2017

Vertebral Pathologies and Implications for Economic Lifestyle Changes in Two Prehistoric Skeletal Populations

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VERTEBRAL PATHOLOGIES AND IMPLICATIONS FOR ECONOMIC LIFESTYLE CHANGES IN TWO PREHISTORIC SKELETAL POPULATIONS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Arts

in

The Department of Geography and Anthropology

by
Alyxandra Leigh Stanco
B.A., University of Oklahoma, 2015
May 2017

ACKNOWLEDGEMENTS

I would first like to thank my thesis committee members, Dr. Robert Tague, Dr. Juliet Brophy and Dr. Kevin McCarter for their support, guidance, and advice. I would also like to thank Dr. Bin Li for providing me with advice in conducting statistical analyses on my data. This research was funded in part by a Robert C. West Graduate Student Field Research Award from the Department of Geography and Anthropology at Louisiana State University.

I would like to thank Dr. Keith Jacobi, curator of Human Osteology at the Alabama Museum of Natural History at the University of Alabama, for allowing me access to the Moundville collection. Without him and our many discussions, I would not have been able to complete my research.

I would also like to thank Nancy O'Malley, Assistant Director of the William S. Webb Museum of Anthropology at the University of Kentucky, for allowing me access to the Indian Knoll collection. Without her, I would not have been able to obtain access to the collections and complete my research.

I am beyond thankful to my parents, Henry Stanco and Jessica Stanco, for their overwhelming emotional and moral support. I am extremely grateful that they dealt with my numerous phone calls and complaints. Their unending love and support helped me to complete both my thesis and the rigorous graduate program at LSU. I am also thankful for the love and encouragement of my boyfriend, Tyler Connell. Lastly, I would like to thank all of my friends I have made while attending LSU for putting up with me. You inspired me to push through, no matter how much I struggled along the way. For that, I am forever grateful.

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ABSTRACT

Little research considers the vertebral column in relation to inter-populational variation and changes in economic lifestyle. Numerous studies have been conducted regarding the influence of activity-related stress on post-cranial elements such as the knees, hips and shoulders, but few studies have considered the vertebral column. This study examined the vertebral columns of two prehistoric skeletal populations. The Indian Knoll site, home to a population of early hunter-gatherers, is located in Ohio County, Kentucky along the Green River. Indian Knoll was first excavated in 1915 by C.B. Moore. The Moundville site, a chiefdom of early agriculturalists, is located in the Black Warrior River Valley in west-central Alabama and was first excavated by the Alabama State Museum of Natural History in 1929. Data were collected and analyzed based on type and location of pathologies to determine if economic lifestyle led to inter-populational differences in vertebral pathologies including osteoarthritic and osteophytic development and vertebral compression fractures (n=98 Indian Knoll and n=58 Moundville). Vertebrae were scored from 0-3 based on severity of osteoarthritic and osteophytic development. Results show that males had significantly higher frequency of osteoarthritis, osteophytosis and compression fractures than females in Indian Knoll, whereas there was no significant difference in frequencies of these pathologies between the sexes in Moundville. Results also show that Indian Knoll and Moundville were not significantly different from one another in frequency of both osteoarthritis and osteophytosis. However, there was a significant difference in compression fractures between both populations. Results indicate a relationship between economic lifestyle with compression fractures, but not with osteoarthritis and osteophytosis.

CHAPTER 1. INTRODUCTION

The human skeleton is complex in that it is responsive to a number of influences including advancing age and physical stress (Listi and Manhein 2012) that result in the development of pathological conditions. Numerous studies have been conducted regarding the influence of activity-related stress on the human skeleton that focused largely on the post-cranial elements such as the knees, hips, and shoulders (Larsen 1981; Bridges 1994; Derevenski 2000). However, vertebral pathology has also been considered a useful criterion for the assessment of physical activity patterns, stress, and overall health of prehistoric populations. While many researchers have addressed the issue of shifts in economy and lifestyle from hunting and gathering to agriculture, there is limited research that considers the vertebral column in relation to inter-populational variation and sex-related divisions of labor. One of the major studies published in this area is from Patricia Bridges (1994) who observes vertebral arthritis in several Alabama archaeological sites. Her research suggests that there is variation in the frequency of vertebral arthritis among the different agricultural and hunter-gatherer populations. Her research became the foundation for the research presented in this paper because it compared osteoarthritis in the post-cranial skeleton within several populations of prehistoric peoples. The focus on the vertebral column in the current study stems from an interest in changes in weight-bearing activities associated with economic lifestyle change.

The research presented in this paper examines the relationship between economic lifestyle and the development of pathological conditions in the vertebral columns of prehistoric hunter-gatherers and agriculturalists. Two large, prehistoric populations were used in the study, Indian Knoll and Moundville. The Indian Knoll collection, which is

curated at the William S. Webb Museum of Anthropology in conjunction with the University of Kentucky, is a group of Late Archaic hunter-gatherers, dated between 2558 and 4160 B.C. (Webb 1946). Moundville, which is curated at the Alabama Museum of Natural History associated with the University of Alabama, is a group of agriculturalists, dated between A.D. 900 and 1520 (Powell 1988).

This research had two objectives. The study examined the vertebral columns of two prehistoric populations to determine 1) if economic lifestyle led to inter-populational differences in vertebral pathology, and 2) whether there are sexual differences in these pathologies that would be consistent with divisions of labor within the populations. The vertebral pathologies studied include osteoarthritis, also known as degenerative joint disease, osteophytosis, and collapse in vertebral bodies (i.e., vertebral compression fractures). This study considered two issues. First, do the populations in question differ in type and severity of vertebral pathologies due to activities associated with their economic lifestyles? Second, do hunter-gatherers and agriculturalists differ in vertebral pathologies as a result of differences in divisions of labor? Data collected on type, severity and location of vertebral pathology from two prehistoric skeletal populations separated by region should yield information on the prevalence of osteoarthritis, osteophytosis and vertebral compression fractures with the transition from hunting and gathering to an agricultural lifestyle. This research contributes to the expanding literature regarding the biomechanical impact of transitioning from hunting and gathering to agriculture on the human body.

