ABSTRACT

WELSER, ALISON GUYITT. Examining Patterns and Relationships of Degenerative Joint Disease in a Historic Population. (Under the direction of Dr. D. Troy Case).

This study examines potential relationships between physically taxing occupations and degenerative joint changes. There have been many similar studies, but studies that examine multiple regions of the body for degenerative change and examine their relationships to a quantifiable activity variable are limited. For this analysis, gleno-humeral osteoarthritis, rotator cuff disease, and intervertebral disc disease were selected for examination, as all have been associated with over-loading of the joints in anthropological or clinical literature.

The humerii, scapulae, and vertebrae of 195 individuals from the Robert J. Terry Anatomical Collection were examined macroscopically for evidence of the aforementioned diseases. All individuals with a specified occupation, a documented age-at-death between 30 and 88 years, and who were of African-American or European-American ancestry, were selected for analysis. Occupational stress – categorized as light, moderate, or heavy – was one of several etiological factors examined to assess which may actually contribute to disease development. Approaching the study, it was expected that correlations would be found between all three joint diseases and the activity variable. Based on this premise, it was expected that different patterns of joint disease development would be visible between the two ancestries and between the sexes based on the historical context of the sample.

Of the etiological factors examined here, age had a clear effect on osteoarthritis, as did ancestry, and these two factors also have an effect on the severity of the disease. However, there is a considerable difference in age between the two ancestral groups, so the effect on ancestry may, partially or fully, be an age effect. Ancestry, age, and sex have an

effect on rotator cuff disease development, while only ancestry and birth decade affect the severity of the disease. Ancestry and age were found to have an effect on intervertebral disc disease development, and these factors in combination with occupation affect the severity of the disease.

Joint diseases have been used in past literature to make inferences about many aspects of past civilizations, but in recent literature, many researchers have questioned the approach. Based on the findings of this study, relying less on osteoarthritis alone to derive the past seems justifiable, but perhaps there are other areas of the body and other joint diseases that might contribute more to activity-related study.

Examining Patterns and Relationships of Degenerative Joint Disease in a Historic Population

by
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DEDICATION

For my parents and sister, the people who keep me going.

BIOGRAPHY

Alison Welser was born and raised in beautiful Mayo, Maryland. Her love of traveling, culture, and digging in the dirt led her to introductory courses in anthropology and archaeology, and her love for these subjects was undeniable. Alison completed her undergraduate studies at the College of Charleston, graduating with a Bachelor's of Science in Anthropology and two minors, one in archaeology and one in music. Her love for archaeology and her fascination with the human skeleton led her to her current position, as a Master's student of Anthropology at North Carolina State University.

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CHAPTER 1

INTRODUCTION

It seems there is no limit to what one can learn through the study of the human skeleton. As a field that continues to expand its reach, bioarchaeology has used the holistic approach of anthropology to delve into studies that both utilize, and have implications for, a wide variety of other fields. Perhaps the most impressive progress made by this field of study is in its examination and analysis of health and disease; it continues to divulge invaluable knowledge that can, in particular, provide new insight into human populations that are long since gone from the world.

The study of joint diseases by means of the human skeleton is not a new concept. Nevertheless, it has become an increasingly vital tool in bioarchaeological research in recent years. In a bioarchaeological context, researchers have found studies of degenerative diseases of the skeleton - including interpretation of their prevalence and pattern - to be useful in reconstructing activity patterns of past populations (Henderson and Cardoso, 2013; Larsen, 2006; Schrader, 2012; Palmer et al., 2014). As one prominent bioarchaeologist states, “Biomechanical evidence provides clear biological evidence for changing patterns of lifestyle and behavior not possible from other sources” (Larsen, 2006:367). In recent years, bioarchaeologists have attempted to discern not only levels of physical activity, but also such precise details as the type of activity that led to the changes observed on the skeleton and the sexual division of labor (Merbs, 1983; Sofaer Derevenski, 2000; Nagy, 2000). The pursuit of this particular knowledge - the drive to understand aspects of the daily lives of past peoples –

such as the activities engaged in, and by whom, has been described by some as the "Holy Grail of bioarchaeology" (Jurmain et al., 2012).

However, behavioral reconstruction of past populations based on the presence and prevalence of joint diseases can be complex. Like many methods, it should be approached and applied with care until more comprehensive studies on a wealth of disease patterns have been conducted. A holistic approach to the study of human beings necessitates an understanding of the variation between and within populations that have existed and evolved throughout history and prehistory. Contemporary medicine has taught us that variation exists in the way in which diseases affect people of different ancestral backgrounds (Allen et al., 2010; Anaya et al., 2013; CDC, 1996; Hoaglund, 2013). In some cases, one ancestral group may be genetically predisposed to developing a certain disease, while in other cases, one group might exhibit more disease than another because of greater exposure to poor living and working conditions. This is an issue that may be relevant to the current study, as the historic population examined experienced disparities of living and labor conditions, among other problems. As many times and ways that disease has been examined through bioarchaeology and paleopathology, there are still many aspects of disease that remain a mystery, and many problems that arise in the application of bioarchaeological knowledge to past populations. If we are truly able to use the results to examine the past, it is important that these studies continue to be carried out on various populations across a wide range of time periods.

Of the many kinds of joint disease than bioarchaeologists can use to reconstruct labor patterns, osteoarthritis is exceedingly popular. It is a disease largely caused by "wear and tear," and therefore has been used to make inferences about the physical activity and lifestyles of past populations (Larsen, 2006). Two joint diseases that are closely related to osteoarthritis were selected for study, as they are similarly associated with overuse and overloading of the joints. Rotator cuff disease, which affects the humeral head, and intervertebral disc disease, a condition of the spine, were chosen for macroscopic examination, along with osteoarthritis of the gleno-humeral joint. All three have been associated with activity in the clinical literature, and the shoulder was of particular interest because it is not a weight-bearing joint. If, as is hypothesized here, there is a true relationship between degenerative joint disease and activity, then differences in activity between groups should be best seen in a joint that is utilized more by some groups than by others. Weight-bearing joints, like the knees and hips, are more susceptible to joint disease Though diagnostic criteria for these diseases have been debated in the anthropological and palaeopathological literature, there are symptoms that manifest in the skeleton that many consider indicative of these diseases. Waldron (2009) produced the standards that were used for the identification of all three diseases in this study. For osteoarthritis, the presence of eburnation, marginal osteophytes, new bone on the joint surface, and/or pitting on the joint surface are suggestive of osteoarthritis. With intervertebral disc disease, the bodies of the vertebrae are of concern, which will display some level of pitting and osteophytic growth. Rotator cuff disease creates pitting in areas of the rotator cuff muscle insertion, as well as new bone growth in these areas and alteration to the contour of the insertion areas. Various researchers have pursued the etiologies of these diseases in an attempt to apply their studies to archaeological populations, and it is clear to all who have pursued such studies that the etiologies are complex and multi-factorial. One of the goals of this study is to better narrow the list of contributing factors, and to potentially discern which factors have the biggest role to play in joint disease development.

In studying joint diseases within this context, it must be acknowledged that biological factors such as age, sex, and ancestry may all have implications for labor within a society. Examining patterns of skeletal degeneration can help illuminate the interactions and results of these etiological components. To accomplish that task in this study, 195 individuals were selected for analysis from the Robert J. Terry Anatomical Collection, a skeletal collection of individuals who lived, worked, and died in St. Louis and surrounding areas of Missouri throughout the 19th and 20th centuries (Hunt and Albanese, 2005). All of these individuals had a record of the occupation which they held at the time of their death. The vertebral columns, humerii, and scapulae of the selected individuals were examined macroscopically for the presence of the three joint diseases mentioned above. The aim of this paper is to present the pathological analysis of the chosen population within a historically documented context, in an attempt to garner a better understanding of the population-specific behavior of the diseases selected for study.

In order to examine potential disease etiologies from all angles, individuals were grouped by age, sex, ancestry, and occupational category for statistical analysis. Approaching this study, I expected to find significant correlations between joint disease and occupations with heavy physical workloads. I also expected to find a greater number of African American individuals affected by joint disease overall, based on the historical context applied to the sample of study. The aforementioned context came from research on the history and development of St. Louis and the effects on the people who called it home.

The chapter that follows examines the historical setting in which the studied individuals lived, providing insight into such things as the hierarchy of labor and the living and working conditions during the time period in question. The subsequent chapters detail the materials and methods of this study, review the literature from bioarchaeological and paleopathological standpoints as well as materials from contemporary medical literature, and present the results of the study and discuss the implications. The thesis closes with possible directions for future research based on the findings of this study.

The information that can be gleaned from this study may have significance for several fields, both within anthropology and outside it. First and foremost, the osteological evidence of joint diseases within this population and the accompanying contextualization is potentially valuable information to researchers who work on the Terry Collection, as well as to historians who delve into the Industrial Revolution period in the U.S. Second, this study has the ability to examine correlations between an activity variable (an individual’s occupation) and different joint diseases. In doing this, the three joint diseases can be evaluated for their usefulness as potential indicators of activity level, which is valuable knowledge for future studies of this nature, particularly those which seek to explore other joint diseases besides the heavily used osteoarthritis.

CHAPTER 2

POPULATION BACKGROUND

Early St. Louis: Growth, Change, and Troubles

The individuals in this study lived and died in Missouri during a period spanning from the early 1840s to the early 1940s. This time period represents several transitions in American history, including the interconnection of the nation through railroads, the Civil War, the abolition of slavery, a period of unparalleled growth and prosperity, and a period of dramatic decline during the Great Depression. This period triggered a shift from small farmsteads to industrial cities, and produced jobs that required low wages, long hours, and tediously repetitive tasks (Dubofsky, 1996). Though national prosperity was the general marked result, this economic improvement most often came at the expense of the people who were key to bringing it about. The economy of this period was unstable, and a scramble for industrialization created a turbulent life for the average American citizen. Some likened the lives and conditions of the working class to those of the slaves in the south and suggested that the rise of the industrial economy "had resulted in perhaps unavoidable inequalities between 'masters' and 'workers'" (Henretta et al., 2008).

St. Louis, located on the Mississippi River, became a major river port following the invention of the steamboat in the early 1800s. The times that followed saw the same regional economic specialization and interregional trade that gave rise to the "factory system" across the United States (Purdy, 1945). However, like many other American cities at this time, the good and bad times ebbed and flowed. Before the city could reach its booming best, it had to suffer hard times. Life in St. Louis in the 1820s was characterized by depression and business failure, and rampant disease meant that the city's population decreased at one point to only 3,000 people, when just years before it had seemed the city was destined to be large and thriving (Primm, 1998). However, continued work by its few remaining inhabitants, along with an influx of migrants from the Southeast allowed for a renewed drive toward the dream of a prosperous metropolis. It was estimated that the population grew more than 50% in only four short years, from 1865 to 1869 (Parrish, 1973). A growing city meant there was no shortage of jobs, particularly for bricklayers, carpenters, laborers, and the like (Primm, 1998).

The main revenue of the state originally came from its farms, but there was also profit to be had in mining, as well as manufacture of clothing, liquor, and canned goods, among others (Violette, 1918). Previous to the industrialization of the state, its farmlands were valued at $231 million, and the early 1800s were a prosperous time for the farming industry (Primm, 1998). In the shift from small farming operations to large-scale industrialization, some farmers scrambled to incorporate technological advancements, while others attempted to resist the sweeping changes (Steiner, 2004). The average farm size decreased throughout the late 1800s, and even though production rates for some crops doubled during this period, farms saw an extreme increase in indebtedness, and farmers' incomes did not rise (Steiner, 2004). Annual, unpredictable price fluctuations and long-term decline in income for Missouri farmers made life difficult for those pursuing agricultural work (Steiner, 2004). St. Louis faced an economic depression from 1893-1897, which only exacerbated the problem, as farmers who had for years been overplanting and overproducing now faced global competition and an over-saturated market for wheat and cotton (Primm, 1998). By the early 1900s, the majority of farmers and farm laborers were experiencing poor sanitation and insufficient living conditions, as industrialization continued to overhaul and essentially ravage the farming industry (Steiner, 2004). The lifestyle that had supported the majority of Americans before the Industrial Revolution was no longer a profitable, sustainable way of life, and eventually, farming too had to succumb to the industrialization of production.

By the mid-1800s, the massive growth of the railway system allowed for a continued increase in city populations. Steamboats were also a major contributor to St. Louis' success, and by 1841, the city was second in the United States for river traffic, with 186 steamboats discharging 260,000 plus tons in nearly 2,000 landings (Primm, 1998). The population of Missouri grew from 383,702 in 1840, to over 3 million by 1910. Already by 1870 the state had the fifth highest population in the nation and St. Louis ranked as the nation's eighth largest city by 1860 (Violette, 1918; Primm, 1998). The city's manufactured products were abundant, valued at \$27 million dollars in the mid-1800s. Iron production attained a value of nearly \$9 million by 1870 and employed over 2,300 workers (Parrish, 1973). Flour mills were valued at \$3,850,000 in 1870, and the brewing industry developing in southern St. Louis was valued at \$5 million (Parrish, 1973). However, this success came at a cost to the work force who produced it . Among the consequences for growing city populations was lower quality of life, including a greater exposure to infectious diseases. In one such instance, Chouteau's Pond, considered to be a pristine recreation center in the early 19th century, quickly became a sewage, waste, and garbage dump for local butcheries, residences, and industries on its banks (Primm, 1998). The cholera outbreak of 1849 led to the denouncement of the once unsullied resource as a “menace to public health,” and this example was not a singular occurrence (Primm, 1998).

There were certainly fluctuations in the economy throughout the 19th century, like the economic depression mentioned above that spanned the mid- to late-19th century, but other problems arose as well. The Great Fire of 1849 caused a major disruption to the industrial sectors, with thousands losing their jobs and hundreds becoming homeless, the majority of whom were members of St. Louis’ working class (Arenson, 2010). Though larger businesses were able to recover quickly to re-establish their operations, small businesses along the waterfront areas suffered greatly. The fire also disrupted the lives and livelihoods of slaveholders and slaves, while some slaves were actually able to flee to freedom in the chaos of the destructive event (Aresnson, 2010). The city and the people, determined to rejuvenate and rebuild after the misfortune, continued to expand despite such setbacks.

The innovations mentioned above, and the ones that followed, spurred on industrialization and urbanization of centralized cities, and created an atmosphere heavily focused on production, usually at the expense of the workers involved. The heavy workload for laborers may have been a factor that contributed heavily to the successful growth of the city. Prior to 1840, mechanics and laborers were required to work for their employers from the time the sun rose, to the time it set again, with only two hours of break time throughout the day (Shepard, 1870). It was not until May of 1840 that an assembly of St. Louis men employed in laborious professions was able to successfully petition the city to limit workdays to ten hours, a measure passed and known as “the ten-hour system” (Shepard, 1870). Unfortunately, these long hours were not adjusted again as time went on. The average workday in 1890 was still 10 hours long, and by 1920, the average skilled laborer worked 50.4 hours weekly, while the unskilled laborer saw 53.7 weekly work hours (Dubofsky, 1996). Despite working these long hours, those in industrial settings rarely had significant money to show for it. Though the market economy was rapidly expanding and overall wealth was increasing, this time period saw a dramatic increase in economic inequality, and great disparities in the distribution of wealth (Henretta et al., 2008). It is within this setting that the population of this study found themselves, as cogs in the growing industrial and agricultural state of Missouri.

Ancestral Background in St. Louis

The city of St. Louis grew rapidly throughout the 19th century, and a large portion of the new population consisted of foreign-born immigrants. An 1851 census showed that the city’s population had increased from 16,649 to nearly 78,000 in just eleven years time (Purdy, 1945). This census showed the city’s ancestral makeup to be mostly European “whites,” with 38,012 people of German, Irish, or English origin (Purdy, 1945). This pattern persisted through time, and in the year 1900 61.3 percent of the St. Louis population were either foreign-born or had foreign-born parents, while only 32.3 percent were considered to be “native whites with native parents” and only 6.4 percent were “native blacks” (Primm, 1998:338).

The ethnic makeup of the city is important to note, as a definitive social hierarchy existed throughout the 18th and early 19th centuries (Dubofsky, 1996). The most valued jobs, such as supervisory positions, were generally held by “native whites”, while foreign-born immigrants and African-Americans were forced into semi-skilled or unskilled positions, which usually meant a job within the industrial sector (Dubofsky, 1996). People who were not considered to be native also suffered in terms of living conditions. In 1900, the majority of the non-native and non-white population in St. Louis would lived in sections near the river and on the edges of the expanding industrial sector, areas that were described by some as slums (Primm, 1998).

