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Cultural Behaviors and Their Influence on the Proximal Femur: Comparisons of Postural Behavior, Occupation, and Subsistence-Settlement Between a Pre-Contact and Historic Sample

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CULTURAL BEHAVIORS AND THEIR INFLUENCE ON THE PROXIMAL FEMUR: COMPARISONS OF POSTURAL BEHAVIOR, OCCUPATION, AND SUBSISTENCE-SETTLEMENT BETWEEN A PRE-CONTACT AND HISTORIC SAMPLE

by

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ABSTRACT

Little is known archaeologically about the Late Woodland Schroeder Mounds mortuary group from west-central Illinois. As such, bioarchaeological data is at the forefront of archaeological problem-solving for not only the site, but the geographical area as well. Skeletal data such as proximal femur angles and activity markers contribute to the understanding of subsistence-settlement trends and postural behavior of the mortuary complex. Femoral neck version is associated with postural behaviors such as squatting and kneeling. The neck-shaft angle is linked to mobility and settlement patterns. Bicondylar angle was explored to see if behaviors had any affect. Allen's fossa and Poirier's facet are linked to squatting and kneeling behaviors.

The Schroeder Mounds (A.D. 650-960) sample consisted of 27 individuals. The early 1900s sample of Hamann-Todd yielded a sample size of 74. I took various midpoints on the femur and used a goniometer to measure each angle. Activity markers were scored as either present (1) or absent (0). The femoral neck version and neck-shaft angle were statistically significantly higher in Schroeder. Bicondylar angle was within normal range in both groups with no statistical differences. Allen's fossa frequencies were nearly the same between groups, but Poirier's facet was nearly double in the pre-contact sample. These results support the idea Schroeder Mounds individuals were habitual squatters/kneelers with a more sedentary lifestyle than expected. Given the geographic location, there was little need to travel long distances for food with the abundance of aquatic resources available. This research presents a new biocultural method for unknown archaeological samples.

ACKNOWLEDGMENTS

I would like to thank my committee, especially Dr. Marie Danforth, for helping me through this strenuous process. I would also like to specially thank Dr. Maria O. Smith for supporting my inspiration for this project all those years ago. I would like to acknowledge the Illinois State Museum and the Cleveland Museum of Natural History for allowing me access to their collections.

DEDICATION

Special thanks go to my mom and dad for supporting my dreams through graduate school. Josh Jackson, your patience and unwavering encouragement were needed and appreciated many times over. Finally, to all my friends who listened to my woes, I thank you sincerely.

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BA	Bicondylar angle
FNV	Femoral neck version
NSA	Neck-shaft angle

CHAPTER I – INTRODUCTION

Bioarchaeology is the study of the human skeleton in archaeological contexts. The New Physical Anthropology movement in the 1950s and the New Archaeology movement of the 1960s led to a more systematic, holistic study of the human skeleton. New Physical Anthropology was initiated by Sherwood Washburn who called for physical anthropologists to move away from measurements and classification systems to a more interpretive field of research. Emphasis was placed on function and behavior as well as biology (Fuentes 2010). Within a decade of the formation of New Physical Anthropology, the New Archaeology movement begun by Lewis Binford posited that culture is a means by which people adapt to their environments (Meltzer 2011). Individuals make up the population, and although the population is the focus of meaningful research, individuals can participate in culture differently (Armelagos 2003). The goal of bioarchaeology is therefore to systematically analyze skeletal populations by documenting information on individual lives, both behavioral and morphological, to produce dialogue concerning past as well as present populations. Together, the osteological data and archaeological data shed light on past lifeways and lead to meaningful comparisons across time and space.

Bioarchaeology can be utilized as archaeological problem solving, especially when there is a lack of archaeological evidence but a presence of burials (Roberts and Manchester 2007). The discipline has been used to gather information on the movement of people, adaptations to environmental changes, origins and spread of diseases, diet and economy, treatment of children, socioeconomic status, hierarchy, and occupation (Atwell and Conner 1991; Roberts and Manchester 2007). There are many avenues that might be pursued to learn about past populations, including biomechanics, which is the application of mechanical principles to the human skeleton (Ruff 2008). Biomechanics can reveal information about skeletal populations as well as individuals, but there is also clinical importance in its study. Skeletal variation due to mechanical factors has the potential to reveal evidence of occupation, mobility patterns, and disease (Weiss 2012). Lines of biomechanical inquiry include, but are not limited to, diaphyseal variations, musculoskeletal markers, stress fractures, and geometric morphometrics.

One of the diaphyseal markers commonly used are squatting or kneeling facets. These facets can present themselves anywhere on the lower extremity, including the femur, tibia, ankle bones, and toe bones (Ubelaker 1979; Nelson 2011; Weiss 2017). Facets are caused by joint displacement such as those associated with prolonged squatting or kneeling (Ubelaker 1979). "Extreme hyperdorsiflexion of the metatarsophalangeal joints with subsequent extension of the synovial capsule and articular cartilage" in the foot cause marked changes on the bone indicative of kneeling due to the bent position of the toes (Ubelaker 1979, 682). These types of marked changes on bone can reveal information about behaviors individuals participated in during their lifetime, especially those performed in high frequency. Specifically, Poirier's facet and Allen's fossa, both considered types of squatting facets, are of interest in this study. Allen's fossa can present as a small depression or a large eroded area along the border of the femoral head (Finnegan 1978; Weiss 2017). Poirier's facet appears on the articular surface of the femoral head toward the anterior portion of the neck (Finnegan 1978).

Yet other biomechanical markers studied are various angles of the femur, which have been included in a limited number of biomechanical analyses. Three of the angles of the proximal femur are femoral neck version (FNV), neck-shaft angle (NSA), and bicondylar angle (BA). FNV focuses on the antero-posterior position of the neck in relation to the shaft (Murphy et al. 1987; Jain et al. 2005; Khamanarong et al. 2014). NSA can be described as the proximo-distal angle created by how the neck is positioned in relation to the shaft (Gilligan et al. 2013). BA measures the orientation of the femoral shaft in association with the condyles when they are positioned on a flat plane, either a table or an imagined straight line (Shah n.d.). Variations have been found both within and among populations, including laterality, age, sex, and subsistence-settlement patterns (Tardieu and Trinkaus 1994). In addition, there are clinical implications for variation in femoral angles, especially when focusing on FNV. For example, those with cerebral palsy have extremely high FNV measurements due to their disease (Souza et al. 2015).

One issue within the present research is the lack of meaningful explorations and connections among the various angles of the femur and behavioral contexts. Several authors researching angles of the femur have posited population differences are derived from differences in physical behaviors such as squatting patterns (Khamanarong et al. 2004; Gilligan and Bulbeck 2007; Zalawadia et al. 2010), whereas others have suggested mobility patterns like a highly nomadic lifestyles or more sedentary lifestyles are key factors in population differences (Trinkaus 1976; Tardieu and Trinkaus 1994). Size of the pelvis, age, laterality, and genetics are other possible influences on morphology of the proximal femur (Macho 1991; Gudiera et al. 1994; Tardieu and Trinkaus 1994; Hernandez-de Sosa et al. 2016).

My research in this thesis focused on two primary questions. The first was to explore how proximal femur angles and activity markers might relate various activities in two distinct populations, one a prehistoric population from Illinois and another a 20th century population from the U.S. The second was split the historic group into two occupation groups which reflects high and low levels of activity, and then use the patterns seen to establish a model could be applied to less well-document populations to reconstruct lifeways, especially those concerning subsistence-settlement practices and postural behaviors.

Morphological data collected concerning frequencies of angles and facets of the proximal femur were collected for the Hamann-Todd collection, a modern sample with documentation on the age and sex of previous cadaver individuals that make up the collection. These individuals were unclaimed remains from the city morgue between 1912 and 1938 (Gillespie et al. 2011). These individuals have known occupations documented, which assisted in identifying harder manual labor groups to compare to lighter manual labor groups.

The resulting model was then applied to human remains recovered at Schroeder Mounds in Henderson County, Illinois. There is little archaeological data on such cultural traits as diet, tool use, and pottery use for the site (Kolb 1982), but much research has been generated concerning the human remains of Schroeder Mounds (e.g., Langford 1999; Hitzmann 1997; Boncal and Smith 2013; Mosher et al 2015; Durchholz 2017; Woollen and Smith 2017, 2021; Keeling 2019). The skeletal data suggests more reliance on non-maize agriculture (Specht 1995), such as horticulturalists who were becoming more sedentary (Mosher et al. 2013; Smith et al. 2016), but a few indicators are more consistent with maize agriculture. Therefore, information concerning activity patterns can theoretically aid in the most accurate reconstruction of their cultural ways. Expected patterns included:

1. A higher frequency of Allen's fossa and Poirier's facet in the Schroeder Mounds group compared to Hamann-Todd. This would reflect behavioral differences such as squatting and kneeling versus sitting in a chair to rest or work.
2. FNV will be lower in the heavy labor group due to mechanical stress on the femoral neck. This would also be reflected in the Schroeder Mounds group, with FNV more closely aligned with the heavy labor group.
3. BA would be similar to each other between Hamann-Todd and Schroeder Mounds.
4. NSA would be lower in the heavy labor group compared to the light labor group. Schroeder Mounds would have an NSA mean similar to the heavy labor group, but possibly lower.

In this thesis, Chapter 2 covers literature associated with the hip joint and the morphology of the proximal femur. Chapter 3 reviews the history of the two sample groups. Chapter 4 presents materials and methods. Chapter 5 presents not only results, but initial discussion points as well. Chapter 6 contextualizes the data and offers possible explanations, limitations of the study, research contributions, future studies, and conclusions.

The contributions of this study are three-fold. Firstly, the study contributed knowledge about subsistence-settlement and postural behavior for a site with little archaeological data. Schroeder Mound's lack of material culture has resulted in a deficit in the possible knowledge it could produce, placing great importance on the bioarchaeological data. Secondly, this research has expanded the sparse literature concerning the viability of proximal femur angles as activity indicators. Thirdly, the study adds valuable data to compare with future studies on proximal femur angles and activity markers in both prehistoric and historic populations.

CHAPTER II – THE HIP AND ITS ASSOCIATED MORPHOLOGICAL TRAITS

This chapter first gives an overview of the morphology of the hip and its importance to the human body. Second, I review the literature of each angle of concern in this study: FNV, BA, and NSA. Lastly, I review the literature surrounding the two activity markers addressed in this study: Allen's fossa and Poirier's facet.

The Anatomy of the Human Hip

Basic Structure

The hip is a ball-and-socket joint and is known as the most powerful muscular area of the human body (Figure 1) (Moore et al. 2018). The basic anatomy of the hip includes a multitude of muscles which attach to the bones of the pelvis (os coxae and sacrum), the femur, patella, or the tibia (Table 1) (Moore et al. 2018). The ball-and-socket structure consists of the head of the femur that sits in the acetabulum. There is very little direct attachment of the head of the femur to the acetabulum inside the joint except for the ligament of the head of the femur which attaches at the fovea capitis and the acetabular fossa (Moore et al. 2018). There are either 21 or 23 muscles which contribute to the stability and movement of the hip joint (Zaghloul and Mohamed 2018). The difference in number depends on if the reference splits the iliopsoas into the iliacus, psoas major, and psoas minor muscles, or combines them into one large muscle. Usually it is discussed as the iliopsoas muscle, the major flexor of the hip, because of the shared tendons, though each has the ability to perform different actions (Moore et al. 2018). All the muscles of the hip assist the lower limbs in extension, abduction, adduction, and internal and external rotation (Zaghloul and Mohamed 2018).

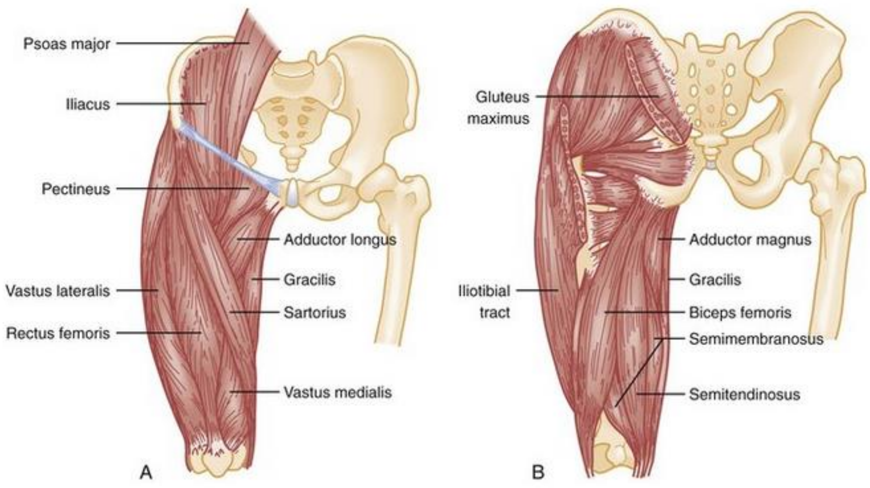

Figure 1. Musculature of the hip, where A is an anterior view and B is a posterior view (Murray 2015, Figure 56-3).

Table 1 *Muscles of the Pelvis (coloration denotes groups of muscle by the action they perform).*

Muscle	Origin	Insertion	Action
Iliopsoas (iliacus, psoas major, psoas minor)	T12-L5 transverse process, iliac crest, sacrum	Lesser trochanter	Flexion
Rectus femoris	ASIS*, anterosuperior acetabulum	Superior patella	Flexion
Tensor fascia latae	ASIS, iliac crest	Iliotibial tract	Flexion
Sartorius	ASIS	Anteromedial tibial plateau	Flexion
Gluteus maximus	Outer cortex of ilium, posterior sacrum and coccyx	Posterior iliotibial tract, gluteal tuberosity	Extension
Biceps femoris	Ischial tuberosity	Fibular head and posterolateral tibial plateau	Extension
Semimembranosus	Ischial tuberosity	Fibular head and posterolateral tibial plateau	Extension
Semitendinosus	Ischial tuberosity	Anteromedial tibial plateau	Extension
Gluteus medius	Anterior gluteal line	Lateral surface of greater trochanter	Abduction

Table 1 (continued).