CHAPTER 2. LITERATURE REVIEW

2.1 Indian Knoll

Indian Knoll is one of the most famous Late Archaic period shell midden sites in the United States. The site is located off of the Green River in the southern portion of the Green River Valley in western Kentucky. It was first excavated in 1915 by archaeologist Clarence B. Moore. During the excavations at Indian Knoll, Moore recovered nearly 298 burials and associated artifacts. Later, during the 1930s and 1940s, under the direction of the Works Progress Administration (WPA), Indian Knoll was re-excavated by William Snyder Webb. Webb (1946) recovered an additional 880 burials from the site and over 50,000 associated artifacts. The work conducted at the site contributed to what would be a long history of skeletal research on the Indian Knoll collection and understanding of health and nutrition during the Archaic period. Because of the large sample size, the Indian Knoll collection quickly became the most utilized collection for Archaic period research in the eastern United States (Rothschild 1979).

The Archaic period (ca. 2000-8000 B.C.) is defined by a lack of permanent residence, food production and specialized crafts (Rothschild 1979). Archaic period cultures are often associated with a diverse subsistence-settlement system in which resources are hunted, fished and gathered. Societies living within this subsistence system are often classified as small-scale societies and are characterized by having an egalitarian social organization.

The occupants of the Indian Knoll site, in comparison to the previously defined concept of Archaic period societies, were a group of mobile hunter-gatherers who subsisted on foraging for nuts, collection of shellfish, and fishing. Indian Knoll can be

classified archaeologically as a shell midden due to the amount of shell refuse present at the site. Archaeological analysis of the site and its classification as a shell midden (Rothschild 1979; Nealis and Seeman 2015) suggest that the occupants were heavily exploiting shellfish as a primary resource. Webb (1946) also reveals that a variety of faunal remains recovered from the site reveal that the occupants had diversity in the resources they were exploiting. Deciduous forests and floodplains that would have been abundant in food rich resources for the inhabitants mark the Green River Valley region. These conditions would have allowed the occupants of the Indian Knoll site access to a variety of terrestrial and aquatic animals and plants.

Nealis and Seeman (2015) assessed the impact of subsistence on dental attrition of teeth from three Late Archaic populations: Indian Knoll, Black Earth, and Libben. Their results suggested that the increased amount of early adult dental wear observed at the Indian Knoll site could be attributed to exploitation of shellfish as a subsistence resource (Nealis and Seeman 2015). Early adult dental wear at the site has implications for post-cranial stress because of the exploitation of shellfish as a subsistence resource. Repetitive motions associated with harvesting shellfish would have contributed to the increase in post-cranial skeletal pathologies. In fact, Cassidy (1984) suggests that the presence of arthritis in the lumbar and thoracic regions at Indian Knoll is associated with poor diet and repetitive activities.

2.2 Moundville

Moundville is located along the Black Warrior River in west-central Alabama and is considered part of the Mississippian period. The Mississippian period occurred

between A.D. 800-1600 and is characterized by the development of large-scale and complex societies. Mississippian period cultures were typically horticulturalists, subsisting on food that they cultivated. The Mississippian diet would have selective utilization of a number of diverse species of wild animals and plant groups. The societies in the Mississippian period were considered to be sedentary, since their subsistence techniques required them to remain in one place unlike the societies of the Middle and Late Archaic period. Mississippian period societies were also organized in hierarchies or chiefdoms with elites having more power and status over non-elite or commoner peoples.

Moundville is one of the largest mound sites in the southeastern United States, only second to the Cahokia Mounds in eastern Missouri. Archaeological analysis suggested that Moundville was heavily populated and served as a political and religious center with a hierarchical social organization, which featured a large central plaza and 26 earthen mounds. Moundville is considered to be a palisaded ceremonial center that incorporated a number of peripheral sites and outlying farmsteads (Hodge 2011).

Moundville is a multicomponent site that went through several occupational phases during its existence. The West Jefferson phase of the site (A.D. 900-1050) was marked by the establishment of small villages located on the western periphery of the site (Powell 1988). Moundville I (A.D. 1050-1120) replaced the West Jefferson villages with larger established villages that had the first evidence for shell-tempered vessels (Powell 1988). Moundville II (A.D. 1250-1400) was characterized by the construction of mounds near the site's center. This phase reflected a growing complexity of the social organization within Moundville because of its distribution of vessels and burials over the landscape. The last phase, Moundville III (A.D. 1400-1550), is distinguished by the

construction of the last mound sites and the beginnings of settlement abandonment. The largest of these settlements is suggested to have held close to 3,000 individuals (Powell 1988). Early archaeological analysis of the site reveals that the residential area, which is marked by elevated platform mounds, was reserved for the elite that confirms Moundville's status as a ranked society (Steponaitis 1986).

The literature on Moundville documents the chiefdom's social organization as well as aspects of political organization, cultural history, economy and diet (Peebles 1974; Welch 1991; Bridges 1994). For example, Welch (1991), in his book *Moundville's Economy*, discusses the political and economic gains of the elite in the redistribution of resources across the site. He explains that the chiefs would have gathered the resources that they would have needed such as high-quality food products, high-quality materials for crafts, and other resources, leaving the non-elites with low-quality foods and materials (Welch 1991). He does suggest that all of the sites at Moundville had direct access to the same overall faunal and agricultural resources and would have exploited them in similar ways (Welch 1991). Powell (1988) suggests that the population at Moundville subsisted off of a variety of food resources including both domesticated and wild plant and animal groups. The elite having access to higher quality resources meant that the non-elites were consuming lower quality sources, which would have led to a decrease in health and the development of nutritional deficiencies.