Women and the Workforce

Though it was comparatively rare to find women working in the same strenuous factory conditions as men, it was not unheard of. Around 1870, some parts of the country saw 18% of the female population employed in factories, and by 1920 that portion of the population rose to 24% (Kleinberg, 1999). In some cases, mostly for younger, single women, working in factories meant also living in harsh conditions, as the money was not enough to support them. A historic account on female factory workers in New England noted that the girls “have no private apartments, and sometimes sleep six or eight in a room, and even three in a bed” (Henretta et al., 2008). In particular, the growing textile industry in America leaned heavily on the labor of women, but on average tended to pay a paltry sum, around 12.5 cents ($3.39 in today’s dollars) per item sewed, when some items took an entire days work to sew (Kleinberg, 1999; Measuring Worth, 2015).

For those women not employed in factories or day labor jobs, there were still plenty of jobs to go around. At this point in history, women who were able to seek and find work outside of the household usually did so in semi-skilled or unskilled occupations (Dubofsky, 1996). Women from poorer families often had no choice but to work outside the home, while also maintaining their own household. Likely due to a great increase in demand for such workers, domestic service was a common occupation for both European-American and African-American women, and while the latter usually dominated the field, three-fifths of European-American women who sought work, worked in this realm (Kleinberg, 1999). For some women, domestic service meant living with the family for whom they worked, with staggeringly long work hours, sometimes also enduring abuse from the family, and all with very little pay to show for it (Dill, 1994). An important distinction in female job classification is made in the sample being studied here, based on the context from which these women come. A woman with the job title "housewife" is not classified in the same way as a woman with the job title "housework" or "housekeeper". Most often, the housewife is the woman who employs another to do at least some portion of the household tasks (Dill, 1994). These women more likely came from upper class, or otherwise financially well off families, and were therefore able to choose to stay at home and not work. Whatever portion of housework these women may or may not have been doing on a daily basis, it is highly likely that their burden was considerably lighter than those who were employed in the realm of domestic service.

Race and Labor

An African American living in Missouri in the 19th century, whether as a slave or a free man or woman, faced a life much more burdensome than their “white” counterparts. For those African American’s who escaped persecution as a slave, job prospects and work conditions were still not promising. The stratification of labor during this time period, which initially put freed slaves at the bottom, meant that the only open positions for non-white men were generally unskilled occupations, and a large portion of these jobs were in the newly expanding industrial sector (Dubofsky, 1996). One survey from the late 1860’s on occupations held by the parents of African-American children enrolled in St. Louis schools showed a predominance of laborers, boatmen, and laundresses (Parrish, 1973). A tense social climate did nothing to lessen the strenuous burdens faced daily at work. The state constitution that was passed in 1820 ensured a political-economic order that kept slaves as human property, completely without rights, and marked free black men and women as second-class citizens, unwanted and unwelcome throughout the entirety of the state (Graff, 2004). Missouri had essentially legalized the harassment of its African American citizens, allowing them to become targets of “extralegal actions” from the upper echelons of the community, namely in the form of brutal mob violence (Graff, 2004). Yet for all of the hatred directed at this part of the population, the leaders of St. Louis were well aware that the city’s economy and continued growth were extremely dependent upon these laborers. The tumult of the 1800s saw a struggle for balance between pleasing the average citizen who feared and reviled the African American community, and keeping the city's industries running smoothly.

Slavery was still alive and well in 1800's Missouri, and therefore must be taken into consideration when analyzing the African American individuals of the study sample. St. Louis had its fair share of slavery, and the city was actually the chief slave market in the state in the early 1800s (Violette, 1918). The rivers surrounding St. Louis facilitated the transfer of slaves, and allowed St. Louis merchants to hold profitable slave markets from New Orleans to Texas (Arenson, 2010). The 1830 census of St. Louis revealed that slaves made up 20 percent of the population, while freed African American men and women were at a low 4.9 percent (Primm, 1998). As late as 1860, there were still areas of Missouri where approximately twenty percent of the population were enslaved, and every county in the state still housed slaveholders and slaves (Andrews, 2004; Primm, 1998). Estimates across the state in 1860 suggest that there were 114,931 slaves and only 3,572 freed African-Americans residing in Missouri (Trexler, 1914). The proslavery majority was also present in St. Louis, as the men who led the town – politicians, merchants, and the like – generally all owned slaves (Primm, 1998). Life as a slave was far more burdensome than even those of factory workers, and meant working full days, men and women, children and elderly alike (Durbin and Bertling, 2009). Historical accounts suggest that slaves could have worked in a number of capacities, some as farm hands, some as household servants, and others may have worked on the river boats or in the lead mines (Violette, 1918). Both men and women were documented as frequently working on river boats, with women often employed as chambermaids and men as deck hands (Buchanan, 2004). In most cases, slaves were given only the bare minimum in food and other necessities, and obtaining anything beyond that meant more work for the enslaved individual, whether it was growing their own food, making their own clothes, or anything of the sort (Durbin and Bertling, 2009). Due to their poor living conditions, slaves were also the ones who suffered most when epidemics broke out – the first people infected, and sadly often also the first to die (Primm, 1998). Even as slavery declined in St. Louis, it was men who saw freedom much more frequently than women, as high demand for domestic workers remained (Primm, 1998). Yet even as the prevalence of slavery dwindled, the cruelty inflicted upon slaves and the difficulty of life for African Americans remained.

Within the context of this study, it is important to remember that some of the African Americans living in St. Louis in the early 1800s may have been born into slavery. This would have meant starting work at a young age, enduring difficult, strenuous labor and long hours of labor for at least some portion of their lives. Although we have record of the occupations at death for the studied individuals, their early lives remain a mystery, and as such it is vital that we remain cognizant of factors such as this.

It is from these groups detailed above that the studied sample is drawn, as the Robert J. Terry Anatomical collection consists mostly of individuals of lower socioeconomic status who died in the St. Louis area. Individuals who went through the morgue and whose relatives did not claim them would have had to be buried at the state’s expense, and so they were given to the medical school for use in anatomy classes (Albanese and Hunt, 2005). More details on this collection will be discussed in a following chapter. Based on the historical context discussed here, it is clear that different patterns of work existed between the sexes and between the two different ancestries under examination. African-Americans had more strenuous lives both during and after slavery than their European-American counterparts. Men more often filled positions of strenuous labor than did women, but women also held a variety of jobs with different levels of strenuous or repetitive work. These patterns appear to have remained consistent through the 100 years under study here.

CHAPTER 3

REVIEWING THE LITERATURE

Though the term "bioarchaeology" was not coined until 1977, the field has deep roots in physical anthropology and archaeology (Buikstra, 1977). The application of physical anthropological methods to archaeological investigation has been popular since the time of Hrdlicka and Hooton, two of the field's most prominent founding figures (DiGanigi and Moore, 2013). It is a field that, by definition, "helps to contextualize past populations and their individuals, by answering questions about behavior, quality of life, lifestyle, gender, and politics, among others" (DiGangi and Moore, 2013:13). One of the lenses through which bioarchaeologists can view such questions is through utilizing the field of paleopathology – the study of disease. These two fields are so strongly compatible, and interdisciplinary work between them so common, that "bioarchaeology and paleopathology are linked in the minds of most skeletal biologists" (Armelagos and Van Gerven, 2003). The following is a review of the literature that has put this relationship to use to explore degenerative joint diseases and their potential use as interpretive tools when applied to the study of past civilizations.

Degenerative Joint Disease and Activity Inferences

Degenerative joint disease has been a popular tool for analyzing past populations for many years. The application of such a tool has varied, as has the success of such applications. An early, oft cited example is that of Merbs (1983), and his research on the Sadlermiut. Using both known and reconstructed activities from the population, he analyzed patterns of activity, including spear throwing and kayak paddling, and correlated them with observed pathological changes on the skeletons (Stirland and Waldron, 1996). A less successful activity-related study was that of Bridges (1989), which used activities that were not truly verified as associated with the populations used, and suggested that osteoarthritis presence was a consequence of activity without discussing other possible causes for the disease (Stirland and Waldron, 1996). Since that time, many studies have continued to produce results of pathological observations on skeletal materials, and over time a pattern emerged that used degenerative joint changes to draw inferences about divisions of labor, activity level, and even specific activities. Some of these studies have remained tentative with their conclusions, while others have relied heavily on degenerative changes observed in the joints to make statements about the population being studied. Throughout this chapter, many such studies will be discussed in relation to the diseases selected for study here, and in following chapters, the validity and the appropriateness of continuing such studies will be evaluated based on the obtained results.

Osteoarthritis

In life, osteoarthritis is a disease of the articular cartilage, which breaks down as the disease progresses, but it ultimately affects all elements of the joint, including the ligaments, subchondral bone, capsule, and synovial membrane (Brandt, 2001). The primary clinical symptoms include pain and stiffness of the affected joint (Arden and Nevitt, 2005). Brandt (2001) narrows the mechanical reasons for failure to the following points: normal articular cartilage and subchondral bone are exposed to excessive joint loading and fail, and/or the amount of loading is reasonable, but the cartilage cannot adequately respond to the loading.

Symptoms visible through radiographic examination include narrowing of the joint space, osteophytosis, and cyst formation (Arden and Nevitt, 2005). The changes that can occur in articulating bones as a result of osteoarthritis include: formation of marginal osteophyte(s) (new bone around the margins of the joint), subchondral bone turnover on the joint surface, pitting on the joint surface (a series of holes on the surface), changes in the joint contour, and eburnation, or polished areas on the joint surface, sometimes accompanied by scratches or grooves in the direction of movement of the joint (Jurmain and Kilgore, 1995; Creamer and Hochberg, 1997).

Osteoarthritis: An Etiological Review

According to recent research, there is not yet complete agreement on whether development of osteoarthritis is significantly impacted by occupation or other factors that determine an individual's workload. A review of osteoarthritis etiologies presents a wide range of possible answers, as knowledge of the disease progressed from characterizing it as a disease of "wear and tear", to studying the more complete picture (Dieppe, 1999). Paleopathologists have identified age, genetics, sex, race, obesity, trauma, and movement as likely culprits in the development of osteoarthritis (Jurmain, 1991; Jurmain, 1999; Rogers and Waldron, 1995; Larsen, 1997; Weiss, 2006). Clinically, these factors and several others have been identified and considered. Researchers have been working for years to understand which of these factors play roles in the development of osteoarthritis in various populations, and to what extent. Countless studies have come across young individuals affected by osteoarthritis, and have also examined older subjects who were completely unaffected by the disease, and so researchers face a conundrum (Jurmain, 1977). Studies of contributing mechanical factors such as obesity suggest that systemic factors likely play some role in development of the disorder, as obesity was found to be highly correlated with knee osteoarthritis, less strongly correlated with hand osteoarthritis, and weakly correlated with hip osteoarthritis (DT Felson, 1988; Waldron, 2009). Thus, age seems not to be the only antecedent, and perhaps it is not the most important factor in the equation. Where does each of the contributing components fall on the scale? Though osteoarthritis is a disease that has long been present in human history, having been found in ancient skeletal remains from sites such as Gore Creek and Kennewick, it seems the puzzle of osteoarthritis etiology is not solved quite yet (Cybulski, 2006).

The correlation between osteoarthritis and age is clearly a strong one, as the scientific literature confirms. Some clinical literature states without hesitation “Age is the most powerful risk factor for OA” (Brandt, 2001:7). Estimates from the World Health Organization, as reported by Buckwalter and Martin (2006), stated that approximately 10% of people over the age of 60 suffer from osteoarthritis globally (World Health report, as cited in Buckwalter and Martin, 2006). Studies conducted by the National Health and Nutrition and Examination Survey found that cases of knee osteoarthritis increases from less than 0.1% in an age cohort of 25 to 34, to 10-20% in individuals aged 65 to 74 (Brandt, 2001). It has been noted that the age-related increase of osteoarthritis and the factors involved may vary among different joints (Arden and Nevitt, 2006). Additionally, researchers have acknowledged that the strong relationship between age and osteoarthritis development is likely affected by increases in systemic and biomechanical risk factors that accompany the aging process, such as excess joint loading from obesity and increased joint instability (Arden and Nevitt, 2006). Arthritis is a well-documented degenerative disease, and studies have found that nearly half of all individuals in modern populations will have arthritic symptoms in at least one joint by age 65 (Jones and Doherty, 1995). The relationship between osteoarthritis and age is facilitated by changes in the body that come along with advancing age. At the cellular level, healthy articular cartilage does not undergo terminal differentiation of chondrocytes, but around age 40 this begins to change, and degenerative cartilage is the result (Madry et al., 2011). Joint tissues are more susceptible to stress, including excessive joint loading, as the body ages and cartilage becomes less resilient (Arden and Nevitt, 2006).

Other factors that have been suggested as contributive to osteoarthritis development include obesity, nutrition, and bone density. Obesity, however, has so far only been shown to have an effect on the weight-bearing joints, such as the hips and knees, suggesting that mechanical factors play some role in the development of osteoarthritis in other, non-weight-bearing joints (Brandt, 2001). Vitamin D deficiency has been associated with an increase in progression of osteoarthritis but not in onset, and high vitamin C intake appears to lessen the risk of osteoarthritis development, though this is still under investigation (Brandt, 2001). Studies on hip and knee osteoarthritis in women demonstrated a higher prevalence of osteoarthritis in those with higher bone mineral density (Sowers et al., 1996; Arden and Nevitt, 2006). Genetic predisposition has been studied using heterozygous twins, and this predisposition can account for a sizable portion of the variance seen in osteoarthritis development: “39% and 65% in radiographic OA of the hand and knee in women, about 60% in OA of the hip, and about 70% in OA of the spine” (TD Spector and AJ MacGregor, 2004:39). Sex and ancestry will be discussed below as etiological factors and their relation to occupational studies.

Osteoarthritis and Occupation

In studying the link between occupation and joint disease development, osteoarthritis has undoubtedly been more thoroughly examined than the other diseases selected for study. As Larsen phrases it, “In order to reconstruct and interpret behavioral patterns in past humans, bioarchaeologists commonly rely on the study of osteoarthritis, primarily because the disorder is caused in large part by wear and tear on the joints of the skeleton” (Larsen, 2006:366-367).

Some research has found that arthritic symptoms are present at an earlier age in laborers than in those working in less physically demanding occupations. A 1977 study involving 798 skeletal individuals compared black and white individuals from the Terry collection, individuals from the Pecos Native American collection, and those from an Eskimo collection to examine differences in manifestation between sexes and among ancestral backgrounds, as well as to compare those populations under an assumed greater amount of stress, to those with fewer stressors present in life (Jurmain, 1977). Knee, shoulder, elbow, and hip joints were all examined, and the analysis that followed determined that external stress factors most likely play a role in the development of osteoarthritis (Jurmain, 1977).

The Eskimo population that was studied exhibited the earliest age of osteoarthritis onset in all examined joints, and the researchers allude to the fact that the subsistence and behavioral patterns of this population suggest the highest amount of continuous stress of all the groups considered (Jurmain, 1977). It was their conclusion that excessive, constant stress on an individual actually overshadows other etiological factors when it comes to the origin of osteoarthritis. Following this in 1989, a sample of 968 skeletons from the Spitalfields Collection was studied for the relationship between occupation and osteoarthritis, with particular focus on the relationship between weaving and osteoarthritis of the hands (Waldron and Cox, 1989). This, however, did not produce any statistically significant findings on the matter.

Walker's (2006) study of arthritis patterns from central California skeletal collections explored changes in the sexual division of labor. Walker suggested that reduced osteoarthritis rates in men indicated a reduction in workload for men, but a greater workload for women when the population shifted to a different means of subsistence (Walker, 2006). Similarly, osteoarthritis patterns in the Santa Barbara Channel area were seen to be correlated with a shift toward more intensive exploitation of marine resources (P.L. Walker and S.E. Hollimon, 1989). This research tracked the increasing rate at which people in this population developed osteoarthritis, which they inferred to be a result of an increased amount of time spent participating in strenuous physical activity. Males were more often affected by that rate increase, and the researchers suggest this is consistent with ethnographic evidence that portrays fishing as a task predominantly performed by males (P.L. Walker and S.E.

Hollimon, 1989). In 1983, Merbs studied patterns of osteoarthritis, osteophytosis, compression of vertebral bodies, spondylolysis, and antemortem tooth loss in a Sadlermiut population, and examined their link to ethnographically documented physical activities like kayak paddling and harpoon throwing (Merbs, 1983). Very specific studies in occupational activities of jackhammer operators, shipyard workers, coal miners, and similar jobs found that such activities lead to osteoarthritis in joints exposed to such repetitive use (Brandt, 2001).