Gluteus minimus	Outer cortex of ilium	Anterior surface of greater trochanter	Abduction
Tensor fascia latae	ASIS, iliac crest	Iliotibial tract	Abduction
Adductor magnus	Inferior pubic ramus, ischial tuberosity	Gluteal tuberosity, adductor tubercle of medial femur	Adduction
Adductor longus	Body of pubis	Middle third of linea aspera	Adduction
Adductor brevis	Inferior pubic ramus, body of pelvis	Proximal linea aspera, pectineal line	Adduction

*ASIS: anterior superior iliac spine.

All these muscles associated with support and movement of the hip working together result in the ability to walk bipedally (Moore et al. 2018). The upper limbs act as an inverted pendulum in tandem with the lower limbs producing a normal gait, swinging at the same frequency to counterbalance the weight of the body (Schmeltzpfenning and Brauner 2013). The sequence of the human walking gait involves the stance phase, toe-off, swing, and heel strike (Schmeltzpfenning and Brauner 2013; Moore et al. 2018). At this point the sequence begins again in order to further move the individual forward. The femora of an individual help to bring the lower limbs closer to the midline in order to support the rest of the body (Moore et al. 2018).

Comparisons with Non-Human Models of the Hip

In addition to studying the normal human gait, comparisons can be made with models with other animals in order to assess how morphology affects gait. In relation to assessing appropriate models to utilize for human hip replacements, canine and primate morphology were compared to that of humans by Kuo and colleagues (1998). Some argued canines were a reasonable and appropriate model due to similarities in cancellous bone distribution, the medullary canal, and the neck-shaft.

Canid Model. While walking, canines have a similar load on the hip compared to humans, although this can be argued. The force on a single hip of a canine is approximately 1.5-1.7 times its body weight, while in humans the force is 2.4-5.0 times the individual's body weight. Further differences between the quadrupedal canine and the bipedal human can be attributed to the different number of limbs and different configurations associated. In canines, the body weight of the animal acts on the spine slightly closer to the shoulders than to the hindlimbs. This makes the forelimbs have a greater ability to support the weight and gait of the individual. In humans, this configuration is not possible due to the bipedal configuration of the spine, or the resultant "S" curve of the spine to balance the weight of the skull. Others argue that differences in morphological features such as anteversion and neck-shaft angles are much too large to compare to humans. Along with the medullary canal, these features are much larger in canines compared to humans (Kuo et al. 1998).

Non-human Primate Model. The second model proposed involving non-human primates has evidence to support both the utilization and non-utilization of the model. While non-human primates have a similar hindlimb dominance and the ability to adopt an upright posture with small bursts of bipedal locomotion, the walking gait of non-human primates utilize different muscles and velocity of the gait (Kuo et al. 1998). A study concerning the energy expended by muscles during standing showed chimpanzees expend higher energy levels than humans in order to maintain the stance position, suggesting a higher amount of stress across the hips (Kuo et al. 1998, 477).

Electromyography, or the electrical activity of muscles, was especially high in the gluteal region of the pelvis and three muscles of the thigh (vastus medialis, vastus lateralis, and the long head of the biceps femoris) (Kuo et al. 1998).

These studies help explain the modern human characteristic of endurance and its effects on human gait and the importance of these considerations in hip replacement surgeries. Where canines have a large force on each hip, humans have at two times as much, if not more, force placed on each hip due to only utilizing two limbs for walking as opposed to two. Where chimpanzees do not have the hip musculature adapted to obligate bipedal motion, humans do from millions of years of adaptation. Utilization of these models allows for a better overall understanding of the human gait and how to better assist people with hip replacement surgeries.

The Proximal Femur Angles and Their Analyses

The osteological morphology of the hip joint is complex due to the large number of muscles which attach to these bones, and different activity patterns can theoretically shape the joint area in distinct ways. Angles of the femur are one way to quantify these activity patterns that might be associated with different age and sex groups as well as with certain economic strategies and geographical adaptations (Bonneau et al. 2012; Gilligan et al. 2013; Khamanarong et al. 2014). Of primary concern for my research are three angles that affect the hip area: femoral neck version (FNV); neck-shaft angle (NSA), which is also referred to as the angle of inclination and the cervico-diaphyseal angle; and bicondylar angle (BA). The last has been studied extensively in association with evolution of bipedalism in humans, while the former two angles seem to have been studied in moderation by those concerned with biomechanics and the morphological differences between groups.

This section will discuss the three angles of the femur included in this research: femoral neck version, neck-shaft angle, and bicondylar angle. In addition to angles of the proximal femur, effects concerning the formation of arthritis of the knee and femoroacetabular joint are discussed along with the effects of activities on the joint.

Femoral Neck Version

Femoral neck version (FNV) is defined as the angle created by an imaginary line that bisects the femoral head and neck and a second line which is created by the surface on which the posterior portion of the femur rests (Murphy et al. 1987; Jain et al. 2005; Khamanarong et al. 2014) as defined and measured by the Kingsley-Olmsted method and its variations on dry femora (Kingsley and Olmsted 1948) (Figure 2). The angle measures the antero-posterior position of the neck in relation to the shaft. Kingsley and Olmsted first defined “normal” adult FNV measurements as anything between 0 and 15 degrees. Most FNV measurements of populations average above 0 degrees, with most averages between 9 degrees and 15 degrees (Korukonda et al. 2007; Maheshwari et al. 2010; Ejnisman et al. 2013; Khamanarong et al. 2014). The angle of torsion is called anteversion if it points anterior to the transcondylar plane, and retroversion if it points posterior to the transcondylar plane (Figure 2) (Zalawadia et al. 2010). This angle will be referred to as FNV in reference to both anteversion and retroversion and will be specified when needed.

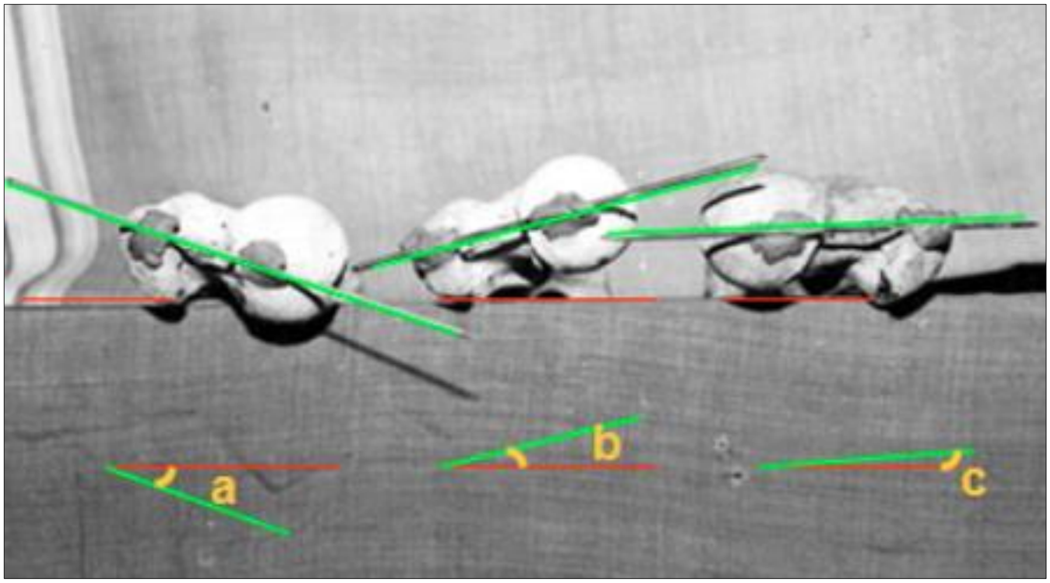

Figure 2. Variation in the FNV (left to right) - a: retroversion (-13.7 degrees); b: normal anteversion (9.6); and c: neutral version (-1 to 1 degree) (Zalawadia et al. 2005, 7).

FNV was demonstrated in Da Vinci's anatomical drawings in the 1500s, and has been noted to normally be anteverted in humans (Tayton 2007). One hypothesis concerning why anteversion exists draws upon Wolff's Law, which explores consequences of external forces on bone morphology, whereby the bone gains strength from more load bearing or use of the bone (Wolff 1892). The hypothesis states that it is the forces applied on a developing fetus' bones inside the womb which create the subsequent anteversion. Tayton (2007) conducted a study where human and animal FNV was considered. As may be seen in Table 2, he compared femoral structure from a variety of mammals as well as from several primates such as the baboon, gorilla, colobus, with that of humans.

Table 2 *FNV Means and Ranges in Selected Species (Tayton 2007, 1285).*

Species	FNV Mean	FNV Range
Chimp	4.00	N/A
Cat	8.00	N/A
Talapoin	12.50	11.00-14.00
Gorilla	14.70	9.00-18.00
Gray's monkey	16.50	13.00-20.00
Colobus	18.00	17.00-19.00
Lamb	20.00	N/A
Mouse	23.50	23.00-24.00
Badger	24.00	22.00-26.00
Eland	26.00	N/A
Leopard	26.00	N/A
Pig	32.00	N/A
Zebra	33.00	N/A
Giant forest hog	41.00	N/A

Mathematical models were used to simulate forces placed upon the model femora in anatomical position (Tayton 2007). For each of the chosen femora, two models were constructed where the femur was in a neutral position and another where the femur was in an anteverted position with FNV at 30 degrees. In humans, the turning moment decreased from an anteverted angle of 0 to an angle of 20. The same amount of force was applied on 3D models which had FNV measurements of 0, 5, 10, 15, and 20 degrees. At 15 degrees, there is a noticeable difference whereas between 0 degrees and 5 degrees, there is only a 0.1 change in the turning moment (Nm) between 0 degrees and 15 degrees there is a 1.0 Nm (3.4%) decrease. Although this is not a significant decrease, it could be important when considering long-term impacts of stress on the femur (Tayton 2007). Most of the averages for each species were gathered with very small sample sizes, most only including one or two individuals (Tayton 2007, 1285). In Table 2, where no range is given, there was only one specimen measured in the study (Tayton 2007).

Variations in FNV measurements have been related to age, population, sex, laterality, and pathology (Kinglsey and Olmsted 1948; Korukonda et al. 2010; Maheshwari et al. 2010; Khamanarong et al. 2014). FNV variations are most commonly attributed to developmental milestones in children as they learn to walk, putting an increased amount of pressure on the hip joint as they become obligate bipeds instead of casual bipeds (Dunlap et al. 1953; Djukic et al. 2014). Nearly all studies concerning FNV find a higher mean for females, although the differences vary. Khamanarong et al. (2014) found a mean of 16.59+/-5.05 degrees in females, whereas males had an average of 15.83+/-5.20 degrees. Korukonda et al. (2017) observed a mean of 21.3 degrees in the females of a South Indian population, whereas the males of the population had a much lower mean of 16.8, a statistically significant difference. Pelvic morphology could play an important role in these differences. In females, the pelvic girdle is wider, requiring the head and neck of the femur to be positioned in a way that would allow the leg to rotate while still maintaining center of gravity at the knee joint (Gulan et al. 2000).

Observations in differences based on side are also present in the literature. Khamanarong et al. (2014) note an average of 17.21 degrees for the left side and 15.16 for the right side when both sexes are combined and averaged together. When sexes were combined and averaged by side in Korukonda et al. (2010), the mean for the left side was found again to be much higher. The left femora averaged 22.15 degrees and the right side averaged 15.74. When sex was accounted for, the right sides had larger ranges of value. Right femora in males had an average of 13 degrees whereas in females it was 19.4

degrees. This is a statistically significant difference. The left sides showed less of a range with only a 2.3 degree difference (FNA mean in males was 20.0 degrees, FNA mean in females was 22.3 degrees). Although no research has pinpointed a direct cause or another possible explanation other than differential use of the legs (Korukonda et al. 2010), it has been suggested that there might be a preferential leg use similar to handedness.

Various health conditions have also been implicated in differences in FNV. Anything above 15 degrees for the FNV is considered pathologically abnormal, which could result in labral tears or indicate diseases which may be related (Kingsley and Olmsted 1948; Ejnisman et al. 2013), although a larger range of up to 38 degrees has been stated as normal but is not widely accepted (Gulan et al. 2000). Cerebral palsy especially has been linked to an increased FNV angle because of an imbalance of muscle tension (Tayton 2007). It is important to note that while most studies do not investigate such occurrences as tears in the labrum of the acetabulum or the ring of fibrous cartilage around the acetabulum in association with femoral neck version, Ejnisman et al. (2013) found individuals with angles less than 5 degrees were prone to labral tears, but the higher degree of FNV, the larger the possible tear. Patients with measurements smaller than 5 degrees presented with labral tears averaging 30mm in size, those with measurements between 5 and 15 degrees averaged 34mm in size, and those with 15 degrees or higher had labral tears averaging 38mm in size (Ejnisman et al. 2013).

Some authors (Tayton 2007; Korukonda et al. 2010; Khamanarong et al. 2014) argue FNV is diagnostic for studying behaviors. No studies truly focus on the connection between FNV and behavior, but Korukonda et al. (2010) and Khamanarong et al. (2014) strongly imply the connection and postulate squatting behaviors may be a causal factor for differences in values seen among cultural groups in India. Most studies like the aforementioned (Tayton 2007; Korukonda et al. 2010; Khamanarong et al. 2014) aimed to collect data for hip replacements to make them more accurate to a given population. FNV is an important factor in hip replacements as it is directly related to the orientation of the femoral head and neck in the acetabulum (Tayton 2007).