Larsen (1981) suggests that there is a significant decline in health in late prehistoric agricultural communities across the United States. However, according to Powell (1988), the overall health of the Moundville population was good in comparison to other southeast agricultural populations. Concentration of the population was one

source of stress in the population. Smaller populations living on the periphery of the site would have had enhanced food resource availability over communities living closer to the center of the site that contain large populations. Living in proximity to large numbers of people would have led to an increase in exposure to a variety of diseases. Division of labor can be considered one additional source of stress because subsistence activities would have influenced development of pathologies unequally within males and females.

Prior research on degenerative joint disease at Moundville was conducted, but the research does not consider both economic lifestyle change and sexual differences as factors in the etiology of the disease. Hodge (2011) observed the changes in degenerative joint diseases and other pathological conditions among the different components at Moundville and found an overall pattern reflecting little change in human health between pre-dispersal and post-dispersal periods.

2.3 Paleopathology

Paleopathology is the study of pathological conditions found in earlier historic or prehistoric human remains. Paleopathology is an important condition for understanding both biological and cultural processes of adaptation in modern and prehistoric peoples to their surrounding environment. Bioarchaeologists rely heavily on paleopathology in order to understand the lives of earlier historic and prehistoric peoples. Skeletal pathology, according to Powell (1988), has two main functions: 1) to reveal the effect of certain pathological conditions on mortality distributions and 2) to reveal historical and geographical distributions of certain diseases.

One advantage of paleopathological studies is that one can observe behavioral patterns within cultures spanning hundreds or even thousands of years (Ortner and Aufderheide 1991). Observations of pathological conditions can also lead to a general understanding of health within a prehistoric population. The assessment of the skeleton provides unique information about general health, diet, and stress that is not available in soft tissue analyses.

2.4 Degenerative Joint Disease

Osteoarthritis, or degenerative joint disease, is one of the most commonly identified pathologies of the human skeleton. This pathological condition is associated with degeneration of diarthrodial (i.e., synovial) joints and commonly affects the regions of the knees, hips and shoulders. Osteoarthritis is characterized by the three major biological components that are described by Ortner (2003:546): "(1) the breakdown of articular cartilage, which may result in bone on bone contact and abnormal abrasion of the subchondral bone, (2) reactive bone formation both in the subchondral compact bone (eburnation) and in the trabeculae…and (3) new growth of cartilage and bone at the joint margins (osteophytes)". Often, osteoarthritis includes a degeneration of articular cartilage and increased friction in joint margins. It is often associated with advancing age and physical stress (Listi and Manhein 2012), but can also be useful in determining activity associated with subsistence patterns. In fact, osteoarthritis is typically thought to be directly related to old age. However, Jurmain (1977) argued that juveniles have also been known to develop severe osteoarthritis while older adults in the same population show no pathology.

Osteophytosis of vertebrae, on the other hand, is "the outcome of deterioration of the vertebral disks, which results primarily in bony lipping or spurs around the margins of the vertebral bodies" (Bridges 1994:84). Age is often considered the primary factor in the etiology of osteophytosis. However, the etiology of osteophytosis is multifactorial. Osteophytosis involves the degeneration of fibrocartilaginous tissue between vertebral bodies. Maat et al. (1995) suggest that osteophytosis results primarily from weight-bearing functions Their analysis of vertebral osteoarthritis and vertebral osteophytosis in individuals from medieval Dordrecht, the Netherlands reveals that vertebral osteophytosis occurred more frequently than vertebral osteoarthritis. They suggest that the sharp contrast in development of both pathologies relates to the frequency of heavy weight-bearing activities that occurred in the population.

Research examining the relationships between vertebral arthritis and entheseal changes have also been conducted in order to answer whether activity patterns affect the development of morphological changes described by Ortner (2003). One example of this type of research is a study conducted by Myszka et al. (2014) that suggests a positive correlation between the severity of vertebral arthritis with an increase in entheseal changes. This study concerned individuals from a Polish skeletal sample that were observed for entheseal and osteophytic changes in the post-cranial skeleton in relation to occupational stress. Myszka et al. (2014) revealed that males had a relatively higher proportion of severe vertebral arthritis than females within the Polish skeletal population. The biomechanical changes were apparent in the joint margins of the post-cranium, but were more pronounced in the joint surfaces of the vertebral column. These changes, while associated with advancing age, also reflect periods of high physical stress.

Two main factors influence the etiology of degenerative joint disease. First, mechanical stress is the measure of internal forces that arise in a body that is being acted upon by external forces. Examples of factors that induce mechanical stress include increased weight bearing and loading on joints, trauma, environment as well as occupational factors. Systemic factors, which can include predisposing factors such as age, nutrition, sex, and general health, are another influence in the etiology of degenerative joint disease (Sokoloff 1969). Jurmain (1977) suggests that these systemic factors relate to the entire individual rather than individual parts, affecting joints in an almost equally uniform fashion on both sides of the body. The incidence of degenerative joint disease is attributed to a multitude of factors. However, the specific activities that directly affect joints that result in the development of degenerative joint diseases remain unclear. Degeneration that occurs as a result of age can be problematic in studying degenerative joint diseases in skeletal populations because there are differences in life expectancies between modern populations and earlier historic or prehistoric populations.

Numerous research has been conducted regarding the prevalence of degenerative joint disease in the human skeleton associated with cultural and economic change. Larsen (1981), in his research on post-cranial reduction size in prehistoric remains from the Gulf Coast, reported higher prevalence of osteoarthritis in cervical and lumbar vertebrae in hunter-gatherers compared to agriculturalists, most likely derived from functional stress. Bridges (1994) study of hunter-gatherer and agricultural populations from Alabama reveals that osteoarthritis is most prominent in cervical and thoracic segments, and shows that osteophytic development is more asymmetrical in thoracic segments than in other parts of the vertebral column. Bridges' (1991) comparison of post-cranial elements in