Sex and ancestral background have both been examined as etiological factors in the development of osteoarthritis. Different patterns of osteoarthritis development and progression have been found among individuals of different ancestral backgrounds and between the sexes. Osteoarthritis is generally more common in females than males, particularly in older age cohorts (Heine, 1926; Brandt, 2001; Arden and Nevitt, 2006; Yoshimura, 2009). Ancestral origin may also play a role in osteoarthritis development. Studies have shown that, generally, individuals of African descent have lower rates of osteoarthritis of the hip and knee than do those of European descent, though in some population studies, African-American women have exhibited higher risk for osteoarthritis of the knee than Caucasian women (Chambers, 2012; Dominick and Baker, 2004). It has been noted that manifestations of osteoarthritis varies in different populations, and across time periods; some are more likely to develop osteoarthritis of the hip, but for others, osteoarthritis of the knee has been most prevalent (Waldron, 1997). Considering the history of the sample to be studied, it is not unreasonable to expect to see high rates of osteoarthritis in those individuals who worked in heavily strenuous manual labor jobs, such as factory labor, day labor, etc. Although osteoarthritis is usually found to be more prevalent in older females than in males, it is possible that, because of the distribution of labor during the time period (in which women were less likely to be working in heavy manual labor jobs than men), there will be higher rates in males of the population being examined for this thesis than in females of any selected age group (Heine, 1926). The comparison of ancestral groups will also be important within this study. Will all laborers exhibit the same prevalence and degree of osteoarthritis, or will certain groups be more prone to the disease simply because of genetic predisposition? Osteoarthritis, as discussed, has a long history of examination in skeletal collections and archaeological populations. However, the two following diseases, intervertebral disc disease and rotator cuff disease, have not received the same degree of attention in the literature.

Rotator Cuff Disease

In life, rotator cuff disease is characterized by pain, usually in the upper arm, which may worsen when reaching or rotating the arm, and is caused by a range of symptoms from inflammation to full thickness tears (Seagger and Wallace, 2010; Nho et al., 2008). Radiographic symptoms that may be visible in a patient suffering from rotator cuff disease include decreased subacromial distance, cyst formation at the greater tuberosity, subchondral sclerosis at the greater tuberosity, disruptions of the rotator cuff tendons, and a distinct gap between the articular surface of the head of the humerus and the greater tuberosity (Jarit and Diduch, 2010). In the skeleton, these symptoms present as changes to the greater tubercle of the humerus, the area at which the rotator cuff muscles insert on the bone. These changes include: cortical irregularity or trabecular atrophy, irregular new bone formation, changes to the contour of the insertion areas for the rotator cuff muscles, all of which are most often found on the greater tubercle of the humerus (Cotton and Rideout, 1964;Corroller et al., 2009). An exaggeration of the groove between the greater tuberosity and the articular surface of the head of the humerus may also be encountered (Cotton and Rideout, 1964). Additionally, bony addition to the coracoid and acromial processes of the scapula, often associated with impingement syndrome, may also be related to rotator cuff disease (Tucker and Snyder, 2004).

Some medical researchers who have investigated the process that leads to development of this disorder suggest that normal activity can lead to tears in a tendon that is weakened, and weakness is common due to structural alterations that begin around age 50 (Uhthoff and Sarkar, 1991). Histological studies have been carried out on torn rotator cuff tendons in an attempt to determine the cause of tears (Hashimoto et al., 2003). One researcher pinned the cause on degenerative processes in association with trauma (Codman, 1934). Other researchers who histologically examined the supraspinatus tendons concluded that degenerative lesions are the cause of the weakening that leads to rotator cuff tears (Wilson and Duff, 1943). Uhthoff and colleagues noted that all partial rotator cuff tears (that they studied) begin on the articular side of the tendon, and pointed to degenerative changes and insufficient vascular supply as the most likely culprits (Uhthoff et al., 1986; Hashimoto et al., 2003). Hashimoto and colleagues attempted to isolate the particular "pathomechanism" responsible for rotator cuff tears in a histological study on seven degenerative changes (Hashimoto et al., 2003). They noted that three changes were found in all cases: thinning of collagen fibers, myxoid degeneration, and hyaline degeneration (Hashimoto et al., 2003). The frequencies and distribution of these factors in their findings led them to suggest that these types of degeneration are common changes that result in rotator cuff tendons before a tear occurs (Hashimoto et al., 2003). There is considerably less literature concerning the assessment of the disease in skeletal materials, though this lack of archaeological and paleopathological examination will hopefully be supplemented by the results of this study.

Rotator Cuff Disease and Occupation

Much of the osteological work done on rotator cuff disease examines impingement syndrome, which generally affects the head of the humerus or the acromion of the scapula, while paleopathological studies on the disease itself are relatively rare (Roberts et al., 2007). A search of the literature failed to produce any useful studies of archaeological or modern skeletal populations relating rotator cuff disease or intervertebral disc disease and occupation. Therefore, the following discussion will rely on clinical studies of the diseases and archaeological and paleopathological literature that detail the diseases as found in the skeleton.

Clinically, rotator cuff disease has been linked to overuse of the joint, and has also been attributed to muscle dysfunction, acromial shape, and os acromiale, though these are all studies done from a clinical perspective (Seagger and Wallace, 2010). Interestingly, 90% of cases of rotator cuff tears are associated with disorders of the long head of the biceps tendon, and glenohumeral arthritis is also often associated with pathology of this tendon (Khazzam et al., 2012). Some clinical studies have found occupation to be an important contributing factor, but also noted that activities aside from occupation should also be taken into account. Other researchers postulate that the disease occurs as a result of a combination of multiple extrinsic and intrinsic factors – including occupational activities – however the degree to which each of these factors may contribute to the disease still remains to be seen (Seagger and Wallace, 2010). One such study found that patients at an increased risk for developing rotator cuff injury included those who participated in manual work and work that involved overhead lifting, and, interestingly, also identified the presence of osteoarthritis in the shoulder as a risk factor (Northover et al., 2007). A 2006 clinical study in France examined manual laborers for prevalence of upper limb diseases, including rotator cuff disease, and used a sample of 2656 men and women considered to be either "manual workers" or "non-manual workers". The highest difference in disease prevalence between these two classes when studying the men, was rotator cuff disease, and it was decided that these findings showed a definitive link between physical, strenuous occupations and upper limb disorders (Melchior et al., 2006).

The Shoulder and Skeletal Studies

Although rotator cuff disease has not been diagnosed or well examined in the anthropological literature, there are other pathological conditions of the shoulder that have been given attention through skeletal studies. A 1922 study identified what the researcher called "plaques", located on the inferior surface of the acromion process of the scapula, with a smooth, concave surface that was elevated at least 2mm above the acromial surface (Graves, 1922; Miles, 1996). In a 1942 study on the scapula, Gray identified elevated "facets", a portion of which displayed eburnation (Gray, 1942; Miles, 1996). These two changes are, according to Miles, undoubtedly associated with the disorder known as acromial impingement syndrome (Miles, 1996). In his study, Miles selected scapulae, and their associated humerii, that displayed such symptoms, and observed that the individuals affected were all estimated to be over 50 years of age (Miles, 1996). Miles concluded that the mechanism that caused the disorder in question was mainly a combination of degenerative changes associated with aging and repetitive trauma to the shoulder (Miles, 1996).

Intervertebral Disc Disease

The intervertebral disc received little treatment in pathological literature until the early 1900s. Christian Schmorl's research on the spine brought disc degeneration – among other spinal pathologies – to light, as well as age-related degenerative changes, annular tears, and more (Wang and Battie, 2014). Schmorl's work was followed by Walter Dandy, who linked his pathological findings to the clinical findings and symptoms, and William Mixter, who has been credited with creating the foundation for contemporary understanding of disc herniation and its clinical manifestation (Wang and Battie, 2014).

On average, the intervertebral discs make up about 15-20% of the length of the spine, depending on factors such as age, time of day, occupation, and disease (Shapiro and Risbud, 2014). The primary functions of the discs are to absorb biomechanical forces and to allow the vertebral column to move (Shapiro and Risbud, 2014). In a healthy individual, intervertebral disc height is generally around 3 mm in the cervical spine, 5 mm in the thoracic spine, and ranges from 9 to 17 mm in the lumbar spine (Shapiro and Risbud, 2014). The discs consist of the outer annulus fibrosus, a central core, called the nucleus pulposus, and cartilaginous endplates (Cortes and Elliott, 2014). These discs are subject to biochemical and structural changes due to degeneration, including a decrease in proteoglycan content, changes in collagen type and distribution, height decrease, bulging of the annulus, and loss of lamellar organization (Cortes and Elliott, 2014). Any disruption or change in the mechanical properties of one of the disc's elements can impair the overall function of the disc, as changes or damage to the disc facilitates a host of biochemical, structural, and morphological changes that are characterized as degenerative disc disease (Cortes and Elliott, 2014).

Intervertebral disc degeneration actually begins fairly early in life, as onset is sometimes in the second decade of life (Schmorl and Junghanns, 1971). The degeneration of the intervertebral discs causes the nucleus of the disc to bulge outwards and the annulus to collapse, which narrows the joint space (Waldron, 2009). All of the tissues face degenerative changes, but the most affected tissue is the nucleus pulposus, and degeneration here leads to a decrease in disc height and an increase in disc instability (Cortes and Elliott, 2014). Some of the changes that manifest in the skeleton that are secondary to disc degeneration are as follows: cortification of trabecular bone, and ostephytic formation (Schmorl and Junghanns, 1971; Lane et al., 1993). In severe cases, other symptoms such as change to the shape of the vertebral body and even fusion can result. According to recent research in current United

States populations, degenerative disc disease is the most frequent reason for lumbar fusion (Rajaee et al., 2012).

Intervertebral Disc Disease: An Etiological Review

Factors that have been identified as contributing to disc degeneration include: structural injury, genetics, age, inadequate metabolite transport, nutritional pathways, and loading history (Adams and Roughley, 2006; Urban and Roberts, 2003; Battie et al., 2008; Buckwalter, 1995; Hsu et al., 1990; Pye et al., 2007; Rannou et al., 2004; Cortes and Elliott, 2014). Researchers have identified mechanical loading or injury (generally work-related, as found in clinical studies) as contributing factors toward disc degeneration, which translates in the skeletal material as intervertebral disc disease (Urban and Roberts, 2003). Consistently repetitive low-magnitude loading (applying the load many times over) has been linked to the onset of tears and herniation in the discs (Cortes and Elliott, 2014). Other degenerative spinal disorders have also been linked to repetitive physical motions, as in the case of kyphosis, which has been linked to excessive posterior bending (Shapiro and Risbud, 2014).

The lumbar spine is susceptible to two different kinds of mechanical loading: the upper region may undergo degeneration because of compression overload, and the lower region may be more affected by torsional injury (Ball, 1978). Throughout the whole spine, cervical vertebrae undergo high amounts of rotation but low compression, while the lumbar undergo low rotation and high amounts of compression (Lotz and Hsieh, 2014). Compression loading comes from the weight of the upper body and from forces exerted by muscles in the torso during normal activity (Cortes and Elliott, 2014). In a loading state in a healthy disc -

whether from compression, flexion, or torsion - the nucleus pulposus expands radially, causing outward bulging of the annulus, and the lamellae in the annulus buckle inward (Cortes and Elliott, 2014). A healthy disc is capable of handling the loading of everyday activities, but when the discs begin to degenerate, loading – particularly in excess – becomes a problem for the spinal column. In healthy discs, even high magnitude stress can be compensated for when it is brief and not repeated often. However, high amounts of stress on the spine at low frequencies and for long periods of time leads to a change in the function of the disc cells and changes the morphology of the disc's tissues (Lotz and Hsieh, 2014). Studies done on stature loss in the spinal column have noted that even low-impact activities do cause a redistribution of fluids that contributes to this loss, but strenuous exercise, work-related activities, and high body mass have been shown to intensify the loss of stature (Hoe et al., 1994; Garbutt et al., 1990; McGill et al., 1996; Leivseth and Drerup, 1997; Rodacki et al., 2005; Lotz and Hsieh, 2014).

In the early 1990s and in previous decades, the model for disc degeneration etiology in clinical literature was focused on wear and tear and repetitive loading (Wang and Battie, 2014). Not until the end of that decade did other factors, including age, sex, genetics, and others, gain more consideration.

It has been clear to researchers working on this topic for years now that disc degeneration is very closely associated with age. Miller's study on the frequency of macroscopic disc degeneration showed an increase from 16% at age twenty to 98% at age seventy (Miller et al., 1988). Research on the histological findings associated with disc degeneration, including disc cell death and annular tears, verified that such changes increase steadily with age (Schmorl and Junghanns, 1971; Coventry et al., 1945a). However, there are some puzzles that arise with the relationship between age and disc degeneration. Some common degenerative changes have actually been recorded in children as young as two, and high variability in degenerative findings within age groups is common (Boos et al., 2002; Wang and Battie, 2014). Cases such as this one indicate that other etiological factors cannot be ruled out, and must continue to be investigated.

Trauma is considered a definitive risk factor for the onset of disc degeneration. Studies have noted that injury to the annulus fibrosus, or any other direct trauma or injury that disrupts the homeostatic state of the disc can lead to accelerated disc degeneration (Wang and Battie, 2014). Clinical long-term studies on people with pre-existing conditions such as compression fractures showed higher amounts of degeneration in those people than in people without such problems (Kerttula et al., 2000). The amount of force or trauma necessary to facilitate the increase in degeneration is still under examination.

Another factor that has been studied for potential effects on disc degeneration is cigarette smoking. To date, it is the only chemical exposure that has been associated with disc degeneration in the lumbar spine, and recent research has begun to investigate the mechanisms of this factor (Wang and Battie, 2014). While interesting, this factor is known to play only a very small part in disc degeneration. A study in identical twins showed that cigarette smoking accounted for no more than 2% of variation in degeneration scores (Battie et al., 1991).

Interestingly, a study on the relationship between spinal diseases found a slight correlation between the occurrence of osteoarthritis and intervertebral disc disease when examining correlation coefficients on the number of vertebra affected by the diseases. However, their multivariate analysis led to the conclusion that the occurrence of each disease was separate from the others in that particular population (Waldron, 1991).

Clinical studies have been conducted on subjects working in "light industry", or those occupations that do not involve extreme physical effort, examining both osteoarthritis and disc disease pervasiveness - among other diseases that fall under the heading of "rheumatism" - in males and females. The study surveyed an engineering factory in Edinburgh, and found that nearly 79% of sick leave taken from work was due to pain caused by disc disease, specifically in the lumbar vertebrae (Partridge et al., 1965). It was noted that a number of the workers had changed jobs, moving to jobs of lighter industry, and approximately 7% of the total sample identified that they had changed jobs because of their disc disease (Partridge et al., 1965). A review of the subject several years later concluded that there had not been a significant correlation found between occupation and rheumatism etiology, though much further study would be required to establish the roots of the diseases under scrutiny (Anderson, 1971). Early clinical studies on occupational differences in disc degeneration observed a higher prevalence of narrowing disc space and endplate sclerosis in miners and other manual workers than in non-laborers, and found the age of onset in those individuals with strenuous occupations to be approximately ten years earlier than for individuals with less physically taxing occupations (Lawrence, 1955; Hult, 1954; Wang and

Battie, 2014). However, other studies on disc degeneration based on narrowing disc space and osteophyte development did not find it to be associated with strenuous manual labor (Friberg and Hirsch, 1949). This pattern of varied results has continued even in contemporary studies. Today, some researchers suggest that the key to this etiological factor may lie in the amount of loading to the spine and the manner in which that loading is inflicted on the spine in relation to tissue strength, a factor that varies from one person to another (Wang and Battie, 2014).

Aside from occupation, clinical research has also studied potential links between disc degeneration and activity by comparing athletes and non-athletes, and many of them reported an association between them (Bartolozzi et al., 1991; Goldstein et al., 1991; Elliott and Khangure, 2002; Kaneoka et al., 2007). One such study found significant differences between groups, with higher proportions of individuals with disc degeneration among two particular sports (swimming and baseball) as compared to non-athletes (Hangai et al., 2009).

In summary, the disorder known in clinical literature as “degenerative disc disease” exhibits symptoms during life that include bulging, herniation, disc space narrowing, and annular tears, all as result of degeneration of the intervertebral discs (Wang and Battie, 2014). The disease is sometimes, though not always, associated with a pain diagnosis in the spine, particularly in the lower back (Wang and Battie, 2014). It is most common in the lumbar and cervical regions of the spine, and the development of the disease, though often associated with aging, can be exacerbated by intrinsic and extrinsic factors such as sex, genetics, smoking, and an occupation that involves repetitive manual labor (Wang and Battie, 2014).