Neck-Shaft Angle

Neck-shaft angle is the second angle included in this study and can be described as the proximo-distal angle created by the position of the neck in relation to the shaft (Figure 3). Despite the limited number of studies focusing on this aspect of hip morphology, general values range from 120 degrees to 140 degrees in modern humans, although coxa varus (<120 degrees) and coxa valgus (>140 degrees) is not uncommon (Gilligan et al. 2013). Currently, debate concerning methodology and explanations for femoral neck-shaft angle variations is rampant in the literature (Anderson and Trinkaus 1998; Bonneau et al. 2012; Gilligan et al. 2013). Morphological explanations include age-related growth patterns and climate associated body proportions (Bergmann's and Allen's Rules) (Bonneau et al. 2012; Gilligan et al. 2013).

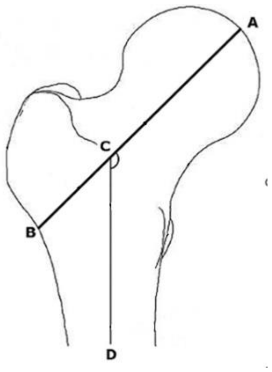

Figure 3. Diagram of the neck-shaft angle (lines AB and CD) (adapted from Hernandez-de Sosa et al. 2016, Figure 2).

As with FNV, developmental milestones are pertinent in the development of a normal NSA (Anderson and Trinkaus 1998). Within normal ranges of activity, without other complications such as pathologies, children will develop the normal range of NSA (120-140 degrees) by adolescence (Anderson and Trinkaus 1998). By having a smaller NSA, the moment at the hip joint is reduced (Tavares 2012). Reduction of the moment at the hip likewise results in subluxation of the femoral head within the femoroacetabular joint where there is partial contact between the head of the femur and the acetabulum itself (Tavares 2012).

In cases where children are unable to participate in normal weight-bearing activities, including walking and running, as a result of paralysis or cerebral palsy, the femoral neck angle remains high into adulthood. This unusual NSA in turn results in a coxa valga (an abnormally high NSA) position of the femoral neck and a genu vara (also known as bowlegged) position of the knee. During development, high physical activity results in a greater decrease in NSA, and can lead to genu vara at the knee (Yoshioka et al. 1987; Anderson and Trinkaus 1998, 281). In a study by Yoshioka et al. (1987) it was noted a wide distal femoral valgus angles (10+ degrees) have been associated with notable tibia vara, here the proximal end of the tibia has a deformity which causes it to lean outward) in patients with arthritis of the knee, while little variation was found in the shaft of the femora in those 32 cadaveric bones (Yoshioka et al. 1987, 873). No angles of the distal end of the femur (condylar or transcondylar valgus angle) were correlated to proximal angles of the femur (anteversion or neck-shaft angle); however, the authors note anteversion measurements were not taken in accordance with previously performed studies by others. The authors used the transverse functional axis rather than the posterior condylar line (Yoshioka et al. 1987). It is unclear how these differences could have affected the final results, but would call into question their comparability to data from other studies.

Other pathologies associated with NSA include hip developmental dysplasia, cerebral palsy, varum thigh, and congenital club foot (Souza et al. 2015). In developmental dysplasia of the hip, abnormal growth or development of the hip is congenital (Tavares 2012). In severe cases of developmental hip dysplasia, luxation, or dislocation, can occur. In this case, there is no contact between the head of the femur and the acetabulum. In cases of subluxation, however, there is contact between the head of the femur and the acetabulum. When subluxation is diagnosed in children, an Ilfeld abduction splint can be utilized to correct the position of the head of the femur within the acetabulum to treat both subluxation and hip dysplasia in general (Tavares 2012). Tavares (2012) argues differentiation between luxation and subluxation of the joint is imperative in order to give accurate treatment, especially in cases where early diagnoses can be made in children. Out of the five patients with subluxation, those that wore the brace around 22 hours per day, every day for at least six months, showed a normal orientation of the hip joint in consequent radiographs. Thus, early diagnosis of hip dysplasia with an accurate diagnosis of either luxation or subluxation leads to in treatment and correction of the morphology of the joint.

Other explanations for variations in NSA include level of mobility and physically demanding lifestyles (Bonneau et al. 2012; Gilligan et al. 2013). Anderson and Trinkaus (1998) found no patterns in respect to sexual dimorphism, laterality, and geographical patterns, when analyzing 30 modern, historic, and prehistoric populations. Although in

58.8% of the 17 samples utilized in the comparative study female mean angles are higher, in only six of the 17 samples is the difference statistically significant, leading the authors to conclude sex differences are inconsistent at best (Anderson and Trinkaus 1998, 282-283). Economic categories (foragers, agriculturalists, and urban), however, did present a significant difference. The strongest correlation they identified was an increase in mean NSA with an increase in sedentism, which is connected to economy and activity levels. Hunting and gathering groups were found to have the lowest angles (with means ranging from 123.2-127.6), with urban groups having the highest NSA measurements (128.4+/-.09-136.2+/-3.6) (Anderson and Trinkaus 1998, 284). Agricultural groups varied the most (121.9+/-4.6-133.7+/-5.6), appearing to have distributions overlapping hunting and gathering and urban groups, but a clear general pattern of increasing NSA with decreased mobility and mechanization (Anderson and Trinkaus 1998, 284) is seen.

Bicondylar Angle

One of the defining features of bipedalism is adduction of the knee, which is associated with bicondylar angle, or the "obliquity" of the femoral shaft (Heiple and Lovejoy; 1971, 75; Tardieau and Trinkaus 1994). This angle measures the angle of the femoral shaft in association with the condyles when they are positioned flat on a plane, such as a table or an imagined orientation of a straight line. The first line is where both condyles rest on the flat plane. The second line bisects the femoral shaft. The angle is then taken from the lateral side of the femur (Figure 4). This angle helps maintain a horizontal striding gait and vertical balance in humans because it maintains a smaller center of gravity while still allowing for a large interacetabular distance in the pelvis (Tardieu and Trinkaus 1994; Sharma et al. 2014).

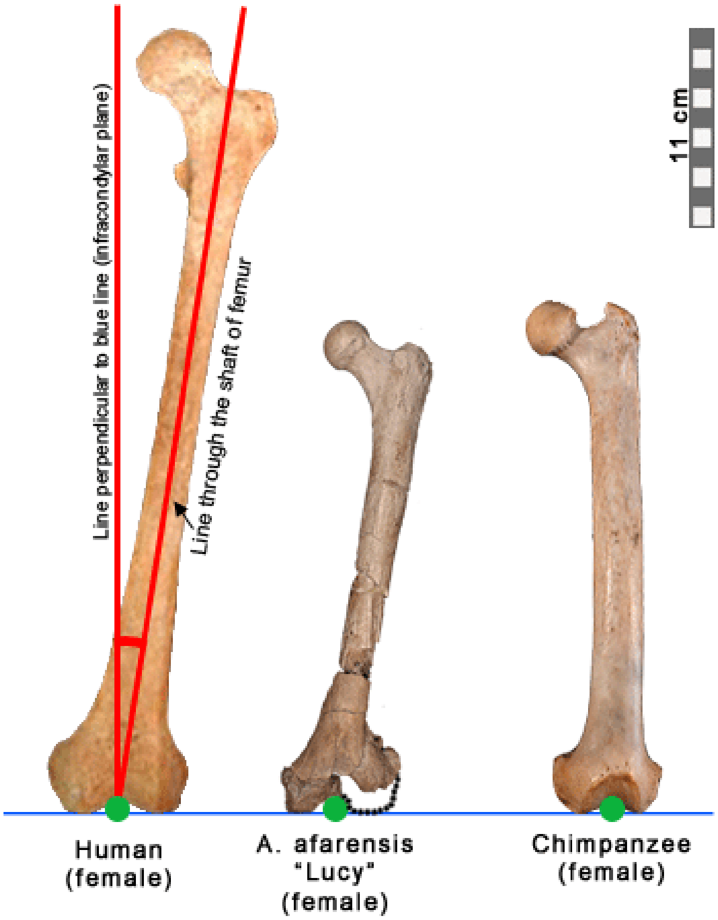

Figure 4. Bicondylar angle of humans, *Australopithecus afarensis*, and chimpanzees (Texas at Austin efossils Productions Lab).

Variation in the angle has been studied among modern humans, chimps, and hominines because of its connection to the evolution of bipedalism. Modern humans were found to have a mean bicondylar angle of 10.9 degrees, forest dwelling chimps -0.3, 4.2 degrees in Semliki chimps, and australopiths 12.0 degrees (Hunt et al. 2011). The first documentation of the bicondylar angle of the *Aust. africanus* femur, found at the Sterkfontein site in South Africa, was by LeGros Clark in 1947 (Heiple and Lovejoy 1971). Clark noted the femur of TM-1513 was at least 7 degrees, compared to the normal 4 to 17 degrees found in English males. Heiple and Lovejoy (1971) note that consequently, other authors have taken his statement to mean the bicondylar angle in the *Aust. africanus* specimen is exactly 7 degrees, and have used this measurement in comparison to other specimens without verification. Heiple and Lovejoy (1971) therefore conducted a study utilizing two femoral specimens, STS-34 and TM-1513, in order to reevaluate the assumed bicondylar angle of the *Aust. africanus* species. Their study concluded STS-34 has a bicondylar angle of 15 degrees and TM-1513 has a bicondylar angle of 14 degrees with no more than one to two degrees lower than those measurements in case of error.

Similar to FNV and NSA, the bicondylar angle changes as milestones in bipedal locomotion occur (Sharma et al. 2014). The BA of newborn infants is 0 degrees and is between 8 and 14 degrees by adulthood. Likewise, an appropriate angle is not reached if children do not walk, remaining abnormally low throughout their lives. Variations are seen between sexes. Women tend to have higher BAs due to the morphology of the pelvis, resulting in a wider interacetabular gap. In the study conducted by Sharma et al. (2014), researchers compared what they call the "genders" in the Pradesh region of India, although I am sure they mean "sexes." A total of 130 adult femora (68 males, 62 females) of individuals who did not have any pathologies or fractures, and were from the Pradesh region were included in the study. Males had right femoral average of 6.371+/- 1.821 (n=35) and a left femoral average of 7.348+/- 2.366 (n=33). Females had a right femoral average of 8.206+/- 2.119 (n=31) and a left femoral average of 8.729+/- 2.302 (n=31). Side differences in the sexes were not statistically significant, but it is interesting to note both Sharma et al. (2014), who focused on the people of Gwalior in the Pradesh region, and Pearson and Bell (1919), who focused on an English population, found the same pattern of the BA in left femora in both sexes to be larger.

In conclusion, angles of the femur, including the FNV, NSA to BA, have been the focus of a number of studies in the biological sciences. They each have implications stemming from evolutionary changes and morphological adaptions resulting from bipedal locomotion (Heiple and Lovejoy 1971; Trinkaus 1976; Tardieau and Trinkaus 1994; Anderson and Trinkaus 1998; Tayton 2007; Tavares 2012; Sharma et al. 2014; Souza et al. 2015). Each has also been studied, to a certain degree, in association with sex and laterality with varying patterns emerging (Pearson and Bell 1919; Anderson and Trinkaus 1998; Gulan et al. 2000; Khamanarong et al. 2014; Sharma et al. 2014). Lifestyles and cultural differences have also been implicated in the differences between populations, especially with FNV and NSA (Korukonda et al. 2010; Bonneau et al. 2012; Gilligan et al. 2013; Khamanarong et al. 2014).

Activity Markers in the Proximal Femur

Many scholars, from ethnographers to osteologists, have observed squatting postures in a multitude of peoples including Neandertals, a number of precontact populations from the Americas, and blacks and whites from the midwestern United States in the Terry Collection at the Smithsonian Institution (Corruccini 1974; Nelson 2011; Ubelaker 1973; Smith and Woollen 2021; Ubelaker 1979; Wilk 2014, respectively). Squatting is a convenient positioning for the body, but puts considerable force on the joints of the lower limbs. The hip and knees are in hyperflexion while the ankle joint is in hyperdorsiflexion, as shown in Figure 5 (Trinkaus 1976, 330; Ubelaker 1979). Squatting behavior such as crouching and kneeling will create more stress on the femoroacetabular joint and the femur itself, such as the posture observed in Figure 5 (Trinkaus 1976).

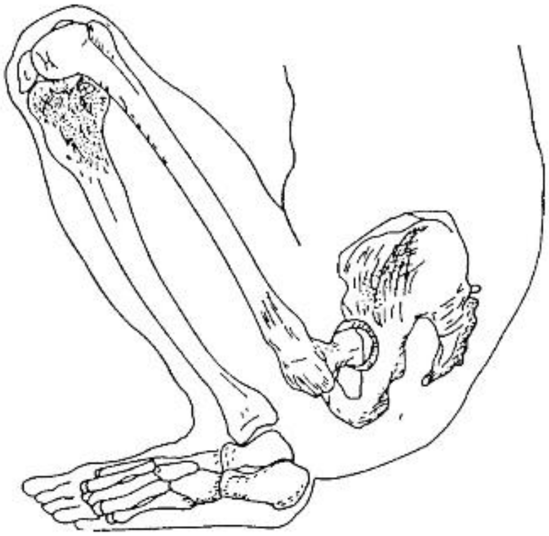

Figure 5. Squatting behavior putting pressure on the hip joint (Trinkaus 1975, 330).