Archaic and Mississippian groups revealed that the Archaic group had higher frequencies of moderate and severe arthritis than the Mississippian sample. Additionally, Bridges (1991) observed sex differences between the populations and found that the Mississippian sample showed less sexual difference in degenerative joint disease than the Archaic sample. She suggests that more severe degenerative joint disease in males than females in the Archaic group "implies that there were different levels or types of activities leading to DJD in the sexes" (Bridges 1991:385). The transition to agriculture involved shifts in the types of activities carried out by populations. Bridges (1991:386) suggested that these changes would include: "clearing fields, as well as planting, harvesting and processing of domesticated crops". The shift to an agricultural economic lifestyle would have meant that other activities, such as the gathering of resources, became less utilized than harvesting domesticated crops. Furthermore, Lieverse et al. (2007) reported a high prevalence and distribution of osteoarthritis among five Cis-Baikal groups in Siberia related to variations in mobility and subsistence activities. These three studies suggest that there is an association between cultural shifts in economic lifestyle and prevalence in the development of pathological conditions. Ruff (2008:190) also observed that, "it is likely that changes in subsistence strategy will have varying effects on both activity and mechanical loading of the skeleton, depending on the particular culture as well as on the physical environment". Additionally, Sanders and Reinhard (1992) reported higher frequencies of degenerative joint diseases in prehistoric populations compared to historic populations from northeast Nebraska. They suggest that the frequency of degenerative joint disease found in the prehistoric population is

associated with increased trauma and repeated mechanical stress that trigger the onset of degeneration in post-cranial joints regardless of age (Sanders and Reinhard 1992).

Vertebral compression fractures that result in collapse of the vertebral body are also a pathological condition that is affected by both biological and environmental factors. Collapse occurs primarily through degeneration of diarthrodial joints and compression (Clark et al. 1986). However, collapse can be an effect of poor diet and increased physical stress. Clark et al. (1986) reported higher frequencies of vertebral body collapse (or higher frequency of vertebral "wedging") in individuals that are associated as having a poor quality diet. In their study, Clark et al. (1986) examined the vertebral neural canals of skeletons in the Dickson Mounds collection to understand the relationship between poor early growth and decrease in size of vertebral neural canals. They suggest that poor early health was a predisposing factor for micro-collapse of vertebral bodies later in life. Vertebral compression fractures are often associated with the development of Schmorl's disk herniation (i.e., Schmorl's nodes) that are distinguished by the presence of crescent-shaped lesions on the body of the vertebra (Kennedy 1989).

Numerous studies have also examined sexual dimorphism between populations for pathological conditions. Many of the studies consider the effects of pathology in relation to sexual divisions of labor in post-cranial elements. Derevenski (2000) showed that there are less marked sexual differences in arthritic development in the vertebral column because there is not a meaningful difference in physical activities between males and females within the Ensay and Wharram-Percy populations in the United Kingdom. Additionally, van der Merwe et al. (2006) observed the pattern of osteophyte

development in the vertebral columns of male and female South Africans. Their results showed that males exhibited more severe osteophytic growth than females, primarily in the cervical and lumbar regions. They attributed the increased prevalence of osteophyte development to increased load-bearing in males (van der Merwe et al. 2006). Furthermore, they observed that osteophyte development was more pronounced in males than in females in the population (van der Merwe et al. 2006). There is some disagreement about whether hunter-gatherers or agriculturalists had a more arduous lifestyle. Larsen (1981:496) reports that, "[E]thnographic literature…suggests that human adaptations utilizing wild plant and animal resources as the primary sources of diet are under a greater degree of physical stress than adaptations dependent on agricultural foodstuffs…[F]emales spend the greater part of the day either collecting or preparing edible plants for consumption; males…devote much of their time to hunting…". In contrast, Bridges (1989) reports that ethnographic literature showed that the agricultural lifestyle was more physically arduous than hunter-gatherers and that females participated in more strenuous work roles than males.

This research addresses the impact of economic lifestyle and sexual division of labor in association with the development of pathological conditions in the Indian Knoll and Moundville skeletal populations. Based on the information presented, hunter-gatherers are anticipated to have a higher prevalence of pathological development than agriculturalists. Therefore, Indian Knoll is expected to have higher frequencies of osteoarthritis, osteophytosis and vertebral compression fractures when compared with Moundville. Additionally, Indian Knoll is expected to have significant differences in

frequency of pathology between males and females within the population, while males and females in Moundville are expected to be similar in the frequency of pathology.

CHAPTER 3. MATERIALS AND METHODS

3.1 Sample

The sample for analysis of pathological conditions consists of two prehistoric skeletal populations. The minimum target sample size for the study was 100 individuals, 25 males and 25 females from each group respectively. Only "adult" individuals, those between the ages of 18 and 49, were used. State of preservation for both collections was an issue for selecting individuals for analysis. Individuals were selected if they had a mostly complete vertebral column. Of the 24 presacral vertebrae, the individual had to have at least 17 usable vertebrae. "Usable" refers to the completeness of a vertebra: zygapophyses were intact and there was no damage to the vertebral bodies. Tables 3.1 and 3.2 show the frequency distribution for number of individuals with number of usable vertebrae. The total sample size after selection based on the given criteria was 156 individuals, with 98 individuals from Indian Knoll (37 females and 61 males) and 58 from Moundville (32 females and 26 males).

Table 3.1 Frequency distribution for number of individuals with usable vertebrae at Indian Knoll

Number of Vertebrae	Number of Individuals
17	8
18	14
19	13
20	13
21	13
22	12
23	16
24	9
Total	98

Table 3.2 Frequency distribution for number of individuals with usable vertebrae at Moundville

Number of Vertebrae	Number of Individuals
17	10
18	3
19	11
20	13
21	9
22	5
23	2
24	5
Total	58

3.2 Methods for Determination of Sex and Age at Death

Due to the varying levels of completeness/preservation of skeletons, I used multiple methods of assigning sex and age at death such as methods employed by Phenice (1969), Buikstra et al. (1994), Brooks and Suchey (1990), and Meindl et al. (1985). My evaluations were supplemented with assessments by Webb (1946) for Indian Knoll and by Snow (1941) for Moundville.