The Vertebrae and Paleopathological Studies

Though disc disease has been relatively overlooked in paleopathology, there is another type of vertebral affliction that has received ample treatment in the literature: Schmorl's nodes. This potential symptom of disc degeneration has been defined simply in the clinical literature as cortification of trabecular bone (Wang and Battie, 2014). They are a type of lesion in the vertebral endplate, wherein the nucleus pulposus bulges into the vertebral body, which in turn causes a depression in the surface of the affected vertebral body, leaving a "smooth-walled lesion" behind (Faccia and Williams, 2007; Wang and Battie, 2014).

Etiological factors that have been discussed with regard to Schmorl's nodes include age, intrinsic abnormalities, trauma, and repetitive stress, and the nodes have been associated with, and sometimes are considered a result of, degenerative disc disease (Burke, 2012). Medical researchers have attempted to extrapolate the pathogenesis of the nodes, some suggesting they are a developmental disease and other viewing them as a degenerative bone disease (Kyere et al., 2012). In a clinical context, multiple studies on young athletes whose sports put sufficient strain on the spine show a high prevalence of nodes, suggesting that, at least in some cases, Schmorl's nodes are correlated with physical activity (Ogon et al., 2001; Baranto et al., 2006).

Schmorl's nodes are commonly found in archaeological populations of all time periods, cultures, and geographic locations, and many of the studies that report their presence also interpret them as indicative of heavy physical activity in a population (Kelley and Angel, 1987; Faccia and Williams, 2007; Ustundag, 2009; Jimenez-Brobeil et al., 2010). A 1996 study on the remains of the crew of the ship the Mary Rose observed levels of spinal afflictions, including Schmorl's nodes and osteoarthritis, that they suggested were caused mainly by the activities carried out on the ship (Stirland and Waldron, 1995). Variation in frequency between males and females has also been examined, and sometimes applied as an indication of difference in activity level in a population. Jimenez-Brobeil and colleagues found a higher frequency of nodes in males, at 56.6%, than in females, at 30.8%, and in comparing these proportions to modern populations, the researchers found the high number of nodes in males to be congruent with the intense physical activity associated with males in the Agraric population (Jimenez-Brobeil et al., 2010). Ustundag (2009) found a similar pattern, with greater prevalence and severity of Schmorl's nodes in males than in females in a post-medieval Austrian site. Interestingly, this same study found no significant differences between age groups, and all of the assigned age groups had nearly identical frequencies of nodes (Ustundag, 2009). Another route suggested for bioarchaeology that may utilize Schmorl's nodes is the analysis of quality of life and pain in past populations. Faccia and Williams (2008) conducted a clinical study on that particular research track, and found evidence that centrally located nodes are correlated with pain. The researchers suggested that their study could be used in combination with other skeletal pain indicators to create better interpretations on quality of life in the past (Faccia and Williams, 2008).

Degenerative Joint Disease Studies and the Terry Collection

Although the Terry Collection has been extensively used for a wide variety of studies, including those on degenerative joint disease, the study conducted here has several new contributions to add to the literature that have not been previously researched. De la Cova's (2008) dissertation utilized the Cobb, Hamann-Todd, and Terry collections to assess a wide variety of pathologies, including osteoarthritis. The study examined all joints in the upper body, the hands and feet, and the lower limb for evidence of osteoarthritis. There are two major differences between the present study and this dissertation. First, the scoring criteria used for osteoarthritis was admittedly "simple" in the dissertation study, which may have allowed for misdiagnosis or over-diagnosis of osteoarthritis in the sample. Second, while the dissertation thoroughly examined patterns of osteoarthritis between time periods and between individuals of different ancestries, the author did not determine whether or not the osteoarthritis cases being diagnosed were actually a product of activity. Considering the reliance within that study, and many others, on osteoarthritis as a marker of physical stress, continued testing of relationships between osteoarthritis in different regions of the body and activity should be promoted.

Edelson's (1995) study on individuals from the Terry Collection documented degenerative changes in the glenohumeral joint, but lacked analyses on differences between ancestral groups, and did not consider the implications for degenerative change. The goal of the study was solely to document the changes, and did not provide any historical context that may have been related to the degenerative changes.

Robert Jurmain has conducted multiple studies (1977, 1980, 1991) on osteoarthritis in the Terry collection. His 1980 study examined patterns between osteoarthritis manifestation in the shoulder, elbow, hip, and knee joints. Age, body size, and ancestry were considered for their role as etiological factors, and relationships between degenerative joint disease and cause of death, bilateral involvement, and joint involvement patterns were examined (Jurmain, 1980). The unique piece offered by the present study that Jurmain did not consider is the use of three different joint diseases, which has the potential to assist future activity related studies in focusing their research on particular areas of the body. Additionally, looking at differences between two disorders that affect areas of the shoulder that are very close in proximity demonstrates the benefits of deviating from the usual approach of using only osteoarthritis, as rotator cuff disease displays some interesting patterns between age and ancestry groups in this study. Jurmain's 1991 study on the Terry Collection examined patterns of joint disease in the shoulder, knee, hip, and elbow and compared these to patterns found in an Alaskan Eskimo sample. The author concedes that there is still no clear evidence, even within his own study, that physical stress leads to degenerative joint disease, but perhaps if he had made use of the occupational data available to him, the results may have been more detailed. Additionally, while he addresses the importance of age in osteoarthritis etiology, his treatment of other etiological factors, such as sex and ancestry, is unclear. The ability of the study conducted here to take muliple etiological factors and determine their relationships to osteoarthritis development is useful for future research on osteoarthritis, and the results obtained may encourage other researchers to include other degenerative joint diseases in their studies, rather than focusing solely on osteoarthritis.

Considering that the Terry Collection has also been used in the capacity of "control sample" for making inferences about activity in prehistoric populations based on osteoarthritis patterns, it is important that studies assessing the relationships between degenerative joint disease and activity continue, until the true nature of that relationship has been determined (Bridges, 1994; Green, 2008).

The three diseases discussed all obviously have complex, multi-factorial etiologies, and further research may hopefully contribute towards further resolving the issue of determining which factors play a large role, and which should perhaps be disregarded when investigating these disorders in the future.

CHAPTER 4

MATERIALS AND METHODS

Skeletal Collection

The study conducted here draws its data from the Robert J. Terry Anatomical Collection, a collection that began in St. Louis under the direction of Dr. Robert Terry. Robert Terry's medical training and interests in human anatomy alerted him to the need for documented human osteological samples that could be used for studies of skeletal biology, pathology, and more (Albanese and Hunt, 2005). Curation of skeletons originally began in 1898, but fire and other destructive incidents delayed the process until 1910, by which time Terry was chair of the Missouri Medical College's Anatomy Department, a position that allowed him to collect the skeletons of the cadavers used in anatomy courses (Albanese and Hunt, 2005). Primarily, the collection comes from hospitals and morgues in the St. Louis area, with a small portion coming from other areas across Missouri (Albanese and Hunt, 2005). Those individuals who were not claimed by relatives became property of the state, and so the collection is primarily made up of people from lower societal classes, as money would have been a factor in claiming and burying deceased relatives (Albanese and Hunt, 2005). However, it has been pointed out that although these individuals likely died in poverty, they may not have been impoverished throughout their entire lives (Albanese and Hunt, 2005). Robert Terry retired in 1941, and Mildred Trotter took up the collection in his stead and continued it until her retirement in 1967, at which point the collection was transferred to the Smithsonian Institution for permanent curation (Albanese and Hunt, 2005).

The collection now contains 1,728 individuals, whose birth years span from 1822 to 1943, most of whom have a definitively recorded age, sex, cause of death, and place of death (Hunt and Albanese, 2005; de la Cova, 2008). Other basic information on record for many of the individuals includes name, racial classification, date of death, morgue or institution of origin, and dates related to the processing of cadavers (Hunt and Albanese, 2005). Dr. Terry ensured that extreme care was taken throughout the processing and inventory of each individual, and as a result the collection has endured well through years of constant study (Hunt and Albanese, 2005). Age at death in this collection ranges from age 14 to 102, though the majority of individuals fall between 20 and 80 years (Hunt and Albanese, 2005). The mean age at death for males in the collection is 53, and for females 58 (Hunt and Albanese, 2005). Of the 1,608 individuals for whom age is certain, 950 are male and 658 are female (Hunt and Albanese, 2005).

Recently, several skeletal biologists have considered the biases that are inherent in the Terry Collection. Dr. Terry's main research interests lay in human variation and the study of pathologies, and consequently, under his direction, the collection was somewhat biased towards poor individuals and had a higher percentage of African Americans than any other ancestry (De la Cova, 2008). Also, in the time before World War I, the collection had fewer females than males (Hunt and Albanese, 2005). This led Trotter to attempt to balance the collection of females, and she altered her collection strategy accordingly. However, this change resulted in yet another issue with the demographics of the collection. As a result of Trotter's new strategy, males over age forty with a birth year after 1900 were very rarely included in the collection (Hunt and Albanese, 2005). Also, around 1955, the individuals procured for the collection changed from mainly unclaimed individuals to those who willed their bodies to the collection at death, due largely to the passing of the Willed Body Act in the state of Missouri (De la Cova, 2008). De la Cova's research on the differences between these two types of acquisition has shown that unclaimed individuals are usually more representative of the general population. As such, those who willingly donated their bodies to the collection likely had higher economic status than unclaimed individuals (De la Cova, 2008).

Over the years of its curation, the Terry collection has been studied extensively. It has been fundamental to the development of standards for forensic identification, including those for sex, age, and ancestry estimation (De la Cova, 2008). Health and disease has also been studied in portions of the collection, including De la Cova's (2008) dissertation study documenting pathologies and trauma (De la Cova, 2008). Ultimately, it has been noted that the Terry Collection cannot be considered as representative of the 20th century St. Louis population, as it is only a small sampling from that time period, and consists of many individuals from the lower rungs of society (Hunt and Albanese, 2005). Though considering the state of St. Louis during the time period being considered, it is possible that these individuals of lower socioeconomic status did represent a large proportion of the population. However, researchers agree that the collection "is still very useful for understanding human skeletal biology, variation, secular change, and the effects of age on the skeleton" (Hunt and Albanese, 2005: 416).

The Sample

This study utilizes the humerii, scapulae, and vertebral columns of 195 individuals from the Robert J. Terry Anatomical Collection. Of the over 1,500 individuals in the collection, only approximately 250 have a specified occupation at death on record. Out of these individuals, those for whom age at death was uncertain were eliminated from this investigation. Individuals whose occupation was listed as something nondescript, such as "Robber" or "Odd Jobs" were also eliminated from study, as these identifiers convey very little about the amount of physical labor that may have been required. One individual was removed from the sample based on their Mexican ancestral background, as this study is focused only on African-American and European-American groups. It is also worth noting that the Terry Collection often has individuals removed for display or study at another Smithsonian Museum building, and so such individuals were also necessarily eliminated from the sample. An unfortunate side effect of this practice is that many of the removed individuals who would otherwise have been in the sample likely have some of the pathologies under investigation here, and likely more severe cases at that.

After these eliminations, a total sample of 195 individuals was available for use in this investigation. The sample is split into male and female groups, of which there are 87 females and 108 males. These groups are further divided into African-American and European-American ancestral groups for statistical analyses. Based on availability, the male sample is evenly divided at 54 African-American males and 54 European-American males. However, the female sample is not evenly distributed, with 52 African-American females, but only 35 European-American females. This is a result of one of the problems discussed earlier in the collection background. Ages in the sample range from 30 to 88, and were grouped into cohorts based on ten-year age ranges, with all ages over 80 grouped together. Additionally, for logistic regression analyses on severity, individuals were grouped into the following categories: Young adult (20-34), Middle adult (35-49), and Old adult (50+). Individuals were also grouped into birth year cohorts by decade.

Identification of Pathologies

Disagreement on the proper diagnosis of degenerative joint diseases by means of only skeletal remains is still prevalent in the paleopathological literature. Clinical literature obviously favors radiographic diagnosis, but when only dry bone is available for study, paleopathologists must rely on macroscopic examination, and must decide which characteristic signs are sufficient to positively identify joint disease in a long dead individual. Palmer and colleagues (2014) study used the methods outlined in Waldron's 2009 textbook. In contrast, Schrader's (2012) study on a Nubian sample utilized Buikstra and Ubelaker's standards for scoring severity, but determined that only cases that displayed eburnation would be definitively identified as osteoarthritis within their study (Schrader, 2012). It seems that even today there has yet to be a consensus on the best methods, and a standard method for diagnosis is still non-existent. The latter method undoubtedly ensures that there will be no misdiagnosis, as eburnation is considered to be a pathognomic indicator of osteoarthritis, but perhaps this method is too cautious, as it ignores all other changes that occur as a result of the disease.

Rothschild (1997) addressed the diagnosis of osteoarthritis and the problems with using one diagnostic characteristic over another. He suggests that using eburnation as a sole marker for osteoarthritis is a flawed approach, for according to him it is actually an indicator of the severity of arthritis, but not necessarily for the presence of the disease. According to his assessment, eburnation is caused by severe joint space narrowing and therefore will not be present in more moderate cases of osteoarthritis. He also warns against using the presence of porosity alone to diagnose the condition, as it is a symptom not unique to osteoarthritis. Waldron (2009:33) also urges against using marginal osteophytes as a sole diagnostic criterion, as osteophytic formation can also occur as an "independent age-related phenomenon", and can also be indicative of other diseases aside from osteoarthritis.

Similarly, a standard diagnostic indicator for rotator cuff disease or intervertebral disc disease has not been decided upon amongst paleopathology professionals. Of the few available pieces of skeletal literature that reference these diseases, one on spinal disease was published by Waldron in the early 1990s in which his descriptions used to identify intervertebral disc disease very nearly match his operational definition published in 2009 (Waldron, 1991). Thus, for the sake of continuity in this study and in the hopes that these methods will eventually become the standards for diagnoses, the operational definitions proposed by Waldron in his 2009 textbook are used for all three diseases in this investigation.

Scoring Methods

Osteoarthritis, rotator cuff disease, and intervertebral disc disease were all diagnosed based on criteria published by Waldron (2009), with additional description and scoring based on Buikstra and Ubelaker (1994). Waldron's diagnoses were all developed with the intent of becoming standards for paleopathological studies, and all of them tend to approach diagnosis with caution. In particular, his osteoarthritis criteria is divided into pathognomonic changes and minor changes, and he notes that the disease should never be diagnosed based on the presence of only one minor criterion (Waldron, 2009). These operational definitions take into consideration the potential issue of diagnosing based on the presence of new bone, which can be found for a relatively large number of reasons. By requiring that a characteristic like the addition of new bone be found in conjunction with another symptom associated with osteoarthritis, hopefully misdiagnosis can be avoided. Per Waldron's operational definition, osteoarthritis was diagnosed in this study if eburnation was present by itself, or if at least two of the following changes were apparent in the gleno-humeral joint: marginal osteophyte(s), new bone on the surface of the joint, pitting on the joint surface, or alteration of the joint contour (Waldron, 2009). Alteration of the joint contour and bony addition to the joint surface can be seen in Figures 1 and 2 below, and the polish and shine of eburnation is visible in Figure 3. The gleno-humeral joints were examined and scored bilaterally in each individual for the presence of osteoarthritis.

Standards for scoring the severity of osteoarthritis are available from Buikstra and Ubelaker (1994). Degree and extent of the bone affected by lipping, pitting, eburnation, and surface osteophytes were recorded using these standards. For all changes, the extent is recorded as one of the following: less than one third, between one third and two thirds, or greater than two thirds (Buikstra and Ubelaker, 1994). Severity of new bone development and the physical appearance of that new bone can be categorized using the standards under "Abnormal Bone Formation".

Intervertebral disc disease can be diagnosed based on pitting of the vertebral body (inferior, superior, or both surfaces may be involved), and the presence of one or more marginal osteophytes (Waldron, 2009). Degree of severity for the osteophyte formation was scored using the standards on vertebral pathology presented by Buikstra and Ubelaker (1994), and degree and extent of pitting was scored on the same scale as osteoarthritis pitting. For vertebral pathologies, osteophytic formation was scored based on maximum expression found in the vertebral column, and the levels are as follows: barely discernible, elevated ring, curved spicules, and fusion present. A raised ring of osteophytes around the vertebral body is shown in Figure 9, and pitting to the vertebral body is visible in Figure 10. If shape change of the body was visible, it was also scored based on standards for "Abnormality of Shape: Spinal Column". This classified form change as either "angular" or as "gradual change in body height" (Buikstra and Ubelaker, 1994). The angular shape change, or "wedging", is visible in Figure 8 below.