Facets associated with this specific activity may appear on multiple areas of the same bone in addition to multiple bones of the leg (Ubelaker 1979; Nelson 2011). One example of the use of multiple bones of the lower leg in constructing past postural behaviors comes from a study by Nelson (2011). He utilized tibiae, tali, proximal pedal phalanges, and first through fifth metatarsals to find patterns of kneeling and squatting behaviors at the Archaic Period hunter-gatherer Gauthier site in Florida. The Gauthier population showed a significantly higher frequency of squatting/kneeling facets (37.5%) in comparison to the historic Ecuadorian sample of the Ayalans (20%), prehistoric Inuit (2%), and prehistoric Native American groups such as the Mobridge (5%) and the Najemoy (1%); it was also higher than rates seen in the modern Terry collection (<1%) (Nelson 2011, 39). This shows evidence of extreme hyperdorsiflexion, which indicates a high level of squatting or kneeling activities (Nelson 2011). By comparing and contrasting frequencies of postural facets, activity patterns may be inferred and additional lifestyle patterns compared.

Facets on the Femur

Facets that form on the proximal end of the femur include Poirier's facet and Allen's facet/fossa, both located on the anterior femoral head (Finnegan 1978) (Figure 6). Allen's fossa is known by many names including the cervical fossa of Allen, Allen's facet, fossa of Allen, and plaque (Pitt et al. 1982), while some researchers such as Finnegan (1978) differentiate between plaque and Allen's fossa by texture. Erosion of cortical bone may reveal cancellous bone underneath if eroded badly enough and can cause pain in some individuals, and is the process which creates the fossa. Clinical usage of Allen's fossa to explain hip pain in middle and older adults can be diagnosed through radiographs. Figure 7 shows the reaction area from a radiograph taken of an adult female who had intermittent pain in her right hip, which was related to the presence of Allen's fossa. The patient did not reveal any abnormalities during a cursory examination, though the radiographs reveal the underlying issue (Pitt et al. 1982). Allen's fossa has been found to be indicative of squatting behavior, although it can also be associated with walking or running downhill, sitting cross-legged, and normal wear and tear during flexion and abduction of locomotion (Pitt et al. 1982; Weiss 2017).

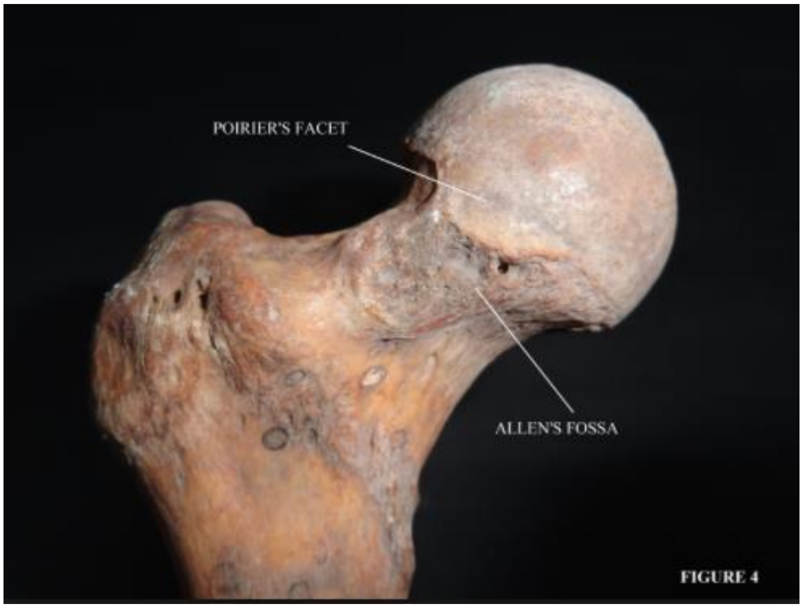

Figure 6. Allen’s fossa and Poirier’s facet (Ghosh et al. 2014, 6).

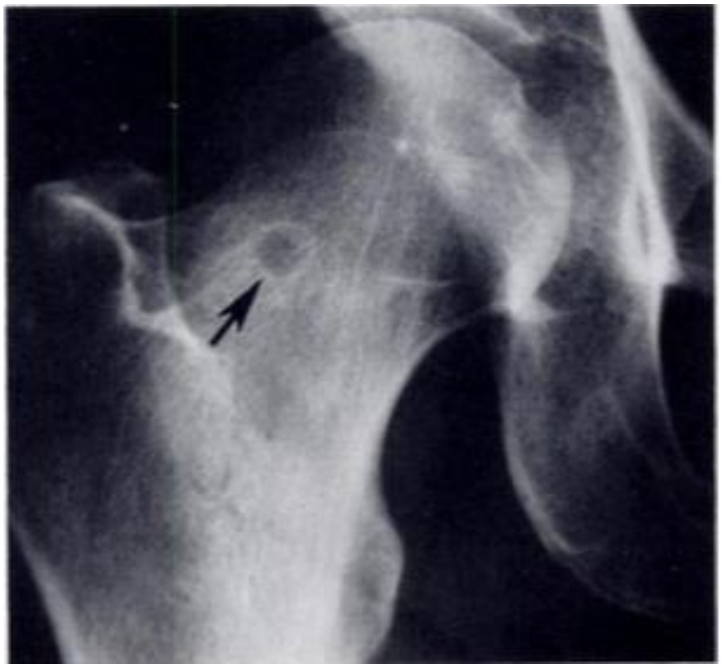

Figure 7. Allen’s fossa in a 46-year-old woman who presented with hip pain (Pitt et al. 1982, 1116).

Poirier’s facet is indicated by a slight bulging of the articular surface of the femoral head on the anterior posterior portion (Finnegan 1978, 24). It is indicative of squatting behavior (Weiss 2017). The facet has also been linked to horseback riding (Molleson and Blondiaux 1994). Molleson and Blondiaux (1994) found that two of the four femora from the Kish site, dated to circa 2375 B.C., in Iraq presented with Poirier’s facet, which they associated with the iconography of horseback riders found on artifacts from the same site. Additionally, Molleson and Blondiaux (1994) identified many musculoskeletal markers such as an enlarged linea aspera where multiple adductor muscles attach and trochanteric spicules which indicate strong laterally rotating muscles.

In conclusion, proximal femur angles and activity markers can help suggest past lifeway trends. FNV, Allen’s fossa, and Poirier’s facet are associated with behaviors such as squatting and kneeling. NSA is associated with mobility and settlement patterns. Bicondylar angle is associated mainly with bipedalism, but was explored in this thesis to see if it was perhaps affected by changes in FNV and NSA in relation to differences in lifeways such as subsistence and labor differences. Subsistence-settlement patterns in the region of interest are discussed in the following chapter.

CHAPTER III - SUBSISTENCE AND LABOR STRATEGIES

This chapter presents a description of the Schroeder Mounds of west central Illinois. While the culture and exact subsistence-settlement pattern of the Schroeder Mounds population will never be fully understood due to the lack of material culture associated, they can be contextualized within the Late Woodland period in addition to information produced from skeletal data. Therefore, this section describes what is known about the Late Woodland period generally and the Schroeder Mounds group specifically. In addition, the history of the Hamann-Todd collection will be discussed, including how the collection was established and background information on the individuals in the collection.

Setting the Scene: The Late Woodland Period and West-Central Illinois

West-central Illinois includes the Mississippi River and Illinois River valleys along with the Green River drainage (Green and Nolan 2000, 345). The region is characterized by upland areas with level ground (Green and Nolan 2000, 346). The region's flora consisted of prairie and floodplain forests. Fauna consisted of aquatic, terrestrial, and avian species supported by these habitats and the rivers, backwaters, and tributary streams there, with variable diversity dependent upon the exact habitat (Emerson et al. 2000).

Generally, the Late Woodland period in west-central Illinois (~ AD 600-900) was characterized by forager-farmers with seasonal sedentary settlement patterns (Emerson et al. 2000; Benn and Lee 2002). A model of frontier settlement has been applied to interpretations of Late Woodland peoples in this region (Green and Nolan 2000, 348-349). The term frontier is used in this model to describe areas that are not yet developed or not yet occupied (Lerner 1984, 67). In this model, settlement begins with "nucleated villages that serve as focal points for the pioneer group" (Green and Nolan 2000, 349). Next, the group spreads out further into new spaces in the area (Green and Nolan 2000). Economic changes would follow depending on new environmental pressures and social changes. Group identity would further separate from the original identity. The final stage would result in a "reduction in social stratification" (Green and Nolan 2000, 349).

Green (1987, 1993) outlined these four stages of settlement by time period. The longest was Stage III (ca. A.D. 600-950), the exact time period that Schroeder Mounds would have been utilized as a mortuary site (i.e., ~AD 660-960) (Illinois State Archaeological Society 2019). During this time period, the uplands had small households dispersed as homesteads (Emerson et al. 2000). At the same time, the main valleys had large populations with large meeting areas including mortuary complexes along the bluffs of the Mississippi River (Green 1993).

Sunflower, chenopods, and squash seem to be a complex adapted for the drier Plains environment (Simon 2000, 56). During the early Late Woodland period (ca. A.D. 600-900) at the Shaw site on the upper Rock River in north-central Illinois, Indigenous people relied heavily on wild plants and had slight supplementation of the diet with cultivated plants like little barley and chenopods, along with horticultural plants like pepo squash/gourds (Parker 1996). Domesticated sunflower and sumpweed was found along the Rock River as well (Simon 2000). Temporary garden plots were employed for relatively mobile populations at this time (Simon 2000).

Maize was found as early as the latter part of the 9th century in northern Illinois (Simon 2000, 59). A "two-pronged" entry into Illinois and Wisconsin has been proposed

(Simon 2000). Although there is little evidence to support this, it is intriguing. One "prong" of corn's entry is suggested to originate in the eastern Great Lakes, spread into southeastern Michigan and into northern Illinois. The second "prong" is suggested to come from the south up the Mississippi River.

Maize agriculture and maize production seems to have begun in the central Illinois River Valley ca. A.D. 1100 (VanDerwarker et al. 2013) with Mississippianization following (VanDerwarker et al. 2013, 147). Variables such as political organization and environment played a key role in the adoption and intensification of maize at this crucial junction, resulting in changes in the subsistence economy of the Central Illinois River Valley (CIRV) and the rest of the northern Illinois region (VanDerwarker 2013). Mississippian societies were characterized by hierarchical systems, craft specialization, and a seasonal subsistence including farming. During the summer, it is presumed that Mississippians populations tended their crops, but also foraged and fished (Yerkes 2005). Fields were prepared for planting crops, and were planted at the start of the growing season (Yerkes 2005). During the fall and winter, they would forage, store, and hunt for food (Yerkes 2005). Although these regional trends set the stage for reconstructing lifeways at the Schroeder Mounds in general, unfortunately very little is known about the site and its immediate area (Smith and Woolen 2020).

Kuhlman Mounds

Kuhlman Mounds, located in the Mississippi River Valley of west-central Illinois (Atwell and Conner 1991), exhibit many of the cultural developments of this time period. Population size in west-central Illinois increased steadily during the Late Woodland period, with some data suggesting populations tripled by the terminal Late Woodland

(Garner 1991). Data from the Kuhlman Mounds group supports the overall reported trend of a focus on cultivated seed plants and squash (Garner 1991; Simon 2000). In addition, the area seems to have been abundant in aquatic food resources with a clear focus in the diet on aquatic resources (Garner 1991).

Based on the sparse grave goods at Kuhlman, Atwell (1991) and Garner (1991) concluded a lack of extensive trade that was present in the Middle Woodland period in the region. Burial treatments and grave goods suggest an emphasis on group membership rather than a focus on achieved or ascribed status (Atwell 1991). They were variable, including in situ processing, no processing, and processing in the limestone charnel houses located on the mounds (Atwell 1991). A generally low frequency of grave goods (Atwell 1991) was seen. No clear patterns of treatment or burial goods by sex were found, suggesting there was no clear differentiation between men and women; however, infants under 1.5 years of age were more likely to have grave goods (Atwell 1991). Thus, the mortuary practices seen at Kuhlman follow the general patterns noted in Late Woodland literature.

Effigy Mound Culture

The Effigy Mound culture also of west central Illinois may have been greatly influenced by the people in Iowa and Wisconsin (Kolb 1982). The Effigy Mound culture focused on hunting and gathering wild resources (Boeke 1993; Theler and Boszhardt 2000). The inhabitants were reliant on a small number of high-yield cultigens such as squash and chenopods which were harvested seasonally (Theler and Boszhardt 2000) with no evidence of any use of maize. Large mammals were a large portion of the diet during the fall and winter, often reaching 90% or more of a faunal assemblage (Theler and Boszhardt 2000). In the summer there was a focus on freshwater mussel shells and other aquatic resources (Stoltman 1990). Also in the spring and summer it seems smaller family units came back together to form macro-bands who constructed burial mounds and buried their dead together (Theler and Boszhardt 2000). This is indicated by the high amount (70%) of conical mound secondary burials (Theler and Boszhardt 2019).

The Schroeder Mounds

The Schroeder Mounds mortuary complex (Figure 8) in Henderson County, Illinois, was discovered in 1975 by the owner of the property, Charles Schroeder, when he was bulldozing the property to build a new house (Kolb 1982). A master’s thesis by Michael Kolb (1982) one of the only available sources of data for excavations and possible cultural associations at the site based on his presence during the excavations and is therefore heavily relied upon in this section., Stanley Riggle of Western Illinois University subsequently conducted excavations during the field seasons of 1975 and 1976 (Kolb 1982). The project was limited to the planned area of the house construction (Kolb 1982), and it is therefore believed many more burials were not recovered.