3.2.1 Determination of Sex

Two methods were utilized to determine sex of each individual. The primary method of sex determination was the analysis of characteristics of the pelvis, particularly in regards to the pubis. The individuals were assigned sex based on Phenice's (1969) technique. The technique uses three skeletal traits on the pubic bone to evaluate sex: presence or absence of the ventral arc, lateral flare of the inferior pubic ramus, and

thickness of the ischiopubic ramus. The greater sciatic notch and pre-auricular sulcus of the innominate were also used in sex determination (Buikstra et al. 1994).

3.2.2 Determination of Age at Death

Estimation of age at death was based on observing the changes in topography of the pubic symphysis, using the Suchey-Brooks method (Brooks and Suchey 1990). However, Meindl et al.'s (1985) method was secondarily employed. Due to the poor preservation of some of the pubic bones, other techniques of estimating age at death were also utilized. Epiphyseal union of the long bones was the primary determinant of whether an individual was greater than 18 years of age if the pubic symphysis was unavailable. Age at death was also assessed using the third and fourth sternal rib ends (İşcan and Loth 1986).

3.3 Data Collection Methods

Three pathologies of vertebrae were analyzed for this study: osteoarthritis of the zygapophyses, osteophytosis and compression fractures (i.e., collapse of vertebral body). Data collection protocols were limited to nondestructive techniques. Vertebral osteophytosis, vertebral osteoarthritis and vertebral body collapse were assessed using macroscopic observation of zygapophyses and bodies.

Vertebral osteoarthritis of the superior and inferior facets was assessed using a four-scale classification system that was originally proposed by Ubelaker (1999), where "0" indicates no pathology, "1" indicates slight osteophytic development of the joint margins, "2" indicates moderate morphological changes such as lipping and pitting with

slight deformation of the facet articular surface, and "3" indicates severe morphological changes that include lipping, pitting and eburnation of facets.

Vertebral osteophytosis was recorded using a four-scale classification derived from Stewart's (1958) five-scale classification technique that assigns scores based on the degree of bony lipping present in both superior and inferior borders of the vertebrae. The current study modifies Stewart's (1958) original classification system to use only four categories of severity. For this analysis, the four-point scale is as follows: "0" indicates no lipping, "1" indicates mild lipping, "2" indicates moderate lipping and "3" indicates severe lipping. Vertebral body collapse was recorded as either absent or present based on morphological changes of the superior and inferior body surfaces.

Finally, each individual was given a summary categorical score based on the mean scores of each vertebral segment, cervical, thoracic, and lumbar. Each vertebra was assigned a score based on the severity of pathology and a mean score was given based on each vertebral segment. Individuals who were designated scores of "0" across all vertebral segments were given the overall category of "0". Individuals who had summary scores of 1-3 were assigned the overall category of "1". Individuals who were given summary scores of 4-6 were given the overall category of "2". Individuals who were given summary scores of 7-9 were designated the overall category of "3". The total range of summary categorical scores is from 0 to 9, but each skeleton is assigned a single relative severity of 0, 1, 2 or 3. Presence or absence of vertebral compression fractures was evaluated based on whether an individual had one or more vertebrae with vertebral collapse.

3.4 Statistical Analysis

The current study posed two questions for analysis. First, are there sexual differences in frequency and severity of these pathologies that would be consistent with division of labor within the population? Previous research (see above) suggests that sexual differences in vertebral pathology would be seen in both populations, with the sexual difference being greater in Indian Knoll than in Moundville. The null hypothesis was that males and females would not differ in frequency and severity of vertebral pathology. Chi-square test of independence and Fisher's exact test were used in the analyses; the significance level was set at $\alpha = 0.05$. Second, do the populations in question differ in frequency and severity of vertebral pathology due to differences in economic lifestyle? Previous research (see above) suggests that vertebral pathology would be more evident in the hunter-gatherer population (Indian Knoll) than in the agricultural population (Moundville). The null hypothesis for the analyses was that the populations do not differ in frequency and severity of vertebral pathology. Chi-square test of independence and Fisher's exact test were also used in the analyses; the significance level set at $\alpha = 0.05$. Chi-square test of independence was used preferentially in the analyses when the assumptions for that test were satisfied. However, when one of the assumptions of the chi-square test was not satisfied, specifically, when expected frequencies in the contingency table cells were less than five, Fisher's exact test was used. SPSS version 23 for Mac was used for all statistical tests.

CHAPTER 4. RESULTS

4.1 Indian Knoll Sample

Tables 4.1 - 4.3 summarize the frequencies of scores categorized by pathological condition within the Indian Knoll sample. The frequency of individuals who had no evidence of osteoarthritis (*n*=55, 56.1%) was higher than the combined frequencies of scores representing presence of osteoarthritis (*n*=43, 43.9%, Table 4.1). Individuals who were categorized as having "slight" development (31.6%) occurred more frequently than individuals categorized as having "moderate" or "severe" osteoarthritis development (7.1% and 5.1%, respectively).

Osteophytosis had similar results (Table 4.2) with absence of osteophytosis (category 0) having the highest frequency and percentage (*n*=56, 57.1%). Individuals categorized as having "slight" development (30.6%, category 1) occurred more frequently than individuals categorized as having "moderate" or "severe" osteophytosis development (7.1% and 5.1%, respectively). Results for whether or not one or more vertebral bodies were compressed showed that 78.6% (*n*=77) of individuals did not have vertebral body collapse compared to 21.4% (*n*=21) with evidence of collapse (Table 4.3).