Rotator cuff disease was diagnosed based on the presence of pitting in areas of insertion for the rotator cuff muscles, in conjunction with one of the following: new bone on or around the areas of muscle insertion, or alteration in the contour of the insertion (Waldron, 2009). Two of these criteria, pitting and bony addition, can be viewed in Figures 4 and 5. Though unnecessary for diagnosis, other changes that may be present include new bone on the acromion, coracoid, and bicipital groove, all of which were recorded if present. Examples of such bony addition can be seen in Figures 6 and 7 below. Severity of pitting was scored on the same scale as for the other two diseases, and new bone was classified according to the "Abnormal Bone Formation" standards. Extent of involvement was recorded per vertebral body, and the scale for extent was the same as those described above. For this disease, as the degenerative changes occur only on areas of the humeral head, the extent of involvement took into account only the portion of the head that was involved, rather than scoring involvement based on the entire bone.

Fig. 1. OA Picture New bone on joint surface, alteration of joint contour on humeral head

Fig. 2. OA Picture "Lipping" on the glenoid fossa of the scapula

Fig. 3. OA Picture Eburnation polish and shine on the acromial process of the scapula

Fig. 4 & 5. RCD Picture New bone and pitting to areas of insertion of the rotator cuff muscles

Fig. 6 & 7. RCD Picture Body addition to the undersurface of the acromion

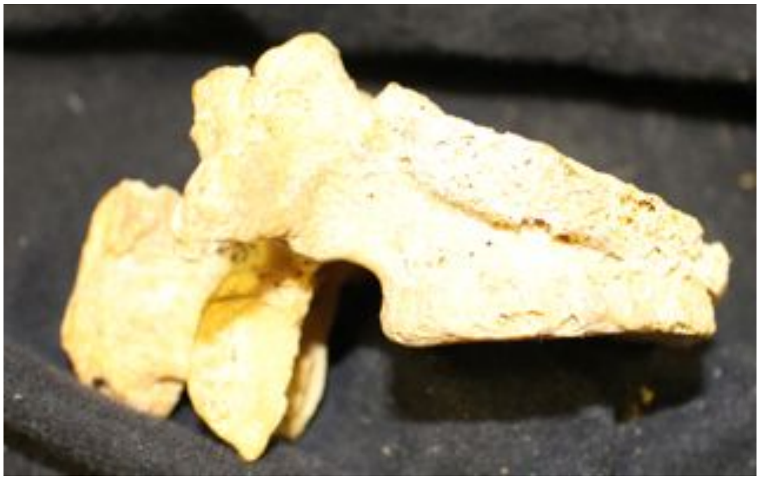

Fig. 8. IDD Picture Angular shape change of the vertebral body

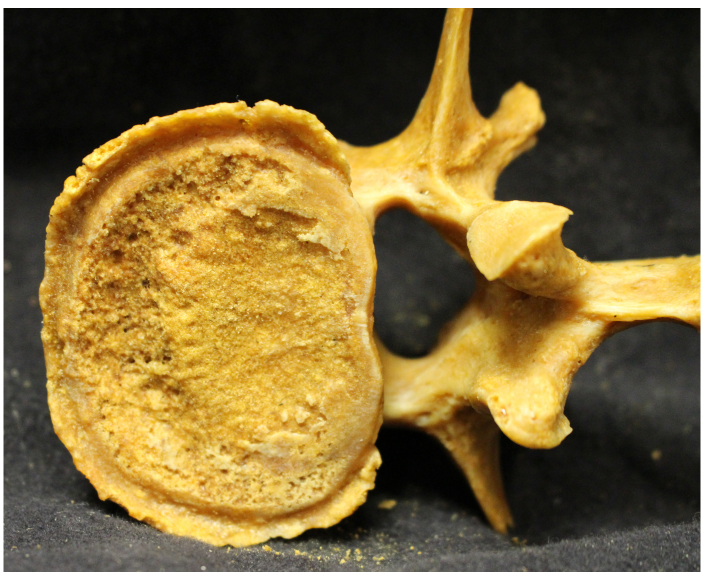

Fig. 9. IDD Picture Discernible ring of osteophytes around the body of lumbar vertebra

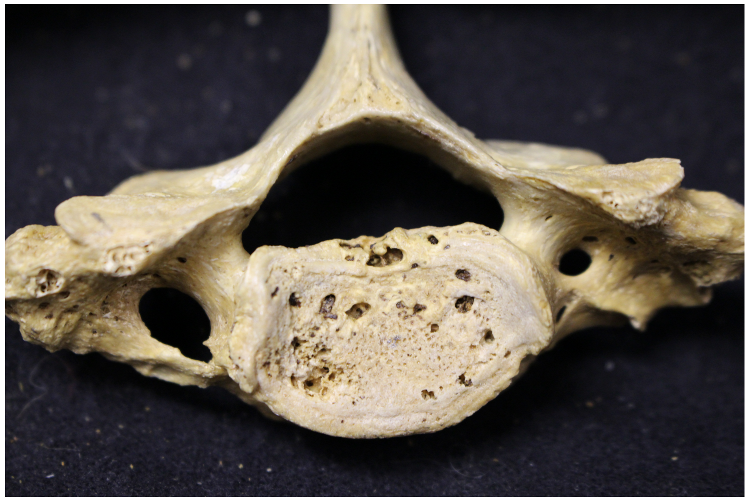

Fig. 10. IDD Picture Pitting on the body of a cervical vertebra

Overall severity of each disease for each individual was then ranked based on a scale of minor, moderate, and severe. If all criteria fell on the lowest portion of the scale as determined by the standards (i.e., osteophytes are barely discernible, extent affected is less than one third, etc.), then the severity is classified as minor. Also classified as minor were those for which the majority of criteria fell on the lowest portion, with one characteristic classifying as moderate (i.e., osteophytes presenting as an elevated ring). Those that classified as moderate had either all moderate changes, or a majority of changes that ranked as moderate with only one that scored as minor or severe. Severe cases were those that had either a majority of, or all of the recorded changes ranked as severe (i.e., greater than two thirds affected, curved spicule osteophyte formation, etc.).

Statistical Analysis

For data analytical purposes, each disease was scored as either 0, meaning “absent”, or 1, meaning “present.” Presence of both rotator cuff disease and osteoarthritis on either one or both joints was scored as well at either level 1 for “unilateral” or level 2 for “bilateral”, and those that lacked any presence of the disease defaulted to 0. Severity was also scored for all diseases on a scale of 1 through 3, translating as “mild” “moderate” and “severe” respectively. For the occupational variable in this study, individual occupations were categorized as “light”, “moderate”, or “heavy”, with regard to the assumed level of physical activity that would have been required. The decisions on which category a particular occupation would fit into were made based on the historical context presented in chapter 2. Job titles of “factory laborer”, “factory worker”, or “day laborer” were considered heavily physical occupations, as history texts tell of factory work at this time as involving overly long hours, poor conditions, and physical exertion. “Domestic”, “housekeeper”, or “houseboy” are considered to be moderately physical occupations, however “housewife” is categorized as “light”, because it is a title generally given to European-American women in this sample, many of whom were likely able to hire other women (often African-Americans) to do the majority of household chores for them, as was discussed in the chapter on historical context. A variety of occupations fell into the “light” category, including “driver”, “cigar maker”, “book keeper”, and “clerk”. “Janitor” and “janitress” fit into moderate, and “fireman” into the heavy category. Table 1.1 below shows the counts and percentages of all occupations present in the sample. Table 1.2 shows the breakdown of labor categories among the sexes and ancestries.

Table 1.1. Occupations in the Sample

Occupation Title	Number	Percent
Baker	1	0.5%
Barber	1	0.5%
Bricklayer	1	0.5%
Chauffeur	1	0.5%
Cook	7	3.6%
Day Laborer	4	2.1%
Dishwasher	2	1.0%
Domestic	6	3.1%
Domestic Work	1	0.5%
Dressmaker	1	0.5%
Driver	1	0.5%
Engineer	1	0.5%
Factory Labor	1	0.5%
Factory Laborer	1	0.5%
Factory Work	2	1.0%
Farm Hand	1	0.5%
Farmer	2	1.0%
Firefighter	1	0.5%
Furniture maker/finisher	1	0.5%
Hairdresser	1	0.5%
Houseboy	1	0.5%
Housekeeper	4	2.1%
Housewife	16	8.2%
Housework	36	18.5%
Janitor	1	0.5%
Janitress	1	0.5%
Laborer	66	33.8%
Laundress	7	3.6%
Maid	1	0.5%

Table 1.1. Continued

Mechanic	3	1.5%
Newspaper salesman	1	0.5%
Nutpacker	1	0.5%
Painter	1	0.5%
Paper cutter	1	0.5%
Paper hanger	1	0.5%
Porter	2	1.0%
Presser	1	0.5%
Railroad Auditor	1	0.5%
Railroad Engineer	1	0.5%
Salesman	1	0.5%
Saleswoman	1	0.5%
Seamstress	1	0.5%
Shoemaker	1	0.5%
Sorority Board	1	0.5%
Tailor	1	0.5%
Teamster	2	1.0%
Telephone Operator	1	0.5%
Vulcanizer	1	0.5%
Waiter	1	0.5%
Watchmaker	1	0.5%
Total	195	100%

Table 1.2. Distribution of Occupations by Sex and Ancestry

	Occupation Classification						Total
	Light		Moderate		Heavy		
	#	%	#	%	#	%	
African-American Males	8	16.3%	6	9.3%	37	45.1%	51
African-American Females	12	24.5%	35	54.7%	5	6.1%	52
European-American Males	13	26.5%	5	7.8%	39	47.5%	57
European-American Females	16	32.7%	18	28.1%	1	1.2%	35
Total	49	100%	64	100%	82	100%	195

To analyze this sizable amount of information, two particular statistical tests were chosen that capitalize on the ordinal data here, as well as the fact that many of the analyses can be run as 2x2 tests. The software SAS, version 9.4, was used to perform all statistical analyses. When the frequency procedure in this software is used it generates, among other things, Cochran-Mantel-Haenszel statistics, odds ratios, and relative risk values. The Cochran-Mantel-Haenszel test generates three statistics: a correlation statistic, a row mean scores statistic, and a general association statistic, which will be explained in greater detail in the following chapter. Cochran-Mantel-Haenszel tests the null hypothesis that relative proportions of one variable are independent of a second variable. Additionally, odds ratios and relative risk can be generated through Cochran-Mantel-Haenszel for those tests that are 2x2 in nature. In the context of this study, odds ratios and relative risk can be used to predict the likelihood that one group will develop the disease as compared to another group (i.e., ancestral groups or sex). Ordinal logistic regression was also utilized here to examine which etiological factors out of those used in this analysis (sex, age, ancestry, occupation) actually have an effect on the development of the three diseases selected for analysis. This type of analysis was also used to examine the effects of the previously listed etiological factors on the severity of the three diseases.

CHAPTER 5

RESULTS

Descriptive Statistics

Table 2.1 shows the number of individuals available for study by sex and ancestry. Table 2.2 shows the distribution of individuals in the study based on ten-year age groups. Table 2.3 shows the number and percentages of individuals by sex and ancestry. Tables 3.1 through 3.3 show the frequency of osteoarthritis, rotator cuff disease, and intervertebral disc disease in this sample based on ancestry. Overall, a greater percent of European-American ancestry suffered from intervertebral disc disease than did those of African-American ancestry, with 72% for the former group and only 33% for the latter. The same is true of osteoarthritis in the sample, as approximately 32% of the European-Americans sampled had the disease, while only 8.7% of African-Americans were found to have OA. These results are not surprising, considering the much greater age of the European-American sample. For rotator cuff disease, the proportions were closer in number. Nearly 37% of African-Americans in the sample had the disease, and approximately 38% of European-Americans were found to have it as well. A result such as this is somewhat surprising given the age difference in the samples.

***Table* 2.1.** Ancestry Distribution of Sample

	Number	Percent	Mean Age
African-American	103	52.8%	41.6
European-American	92	47.2%	54.7

Table 2.2. Sex Distribution of Sample

	Number	Percent	Mean Age
Male	108	55.4%	45.5
Female	87	44.6%	51.1

Table 2.3. Distribution of Sex by Ancestry

	Sex				
	Male		Female		
Ancestry	#	%	#	%	Total
African-American	51	26.2%	52	26.7%	103
European-American	57	29.2%	35	44.6%	92
Total	108	55.4%	87	71.3%	195

Table 3.1. Osteoarthritis in the Sample by Ancestry (by frequency and proportion)

Ancestry	**Mean Age**	**Osteoarthritis**		
		Not present	Present	Total
African-American	41.6	94 91.3%	9 8.7%	103
European-American	54.7	63 68.5%	29 31.5%	92
Total		157	38	195

***Table* 3.2.** Rotator Cuff Disease in the Sample by Ancestry

Ancestry	**Mean Age**	**Rotator Cuff Disease**		
		Not present	Present	Total
African-American	41.6	65 63.1%	38 36.9%	103
European-American	54.7	57 61.9%	35 38.0%	92
Total		122	73	195

***Table* 3.3**. Intervertebral Disc Disease in the Sample by Ancestry

Ancestry	**Mean Age**	**Intervertebral Disc Disease**		
		Not present	Present	Total
African-American	41.6	69 66.9%	34 33.0%	103
European-American	54.7	26 28.3%	66 71.7%	92
Total		95	100	195

Tables 4.1 through 4.3 show the frequencies and proportions of the respective joint diseases when categorized by sex. A higher proportion of males in this sample presented with intervertebral disc disease, at 58%, as compared to the females at 42% despite the older mean age for the female group. The same is true of osteoarthritis, with 22% of males in the sample

diagnosed with OA, and only 16% of females. However, females had a higher proportion of rotator cuff disease at nearly 45%, while only 33% of males in the sample displayed RCD symptoms.

Table 4.1. Proportion and Frequency of Osteoarthritis by Sex

Sex	Mean Age	Osteoarthritis		
		Not present	Present	Total
Male	45.5	84 77.8%	24 22.2%	108
Female	51.1	73 83.9%	14 16.1%	87
	Total	157	157	38

Table 4.2. Proportion and Frequency of Rotator Cuff Disease by Sex

Sex	Mean Age	Rotator Cuff Disease		
		Not present	Present	Total
Male	45.5	72 66.7%	36 33.3%	108
Female	51.1	50 57.5%	37 42.5%	87
	Total	122	73	195

Table 4.3. Proportion and Frequency of Intervertebral Disc Disease by Sex

Sex	**Mean Age**	**Intervertebral Disc Disease**		
		Not present	Present	Total
Male	45.5	45 41.7%	63 58.3%	108
Female	51.1	50 57.5%	37 42.5%	87
Total		95	100	195

Tables 5.1 through 5.3 show the distribution of the observed joint diseases based on ten-year age groups. The 60-69 age group had the highest proportion of intervertebral disc disease, with 94% of its members diagnosed with the disorder. Eighty-four percent (84%) of the 70+ age group showed signs of the disease, while 60% or fewer members of the lower three age groups had IDD. For osteoarthritis, the 60-69 group and the 70+ group again had the highest proportions, closely followed by the 50-59 age group. Notably, the 30-39 age group had zero incidences of osteoarthritis. The highest proportions of rotator cuff disease are found in the 70+ group and the 50-59 age group, at approximately 58% and 54% respectively. Age groups 60-69, 40-49, and 30-39 had proportions of 41%, 36%, and 22%, respectively.

Table 5.1. Osteoarthritis by Age Group

Age Group	Osteoarthritis		
	Not Present	Present	Total
30-39	50 100.0%	0 0.0%	50
40-49	66 81.5%	15 18.5%	81
50-59	19 67.9%	9 32.1%	28
60-69	10 58.8%	7 41.2%	17
70+	12 63.2%	7 36.8%	19
Total	157	38	195

Table 5.2. Rotator Cuff Disease by Age Group

Age Group	Rotator Cuff Disease		
	Not Present	Present	Total
30-39	39 78.0%	11 22.05	50
40-49	52 64.2%	29 35.8%	81
50-59	13 46.4%	15 53.6%	28
60-69	10 58.85	7 41.2%	17
70+	8 42.1%	11 57.9%	19
Total	122	73	195

Table 5.3. Intervertebral Disc Disease by Age Group

Age Group	Intervertebral Disc Disease		
	Not Present	Present	Total
30-39	42 84.0%	8 16.0%	50
40-49	38 46.9%	43 53.1%	81
50-59	11 39.3%	17 60.7%	28
60-69	1 5.9%	16 94.1%	17
70+	3 15.8%	16 84.2%	19
Total	95	100	195

Cochran-Mantel-Haenszel Statistics

The frequency procedure in the SAS software computes three Cochran-Mantel-Haenszel statistics: a correlation statistic, an ANOVA statistic (also known as row mean scores), and the general association statistic (SAS Institute, 2015). These three statistics test a null hypothesis, which suggests that there is no association between the variables being analyzed (SAS Institute, 2015). For the nonzero correlation statistic, the alternative hypothesis is that the X and Y variables have a linear association between them in at least one stratum (SAS Institute, 2015). If the null hypothesis for the correlation statistic is rejected in this study, it means that there is a correlation between the independent variable and the joint disease being analyzed. The alternative hypothesis for the row mean scores is that the mean scores of the rows are unequal in at least one stratum (SAS Institute, 2015). In this case, if the null hypothesis is rejected it means that the independent variable being assessed has a significant effect on the presence of the selected joint disease. Lastly, the alternative hypothesis for the general association statistic is simply that there is some kind of association between the X and Y variables for at least one stratum (SAS Institute, 2015).