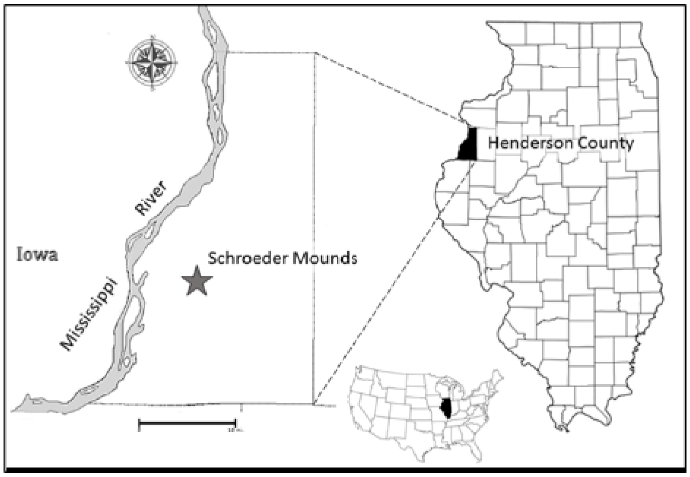

Figure 8. Location of Schroeder Mounds (from Smith and Woollen 2017, Figure 1).

About 123 burials, 70 adults and 53 subadults, were recovered, and exhibited generally very good bone (Kolb 1982). The burials were irregularly located across the site and were positioned towards sunrise and sunset during the summer and winter solstices with positions varying (Kolb 1982, 34) (Figure 9). Some interesting trends in burial treatment included potential cremation in one area of the site, with violent deaths buried more in association with each other Few burial goods were evidently found (Kolb 1982), as was also seen at Kuhlman Mounds, and those that were recovered are evidently no longer accessible for study and appear to have been somehow lost over the last forty years. Interestingly, children received more burial goods in one mound than others. This seems to indicate a point in the use of the Schroeder Mounds mortuary complex possibly reflecting social ranking within children, since they would not have differential burial treatment across the site in an egalitarian society (Kolb 1982, 53).

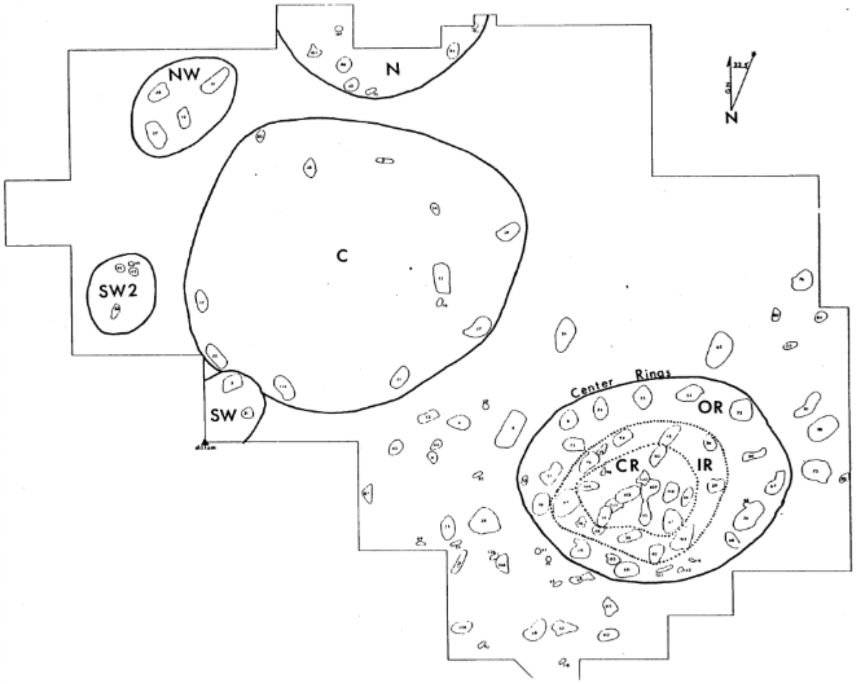

Figure 9. Burial map of Schroeder Mounds (Kolb 1982, Figure 10).

Kolb (1982) did note that the ceramics at Schroeder Mounds appears to be associated with Maple Mills culture, which was a large Late Woodland group in the CIRV (Hedman and Emerson 2008, 58). They were positioned along the Illinois River to exploit riverine and other backwater resources, along with botanical resources including maize, chenopods, knotweed, and wild fruits and nuts. To the north of the Maple Mills populations were the Des Plaines Complex societies who had limited maize horticulture and scattered campsites that were small in nature (Hedman and Emerson 2008, 58). There was no indication of intensive maize agriculture, however. As previously discussed, the Effigy Mound culture could have also been a large influence. Comparison of the meager archaeological findings at Schroeder Mounds with those seen at other contemporaneous sites in the region can provide even further context.

Previous Skeletal Research at the Schroeder Mounds

Although subsistence and labor strategies practiced at Schroeder Mounds are not known for certain, information can be extrapolated from skeletal data from the recovered skeletal population. Activity markers like osteoarthritis location, frequency, and degree, and have been the focus of analysis in a few studies. Keeling (2019) observed that all but one of the individuals surveyed in the population had controvertebral and/or costotransverse osteoarthritis of the ribs with no sex differences observed. He suggested that this indicated either respiratory stress or the possible use of a tump line for load bearing activities. Age-related development of osteoarthritis did not fully explain the frequencies noted, supporting the activity-driven argument (Keeling 2019). (Keeling 2019). Reactive change to the teres major insertion site on the humerus suggested frequent instances where the arms were elevated (Neidich and Smith 2016).

In another investigation of the Schroeder inhabitants, foot and ankle trauma in adults was consistent with misstep injuries, vertical jumps or falls, and stress from overuse (Woollen and Smith 2017, 32), affecting 13.5% (6/37). Foot trauma affected males and females to no discernibly different degree (Woollen and Smith 2017, 32), although the sample size was very small. In addition, the foot and ankle joints indicated that behaviors like squatting, kneeling, and heel sitting were frequent postures exhibited by the people of Schroeder Mounds (Smith and Woollen 2020). Of the adults surveyed in the study, 73.2% presented with tibial or talar squatting facets (Smith and Woollen 2020, 61). The differences in frequencies between the sexes or prevalence by side were not significant (Smith and Woollen 2020, 61). These facets suggest habitual squatting or kneeling, likely related to postural positions like heel sitting and kneeling as a work or rest position as documented in many past and present populations (Dewar and Pfeiffer 2004, 52; Nelson 2011; Javia et al. 2014; Garg et al. 2015; Weiss 2017, 115-130; Smith and Woollen 2020, 58), as it allows for minimal muscle activity and energy (Jin et al. 2009; Lynn and Noffal 2012). These studies suggest a highly active population with little sexual division of labor who regularly squatted, perhaps as a work or rest posture. These findings are expected within the larger context of the Late Woodland period.

In addition, data on health have contributed a small understanding of the subsistence of Schroeder Mounds. Lack of tuberculosis suggests a pre-Mississippian society along (Mosher et al. 2013). High frequencies of caries were reported by Durchholz (2017), which can be explained as high starch EAC crops like squash. Isotope analysis performed in 2019 yielded no indications of maize in the diet (Illinois State Archaeological Survey 2019). As Schroeder Mounds dates to a time when maize was in the region, but seemingly not a staple crop yet (VanDerwarker et al. 2013; Smith, personal communication 2019), this suggests Schroeder was not yet Mississippianized. Additionally, Mosher et al. (2016) suggest a high level of sedentism based on high levels (13.2%-15.1%) of treponemal disease found in the sample.

The Hamann-Todd Collection

The Hamann-Todd sample, housed at the Cleveland Museum of Natural History in Cleveland, Ohio, was assembled between 1912 and 1938 by medical researchers Carl A. Hamann and T. Wingate Todd (Cleveland Museum of Natural History). It is one of the world's largest documented collections of modern human skeletal remains, making it an ideal for gaining insight into morphological differences due to the immense amount of documentation that accompany each individual. The collection is comprised of 1038 black adult males, 375 black adult females, 1931 white adult males, and 321 adult white females (Cleveland Museum of Natural History). The sample favors males over females, with an overall ratio of 6.6:1, a ratio of 3.2:1 black males to black females, and a ratio of 10.4:1 white males to white females (Mensforth and Latimer 1989). Demographic analysis revealed an average age-at-death for blacks at 41.9 years of age, and whites at 53.8 years of age (Mensforth and Latimer 1989).

The collection includes individuals from both rural and urban populations dating to around the American Civil War (1861-1865), in addition to individuals dating to the early 1900s associated with the Great Migration (1910-1970) (Fraser and Williams 2013; Nystrom 2016). Only 13% of the individuals in the collection have birth locations in the District of Columbia, with many other states such as Virginia, Maryland, South Carolina, North Carolina, Georgia, and Florida among the additional states listed (Nystrom 2016, 197). Occupations consist of mostly unskilled labor for both blacks and whites in the collection (de la Cova 2010). In a study utilizing analysis of the distal radius, proximal femur, vertebrae, and sacral fractures, present evidence that the individuals under investigation fit patterns associated with urban industrial communities (Mensforth and Latimer 1989).

Few previous studies have explored femur morphology in the Hamann-Todd collection. However, Maruyama et al. (2001) studied 50 adult males and 50 adult females of a variety of ancestries (African American, white, Asian) to establish future awareness of sex differences in hip replacement implant designs. Maruyama et al. (2001) found that the FNV of the femur ranged between negative 15 degrees to positive 34 degrees, with an average of 9.8 +/- 8.5, with no significant difference between males and females. The NSA was also explored, resulting in an average of 125 +/- 4.8 by direct bone measurement, although the authors do not go into detail explaining their methods of direct data collection versus their radiograph methodology (Maruyama et al. 2001). In another study seeking to better define markers like Allen's fossa and Poirier's facet, Medlej et al. (2021) characterized "femoral head-neck defects" as being very prevalent in the adult population (69.3%) (801).

In conclusion, Hamann-Todd and Schroeder Mounds are at the heart of this study. Hamann-Todd is a historic collection assembled from unclaimed cadaveric individuals from the early- to mid-20th century. The Late Woodland period group Schroeder Mounds of which little is known archaeologically but bioarchaeological analysis has given some insight in which the activities the people of Schroeder Mounds were participating. My study seeks to create a model by which to further offer evidence of activity levels by comparing the historic Hamann-Todd collection sample to the Schroeder Mounds sample, as described in the next chapter.

CHAPTER IV – MATERIALS AND METHODS

This chapter describes the samples that were selected for use from the Schroeder Mounds and Hamann-Todd collections and outlines methods used in data collection for various aspects of proximal femur morphology.

Sample Selection

For both collections, individuals were selected based on age, preservation, and census data for Hamann-Todd. All were adults with fully fused femoral epiphyses, and general preservation ranged from good to great. The outer cortical bone sheath on the center of the head, shaft, and the patellar surface needed to be intact, as this was where points were taken on the femur. If these areas were not fully intact, either the femur was disqualified from use in the study, or only information that could be gathered was collected (e.g., if the patellar surface was not intact only the FNV and NSA values were collected, and not the bicondylar angle). Paired femora with all utilized areas of the bone intact were favored. However, when needed, only one femur was included in the study of a pair, such as the case of a broken femoral neck or shaft, regardless of the level of healing as this would skew the collection of "normal" femoral data. No estimations were ever done. Census data including job title or type of job was needed in order to classify people of Hamann-Todd into the labor groups utilized in this study.

Schroeder Mounds

I utilized an adult sample from the Schroeder Mounds burial complex (N=27). Twenty-two left femora and 25 right femora were deemed to fit the preservation criteria, as mentioned previously. There were 20 pairs of femora and 7 isolated femora. Age and sex estimation for the Schroeder population were undertaken previously and stored in a computer data base. Sex of the individuals meeting the preservation criteria included 15 females, one possible female, 10 males, and one possible male. For the sake of data comparisons in this study, “possible female” was included in the female group, and the “possible male” was included in the male group. Young adults (age 18-34) were 44.44% (9 females, 3 males) of the sample, middle adults (age 35-50) were 37.03% (4 females, 6 males), and old adults (over age 50) were 18.52% (3 females, 2 males).

Hamann-Todd Collection

Some 74 individuals with intact femora were used from the Hamann-Todd Collection. All were of European (i.e., white) ancestry. Ancestry came from the census data. Sex and age determinations were taken from the death certificate, as curated by the Cleveland Museum of Natural History. The young adult age category (age 18-34) accounted for 17.57% (2 females, 11 males) of the sample, middle adults (age 35-50) 36.49% (1 female, 26 males), and old adults (over age 50) 45.96% (3 females, 31 males).

Jobs associated with the individuals in the sample during life were acquired from the 1910, 1920, and 1930 censuses. Positions were broken down into “heavy” and “light” labor groups based on the stereotypical definition and responsibilities associated with job titles. Those in the “heavy” labor group included those that would require a fair amount of manual labor such as laborer, iron works laborer, farm laborer, coal miner, and carpenter. Examples of “light” labor jobs included clerks, cooks, salesmen, and drivers/teamsters. Thirty-four individuals (45.96%) were assigned to the heavy labor group. All were males. Thirty individuals (54.05%) were assigned to the light labor group. Six of the light labor group was female and the remaining 28 were male.

Angle Measurement Determination

In general, the methods employed were easily accessible and non-invasive. So called "table-top" methods were utilized for data collection on the angle measurements as they are comparative in the literature and easy to execute on dry bone. Both femora, if possible, were measured for all angles.

Neck Shaft Angle (NSA)

For the first step in measuring the NSA (Figure 3), the midpoints on the head and neck (anterior and superior surfaces) were found using digital calipers. One midline created by the midpoint through the head and anterior neck while the other was the midline of the shaft (Marmor et al. 2012). The other midline created ran through the intertrochanteric line and the femoral head on the anterior surface of the femur (Marmor et al. 2012). In order for these measurements to be taken, the femoral head had to minimally have cortex in the areas where points were taken (Figure 10). The femoral neck needed to be complete enough to take averages of thickness in order to find the intertrochanteric line. The midpoint of the neck was determined by the most central part of the neck. Calipers were used to find the midpoint of this area and was marked with a small piece of sticky tack. The calipers were adjusted to the midpoint length and used to produce the most accurate marking on the sticky tack. The shaft and patellar surface had enough completeness to find the median point based on thickness. These data points were then taken together with the intertrochanteric line of the neck with the angle measured using a goniometer. Midpoints were measured twice or more if necessary to reduce observer error.