Table 4.1 Frequency of scores for osteoarthritis at Indian Knoll

Rating of Severity	Frequency	Percent
0	55	56.1
1	31	31.6
2	7	7.1
3	5	5.1
Total	98	100.0

Table 4.2 Frequency of scores for osteophytosis at Indian Knoll

Rating of Severity	Frequency	Percent
0	56	57.1
1	30	30.6
2	7	7.2
3	5	5.1
Total	98	100.0

Table 4.3 Frequency of compression fractures at Indian Knoll

Collapsed Vertebral Body	Frequency	Percent
Absent	77	78.6
Present	21	21.4
Total	98	100.0

Tables 4.4 - 4.6 summarize the frequencies of pathological conditions between males and females in the Indian Knoll population. There is a significant difference between males and females (Fisher's exact test, P=0.0005, Table 4.4). Whereas 18.9% (7 of 37) females have some degree of osteoarthritis, 59.0% (36 of 61) of males have osteoarthritis. Males predominately have osteoarthritis with "slight" development (category 1, 75.0%, 27 of 36). There is a significant difference between males and females (Fisher's exact test, P=0.0009) for osteophytic development (Table 4.5). Results show that 18.9% (7 of 37) of females show some degree of osteophytosis compared to 57.3% (35 of 61) of males. In both females and males with osteophytosis, "mild" was its most frequent expression (category 1, 57.2% [4 of 7] in females and 49.5% [26 of 35] of males). When vertebral bodies were compared for presence or absence of collapse (Table 4.6), chi-square analysis showed that there is a significant difference between males and

females, with 10.8% (4 of 37) females having a collapsed vertebral body and 27.9% (17 of 61) of males (χ^2=3.98, *df*=1, *P*=0.046).

Table 4.4 Frequency of osteoarthritis in males versus females at Indian Knoll

	Categories of Osteoarthritis				
Sex	0	1	2	3	Total
Females	30 (81.1%)	4 (10.8%)	2 (5.4%)	1 (2.7%)	37
Males	25 (41.0%)	27 (44.3%)	5 (8.2%)	4 (6.6%)	61
Total	55 (56.1%)	31 (31.6%)	7 (7.1%)	5 (5.1%)	98

Table 4.5 Frequency of osteophytosis in males versus females at Indian Knoll

	Categories of Osteophytosis				
Sex	0	1	2	3	Total
Females	30 (81.1%)	4 (10.8%)	2 (5.4%)	1 (2.7%)	37
Males	26 (42.6%)	26 (42.6%)	5 (8.2%)	4 (6.6%)	61
Total	56 (57.1%)	30 (30.6%)	7 (7.1%)	5 (5.1%)	98

Table 4.6 Frequency of compression fractures in males versus females at Indian Knoll

	Compression Fractures		
Sex	Absent	Present	Total
Females	33 (89.2%)	4 (10.8%)	37
Males	44 (72.1%)	17 (27.9%)	61
Total	77 (78.6%)	21 (21.4%)	98

Location of vertebral body pathologies in the Indian Knoll sample was assessed. Osteoarthritis of the lumbar segment of the vertebral column was more prevalent (39.8%) than either the thoracic (5.0%) or cervical segments (27.6%). Osteophytosis of the lumbar segment of the vertebral column was more prevalent (40.1%) than either thoracic (5.0%) or cervical segments (26.8%). Vertebral compressions most commonly occurred in the lumbar region of affected individuals (62.4%) than either thoracic or cervical (11.3%).

4.2 Moundville Sample

Tables 4.7 – 4.9 summarize the frequency of pathologies categorized by the level of severity given for each individual in the Moundville sample. Table 4.7 reveals that the frequency of individuals with no evidence of osteoarthritis development (58.6%) was higher than the frequencies for individuals that were ranked with mild (25.9%), moderate (12.1%), or severe (3.4%) osteoarthritis. Table 4.8 shows that the frequency for individuals who showed no signs of osteophytic development (60.4%) was higher than the frequencies for individuals who had mild (27.6%), moderate (8.6%) or severe scores (3.4%). Table 4.9 summarizes the frequency of absence or presence of collapsed vertebral bodies in the Moundville sample. The table shows that more individuals showed no collapse of vertebral bodies (96.6%) than those who had collapsed bodies (3.4%).

Table 4.7 Frequency of scores for osteoarthritis at Moundville

Rating of Severity	Frequency	Percent
0	34	58.6
1	15	25.9
2	7	12.1
3	2	3.4
Total	58	100.0

Table 4.8 Frequency of scores for osteophytosis at Moundville

Rating of Severity	Frequency	Percent
0	35	60.4
1	16	27.6
2	5	8.6
3	2	3.4
Total	58	100.0

Table 4.9 Frequency of compression fractures at Moundville

Collapsed Vertebral Body	Frequency	Percent
Absent	56	96.6
Present	2	3.4
Total	58	100.0

Tables 4.10 – 4.12 summarize the proportions of females and males without and with vertebral pathologies (and by degree of pathology) in the Moundville sample. The prevalence of females categorized as having no osteoarthritis (71.9%) is not significantly different from that of males (42.3%; Table 4.10; Fisher's exact test, P=0.1026). Results for osteophytosis also revealed that there is no significant difference between males and females in their frequencies (Table 4.11; Fisher's exact test, P=0.1920). Finally, there is no significant difference between males and females in frequency of vertebral body collapse (Table 4.12; Fisher's exact test, P=0.1966).

Table 4.10 Frequency of osteoarthritis in males versus females at Moundville

Sex	Categories of Osteoarthritis				Total
	0	1	2	3	
Females	23 (71.9%)	5 (15.6%)	3 (9.4%)	1 (3.1%)	32
Males	11 (42.3%)	10 (38.5%)	4 (15.4%)	1 (3.8%)	26
Total	34 (58.6%)	15 (25.9%)	7 (12.1%)	2 (3.4%)	58

Table 4.11 Frequency of osteophytosis in males versus females at Moundville

Sex	Categories of Osteophytosis				Total
	0	1	2	3	
Females	23 (71.9%)	6 (18.8%)	2 (6.2%)	1 (3.1%)	32
Males	12 (46.2%)	10 (38.5%)	3 (11.5%)	1 (3.8%)	26
Total	35 (60.3%)	16 (27.6%)	5 (8.6%)	2 (3.4%)	58

Table 4.12 Frequency of compression fractures in males versus females at Moundville

Sex	Compression Fractures		Total
	Absent	Present	
Females	32 (100.0%)	0	32
Males	24 (92.3%)	2 (7.7%)	26
Total	56 (96.6%)	2 (3.4%)	58

Vertebral segments were compared for osteoarthritis in the Moundville sample. Lumbar vertebrae showed the most pathological development of osteoarthritis of the three vertebral segments (39.6%), followed by thoracic (17.2%) and cervical (13.8%) segments, respectively. Osteophytosis of the lumbar segment of the vertebral column was more prevalent (38.7%) than either the thoracic (12.1%) or cervical segments (8.7%).