Analysis of intervertebral disc disease showed that there is a significant ancestry effect on IDD presence in an individual. There is also a significant ancestry effect on the presence of osteoarthritis, though this is not true of rotator cuff disease. There is also a sex effect on only intervertebral disc disease, but not the other diseases. As expected, an age effect on presence was also evident for all three diseases.

Nonzero correlation of the Cochran-Mantel-Haenszel test revealed that IDD presence is correlated with ancestry and age when each of those etiological factors was assessed individually for their effect on the disease. Significant correlation is also present between osteoarthritis and ancestry, as well as OA and age. Rotator cuff disease is correlated only with age when other etiological factors are excluded. The examination of the occupational variable was performed only when taking other etiological components into account first. When controlling for ancestry, occupation and intervertebral disc disease are correlated, though osteoarthritis and rotator cuff disease show no correlation with occupation under these terms. In an examination of occupation when controlling for sex, none of the diseases were found to correlate with occupation. This may mean that there are other important factors that must be accounted for in order for activity to significantly contribute to disease development. It may also be that differences in sample size between the sexes or between the occupational categories have enough of an effect that they may be affecting the results by obscuring correlations.

Birth cohorts organized by decade were examined to determine changes in proportion of individuals affected by joint disease over time. These cohorts spanned from 1840 to 1910. In the case of intervertebral disc disease, percentage of individuals with the disease decreased as birth decade increased. Osteoarthritis saw a slight increase in proportion of individuals from the 1860s to the 1870s, and then a sharp decrease in proportions in the later decades, with zero individuals diagnosed with osteoarthritis in the final cohort. The pattern is the same for rotator cuff disease, decreasing from 66.7% in the first birth cohort, to 8.3% in the last. However, this is likely due to the distribution of ages within the birth cohorts, as the mean age decreases as the birth decade increases. Table 6.1 shows the number of individuals and the mean ages for each birth decade category. It is interesting to note that decades 1860-1869 and 1870-1879 have greater proportions of osteoarthritis present as compared to the first two decades, despite the younger mean ages. However, the small sample size of those first two decades likely plays a large part in this observed incidence. The proportions of rotator cuff disease and intervertebral disc disease in the latest (and also youngest, by mean age) decade is also of interest.

Table 6.1. Birth Decade Category Makeup

	# of Individuals	Mean Age	Proportion OA Present	Proportion RCD Present	Proportion IDD Present
1840-1849	3	81.7	33.3%	33.3%	66.7%

Table 6.1. Continued

1850-1859	7	76.3	28.6%	85.7%	100.0%
1860-1869	19	65.3	42.1%	57.9%	78.9%
1870-1879	42	53.8	38.1%	47.6%	73.8%
1880-1889	68	45	16.2%	32.4%	50.0%
1890-1899	44	36.7	0.0%	25.0%	22.7%
1900-1910	12	34.4	0.0%	16.7%	8.3%

Common Odds Ratio and Relative Risk

When running a Cochran-Mantel-Haenszel test for a two-by-two table, the analysis provides another means of examining the measure of association in the form of the adjusted odds ratio. Measures of relative risk associated with these odds ratios are useful for studies such as this one, where samples are identified based on presence or absence of the explanatory factor (SAS Institute, 2015). In this study, the odds ratio is used to determine which ancestral groups and which sex have a higher risk of developing the selected joint diseases. When examining odds ratios for ancestry, the risk for developing intervertebral disc disease is 5 times higher for European-Americans of this sample than for African-Americans. The relative risk value for column 1 is greater than 1 (2.37), which validates the fact that the positive response (having intervertebral disc disease) is greater for the European-American group than it is for the African-American group. Similarly, European-Americans are 4.8

times more likely to develop osteoarthritis than African-Americans, confirmed by a low relative risk for the column 2 (0.28) and a relative risk greater than 1 (1.33) for column 1. For rotator cuff disease, the groups are more similar, with European-Americans only 1.05 times more likely to develop the disease, and relative risk values of 1.02 for column 1 and 0.97 for column 2. It should be noted that these odds ratios may be inflated due to an age effect. The mean age for African-Americans of the sample is 41.6 and for European-Americans it is 54.7. The range of difference here, with an older mean age for European-Americans suggests an important age effect. If the two groups had been closer in age, the risk for European-Americans may not have been as great. Females are at approximately half the risk of developing intervertebral disc disease as compared to males in the sample. The relative risk value for column 1 is less than 1 (0.73), confirming that the probability of the positive response (presence of intervertebral disc disease) is less for the females of the group than for the males. Similarly, the risk of osteoarthritis is 0.67 times lower for females than for males, validated by a relative risk value of 1.381 for column 2, and a lower relative risk value for column 1 (0.93). However, females are nearly 1.5 times more likely to develop rotator cuff disease than are males, with a column 1 relative risk of 1.16 and a lower column 2 relative risk of 0.78. The mean ages for these two groups are relatively close, with 45.5 for males and 51.1 for females. With an older mean age for females, it might be expected that females would be at an overall greater risk for developing the joint diseases. However, males are at greater risk for two of the three diseases, and the differences in odds ratios are not so great to think that age is having a great effect on this portion of the analysis.

Ordinal Logistic Regression

The type of ordinal logistic regression used here is known as the proportional odds model. This model assumes that the predictors have the same impact on crossing all thresholds, in this case the threshold being the development of a joint disease (Cohen et al., 2003). In this type of analysis, the model is used to predict probabilities of membership in a certain category (Cohen et al., 2003).

In this study, ordinal logistic regression was used to examine which etiological factors were significant in the development of joint disease when all other factors are controlled for. Based on the Cochran-Mantel-Haenszel tests, those components that were determined to have a significant effect on the presence of a disease were used in a predictive model for the presence of each disease. The type 3 analysis of effects was examined to determine which independent variables are significant in joint disease presence after controlling for all other independent variables. For intervertebral disc disease, ancestry and birth decade are significant variables for the development of the disease. Considering table 6.1 above, the birth decade variable is essentially a proxy for age, thus there appears that age is significant in intervertebral disc disease development. In the regression analysis of osteoarthritis, the only significant variable is age. Ancestry, sex, and birth decade (or age) are all significant factors in the development of rotator cuff disease. Tables 7.1 through 7.3 show the type 3 analysis of effects tables for the three models, which include Wald Chi-Square statistics and p values for each independent variable analyzed.

Table 7.1. Osteoarthritis Logistic Regression for Presence – Type 3 Analysis of Effects

Effect	Degrees of Freedom	Wald Chi-Square	Pr > ChiSq
Ancestry	1	1.7226	0.1894
Sex	1	2.3208	0.1277
Job Category	2	1.4734	0.4787
Age	1	11.5616	0.0007

Table 7.2. Rotator Cuff Disease Logistic Regression for Presence – Type 3 Analysis of Effects

Effect	Degrees of Freedom	Wald Chi-Square	Pr > ChiSq
Ancestry	1	4.2403	0.0395
Sex	1	4.9510	0.0261
Job Category	2	5.9334	0.0515
Birth Decade Category	3	16.2590	0.0010

Table 7.3. Intervertebral Disc Disease Logistic Regression for Presence – Type 3 Analysis of Effects

Effect	Degrees of Freedom	Wald Chi-Square	Pr > ChiSq
Ancestry	1	5.3556	0.0207
Sex	1	2.6846	0.1013

Table 7.3. Continued

Job Category	2	2.6847	0.2612
Birth Decade Category	3	19.6847	0.0002

A cumulative logit model was also used to examine whether any of the selected etiological factors contributed to disease severity in this sample. First, each individual component was run in a model to determine if they had any significant effect on their own. A final model was then generated that determined which variables were significant in the model after all other variables were controlled for. As in the former regression results, type 3 analyses of effects were used to determine a variable's significance in the model. When variables were run independently for intervertebral disc disease, ancestry, age, and birth decade category (which is essentially an age proxy), were significant. In the full model, ancestry, age, and job category all showed a significant effect on the severity of intervertebral disc disease. When run in individual models, ancestry, age, and birth decade category were significant contributors to osteoarthritis severity. In the full model, ancestry and age were both significant contributors to osteoarthritis severity. For rotator cuff disease, only age and birth decade category were significant when run in independent models. When the full model was analyzed with all factors simultaneously controlled for, ancestry, and birth decade category showed significant effect on severity of the disease. Tables 8.1 through 8.3 below show the type 3 analysis of effects for three severity models.

Table 8.1. Logistic Regression Type 3 Analysis of Effects for OA Severity

Effect	Degrees of Freedom	Wald Chi-Square	Pr > ChiSq
Ancestry	1	6.2561	0.0124
Age	1	5.3639	0.0206

Table 8.2. Logistic Regression Type 3 Analysis of Effects for RCD Severity

Effect	Degrees of Freedom	Wald Chi-Square	Pr > ChiSq
Ancestry	1	5.1157	0.0237
Birth Decade	2	17.1042	0.0002

Table 8.3 Logistic Regression Type 3 Analysis of Effects for IDD Severity

Effect	Degrees of Freedom	Wald Chi-Square	Pr > ChiSq
Ancestry	1	9.9954	0.0016
Job Category	2	7.5721	0.0227
Age	2	13.7546	0.0010

Summary

Tables 9.1 through 9.3 below show the summary data for each of the three diseases by sex, ancestry, job classification, and age. The greater proportions of European-American individuals diagnosed with the respective diseases are visible here. So too are the higher proportions of intervertebral disc disease and osteoarthritis for males compared to females, and the higher proportions of rotator cuff disease for females when compared to males. The increasing proportions with age for all three diseases are also seen here, as are the significant proportions of individuals diagnosed with intervertebral disc disease and rotator cuff disease in the youngest age groups.

Additionally, the number of cases diagnosed on the severity scale are visible here. Severe cases are rare for all three diseases, with only two diagnosed "severe" cases for osteoarthritis, nine for rotator cuff disease, and nine for intervertebral disc disease. However, for both rotator cuff disease and intervertebral disc disease, there is an increase in the number of cases diagnosed overall when moving from the "light" occupation group to the "heavy" occupation group. For rotator cuff disease, 18 individuals from the light group were diagnosed, followed by 21 from the moderate group, and 34 from the heavy group. For intervertebral disc disease, 22 individuals from the light group were diagnosed with the disease, followed by 30 individuals from the moderate group, and 48 from the heavy group.

The two severe cases of osteoarthritis were in the upper two age groups, while the mild and moderate cases were spread from the 40-49 age group through the 70+ age group. Severe cases of rotator cuff disease are present in all age groups except for the 60-69 cohort, and the nine cases of intervertebral disc disease are spread between all age groups except for the 50-59 cohort. The male cohort has more diagnosed cases of severe rotator cuff disease, while the female cohort has more diagnosed cases of severe osteoarthritis and severe intervertebral disc disease.

Table 9.1. Summary Data for Osteoarthritis

	Presence/Absence								Severity		
	Absent			Present			Total		Mild	Moderate	Severe
Variables	#	%		#	%		#	%	#	#	#
Sex											
Male	84	54%		24	63%		108	55%	18	6	0
Female	73	46%		14	37%		87	45%	7	5	2
Total	157	100%		38	100%		195	100%	25	11	2
Ancestry											
European-American	63	40%		29	76%		92	47%	19	8	2
African-American	94	60%		9	24%		103	53%	6	3	0
Total	157	100%		38	100%		195	100%	25	11	2
Work											
Light	36	23%		13	34%		49	25%	7	4	2
Medium	56	36%		8	21%		64	33%	5	3	0
Heavy	65	41%		17	45%		82	42%	13	4	0
Total	157	100%		38	100%		195	100%	25	11	2
Age											
30-39	50	34%		0	0%		50	26%	0	0	0
40-49	66	45%		15	39%		81	42%	11	4	0
50-59	19	13%		9	24%		28	14%	5	4	0
60-69	10	6%		7	18%		17	9%	6	0	1
70+	12	8%		7	18%		19	10%	3	3	1
Total	157	100%		38	100%		195	100%	25	11	2

Table 9.2. Summary Data for Rotator Cuff Disease

	Presence/Absence									Severity		
	Absent			Present			Total			Mild	Moderate	Severe
Variables	#	%		#	%		#	%		#	#	#
Sex												
Male	72	59%		36	50%		108	55%		22	8	6
Female	50	41%		37	50%		87	45%		23	11	3
Total	122	100%		73	100%		195	100%		45	19	9
Ancestry												
European-American	57	47%		35	48%		92	47%		22	8	5
African-American	65	53%		38	52%		103	53%		23	11	4
Total	122	100%		73	100%		195	100%		45	19	9
Work												
Light	31	25%		18	25%		49	25%		8	6	4
Medium	43	36%		21	29%		64	33%		14	7	0
Heavy	48	39%		34	46%		82	42%		23	6	5
Total	122	100%		73	100%		195	100%		45	19	9
Age												
30-39	39	32%		11	15%		50	26%		7	2	2
40-49	52	43%		29	40%		81	42%		19	6	4
50-59	13	11%		15	21%		28	14%		7	7	1
60-69	10	8%		7	9%		17	9%		6	1	0
70+	8	6%		11	15%		19	10%		6	3	2
Total	122	100%		73	100%		195	100%		45	19	9

Table 9.3. Summary Data for Intervertebral Disc Disease

	Presence/Absence								Severity		
	Absent			Present			Total		Mild	Moderate	Severe
Variables	#	%		#	%		#	%	#	#	#
Sex											
Male	45	47%		63	63%		108	55%	35	24	4
Female	50	53%		37	37%		87	45%	19	13	5
Total	95	100%		100	100%		195	100%	54	37	9
Ancestry											
European-American	26	27%		66	66%		92	47%	21	11	2
African-American	69	73%		34	34%		103	53%	33	26	7
Total	95	100%		100	100%		195	100%	54	37	9
Work											
Light	27	28%		22	22%		49	25%	15	5	2
Medium	34	36%		30	30%		64	33%	16	11	3
Heavy	34	36%		48	48%		82	42%	23	21	4
Total	95	49%		100	100%		195	100%	54	37	9
Age											
30-39	42	44%		8	8%		50	26%	5	2	1
40-49	38	40%		43	43%		81	42%	26	13	4
50-59	11	12%		17	17%		28	14%	11	6	0
60-69	1	1%		16	16%		17	9%	7	8	1
70+	3	3%		16	16%		19	10%	5	8	3
Total	95	100%		100	51%		195	100%	54	37	9

CHAPTER 6

DISCUSSION

Degenerative joint diseases have been used in the past to identify activity patterns of long dead populations, largely based on the assumption that the development of such diseases is related to movement and physical activity (Jurmain, 1977; Klaus et al., 2009; Schrader, 2012; Palmer et al., 2014). However, research in recent years has led to debate on whether or not this is an appropriate course of action. To find an answer, studies that are able test the association of joint disease development and activity are crucial, and investigations into the etiologies of various joint diseases from an osteological perspective would undoubtedly also be useful. The study presented here attempts to examine both of these issues, with the expectation that the obtained results will contribute knowledge to those studies undertaking the subject of activity in the past.

Joint Disease and Age

In total, only 20% of the 195 individuals examined in this sample were diagnosed with gleno-humeral osteoarthritis. Of the potential etiological components, age can be considered the most influential when examining the results of both the Cochran-Mantel-Haenszel test and the ordinal logistic regression analysis. Ancestry and age showed a statistically significant effect on osteoarthritis presence, and these factors were also the only two to significantly correlate with the disease in the Cochran-Mantel-Haenszel tests. For the logistic regression proportional odds model, age was the only significant factor in the model. The ancestry effect from the Cochran-Mantel-Haenszel test, then, is most likely caused by the age difference in the samples. The concept of age being a crucial factor in the development of this disease is not surprising, as similar results regarding the relationship between osteoarthritis and age have occurred in multiple studies of both anthropological and clinical nature (Jurmain, 1977; Maurer, 1979; Felson, 1990; Waldron, 1991; Yesil et al., 2014). The significance of these studies and the results obtained here have implications for the use of osteoarthritis in activity reconstruction, especially when considering the lack of correlation between osteoarthritis and the activity variable utilized in this study, which is discussed in more detail below.