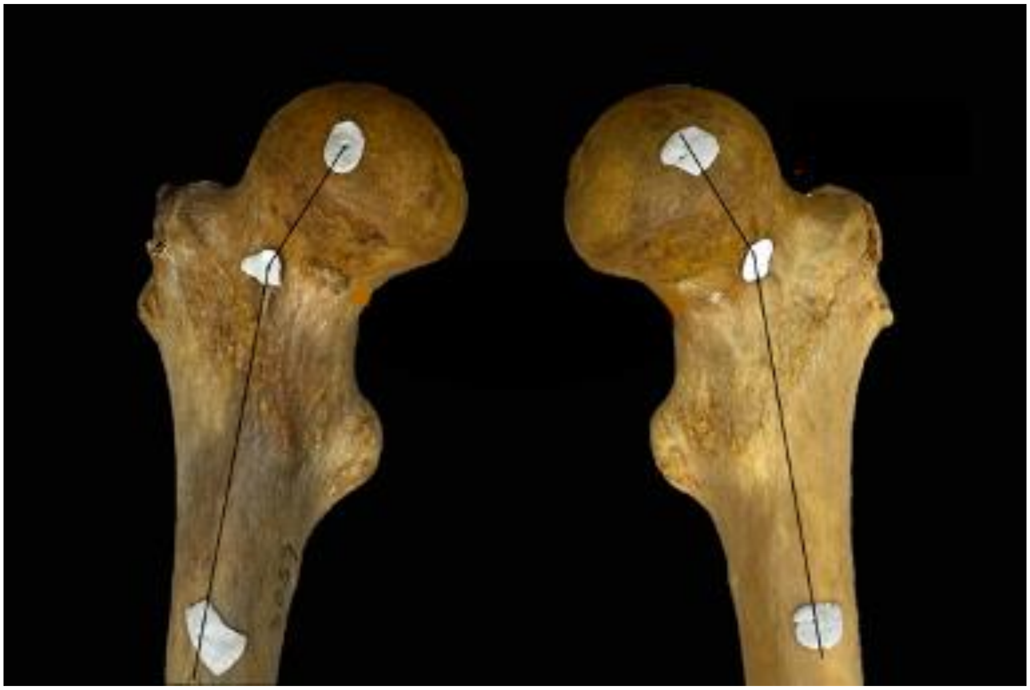

Figure 10. Determination of points used to measure NSA on a Hamann-Todd individual.

Femoral Neck Version (FNV)

To determine the FNV, the femur needed to be able to lay flat on the table in order to utilize the “table-top” method (Kingsley and Olmsted 1951; Zalawadia et al. 2010). Both condyles and the lesser trochanter had to be intact in the area in contact with the tabletop. The central point of the head was determined by the highest point on the center of the head (furthest point from the table). The center of the neck was taken on the superior aspect in the same way as NSA. The goniometer was then lined up, one side with the line created by the midpoint of the neck and the head, the other lined up with the edge of the table. The angle created by these lines was then recorded as the FNV (Figure 11).

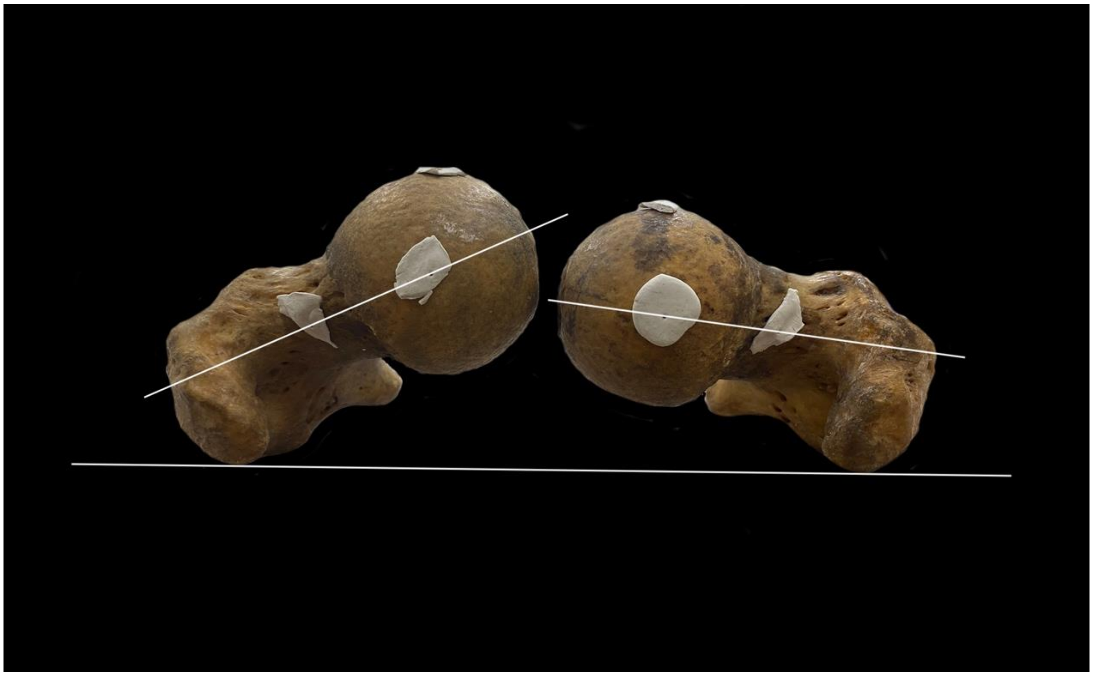

Figure 11. Determination of points used to measure FNV on a Hamann-Todd individual.

Bicondylar Angle (BA)

For the BA measurement, a line was created utilizing a piece of paper attached to the table's surface at a 90 degree angle. A thick piece of cardboard was used in order to make sure the edges of the distal edge of the lateral and medial condyles were situated evenly with the edge of the table. The lowest point of the patellar surface was marked and lined up with 0 degrees on the right angle created by the piece of paper and the edge of the table. One line of the goniometer was lined up with the edge (0 degrees) of the right angle and the other line of the goniometer used to align with the midline of the femoral shaft through the point marked on the patellar surface (Figure 12).

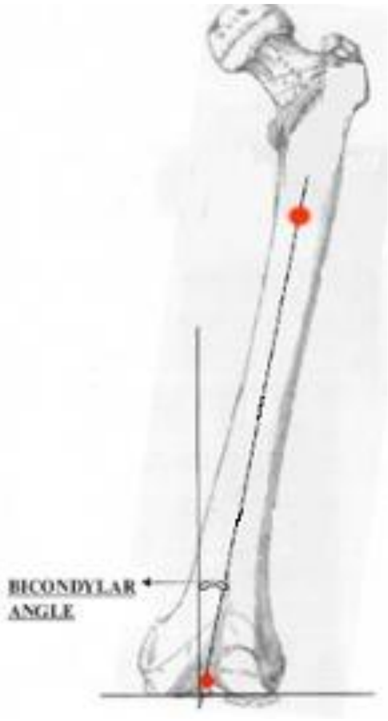

Figure 12. Points of measurement to measure BA (adapted from Shah n.d.).

Activity Marker Scoring

The activity markers observed were Allen's fossa and Poirier's facet. Following Finnegan (1978), each was documented as absent (0) (Figure 13) or present (1) (Figure 14) on both the right and left femoral heads/necks. Notes were kept based on observations of the comparisons between sides, such as the right Allen's fossa being larger or more pitted than the left, the position was noted in a drawing, and any other observations about the femur were noted. Digital photos were taken of each femur in order to confirm documented activity markers. Scoring was made difficult based on presence of plaque, which can appear as Poirier's facet. Photos were referenced later if any questions arose about the likelihood of the presence of Poirier's facet rather than the presence of plaque.

Figure 13. Allen’s fossa and Poirier’s facet scored as absent (0) on a Hamann-Todd individual.

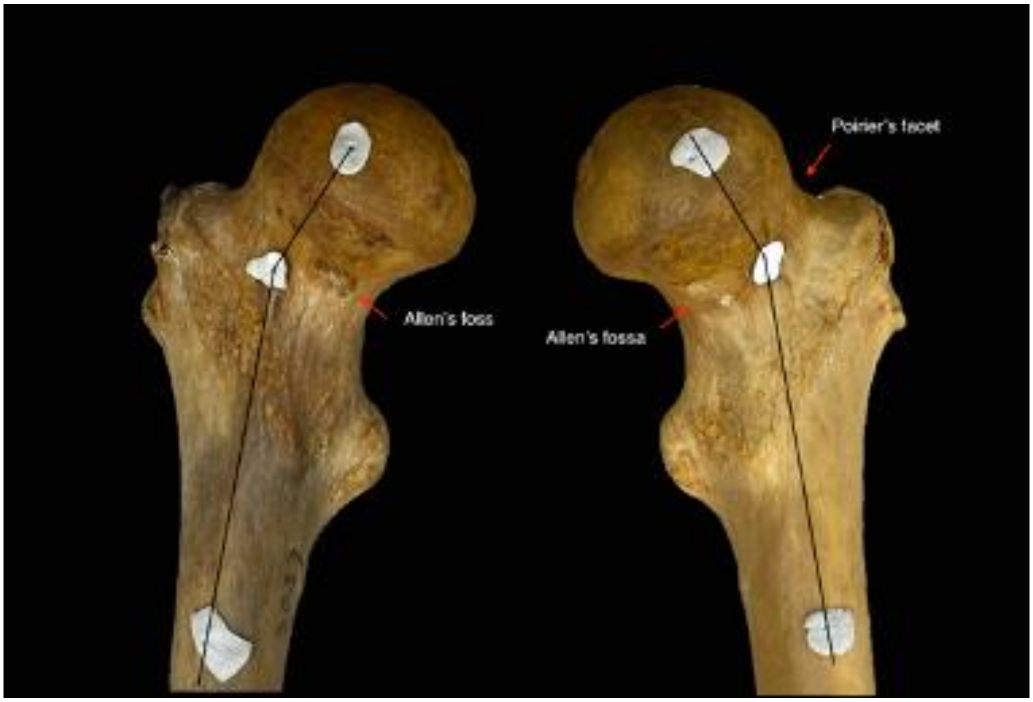

Figure 14. Allen’s fossa and Poirier’s facet scored as present (1) on a Hamann-Todd individual.

Data Analysis

All angle measurements and activity markers were entered into a Microsoft Excel spreadsheet (Microsoft Corporation 2018) sheet along with the burial numbers, activity group (heavy and light labor), sex, age, and age group. Pearson correlations, mean values, and standard deviations were calculated for various variables and relationships utilizing Microsoft Excel. Results such as the p-value are reported, in addition to correlational values derived from computations when needed. As this study is exploratory, p-values were considered significant at $p<.10$. The findings are given in the following chapter.

CHAPTER V – RESULTS AND INITIAL DISCUSSION

This chapter presents the results of the analysis of the proximal femur morphology in the Schroeder Mounds and Hamann-Todd collections. The angle measurements for the two samples considered in this study were analyzed by side, sex, and age, and then by occupation and subsistence-settlement pattern. Each section first presents data for Hamann-Todd, which was utilized as a model group in order to investigate the relationship between activity levels of individuals and proximal femur morphology. Findings are then compared with those for Schroeder Mounds, and finally a discussion of patterns and comparisons is presented. Since few females with job titles were present in the census data, males are the focus in the Hamann-Todd collection. The data for females is presented, but should not be viewed as complete data due to the small sample size of six. Again, a p-value of <.10 was considered significant in this study.

Proximal Femur Angle Results

Angle Means by Sample

As may be seen in Table 3, there was extensive variation in the proximal femur angle values between the two samples under study; however, none of the population-level differences were significant. The possible explanations for differences are discussed in later sections in this chapter, but as will be seen, the values here are very much within the ranges reported in the literature.

Table 3 *Proximal Femur Angle Means in Degrees by Sample.*

Sample	FNV	BA	NSA
Hamann-Todd	11.51+/17.05	9.36+/-2.27	131.23+/-7.05
Schroeder	16.26+/-5.31	10.08+/-2.34	137.17+/-6.23

A lower FNV mean was expected for Schroeder Mounds, as I assumed physical behaviors such as sitting on the ground versus on a chair would increase lateral rotation of the femur; this would pull the shaft outward while the head of the femur and therefore the neck would be more limited by its position in the acetabulum. This would result in the head and neck being rotated more anteriorly and result in a smaller FNV value. In contrast, Hamann-Todd had a higher FNV mean compared to data reported by many authors, including Kingsley and Olmsted (1948), who found a mean of 8.02 degrees, and Kate et al. (1976). However, it was similar to an Indian population, which showed a population mean of 12.4 degrees (Zalawadia et al. 2005). Schroeder Mounds had a similar population-level mean for FNV compared to the Indian samples studied by Khamanarong et al. (2014), who found a mean of 16.21+/-5.24 degrees and Korukonda et al. (2017), who reported a population mean of 17.8+/-7.7 degrees.

In contrast, bicondylar angles were expected to be similar between the two sample populations. For both groups, bicondylar angle was within normal range reported by Shefelbine et al. (2002), which states for modern humans the bicondylar angle is 8-11 degrees. Mean BA values reported by Kharbuja et al. (2018) were 8.65+/-2.03 degrees and 9.35+/-2.05 degrees in a population from Kathmandu. The result of 9.35+/-2.05 is almost exactly that of the Hamann-Todd population. While Schroeder Mounds seems to have a slightly higher BA comparatively, it is still within normal range present in the literature.

