2,3	2,2	2,2	3,3	2,3	1,1	2,-	2	1,1	2,-	1	29.1
198	4,4	3,3		-,3	3,3	3,3	2,2	4,3	3,4	4,3	3,3	3,-	3,-	3,3		5	-,3	3,-		34.4
200						3,2	2,2	4,3	4,3	3,3	2,2	2,3	3,3	2,2		2	1,-		1	30.7
201						3,-	3,-	4,-	4,-	3,-	2,-	2,-	2,-	1,-	-,2	2	1,1			44.6
205	-,6	-,4		-,7	-,4	-,3	-,3	-,5	-,5		-,2	-,6			5,5	5	2,3	2,2	4	82.9
206						2,1	2,2	4,3	3,2	2,2	2,2	3,3	3,3	1,1	2,1	5	1,1	2,2	1	21.1
207						3,2	3,3	2,3	2,3	2,3	2,2	1,2	3,3	1,1	1,2	1	1,1		1	18.8
221						3,3		3,4	3,3		-,3	-,3		-,3	5,-	4	2,2	2,-		69.5
223																4	2,2			73.1
226						3,3	3,3	3,4	2,3	2,2	2,2	3,3	2,3	1,1	2,1	2	1,1	2,2	1	26.4
227						3,3	3,3	4,3	2,3	2,3	2,2	2,2	2,3	1,1	2,2	1	1,1	2,2	1	21.5
228	4,4	3,3	-,1	2,2	1,1	3,2	2,2	4,3	3,4	4,3	2,2	3,3	3,3	1,1	5,2	2	1,1	-,2		23.4
230	3,3	2,3		-,2	2,2	3,3	3,3	4,3	3,2	3,3	2,2	2,3	3,3	1,1	2,2	2	1,1			24.3
236						3,3	3,3	4,4	4,4	5,5	3,3		3,3		3,3	5	2,2			76.2
245	3,3	2,3	3,3	4,4	3,4	3,3	3,3	4,4	3,3	3,3	2,2	3,3	3,3	2,2	5,5	2	2,1			34.1
249	3,-	3,-			2,-	3,-	3,-	2,-	2,-	2,-	2,-			1,-	2,2	3,	1,1			23.6
251																				N/A
263						3,-	3,-	4,-	4,-	3,-	3,-		3,-				1,1			72.7

Ind.	Pubic Symphysis (L, R)					Iliac Auricular Surface (L, R)									Cranial Sutures (L, R)					AGE
	SR	ST	SA	VSM	DSM	SDT	IDT	SSM	ASM	ISM	IST	SPIE	IPIE	PE	*C*	*S*	*L*	*Z*	*IP*	Years
264																4	2,2			73.1
267						2,3	2,3	4,3	4,3	3,3	2,2	2,2	3,3	2,2	5,5	3	2,2	2,2	3	40
269						2,2	2,2	3,3	4,3	3,3	2,2	3,2	3,3	2,1	2,2	1	2,1	2,2		23.1
270	5,5	4,4	4,-	5,5	3,-	3,3	3,3	3,4	4,3	5,3	3,2	3,3		2,2						39.7
272															2,2	2				19.3
274						3,3	2,2	2,3	2,2	2,2	2,2	2,2	2,2	1,1	2,2	1	1,1		1	15.5
275						3,3	3,3	4,4	4,3	5,3	2,2	3,3	3,3	1,2	2,1	2	1,1	2,2	3	33.2
276						3,3	3,3	3,5	4,3	5,5	3,3	3,2	3,4	1,1					1	76.3
280						2,2	3,1	3,2	3,3	3,2	2,2		-,3		5,5	2,	1,1	2,2		32.2
281	5,-	4,-	4,-	6,-	4,-	3,3	3,3	5,3	5,3	4,4	3,2	3,-	3,2	2,2	3,3	5	2,2	2,2		57.9
287	5,5	3,3	4,-	6,-	3,4	3,3	3,3	4,3	3,3	3,3	2,2	3,3	3,3	2,2						39.2
295						3,-		3,-	3,-							5	2,2	2,2	3	35.8
299	6,6	4,4	-,4	7,-	4,5	3,3		4,4	3,4			-,3			3,-	4	2,-		1	74.7
300						3,2	3,3	4,3	4,3	3,2	2,2	3,3	2,2	1,1	5,5					38.5
301																				N/A
303																	2,-		1	15
307						2,3	3,3	4,3	3,3	3,3	2,2	3,3	3,3	1,1	2,2	3	2,1	2,2	1	28.1
316						2,3	2,3	3,3	3,3	3,4	2,2		3,3	1,1		3	1,2	2,-	3	34.7
317						3,3	3,3	2,3	1,3	2,3	2,2	3,2	3,2	1,1						25.7
318	5,4	3,3		6,6	3,3	3,3	3,3	4,3	3,3	3,3	2,2	3,2	3,3	2,2	5,5	3	2,2	2,2	5	37.7
321	4,4	2,2	3,-	5,4	2,2	2,3	3,3	4,4	3,3	5,3	3,2	5,5	3,2	2,2	2,2	2	1,1	2,2		30.6