Vertebral compressions most commonly occurred in the lumbar region of affected individuals (54.3%) than either the thoracic (32.3%) or cervical (13.4%) segments.

4.3 Inter-populational Comparison of Vertebral Pathology

Tables 4.13 – 4.15 summarize the frequencies of the observed pathologies at both Indian Knoll and Moundville. There is no significant difference in osteoarthritis development between the two samples (Fisher's exact test, P=0.6806). Individuals that showed no development of osteoarthritis (Table 4.13) occurred more frequently (over 50% for both populations) than individuals who showed some degree of pathological development. Additionally, results show no significant difference in relation to osteophytic development. (Fisher's exact test, P=0.9134, Table 4.14). Table 4.15 summarizes the frequencies for vertebral compression fractures in the combined sex samples for Indian Knoll and Moundville; chi-square analysis (χ^2=9.37, df=1, P=0.002) reveals that there is a significant difference between the samples. A higher percentage of individuals have compression fractures in Indian Knoll (21.4%) than in Moundville (3.4%).

Table 4.13 Frequency of osteoarthritis in combined sex samples in Indian Knoll and Moundville

Osteoarthritis	Indian Knoll	Moundville
0	55 (56.1%)	34 (58.6%)
1	31 (31.6%)	15 (25.9%)
2	7 (7.1%)	7 (12.1%)
3	5 (5.1%)	2 (3.4%)
Total	98	58

Table 4.14 Frequency of osteophytosis in combined sex samples in Indian Knoll and Moundville

Osteophytosis	Indian Knoll	Moundville
0	56 (57.1%)	35 (60.3%)
1	30 (30.6%)	16 (27.6%)
2	7 (7.1%)	5 (8.6%)
3	5 (5.1%)	2 (3.4%)
Total	98	58

Table 4.15 Frequency of vertebral compression fractures in combined sex samples in Indian Knoll and Moundville.

	Compression Fractures		
Population	Absent	Present	Total
Indian Knoll	77 (78.6%)	21 (21.4%)	98
Moundville	56 (96.6%)	2 (3.4%)	58

Table 4.16 summarizes the frequencies of osteoarthritis distribution between males in Indian Knoll and Moundville. There is no significant difference (Fisher's exact test, P=0.7483). Table 4.17 summarizes the frequencies of osteoarthritis distribution between females in Indian Knoll and Moundville; there is no significant difference (Fisher's exact test, P=0.8341).

Table 4.16 Comparison of osteoarthritis between males at Indian Knoll and Moundville

	Categories of Osteoarthritis				
Population	0	1	2	3	Total
Indian Knoll	25	27	5	4	61
Moundville	11	10	4	1	26

Table 4.17 Comparison of osteoarthritis between females in Indian Knoll and Moundville

Population	Categories of Osteoarthritis				Total
	0	1	2	3	
Indian Knoll	30	4	2	1	37
Moundville	23	5	3	1	32

Tables 4.18 and 4.19 summarize the frequency distributions of osteophytosis between males and between females in Indian Knoll and Moundville. Fisher's exact test reveals no significant difference between males (P=0.9181; Table 4.18) or between females (P=0.8287; Table 4.19).

Table 4.18 Comparison of osteophytosis between males in Indian Knoll and Moundville

Population	Categories of Osteophytosis				Total
	0	1	2	3	
Indian Knoll	26	26	5	4	61
Moundville	12	10	3	1	26

Table 4.19 Comparison of osteophytosis between females in Indian Knoll and Moundville

Population	Categories of Osteophytosis				Total
	0	1	2	3	
Indian Knoll	30	4	2	1	37
Moundville	23	6	2	1	32

Tables 4.20 and 4.21 summarize the frequency distributions of compression fractures between males and between females in Indian Knoll and Moundville. Comparison of males (χ^2=3.25, df=1, P=0.071; Table 4.20) reveals no significant

difference in vertebral compression fractures. Similarly, comparison of females (Fisher's exact test, P=0.118; Table 4.21) reveals no significant difference in vertebral compression fractures.

Table 4.20 Comparison of compression fractures between males in Indian Knoll and Moundville

Population	Compression Fractures		Total
	Absent	Present	
Indian Knoll	44	17	61
Moundville	24	2	26

Table 4.21 Comparison of compression fractures between females in Indian Knoll and Moundville

Population	Compression Fractures		Total
	Absent	Present	
Indian Knoll	33	4	37
Moundville	32	0	32

CHAPTER 5. DISCUSSION

Vertebral pathologies have been useful criteria for assessing human health, diet, and biomechanical stress from prehistoric skeletal populations. Numerous studies have been conducted regarding the influence of physical stress on the development of pathological conditions in association with shifts in economic lifestyle from hunting and gathering to agriculture. Bridges' (1994) study reveals that there is variation in the development of degenerative pathologies between populations that subsisted on foraging and populations that relied on intensive agriculture. Larsen (1981) reported differences between hunter-gatherers and agriculturalists in osteoarthritis. He showed that hunter-gatherers had a higher prevalence of osteoarthritis in cervical and lumbar vertebrae. This study analyzed the vertebral columns of prehistoric skeletal populations in order to determine whether there were significant differences between hunting and gathering and agricultural populations from Indian Knoll and Moundville in terms of vertebral pathologies.