Rotator cuff disease is correlated with age in this sample, and the proportions of the disease found in the upper age groups (50 and up) are significantly higher than for the younger age groups. A recent study of rotator cuff tears and associated symptoms among living people had a similar pattern of pervasiveness: 2.5% of individuals in the thirties age group experienced tears and symptoms, 6.7% of individuals in their forties, 12.8% in the fifties, 25.6% in the sixties, 45.8% in the seventies, and 50% in their eighties (Yamamoto et al., 2010). There are many clinical studies that suggest that age does have an effect on the development of rotator cuff disease, however, all of these studies also found significance in other etiological factors (Northover et al., 2007; Yamamoto et al., 2010), as the present study did.

An association was also found between intervertebral disc disease and age, and like the other diseases, prevalence generally increased from younger age cohorts to older ones, with 16% presence in the youngest group and 84% presence in the oldest. Age has been identified by clinical researchers as playing a huge role in disc degeneration – a problem which leads to skeletal symptoms like IDD – and consider age as perhaps second only to genetic influence (Wang and Battie, 2014). It has also been pointed out, however, that noticeable variation is present within age groups in some findings, and also that degenerative changes can occur earlier on in life, suggesting other factors of importance (Boos et al., 2002; Wang and Battie, 2014).

Thus, in the analyses presented here, all three diseases had significant association with age, supporting the results of previous studies regarding these diseases. Of particular interest is the apparently early onset for rotator cuff disease and intervertebral disc disease compared to osteoarthritis, and also that intervertebral disc disease becomes more common, more quickly than the other two diseases as age increases. However, for two of these diseases, the logistic regression models in particular suggest that other factors should also be considered meaningful with regard to their development.

Joint Disease and Sex

The proportion of males in the sample with gleno-humeral osteoarthritis was higher than that of females, and the odds for females to develop the disease are approximately 67% lower than for males. This is contrary to other studies on osteoarthritis that have also produced results indicating that females are at greater risk of developing the disease (Arden and Nevitt, 2006; Yoshimura, 2009; Chambers, 2012; Yesil, 2014). However, in looking at the relationship between occupation and osteoarthritis, some researchers have found that the disease affected males earlier than females, and usually with more severity (Cobb, 1971;

Roberts and Burch, 1966). As variations in sex differences are often found between different joints, it may be that shoulder osteoarthritis is more common in males than in females. It has also been suggested that age also plays a role in the differences between the sexes, as one study found for multiple joints that males were more affected up to the age of 60, though after that age females were the more affected group (Heine, 1926, as reported by Jurmain, 1977). Clinical texts that have identified women as being twice as likely as men to be affected by osteoarthritis suggest that the pattern is due to a possible link between osteoarthritis development and the estrogen deficiency associated with menopause (Brandt, 2001). It has been suggested by some that differences in distribution of joint diseases between the sexes is indicative of divisions of behavior or labor in the sexes. If this study were to follow such suggestions, it could be inferred that the males in this sample suffered more joint disease in response to an increased load of physical labor. As seen in Figure 11, a relatively large percentage of males in this sample fell into the "heavy" job categorization, which could suggest that activity played some part in the development of the disease. However, the smaller percentage of individuals in both the "moderate" and "light' categories may bias the sample slightly. There may also be an inherent mechanical bias here, considering the differential proportions of male shoulders compared to females, such as the relatively greater width.

Diagnostic symptoms of rotator cuff disease were identified in approximately 37% of the sample utilized here. A higher proportion of females in this study were diagnosed with symptoms of the disease – 42.5% for females as compared to 33.3% of males – and the odds ratio revealed that females of the sample were 1.5 times more likely to develop the disease. In a 2012 study on rotator cuff syndrome, though no odds ratios were calculated, the researchers found a similar result in higher prevalence for females, with 8.5% of women diagnosed with the disease as compared to 6.6% of men in the sample (Bodin et al., 2012). A study in France on individuals working in manual occupations revealed the same heightened prevalence in women, with a 67% proportion for women and a 62% proportion for men in the sample (Melchoir et al., 2006). These findings are congruent with what is expected based on rotator cuff disease being clinically documented as most often affecting elderly women, perhaps also due to estrogen deficiency associated with menopause, which has been suggested as linked to osteoarthritis development in women (Jensen et al., 1999; Brandt, 2001). It is also possible that physical activity could have played some small role in the development of rotator cuff disease in the females of this sample. Though there was no correlation found between the occupation variable and rotator cuff disease in this study, which is contradictory to expectations based on the high association between occupational stress and this disease in clinical literature. However, the p-value of 0.0515 is only slightly higher than the 0.05 threshold, and the addition of a few more individuals to the sample may have yielded different results; results in favor of an association between rotator cuff disease and occupation. Another possibility is that the categorization choices for the occupation variable biased the results. A research study on entheseal change demonstrated that different divisions of occupational categories, whether into two, three, or more, affected the frequencies of entheseal changes found in each category, suggesting high sensitivity of the categories, which has the potential to affect study outcomes (Cardoso and Henderson, 2013). The aforementioned study advocated for the development of standardized occupational categories, and such standardization would undoubtedly add accuracy and credibility to studies such as this one.

Approximately 51% of this sample displayed symptoms indicating the presence of intervertebral disc disease. In examining sex differences, a higher proportion of males in the sample had the disease, and females of the sample had approximately half the risk of developing the disease as compared to males despite their slightly higher mean age. This is as expected, considering that the males of this sample in particular likely dealt with a more physical, strenuous workload on a daily basis. There is also a great deal of clinical research that has either found no significant difference between disc degeneration in the sexes, or has revealed greater prevalence and more severe manifestation of degeneration in males (Partridge et al, 1965; Siemionow et al., 2011; Miller et al., 1988). Considering the correlation found between intervertebral disc disease and the activity variable in this sample (which will be discussed below), the greater prevalence of the disease in males in conjunction with the historical context for the sample that predicted such a result, it stands to reason that activity differences between the sexes are visible in the vertebrae of the individuals in this sample.

Joint Disease and Ancestry

Though proportions of the diseases and relative risk ratios showed differences between the two ancestral groups, there is a condemning factor that makes this portion of the analysis less reliable. The mean age difference of nearly 13 years between the two groups suggests a heavy age component. African-American individuals in their early 40s are less likely to be diagnosed with a degenerative joint disease than are individuals in their mid 50s, as the European-American group is. However, there was one outcome of interest in the ancestral analyses – that of rotator cuff disease proportions between the two groups. Despite the large gap in mean age, 37% of the African-American group and 38% of the European-American group were diagnosed with rotator cuff disease. If, as the clinical literature suggests, activity is indeed a largely contributing factor to the development of this diseases, this may be reflective of the activity differences between the two groups, with African-Americans generally experiencing much greater physical stress than their European-American counterparts.

Occupation and Degenerative Joint Disease

Based on the correlation between intervertebral disc disease development and the activity variable, it is possible that the higher prevalence of the disease in the male sex could be indicative of heavier physical activity for males in this sample. Similarly, the almost equal prevalence of this particular disease in both ancestral groups analyzed here might suggest that they experienced fairly equal stressors in their lifetimes. When the differences in mean age are taken into account, however, a different pattern may be suggested. Considering the close proportions of rotator cuff disease between the two samples, despite the age difference, this may be indicative of greater stress levels in the African-American individuals of the sample. It should also be taken into account, however, that the distribution of jobs defined as light, moderate, and heavy is not the same between the two ancestral groups. Though the "heavy" group is nearly equal, 19.4% of the African-American group held jobs considered "light" and 39.8% considered moderate, whereas the European-American proportions are 31.5% for "light" and 25% for "moderate". Table 1.2, in chapter 4, shows the differences in occupational distribution between the sexes and ancestries.

Following the trend of previous research, the low prevalence of osteoarthritis in this sample (20%) might be considered to be indicative of low stress, as the reverse trend has been used in many studies to infer high stress and high levels of physical activity (Angel et al., 1987; Bridges, 1989; Schrader, 2012). However, when the etiological factors of osteoarthritis were assessed, the activity variable was not found to be significantly associated with this disease in either of the statistical tests utilized. Therefore, to draw conclusions about this population's physical stress based on osteoarthritis should probably be considered a less than sound method. This may be due in large part to the overall younger age distribution of this sample, since osteoarthritis development is generally more pronounced in later age groups. Conversely, as stated above, intervertebral disc disease presence was found to be associated with occupation, and the relatively high prevalence of this disease in the sample (51%), suggests some physical stressors might have been acting on the population overall.

The lack of association between rotator cuff disease and the occupation variable was surprising, considering the abundance of clinical studies that suggest occupational stress plays a role in development of the disorder (Frost and Andersen, 1995; Bernard, 1997; Kaergaard and Andersen, 2000; Melchoir et al., 2006). There are several factors to consider in this study that might have influenced those particular results. First and foremost, the lack of standard diagnostic criteria for rotator cuff disease in skeletal material enables a higher chance of either over- or under-diagnosing the disease in a sample. As discussed above, the lack of standard occupational categories is also a possible condemning factor. Other confounding factors may lie in the makeup of the sample, as neither the distribution of African-Americans and European-Americans nor the distribution of males and females were exactly equal.

However, it is encouraging to see an association between the occupation variable and the severity variable in this study, suggesting that occupation may play a role in the progression of the disease, at least. There is a similar association between intervertebral disc disease severity and the occupation variable, suggesting again that physical activity is visible in the spine. It should be noted, however, that the number of individuals diagnosed with these diseases were relatively small, and separating those individuals into three severity categories made those numbers even smaller. This may have caused some problems with the cumulative logit analyses, and so the results obtained here should be regarded as tentative.

Another important factor to consider for two of these diseases is whether the manifestation was unilateral or bilateral. It has been documented in the clinical literature that both osteoarthritis and rotator cuff disease can be caused by a single injury, rather than continuous stress. Thus, those individuals who had either of the diseases in only one shoulder may have suffered the disease as result of a single incident, which would make that case less indicative of general activity. However, it should also be considered that the joint disease may simply show up in one shoulder over the other because of heavier continuous use of that arm, based on the individual's handedness. Additionally, the historical context detailed in an earlier chapter shows that working conditions for those in "heavily physical" occupations (generally factory jobs) were usually more dangerous overall than those in other occupations, and the assumption would follow that these individuals would be more likely to experience injury than others. Table 10.1 shows the distribution of bilateral and unilateral manifestations of rotator cuff disease and osteoarthritis observed in this sample.

Table 10.1. Distribution of Shoulder Disease Manifestation

	Frequency Unilateral	Percent Unilateral	Frequency Bilateral	Percent Bilateral
Osteoarthritis (n=38)	17	8.7	21	10.8
Rotator Cuff Disease (n=73)	32	16.4	41	21.0
Total Sample:	195		195	

CHAPTER 7

CONCLUSION

The utility and application of the osteological analysis presented here has many implications for anthropological and paleopathological study. First and foremost, the findings of a high correlation between osteoarthritis and age, with low or zero association with other potential etiological factors, appears to validate those researchers who have, as of late, rejected the use of this disease in making inferences on activity in the past. Based on this and other research, both anthropological and clinical in nature, it seems that the age of an individual is a necessary condition for the development of this particular degenerative joint disease. For this sample, gleno-humeral osteoarthritis alone does not appear to be a useful indicator of activity, likely due to the relatively young average age of this group. However, there may still be potential for use of the shoulder in activity investigations if further study is carried out on rotator cuff disease. Additionally, it appears that physical activity is visible in the spinal column, and therefore, future studies on physical activity would likely benefit from use of this portion of the body. It may be that there is a minimum age threshold for the diseases that should be taken into consideration when conducting activity studies. Gleno-humeral osteoarthritis may be better suited to a sample with a mean age over 50, while intervertebral disc disease and rotator cuff disease may be more valuable for samples with a high concentration of younger individuals.

Etiological investigation revealed generally similar patterns of disease susceptibility based on age, ancestry, and sex as former studies have. Prevalence of intervertebral disc disease and osteoarthritis was higher in the male group of this sample, while higher proportions of rotator cuff disease were found in females. Further examination of rotator cuff disease and a potential relationship to occupation in skeletal samples may be warranted if some of the limitations faced by this study are overcome in the future. It may also be pertinent to control for sex if examining any of these diseases in future studies, as female susceptibility is clearly naturally greater than that of males, and this intrinsic component may potentially bias interpretations of physical activity in a population.

Examining prevalence of the three diseases over time yielded surprising results, opposite of expectations presented earlier based on historical context. Proportions of individuals affected actually decreased over time from 1840 to 1910, although this researcher expected to see an increase based on an increase of factory labor towards the end of the 19th century. It must be taken into account, however, that the sample sizes for birth cohorts in the 1890s and 1900s are small when compared to those cohorts earlier in the 1800s. Additionally, an age effect is present in this aspect of the study, as the mean age for each birth cohort decreases as the birth decade increases. Thus fewer cases of degenerative joint disease are expected in the later years based on the association between joint disease development and increasing age. It is notable, however, that while there were no cases of osteoarthritis in the last two birth decades, there were cases of rotator cuff disease and intervertebral disc disease in both. Considering the mean ages of these last two cohorts – 36.7 and 34.4 – this appears to match with other evidence found here, that age is of increased importance for osteoarthritis, but that other etiological factors play a heightened role in the development of both rotator cuff disease and intervertebral disc disease.

Limitations

Several potential problems may have hindered this study, including small sample size, lack of standardization, and overly generic job titles. Though the overall sample size of 195 is relatively large for an osteological analysis, when those portions of the group who are actually diagnosed with a disease are then split into occupational categories, or the progression of their disease is sorted into severity categories, etc., the size of those groups is significantly smaller than the original 195. This may allow for biases in the assessment of certain groupings. Additionally, the p value for the logistic regression analysis of effects between rotator cuff disease and occupation is 0.0515, which is only slightly higher than the 0.05 threshold. If only a few more individuals had been included in the sample, it is possible the p-value would have shown a significant association between rotator cuff disease and occupation. It may still be beneficial to conduct further study on rotator cuff disease as a marker of physical activity. Lack of standardized diagnostic criteria for the diseases examined here is of primary concern, as some researchers will likely disagree with the methods used, believing that they are either too inclusive, or too exclusionary. Lastly, the occupational variables that this research used to assess relationships with activity are not as specific as would be ideally desired, especially considering that those occupations were split into multiple categories for this investigation. This study also focuses on differences between jobs that are considered “heavy” or “light” on labor, but it is also possible that continuous exposure to lower levels of stress over a long period of time might have similar effects on the body as would higher stress levels over a shorter period of time. Judgment on which occupation belongs to which category is fairly subjective, and considering there is evidence that different ways of categorizing is a source of bias it should be taken into advisement that standardization of such categories could be extremely useful to studies such as this one (Cardoso and Henderson, 2013).

Directions of Future Research

The scoring methods practiced in this study were developed by a prominent researcher in the paleopathological field, with the intention that they one day become the standard diagnoses for these diseases. However, it may be useful to thoroughly examine Waldron's operational definition and to test other potential diagnostic models to determine their efficiency and accuracy, particularly for one of the diseases investigated here. If intervertebral disc disease is to be of any use in activity related research, it is imperative that the anthropological and paleopathological communities reach a consensus on diagnostic criteria for the disease. A definitive scale for ranking severity of this, and other, joint diseases may also be of use. Further research of this type, involving an anatomical collection which has documented occupation on record (or some other type of activity marker), would be incredibly useful to compare the usefulness of intervertebral disc disease in this capacity.