NSA was expected to be higher in the Hamann-Todd sample as they were assumed to be more sedentary than the Schroeder Mounds people and the NSA has been associated with sedentism in populations with a higher NSA. However, results showed that the NSA was much higher in the Schroeder Mounds group compared to Hamann-Todd, but was similar to an NSA reported by Gilligan et al. (2013), who found in a group from the Andaman Island a mean of 136.1+/-4.4. Hamann-Todd was closer to most means reported by Gilligan et al. (2013), but was still higher than the European and North American samples studied (Italy 127.7+/-4.3; Canada 124.2+/-4.3; USA 125.6+/-5.3).

Proximal Femur Angles by Side

Left and right proximal femur angle results are presented in Table 4. As may be seen, each sample follows a different pattern by side. In the Hamann-Todd sample, the right side has a higher mean in all three proximal femur angles. The Schroeder sample followed this pattern only for FNV. BA and NSA were the opposite: the left side has a higher mean. FNV differences were highly statistically significantly different between Hamann-Todd and Schroeder (p=.0197 on left, p=.0005 on right), as seen in Table 5, as well as NSA values (p=0.0005 on the left, p=0.0786 on the right), as seen in Table 6. Bolded in each table are statistically significant p-values.

Table 4 *FNV Angle Means and Standard Deviations in Degrees by Side.*

Sample	**FNV (L)**	**FNV (R)**	**BA (L)**	**BA (R)**	**NSA (L)**	**NSA (R)**
Hamann-Todd	10.87 +/-7.58	12.17 +/-6.45	8.47 +/-1.96	10.25 +/-2.23	129.46 +/-6.80	133.01 +/-7.00
Schroeder	14.95 +/-4.85	17.40 +/-5.53	10.30 +/-2.46	9.88 +/-2.26	138.61 +/-6.72	135.79 +/-5.52

Table 5 *Student's T-Test of FNV Angle Means in Degrees by Side.*

	Left FNV		**Right FNV**	
	Hamann-Todd	**Schroeder**	**Hamann-Todd**	**Schroeder**
Mean	10.87	14.95	12.17	17.4
SD	7.58	4.85	6.45	5.53
SEM	0.9	1.03	0.78	1.11
N	22	71	25	69
P-value	**0.0005**		**0.0197**	

Table 6 *Student's T-Test of NSA Means in Degrees by Side.*

	Left NSA		**Right NSA**	
	Hamann-Todd	**Schroeder**	**Hamann-Todd**	**Schroeder**
Mean	129.46	138.61	133.01	135.79
SD	6.8	6.72	6.9	5.52
SEM	0.82	1.4	0.84	1.13
N	23	69	24	68
P-value	**0.0001**		**0.0786**	

Each group was expected to show a side difference as the literature (e.g., Gilligan et al. 2013; Sharma et al. 2014; Khamanarong et al. 2017; Korukonda et al. 2017) routinely reports asymmetries for all angles explored in this study. However, patterns of side differences noted for FNV are inconsistent. Cibulka (2004, 550) states FNV is "typically symmetrical from the left side to the right side." Other studies have noted that a difference between sides was present, but little more (Kingsley and Olmsted 1948; Yoshioka et al. 1987; Zalawadia et al. 2005; Khamanarong et al.2017). Still other publications (Hoaglund et al. 2005, as cited in Jain et al. 2005; Jain et al. 2005) do not even address population means by side.

Unfortunately no clear explanations for side differences in the FNV have emerged. Animal studies showed "uneven forces" from lateral and medial rotation of the hind limbs produced changes in FNV (Cibulka 2004, 551). FNV decreased with lateral rotation and increased with medial rotation. Sitting and sleeping positions where habitual rotation, either medial or lateral, also could change FNV angles and possibly result in side differences with differential rotation of each leg. Again, however, it is not evident if there are any consistent effects on the patterns to be seen here. There are inconsistencies as to which side is higher in each of the angle measurements, discussed further below.

In a large study of NSA expression in 8271 femora from 101 sample groups from around the world, Gilligan et al. (2013) noted a small but statistically significant difference of 1.3 degrees between sides (Gilligan et al. 2013, 144). The left side was higher in 52 of the 62 groups within the larger sample. Observations of paired femora (n=4592) showed a median difference of 1 degree, with the left side presenting as higher in 55% of the pairs, the right side higher in 34%, and right and left equal in the remaining 11%. The Hamann-Todd sample agreed with this pattern, but Schroeder Mounds aligned with the smaller portion paired femora in Gilligan and colleagues' (2013) investigation. The results in both Gilligan et al. and my study at the very least support a large trend towards asymmetry. The left side appears to trend higher than the right, but it is not a strongly consistent pattern.

In two separate studies, BA was found to be higher on the left than the right side (Pearson and Bell 1919, as cited in Sharma et al. 2014; Sharma et al. 2014). Data for BA from the Schroeder Mounds sample matched this identified pattern, but Hamann-Todd did not. Unfortunately Pearson and Bell (1919) did not speculate the reason for this tendency in Indian individuals from the Madhya Pradesh region.

Side differences will continue to be discussed in the presentation of findings for femoral angles by sex, age, and activity level to see whether any additional patterns emerge.

Proximal Femur Angle Results by Sex

Table 7 and Table 8 show proximal femur angle results that are utilized in this section to discuss sex differences. The two tables present similar information, but differently organized, in order to make comparisons clearer. Table 5 compares males and females within their respective samples. Table 6 examines differences between samples for males and females. Females were expected to have higher for all angles, likely due to pelvis morphology differences (Gulan et al. 2000; Purcell 2013), but this was not consistently seen. Comparison of the two samples showed different patterns for FNV by sex. Females in the Hamann-Todd sample followed the expected pattern of a higher FNV value. However, unexpectedly the females of Schroeder had a lower FNV than the males.

Table 7 *Proximal Femur Angle Means in Degrees and Differences by Sample.*

	Hamann-Todd			**Schroeder Mounds**		
Angle (side)	**Male**	**Female**	**Difference**	**Male**	**Female**	**Difference**
FNV (L)	10.69	12.83	2.14	15.11	14.21	0.90
FNV (R)	12.11	12.83	0.72	18.00	16.63	1.37
BA (L)	8.42	9.00	0.58	9.44	11.00	1.56
BA (R)	10.25	10.17	0.08	8.90	10.69	1.79
NSA (L)	129.21	132.17	2.96	137.22	139.67	2.45
NSA (R)	132.85	134.67	1.82	135.22	136.25	1.03

Table 8 *Proximal Femur Angle Means in Degrees) and Differences by Sex.*

Angle (side)	**Males**			**Females**		
	H.-T.	**Schroeder**	**Difference**	**H.-T.**	**Schroeder**	**Difference**
FNV (L)	10.69	15.11	4.42	12.83	14.21	1.38
FNV (R)	12.11	18.00	5.89	12.83	16.63	3.80
BA (L)	8.42	9.44	1.02	9.00	11.00	2.00
BA (R)	10.25	8.90	1.35	10.17	10.69	0.52
NSA (L)	129.21	137.22	8.01	132.17	139.67	7.50
NSA (R)	132.85	135.22	2.37	134.67	136.25	1.58

Patterns of FNV between sexes consistently report that females had higher values (Kingsley and Olmsted 1948; Naga et al. 2000; Korukonda et al. 2014, 465; Zalawadia et al. 2014). Patterns at Schroeder Mounds were comparable to findings in Khamanarong et al. (2014) which showed females had a higher FNV angle. The same trend was seen in the Indian population analyzed by Korukonda et al. (2017) in which females had a mean FNV value 4.5 degrees larger as compared to males; the difference was statistically significant on the right side, but not on the left side (Korukonda et al. 2017, Table 3). This difference was much larger than any differences in the means of either sex from either of the sample groups, but no explanation for this unusual finding was offered. Males in the South Indian population had an overall mean of 16.8 degrees (left mean 20 degrees, right mean 13 degrees). Females had a much larger angle on the right side (19.4 degrees) and slightly higher on the left side (22.3 degrees).

Certain authors (Gulan et al. 2000; Purcell 2013) have noted a wider pelvic girdle in females may play a key factor in their generally larger FNV angles. Korukonda et al. (2017) do not speculate why there was a sex difference other than the fact that the female sample size in their study was smaller (22 females vs. 48 males), but it is unclear how this might have affected results in any way and is thus still considered a viable comparison.

Bicondylar angle by sexes in Table 8 shows Hamann-Todd means either equal or with females having a slightly larger value. Bicondylar angle had a lightly larger difference between males and females in the Schroeder Mounds sample with females again generally having greater values. This pattern was seen by Purcell (2013) who found females had statistically significantly larger BA measurements in a modern white American sample. One explanation offered for larger angles in females relates to their broader pelvic girdles, which result in a larger biacetabular breadth (Gulan et al. 2000). The female pelvis requires the head of the femur to sit in the acetabulum differently than males in order to maintain the center of gravity required for comfortable bipedal locomotion, resulting in a higher BA (Gulan et al. 2000; Purcell 2013). However, Waxenbaum and Stock (2016) found that the degree of difference between sexes in bicondylar angle was inconsistently statistically significant by sex in all populations observed (Terry collection whites and blacks, archaeological South Dakota Arikara, and Native Alaskans). They suggest levels of sexual dimorphism in the pelvic girdle are not universally statistically significant (Waxenbaum and Stock 2016).

For NSA values, overall Hamann-Todd and Schroeder Mounds females had a higher NSA mean compared to males (Table 7). In addition, NSA followed a similar pattern for sex differences within samples by side. There was a larger difference between sexes on the left side, with the right side having a difference over one degree less on the right. Comparing the same sexes from the two samples showed a very large difference between the left sides, but much less of a difference on the right for both males and females. In Gilligan et al. (2011), a combined total sample of 3348 femora showed no sex differences for the angle as males and females both had a mean of 125.5 degrees (Gilligan et al. 2011, 144). Of the 20 individual populations within the larger sample which met criteria set by Gilligan and colleagues (N>5 femora for males or females), nine showed females had a slightly higher NSA; however, 11 of the 20 showed males had a higher NSA. Three of the 20 groups showed differences of less than 0.5 degrees (Gilligan et al. 2011, 144). In a Chinese Han population, males had only a slightly larger mean (0.26 degrees), which was not significant (Gilligan et al. 2011). Overall, a broader pelvis in females is not supported as a reason for NSA differences, as they do not tend to have a larger NSA than males in most groups in the literature with no statistically significant differences (Gilligan et al. 2011; Jiang et al. 2015).

Proximal Femur Angle Results by Age

Table 9 shows the mean angles by age in each sample population. In the Hamann-Todd population, FNV rose slightly over time. In the Schroeder Mounds group, it rose slightly from young adulthood to middle adulthood, but went back down to nearly young adult means again in the older adult group. In the Hamann-Todd population, BA hardly changed between the age groups. In the Schroeder Mounds group, it also stayed relatively the same with a slight decrease from young adult to older adult. NSA showed the most change across age groups in both samples, but in different ways. NSA decreased by 1.3 degrees from young adult to older adult. A much more dramatic and opposite pattern was found in the Schroeder group. Between the young adult and older adult subsamples, NSA increased by 9.52 degrees. This is an anomaly which cannot be explained by the present available literature. Other trends in the data by age are explored in the following two tables.

Table 9 *Proximal Femur Angle Means in Degrees by Age Group.*

Age Group	Sample	FNV	BA	NSA
Young Adult	Hamann-Todd	10.16+/-6.11	9.08+/-2.38	132.28+/-8.37
	Schroeder	15.51+/-5.42	10.06+/-2.59	132.04+/-4.79
Middle Adult	Hamann-Todd	11.69+/-6.45	9.47+/-2.03	130.96+/-6.07
	Schroeder	16.47+/-6.60	9.94+/-3.05	135.50+/-7.84
Old Adult	Hamann-Todd	11.74+/-7.88	9.39+/-2.47	130.98+/-7.39
	Schroeder	15.33+/-3.43	9.22+/-1.39	141.56+/-4.44

Tables 10 and Table 11 show proximal angle values in the Hamann-Todd and Schroeder Mounds by age.