The etiologies of osteoarthritis, osteophytosis and vertebral compression fractures are multifactorial. Quite often, the three pathologies are associated with age, weight, and mechanical loading (Weiss and Jurmain 2007). Increasing age is known to be a factor that heavily influences the development of osteoarthritis and osteophytosis. As an individual increases in age, degenerative changes more likely will be manifested. Cases of osteoarthritis are common in the literature in almost all post-cranial elements and have been discussed extensively in the current study (Larsen 1981; Sanders and Reinhard 1992; Bridges 1994; Derevenski 2000; Hodge 2011). The present study aligned with previous analysis conducted by Larsen (1981) in which hunter-gatherers (Indian Knoll)

had a higher prevalence of osteoarthritis compared to agriculturalists (Moundville) in the cervical and lumbar regions of the vertebral column. However, there is no significant difference overall in frequency and severity of osteoarthritis between hunter-gatherers and agriculturalists in this study (Table 4.13). The results suggest that the populations were doing different subsistence activities that imposed similar types of stress on the vertebral column. The degree to which osteoarthritis is evaluated in the literature suggests that there is some value in reconstructing lifestyles based on the development of certain pathologies. While these pathologies are heavily influenced by age, they also provide some evidence of the amount of physical stress endured by the populations. Additionally, research reveals that osteophytosis, while influenced by age, is also an effect of increased physical stress. For example, Chapman (1972) evaluated vertebral osteophytosis in prehistoric populations of Central and Southern Mexico and found that some individuals had evidence for development of osteophytosis after 21 years of age. The current study revealed that there is osteophyte development among both hunter-gatherers and agriculturalists in adults between the ages of 18 and 49. Osteophytes, while generally associated with age, can also develop as a reaction to other factors such as severe trauma, increased mechanical stress and as a response to infection or disease (Jurmain 1977).

Results of this research show no difference between a hunter-gatherer population (Indian Knoll) and an agricultural population (Moundville) in presence and degree of expression of osteoarthritis or osteophytosis. However, there is a significant difference between the populations in vertebral body collapse. Indian Knoll had higher frequency of vertebral body collapse than Moundville, suggesting that the population at Indian Knoll was putting more mechanical stress on the vertebral column that would have led to

increased compression of the vertebral bodies. One possible explanation is that the individuals at Indian Knoll were participating in activities that were infrequent but required heavy load-bearing, such as lifting heavy objects over short distances. Mensforth and Latimer (1989) studied the vertebral columns of individuals from the Hamann-Todd collection, which consists of skeletons from the United States (mainly in and near Cleveland, Ohio) from the late 19th and mid-20th centuries, and revealed that vertebral compression fractures occurred around the mean age of 60 years as result of skeletal fragility associated with increased bone loss. Increased load-bearing and mechanical stress could result in early development of vertebral compression fractures, as evidenced by the individuals in the present study.

Sexual differences between hunter-gatherers and agriculturalists were also assessed in the current study. Comparisons of osteoarthritis and osteophytosis between males and females in Indian Knoll revealed that males showed more development than females overall, suggesting that males were participating in more repetitive activities than females (Tables 4.4 and 4.5 respectively). Similarly, males had more evidence for vertebral compression fractures in the population than females which suggests that males were consistently participating in activities that involved heavy loads (Table 4.6). In contrast, comparisons of osteoarthritis and osteophytosis between males and females in Moundville revealed no differences between the sexes in the observed pathologies. (Tables 4.10 and 4.11, respectively).

Analyses of inter-populational differences in vertebral pathology revealed that there were no significant differences between Indian Knoll and Moundville for osteoarthritis and osteophytosis. One interpretation is that both populations were

participating in activities that produce similar rates of pathological development. While the populations had different types of subsistence strategies, the analysis suggests that both populations were putting similar amounts of stress through repetitive motions on their vertebral columns. However, the results reveal that there is a higher percentage of individuals that have compression fractures in Indian Knoll than in Moundville (Table 4.15), which suggests that the population in Indian Knoll was participating in more heavy weight-bearing activities than the population in Moundville.

The comparison of degenerative joint disease between hunter-gatherers and agriculturalists provides an analysis of differences in economic lifestyles because of the diverse nature of the populations. The results suggest that Indian Knoll and Moundville were participating in different activities that were putting similar amounts of stress on their vertebral columns. The current study aligns with previous research (Larsen 1981; Bridges 1989, 1991,1994; Derevenski 2000) regarding the influence of subsistence activities on the development of pathology. The current study represents an example of differing levels of variation in pathology among hunter-gatherer and agricultural groups. Therefore, investigations of mechanical and environmental stress on the development of vertebral pathologies can reveal much about the amount of physical activity that occurs in both populations.

The results show increased vertebral compression fractures in the Archaic sample over the Mississippian sample. Bridges' (1994) study was conducted in a similar fashion and revealed similar results for osteoarthritis and osteophytosis, although her samples came from two populations occurring in the same region. Future analyses could reflect on samples that occur in similar environments that would contribute to the knowledge of

transition in economic lifestyles. Additionally, this study could be duplicated to test whether there are associations between development of pathology in the vertebral column and other post-cranial elements.

Lumbar vertebrae are often associated with development of degeneration because of the increased load-bearing on this segment relative to cervical and thoracic segments. The current study reveals that pathologies were more frequent in the lumbar vertebrae, which is consistent with previous analyses (Larsen 1981; Bridges 1994). While the samples do occur in two different environments, the results reflect similarity in location frequency of vertebral pathologies. In both samples, the lumbar segment was the most affected region. However, the Archaic population had increased prevalence of vertebral pathologies in the cervical segment over the thoracic segment. By contrast, the Mississippian population had an increased frequency of pathology in the thoracic over the cervical vertebrae. This difference between the two populations in frequency of pathology of cervical and thoracic vertebral segments warrants further study.

This research sought to answer two questions: 1) did economic lifestyle lead to inter-populational differences in vertebral pathology, and 2) are there sexual differences in these pathologies that would be consistent with divisions of labor within the populations? This research did yield observations of differences in vertebral compression fractures between Indian Knoll and Moundville. However, this research found that there were no meaningful differences in osteoarthritis or osteophytosis between the populations. However, the analysis revealed that there are different types of forces imposed on the vertebral column between the sexes in Indian Knoll, but not necessarily

in Moundville. The information yielded from this study will contribute to the knowledge of transitioning economic lifestyles of past populations.

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