323	4,4	3,3	4,4	3,3	2,2	3,2	2,3	4,3	3,2	3,3	2,2	3,3	-,3	1,1	5,5	5	2,2	-,2	3	31.4
325	5,5	3,3	4,-	6,6	4,3	3,3	3,3	5,4	4,4	4,4	3,3	3,2	2,3	1,1	5,5	4	2,1			60.4
326																5				N/A
348	4,-	2,-		5,-	4,-	2,2	3,3	4,2	3,3	4,3	2,2	3,2	3,3	2,1	5,5	4	1,1	2,2		38.6
349						3,3	3,3	3,3	3,3	2,4	2,2	3,-	3,-	1,-	3,-	4	1,1	2,-		33.5
352						-,3	-,3	-,4	-,3	-,4	-,1	-,3	-,4	-,1	5,5	2	1,-			55.2
365						3,2	3,3	4,3	3,3	4,3	2,2	2,3	3,3	2,2	-,2	4				48.1
369	6,6	4,3		7,7	4,4	-,3		-,3	-,3						5,5	4				72
370						3,3	2,2	3,3	3,3	3,3	2,2	5,5	3,3	2,2						37
372															5,5	1	2,1	2,2	3	23.7
373	4,4	2,3	4,3	5,5	2,2	3,3	2,2	4,4	3,3	3,3	2,2	-,2	2,3	1,2						33.8
394						3,3	3,3	4,5	4,4	3,5	2,3	3,3	3,3	3,3	5,5	5	2,2	1,-	3	78.3
400						3,3	2,2	3,2	4,3	3,4	2,2	2,2	2,3	1,1				1,1		35.1
402	-,4	-,3		-,4	-,2	3,3	3,3	4,4	3,4	3,3	2,2	2,2	2,2	1,1						33.2
404	4,6	3,4	3,3	5,7	3,5	3,3	3,3	4,3	4,3	4,4	3,2							2,-		39.8
408						2,2	2,2	4,3	3,3	3,-	2,3	2,2	3,2	1,1	5,5	5	2,2	2,-		33.4
409	-,4	-,3		-,4	-,2	2,2	3,3	3,3	3,2	3,2	2,2	3,2	-,2	2,2	2,2	3,	1,-	-,2	1	27.2
410	4,4	2,2	3,3	6,6	3,3	2,3	2,2	3,3	3,4	4,3	2,2	3,2	3,3	1,1						35.6
414						2,2	3,3	4,4	3,3	2,2	2,2	3,-	3,3	1,2		1	1,1	-,2		34.3
446						3,3	3,3	3,5	5,5	5,-	3,-	5,6	3,-	2,-	5,5	4	2,2	-,2		82.6
448						3,3	2,3	4,3	3,3	3,4	2,2		3,3	1,2	5,3	4	1,1			42.7
454						-,3	3,3		4,-	4,-	2,2		-,2	-,1	2,1	2	1,1		1	28.4
456						3,3	3,3	4,-	4,4	4,4	2,2	1,1	2,2	1,1						71.7
457						-,3	3,2	-,3	4,3	4,4	2,2				5,5	4	2,2	2,2	1	34.7
469	6,6	4,3	4,4	7,6	5,5	3,3		4,4	5,5					-,2	5,5	2	2,2	-,2		80.2
470						3,2	2,2	4,3	4,5	4,4	2,2	5,5								62.7
473						3,3		4,4	-,3		-,2				5,5	4	2,2	2,-		63.5
477						-,2	-,3	-,3	-,2	-,2	-,2	-,3		-,1	5,-	5	1,-	2,-		28.8
479	5,5	2,2	4,4	6,5	3,3	3,3	2,3	4,4	3,3	3,5	2,2	-,2	3,2	1,1		5				39.4

Ind.	Pubic Symphysis (L, R)					Iliac Auricular Surface (L, R)									Cranial Sutures (L, R)					AGE
	SR	ST	SA	VSM	DSM	SDT	IDT	SSM	ASM	ISM	IST	SPIE	IPIE	PE	*C*	*S*	*L*	*Z*	*IP*	Years
514	6,6	4,4	4,4	7,7	5,5	2,3	2,3	4,4	3,4	3,4	2,3	3,3	3,5	3,3	5,5	5	2,3	2,2		79.5
516						2,-	3,-	5,-	4,-	5,-	3,-	3,-		1,-		3	1,1		3	71.9
522						3,3	2,2	3,3	3,3	3,3	2,2		3,3	1,1			2,-			29.4
534															-,5	4			3	74.9
538						3,3	3,3	4,3	3,3	3,2	2,2	3,2	3,2	1,1						38.2
544															3,-	2	1,1	2,-	1	25.8
553						3,3	-,3	4,4	3,3	-,3	-,2	-,2	-,2	-,1						51.6
557						2,2	3,3	3,3	3,3	2,3	2,2	3,2	3,3	1,1	3,-	3	1,-	-,2	1	29.5
570	4,-	4,-		6,-	5,-	2,-	3,-	4,-	5,-	3,-	2,-	3,-	3,-	1,-	5,-	4	1,2	2,2	3	70.4
587						3,4	2,4	4,3	3,2	3,2	2,2	3,3	3,1	2,2						33.2