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APPENDIX

Table 11.1. Raw data – Demographics

Number	Sex	Ancestry	Birth Year	Age at Death	Age Group	Occupation	Labor Class
1	2	1	1906	33	1	Cook	1
2	2	1	1894	35	1	Domestic	2
3	2	1	1905	33	1	Domestic	2
4	2	1	1901	33	1	Factory Work	3
5	2	1	1899	33	1	Housekeeper	2
6	2	1	1906	33	1	Housewife	1
7	2	1	1894	34	1	Housewife	1
8	2	1	1892	35	1	Housewife	1
9	2	1	1896	35	1	Housewife	1
10	1	1	1898	31	1	Laborer	3
11	1	1	1894	35	1	Laborer	3
12	1	1	1897	32	1	Laborer	3
13	1	1	1896	31	1	Laborer	3
14	2	1	1901	31	1	Laborer	3
15	2	1	1893	34	1	Laundress	1
16	1	1	1893	35	1	Maid	2
17	1	1	1895	31	1	Porter	1
18	1	1	1895	31	1	Waiter	1
19	2	1	1891	35	1	Janitress	2
20	1	1	1908	31	1	Laborer	3
21	1	1	1905	34	1	Laborer	3
22	1	1	1892	33	1	Laborer	3
23	1	2	1893	32	1	Laborer	3
24	2	1	1895	35	1	Housework	2
25	1	2	1879	48	2	Cook	1
26	2	1	1875	49	2	Housewife	1
27	1	2	1883	48	2	Watchmaker	1
28	1	2	1879	47	2	Laborer	3
29	1	2	1885	49	2	Newspaper salesman	1
30	2	1	1893	47	2	Housework	2
31	1	2	1882	46	2	Teamster	2
32	1	1	1877	50	2	Barber	1
33	1	1	1876	49	2	Porter	1
34	2	2	1877	47	2	Housewife	1
35	1	1	1881	49	2	Laborer	3
36	2	2	1890	50	3	Domestic	2
37	2	2	1878	50	3	Housewife	1
38	1	1	1889	40	2	Shoemaker	2

39	2	1	1890	41	2	Laundress	2
40	1	1	1888	40	2	Driver	1
41	2	1	1887	38	1	Domestic Work	2
42	2	1	1904	31	1	Housework	2
43	1	2	1900	39	1	Cook	1
44	1	1	1894	32	1	Laborer	3
45	2	1	1888	40	1	Cook	1
46	1	2	1886	38	1	Laborer	3
47	2	1	1887	46	2	Housekeeper	2
48	2	1	1899	39	1	Housework	2
49	1	1	1882	44	2	Railroad Auditor	1
50	1	1	1884	43	2	Housework	2
51	1	1	1883	46	2	Laborer	3
52	1	1	1892	35	1	Laborer	3
53	1	2	1897	44	2	Salesman	1
54	1	2	1879	45	2	Paper Hanger	2
55	1	1	1888	42	2	Presser	1
56	1	2	1886	42	2	Cook	1
57	2	1	1891	42	2	Housework	2
58	1	1	1883	44	2	Laborer	3
59	2	1	1885	46	2	Laundress	2
60	1	2	1876	46	2	Mechanic	3
61	1	1	1892	47	2	Laborer	3
62	2	1	1879	50	3	Laundress	2
63	1	2	1882	47	2	Firefighter	3
64	1	1	1871	46	2	Laborer	3
65	1	2	1889	40	2	Laborer	3
66	2	1	1891	38	1	Hairdresser	1
67	1	1	1892	37	1	Janitor	2
68	1	1	1885	38	1	Laborer	3
69	1	2	1885	40	2	Laborer	3
70	2	1	1887	38	1	Housework	2
71	1	1	1894	33	1	Laborer	3
72	1	2	1888	40	2	Laborer	3
73	1	1	1885	41	2	Teamster	2
74	2	1	1886	42	2	Domestic	2
75	1	1	1884	42	2	Laborer	3
76	1	2	1884	42	2	Laborer	3
77	1	2	1879	45	2	Farm Hand	3
78	2	1	1886	46	2	Laundress	2
79	1	2	1883	41	2	Laborer	3
80	1	1	1881	44	2	Laborer	3

81	1	1	1882	43	2	Laborer	3
82	1	2	1879	48	2	Cook	1
83	1	1	1882	46	2	Laborer	3
84	1	2	1885	47	2	Chauffeur	1
85	1	1	1876	50	3	Laborer	3
86	2	1	1893	47	2	Housework	2
87	2	1	1888	47	2	Laborer	3
88	1	2	1877	47	2	Laborer	3
89	1	1	1877	47	2	Laborer	3
90	1	2	1889	38	1	Vulcanizer	3
91	1	1	1891	36	1	Laborer	3
92	2	1	1892	40	2	Housekeeper	2
93	2	1	1893	38	1	Housewife	1
94	2	1	1889	40	2	Housework	2
95	2	1	1897	39	1	Housework	2
96	2	1	1892	39	1	Housework	2
97	2	1	1894	39	1	Housework	2
98	2	1	1895	38	1	Housework	2
99	1	1	1894	42	2	Mechanic	3
100	1	2	1883	48	2	Bricklayer	2
101	1	2	1876	50	3	Dishwasher	2
102	1	2	1878	49	2	Paper cutter	1
103	1	2	1869	55	3	Day Laborer	3
104	2	2	1878	53	3	Housewife	1
105	2	2	1885	54	3	Housework	2
106	1	2	1873	52	3	Laborer	3
107	1	2	1875	52	3	Laborer	3
108	1	2	1876	52	3	Laborer	3
109	1	2	1883	48	2	Painter	2
110	2	2	1886	52	3	Saleswoman	1
111	2	2	1903	55	3	Sorority Board	1
112	2	1	1887	44	2	Factory Laborer	3
113	1	1	1865	59	3	Day Laborer	3
114	1	2	1872	57	3	Factory Labore	3
115	2	2	1872	59	3	Housewife	1
116	2	2	1886	60	4	Housework	2
117	2	2	1868	56	3	Housework	2
118	1	1	1877	59	3	Laborer	3
119	1	2	1874	60	4	Laborer	3
120	2	2	1887	59	3	Laundress	1
121	1	2	1875	55	3	Mechanic	3
122	2	1	1868	56	3	Nutpacker	1

123	1	2	1861	63	4	Day Laborer	3
124	2	2	1868	64	4	Domestic	2
125	1	2	1861	62	4	Farmer	3
126	2	2	1875	62	4	Housewife	1
127	2	2	1868	61	4	Housework	2
128	2	2	1864	65	4	Housework	2
129	2	2	1870	63	4	Housework	2
130	1	2	1860	64	4	Laborer	3
131	2	2	1865	61	4	Telephone Op.	1
132	2	2	1873	65	4	Factory Work	3
133	2	1	1883	50	3	Housework	2
134	1	1	1882	47	2	Laborer	3
135	2	2	1872	64	4	Housework	2
136	1	2	1877	67	4	Railroad Engineer	1
137	2	2	1868	67	4	Seamstress	2
138	1	2	1857	68	4	Laborer	3
139	2	2	1862	70	5	Housework	2
140	1	2	1878	66	4	Furniture maker/finisher	1
141	2	2	1869	70	5	Dishwasher	2
142	1	2	1876	50	3	Engineer	1
143	1	2	1877	48	2	Laborer	3
144	1	1	1878	48	2	Laborer	3
145	1	1	1878	48	2	Laborer	3
146	2	1	1884	48	2	Housekeeper	2
147	1	1	1882	46	2	Laborer	3
148	1	1	1880	48	2	Laborer	3
149	1	1	1879	50	3	Laborer	3
150	1	2	1881	48	2	Laborer	3
151	1	2	1882	47	2	Laborer	3
152	1	2	1890	41	2	Laborer	3
153	1	2	1888	41	2	Laborer	3
154	1	1	1884	44	2	Laborer	3
155	1	2	1875	49	2	Day Laborer	3
156	1	1	1886	43	2	Laborer	3
157	1	2	1886	43	2	Laborer	3
158	1	1	1886	41	2	Laborer	3
159	1	1	1883	43	2	Farmer	3
160	2	1	1889	45	2	Housework	2
161	2	1	1891	45	2	Housework	2
162	1	2	1881	45	2	Laborer	3
163	1	2	1883	43	2	Laborer	3

164	2	1	1887	50	3	Housework	2
165	1	2	1882	44	2	Laborer	3
166	1	2	1884	50	3	Laborer	3
167	1	2	1886	46	2	Laborer	3
168	2	1	1887	46	2	Housework	2
169	2	1	1884	50	3	Housework	2
170	2	1	1885	50	3	Housework	2
171	2	1	1888	49	2	Housework	2
172	1	2	1889	43	2	Laborer	3
173	2	2	1853	75	5	Laundress	1
174	2	1	1866	73	5	Laborer	3
175	1	2	1874	70	5	Laborer	3
176	1	2	1872	72	5	Laborer	3
177	2	2	1863	75	5	Housework	2
178	2	2	1858	74	5	Housework	2
179	2	2	1867	71	5	Housework	2
180	2	2	1854	72	5	Housework	2
181	2	2	1860	71	5	Housewife	1
182	2	2	1854	75	5	Housewife	1
183	1	2	1870	74	5	Baker	1
184	2	1	1843	80	5	Domestic	2
185	2	2	1862	78	5	Housewife	1
186	1	1	1897	30	1	Houseboy	2
187	2	2	1898	30	1	Housewife	1
188	2	1	1900	30	1	Housewife	1
189	2	2	1849	77	5	Housework	2
190	2	1	1902	30	1	Housework	2
191	1	1	1890	30	1	Tailor	1
192	2	2	1851	84	5	Cook	1
193	2	2	1852	86	5	Dressmaker	1
194	2	2	1844	88	5	Housework	2
195	1	1	1898	30	1	Laborer	3

Figure 11. Key for Tables 11.1 and 11.2

Sex: 1=Male, 2=Female
Ancestry: 1=African-American, 2=European=American
Age group: 1=30-39, 2=40-49, 3=50-59, 4=60-69, 5=70+
Labor Class: 1=Light, 2=Moderate, 3=Heavy
Disease Presence: 0=Absent, 1=Present
Uni/BiLateral: 0=Absent, 1=Unilateral, 2=Bilateral
Disease Severity: 0=Absent, 1=Mild, 2=Moderate, 3=Severe

Table 11.2. Raw data – Joint Diseases

Number	OA Presence	OA Uni/Bilateral	OA Severity	RCD Presence	RCD Uni/Bilateral	RCD Severity	IDD Presence	IDD Severity
1	0	0	0	1	2	1	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	1	2	2	0	0
9	0	0	0	1	1	1	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	1	1	1	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	1	1	1	0	0
15	0	0	0	0	0	0	0	0
16	0	0	0	1	2	1	0	0
17	0	0	0	0	0	0	1	2
18	0	0	0	0	0	0	1	1
19	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0
23	0	0	0	1	2	3	1	2
24	0	0	0	0	0	0	0	0

25	1	2	2	0	0	0	0	0
26	0	0	0	1	2	1	0	0
27	1	2	1	0	0	0	0	0
28	0	0	0	0	0	0	1	1
29	0	0	0	0	0	0	1	1
30	0	0	0	1	2	1	1	1
31	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0
35	1	1	1	0	0	0	1	2
36	0	0	0	1	2	2	1	1
37	1	2	2	1	2	2	1	1
38	0	0	0	0	0	0	1	1
39	0	0	0	1	2	1	1	1
40	0	0	0	0	0	0	1	1
41	0	0	0	0	0	0	1	1
42	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0
45	0	0	0	1	2	3	1	1
46	0	0	0	0	0	0	1	1
47	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0
50	1	2	1	1	2	2	1	1
51	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0

53	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	1	1
55	0	0	0	0	0	0	1	2
56	1	2	1	0	0	0	1	1
57	0	0	0	1	2	1	0	0
58	0	0	0	0	0	0	1	2
59	0	0	0	0	0	0	0	0
60	1	1	1	0	0	0	1	3
61	0	0	0	0	0	0	1	2
62	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	1	2
64	0	0	0	1	1	1	1	1
65	0	0	0	1	1	3	0	0
66	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0
68	0	0	0	1	1	1	1	1
69	0	0	0	0	0	0	0	0
70	0	0	0	1	1	1	0	0
71	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	1	1
75	0	0	0	1	1	1	0	0
76	0	0	0	0	0	0	0	0
77	0	0	0	1	1	1	1	2
78	0	0	0	0	0	0	1	1
79	0	0	0	0	0	0	0	0
80	0	0	0	1	2	3	0	0

81	1	1	1	1	1	1	1	1
82	1	2	1	1	2	3	1	2
83	0	0	0	1	2	1	1	3
84	1	2	2	1	1	1	1	1
85	0	0	0	1	1	1	1	1
86	0	0	0	1	2	1	1	2
87	0	0	0	0	0	0	0	0
88	0	0	0	1	2	2	1	1
89	0	0	0	1	2	2	0	0
90	0	0	0	0	0	0	0	0
91	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0
93	0	0	0	1	2	2	0	0
94	1	1	2	1	1	1	0	0
95	0	0	0	0	0	0	0	0
96	0	0	0	0	0	0	0	0
97	0	0	0	0	0	0	1	3
98	0	0	0	0	0	0	0	0
99	0	0	0	0	0	0	0	0
100	1	1	1	0	0	0	0	0
101	0	0	0	0	0	0	1	2
102	0	0	0	0	0	0	1	1
103	1	1	1	0	0	0	1	1
104	1	2	1	0	0	0	0	0
105	0	0	0	0	0	0	0	0
106	1	2	2	1	2	1	1	1
107	0	0	0	0	0	0	1	2
108	1	2	1	1	2	2	1	1

109	0	0	0	0	0	0	1	1
110	1	1	1	0	0	0	0	0
111	0	0	0	0	0	0	1	1
112	0	0	0	1	1	1	1	1
113	0	0	0	1	2	2	1	1
114	0	0	0	1	2	1	1	1
115	0	0	0	1	2	1	0	0
116	0	0	0	0	0	0	1	2
117	0	0	0	1	1	1	0	0
118	1	2	1	1	2	3	1	2
119	1	2	1	0	0	0	1	2
120	0	0	0	0	0	0	0	0
121	0	0	0	0	0	0	1	2
122	0	0	0	1	1	2	0	0
123	0	0	0	1	1	1	1	2
124	1	2	1	0	0	0	1	1
125	1	2	1	1	2	1	1	1
126	0	0	0	0	0	0	1	1
127	1	1	1	0	0	0	1	1
128	0	0	0	1	1	1	1	2
129	0	0	0	0	0	0	1	1
130	1	2	1	0	0	0	1	1
131	1	1	3	0	0	0	0	0
132	1	2	1	1	1	1	1	2
133	0	0	0	1	2	2	1	1
134	0	0	0	0	0	0	1	1
135	0	0	0	1	1	1	1	2
136	0	0	0	0	0	0	1	2

137	0	0	0	0	0	0	1	3
138	0	0	0	1	1	1	1	2
139	0	0	0	1	2	1	1	2
140	0	0	0	1	1	2	1	1
141	0	0	0	1	1	1	1	1
142	0	0	0	1	1	1	1	1
143	1	2	1	1	1	1	1	3
144	1	2	1	0	0	0	1	1
145	1	1	1	1	2	2	1	1
146	0	0	0	0	0	0	0	0
147	0	0	0	1	2	3	0	0
148	0	0	0	0	0	0	1	2
149	1	1	2	1	1	1	0	0
150	0	0	0	0	0	0	0	0
151	0	0	0	0	0	0	1	2
152	0	0	0	0	0	0	1	1
153	0	0	0	0	0	0	1	1
154	0	0	0	0	0	0	0	0
155	0	0	0	0	0	0	1	2
156	0	0	0	0	0	0	1	2
157	0	0	0	0	0	0	0	0
158	0	0	0	1	2	2	0	0
159	0	0	0	1	1	1	1	1
160	0	0	0	1	1	1	0	0
161	0	0	0	0	0	0	0	0
162	0	0	0	0	0	0	1	2
163	1	1	2	1	2	1	1	1
164	1	1	2	1	2	2	1	2

165	0	0	0	1	1	1	1	1
166	0	0	0	0	0	0	1	2
167	0	0	0	1	2	1	1	3
168	0	0	0	0	0	0	0	0
169	0	0	0	0	0	0	0	0
170	0	0	0	0	0	0	0	0
171	0	0	0	1	1	2	0	0
172	0	0	0	0	0	0	0	0
173	0	0	0	1	1	1	1	3
174	0	0	0	1	2	1	1	2
175	0	0	0	0	0	0	0	0
176	1	2	2	0	0	0	1	2
177	0	0	0	0	0	0	1	1
178	0	0	0	1	1	2	1	2
179	1	1	2	1	2	1	1	2
180	0	0	0	0	0	0	1	2
181	0	0	0	0	0	0	0	0
182	0	0	0	1	2	2	1	1
183	1	1	1	0	0	0	1	1
184	0	0	0	0	0	0	0	0
185	1	2	2	1	2	3	1	1
186	0	0	0	0	0	0	0	0
187	0	0	0	0	0	0	0	0
188	0	0	0	0	0	0	0	0
189	0	0	0	0	0	0	1	2
190	0	0	0	0	0	0	0	0
191	0	0	0	0	0	0	0	0
192	1	2	3	1	2	3	1	2

193	1	1	1	1	2	1	1	3
194	1	1	1	1	2	2	1	3
195	0	0	0	0	0	0	0	0