Table 10 *Male Femoral Angle Means in Degrees by Side by Age Group.*

Age Group	Sample	FNV (L)	FNV (R)	BA (L)	BA (R)	NSA (L)	NSA (R)
All Ages	**Hamann-Todd**	10.52 +/-7.58	12.11 +/-6.38	8.41 +/-2.00	10.26 +/-2.21	129.15 +/-6.39	132.89 +/-6.80
	Schroeder	15.11 +/-4.59	18.00 +/-7.6	9.44 +/-2.96	8.90 +/-2.28	137.22 +/-8.45	135.22 +/-7.43
Young Adult	**Hamann-Todd**	9.20 +/-7.51	12.00 +/-4.46	8.50 +/-2.80	9.18 +/-2.18	130.90 +/-8.79	132.73 +/-6.29
	Schroeder	16.00 +/-2.83	21.00 +/-4.58	9.00 +/-1.41	9.00 +/-1.73	135.50 +/-4.95	132.00 +/-3.46
Middle Adult	**Hamann-Todd**	11.76 +/-7.37	11.92 +/-5.75	8.30 +/-1.33	10.46 +/-2.06	129.54 +/-5.85	132.78 +/-6.10
	Schroeder	16.00 +/-5.43	17.60 +/-9.40	10.00 +/-4.00	8.20 +/-2.86	134.60 +/-9.29	134.25 +/-9.71
Old Adult	**Hamann-Todd**	9.89 +/-7.91	12.35 +/-7.40	11.00 +/-2.18	10.52 +/-2.30	128.18 +/-5.95	133.04 +/-7.71
	Schroeder	12.00 +/-4.24	14.50 +/-0.71	8.50 +/-0.71	10.50 +/0.71	145.50 +/-4.95	142.00 +/-2.83

Table 11 *Female Femoral Angle Means in Degrees by Side by Age Group.*

Age Group	Sample	FNV (L)	FNV (R)	BA (L)	BA (R)	NSA (L)	NSA (R)
All Ages	**Hamann-Todd**	12.83 +/-7.96	12.83 +/-7.81	9.00 +/-1.55	10.17 +/-2.64	132.17 +/-10.68	134.67 +/-8.33
	Schroeder	14.21 +/-5.19	16.25 +/-4.47	11.00 +/-1.99	10.69 +/-2.07	139.67 +/-5.50	136.25 +/-4.27
Young Adult	**Hamann-Todd**	16.00 +/-8.49	12.00 +/-5.66	10.00 +/-1.41	11.00 +/-0.71	119.00 +/-21.21	128.00 +/-9.90
	Schroeder	16.83 +/-5.99	16.63 +/-4.42	11.29 +/-1.51	10.25 +/-2.19	139.43 +/-4.27	135.25 +/-4.33
Middle Adult	**Hamann-Todd**	8.00 +/-NA*	8.00 +/-NSA*	10.00 +/-NA*	12.00 +/-NA*	126.00 +/-NA*	128.00 +/-NA*
	Schroeder	11.80 +/-5.38	17.50 +/-5.51	11.60 +/-1.71	11.50 +/-3.00	138.20 +/-7.93	136.75 +/-6.43
Old Adult	**Hamann-Todd**	12.33 +/-10.02	15.00 +/-10.82	8.67 +/-2.08	8.67 +/-3.21	133.00 +/-6.08	136.67 +/-9.81
	Schroeder	16.50 +/-4.24	17.33 +/-4.04	7.50 +/-0.71	10.00 +/-1.00	143.00 +/-5.66	137.67 +/-2.52

*Only one female in the middle adult age group in Hamann-Todd. SD therefore cannot be calculated.

FNV did not show any clear patterns by age in either sample by sex. Bicondylar angle increased from young adult to older adults in males from the Hamann-Todd sample, but decreased slightly over time in females. NSA seemed to increase greatly from young adulthood to older adulthood in males from the Hamann-Todd sample. There is a difference of ca. 10 degrees on both sides between the two age groups. A similar trend was seen in NSA of females from the Hamann-Todd group, with smaller differences. Thus, no consistent patterns presented themselves in the male or female groups for differences in correlations among angles by age, except that the Hamann-Todd sample shows smaller angle measurement in nearly every age group for nearly every angle by side as compared to Schroeder Mounds.

The relationship between age and proximal femoral angles is not explored often in the literature, but Yin et al. (2017) did find that NSA was negatively correlated with age. In contrast, Litrenta and Domb (2018, 1) found no statistically significant differences by age in a varied population based on the American Hip Institute Hip Preservation Registry. However, Yin et al. (2017) found it was statistically correlated with age, although they state their study could be biased based on the fact that all of the patients exhibited symptoms possibly related to labral tears caused by the morphology of the proximal femur (Yin et al. 2017). However, most explanations for the effects of age on the femoral angles focus only on early developmental mechanisms.

The NSA increased as age increased in this study, which was opposite of findings by Jiang et al. (2015) who found those under 60 years of age had a statistically significantly higher neck-shaft angle in 466 living Chinese Han individuals. They speculated that bone mineral density may play a key factor in this difference. Bone mineral density decreases with age, leading to the bone gradually losing rigidity (Jiang et al. 2015) and "failing" under normal pressures placed on the hip, such as ambulatory behaviors and an increased weight. While this study used different observation methods (CT scans on live patients) than the present study, meaning the values cannot be compared directly, it is important to note that both samples presented in my research exhibited the opposite trend. In addition, Yin et al. (2017) found NSA was negatively correlated to age in Asian adult patients based on CT scans. They suggested NSA changes over time due to shifts in overall bone composition due to factors such as osteoporosis, endosteal resorption, and medullary expansion with aging.

No other studies other than the present one appears to have investigated whether bicondylar angle values change in adulthood. Instead, the literature on bicondylar angle seems to focus on bipedal locomotion and sexual dimorphism (Tardieu 1994; Shefelbine et al. 2002; Waxenbaum and Stock 2016).

Correlations Between Proximal Femoral Angles

Table 12 shows angle correlation values by sex to test for relationships between pairs of the various permutations of angle variables (each combination of angle measurement for each sex). Again, those correlations that show a strong relationship (+/- .70) are bolded; two other values that were extremely close to meeting the criterion are also bolded and were considered in the overall pattern assessment. Overall, females generally had stronger relationships present in the data, especially in the Hamann-Todd sample. However, because no true pattern emerged in other samples by sex, it is likely this is due to a small sample size of six.

The only moderate or strong relationships found were between left and right FNV values for females and BA between left and right sides for males. It is worthwhile to note the lack of similar correlation values for pairs of angles tested by side. For example, Hamann-Todd males exhibited a correlation value of 0.80 for left FNV and BA, considered a strong correlation, while the right side for FNV and BA only had a value of 0.23, a low correlation value (see Table 10). Thus, no clear patterns emerged, thereby suggesting that the angles tend to operate independently of each other.

No other studies found investigated correlations between these angles.

Table 12 *Correlations between Proximal Femur Angles.*

Angle (side)	**Hamann-Todd**		**Schroeder Mounds**	
	Male	**Female**	**Male**	**Female**
FNV (L) * BA (L)	**0.80***	0.05	0.62	-0.27
FNV (R) * BA (R)	0.23	**-0.83**	-0.12	-0.08
FNV (L) * FNV (R)	0.52	**0.79**	0.63	**0.78**
BA (L) * BA (R)	0.17	-0.49	**0.70**	0.34
FNV (L) * NSA (L)	0.05	**0.79**	-0.43	0.18
FNV (R) * NSA (R)	-0.12	**0.94**	0.54	0.29
BA (L) * NSA (L)	-0.12	-0.39	-0.51	-0.25
BA (R) * NSA (R)	-0.17	**-0.68**	0.15	-0.33
NSA (L) * NSA (R)	0.56	**0.69**	0.53	0.64

*Values exceeding 0.70 are bolded.

Occupation and Subsistence-Settlement Patterns

This study’s primary aim was to explore differences in activity levels and perhaps specific activities such as squatting in order to establish a model by which to compare with samples so as to offer more information on their labor differences and activity level differences. Thus, I compared proximal femur angle values, presence/absence of Allen’s fossa and Poirier’s facet, and the statistical difference between angles above/below the mean and presence/absence of Allen’s fossa and Poirier’s facet in the two labor groups from Hamann-Todd (light and heavy) to the precontact sample Schroeder Mounds.

Proximal Femur Angles by Occupation and Subsistence-Settlement

First, I calculated proximal femur angle means for the three groups invested in this study (Hamann-Todd light labor, Hamann-Todd heavy labor, Schroeder Mounds mortuary group) (Table 13). Then, I compared the angles in an unpaired Student’s t-test. Results for the statistically significant angles are given in Table 14 (FNV) and Table 15 (NSA), where statistically significant p-values are bolded.

Table 13 *Proximal Femur Angle Means in Degrees by Activity Level.*

Sample	FNV (L)	FNV (R)	BA (L)	BA (R)	NSA (L)	NSA (R)
Hamann-Todd Light Labor	9.87 +/-7.80	11.61 +/-6.19	8.77 +/-1.99	10.07 +/-2.16	129.77 +/-7.15	132.13 +/-6.13
Hamann-Todd Heavy Labor	11.44 +/-7.42	12.59 +/-6.62	8.09 +/-1.97	10.42 +/-2.28	128.67 +/-5.67	133.53 +/-7.41
Schroeder Mounds	15.11 +/-4.59	18.00 +/-7.06	9.44 +/-2.96	8.90 +/-2.28	137.22 +/-8.45	135.22 +/-7.43

Table 14 *Student's T-test of Side Differences in FNV Means in Degrees by Activity Level Between Samples.*

	FNV (L)		**FNV (R)**	
	Hamann-Todd Light	**Schroeder**	**Hamann-Todd Heavy**	**Schroeder**
Mean	10.35	14.95	11.81	17.4
SD	7.79	4.85	6.37	5.53
SEM	1.28	1.03	1.05	1.11
N	37	22	37	25
P-value	**0.0155**		**0.0007**	
	Hamann-Todd Heavy	**Schroeder**	**Hamann-Todd Heavy**	**Schroeder**
Mean	11.44	14.95	12.59	17.4
SD	7.42	4.85	6.62	5.53
SEM	1.27	1.03	1.17	1.11
N	34	22	32	25
P-value	**0.0548**		**0.0051**	

Table 15 *Student's T-test of Side Differences in NSA Means in Degrees by Activity Level between Samples.*

	FNV (L)		**FNV (R)**	
	Hamann-Todd Light	**Schroeder**	**Hamann-Todd Heavy**	**Schroeder**
Mean	130.03	138.61	132.65	135.79
SD	7.78	6.72	6.42	5.52
SEM	1.31	1.4	1.05	1.13
N	24	37	23	35
P-value	**0.0001**		**0.0534**	
	Hamann-Todd Heavy	**Schroeder**	**Hamann-Todd Heavy**	**Schroeder**
Mean	128.7	138.61	133.53	135.79
SD	5.67	6.72	7.41	5.52
SEM	0.99	1.4	1.31	1.13
N	24	32	23	33
P-value	**0.0001**		0.2148	

As may be seen, Schroeder Mounds individuals differed extremely significantly from both labor groups for FNV and NSA on at least one side, although not BA. As noted previously, BA is thought to be more related to bipedalism than activity. Its inclusion in this study was based on the curiosity of whether or not FNV and NSA had any effect on BA. I believe between the lack of statistical significance here and the lack of a pattern of strong correlations with the other two angles (see Table 12) suggests that previous conclusions that BA is most heavily reliant on bipedalism for development is supported. The fact FNV and NSA were statistically significantly different in the Schroeder Mounds group from both labor groups is promising as these two angles have been found by others to possibly be linked to activity and behavior differences. This idea will be explored further in Ch. 6: Discussion, but will be discussed briefly here looking further at side, sex, and activity level differences for other variables.

Behavioral activities were noted to play a part in variable forces applied to the hip in Indian populations for FNV (Korukonda et al. 2017, 177-178). Of the three sample groups in this study, Schroeder Mounds had the highest FNV measurements, which were similar to those reported by Korukonda et al. (2017), which was 17.80 +/-7.7. In Western populations reported by Dunlap et al. (1953) as well as Kingsley and Olmsted (1948), researchers found FNV values of 8.70 and 8.02 degrees respectively, both of which are lower than those found in the Western population from Cleveland, Ohio in the Hamann-Todd collection. The authors did not specify the background of their study samples; however as Dunlap et al. (1953) utilized X-rays to achieve their results, their study sample was fairly contemporaneous with the Hamann-Todd cadaveric individuals collected between 1912 and 1938. However, this study utilized the Kingsley-Olmsted method for measuring dry femora and it is thus not entirely comparable by methodology. Nonetheless, the results do follow expectations given presumed activity levels of the groups under comparison.

As Korukonda et al. (2017, 177-178) state, “Since Indians are quite often habitual squatters, they tend to externally rotate the hips and use them in extreme range of motion.” Frequent squatting has been observed by other researchers as well (Jain et al. 2003; Zalawadia et al. 2010). Debnath et al. (2016) found an even higher population average for FNV in a Bengali sample (20.05 +/-5.72). They attribute this to different “ground level” activities like squatting, eating, cooking, and cleaning as compared to activities practiced by other populations (Debnath et al. 2016, 3). All other samples which utilized the Kingsley-Olmsted method were Indian populations (Jain et al. 2003; Zalawadia et al. 2010; Srimathi et al. 2012; Badjatiya et al. 2014). This could suggest the

Bengali individuals participated in these ground level activities at greater frequencies compared to Schroeder Mounds individuals, who have also been suggested to have participated in many ground-level activities such as kneeling and squatting based on the numerous facets indicating such activities (Woollen and Smith 2017; Smith and Woollen 2020).

However, there are contrary studies to this presumed explanation for variation in the expression of FNV. Yadav et al. (2021) noted that when force was applied in an equal or greater amount laterally compared to posteriorly, FNV was reduced compared to the opposite model forces. More lateral than posterior hip contact force takes place in basic activities such as walking, going up and down stairs, jumping, and running (Yadav et al. 2021). Both groups would presumably have been participating in normal walking behavior, with Schroeder participating more in behaviors like jumping and running compared to Hamann-Todd. The data here thus does not support findings and conclusions by Yadav et al. (2021).

Schroeder Mounds had the highest range in NSA compared to both labor groups in Hamann-Todd, while the labor groups differed by 1.40 degrees. Child and Cowgill (2017) state that people with a similar gait and ambulatory behaviors have similar NSA values regardless of body proportions, which may account for the more limited range of values among the Hamann-Todd individuals for this angle. Thus, it may be that Schroeder Mounds individuals were participating in activities that the people of Hamann-Todd, regardless of labor group, were also participating in, or were participating in more frequently, but this is speculation. Anderson and Trinkaus (2017) found a significant increase in the means of more sedentary populations. As such, Schroeder Mounds may have been fairly sedentary. They also suggest habitual activities during the development of the proximal femur in childhood lead to differences seen in adult populations (Anderson and Trinkaus 2017). Both speculations could have led to the significant difference between both labor groups compared to Schroeder Mounds

Activity Marker Results

Chi-square tests were performed to analyze for statistical differences in any patterns between frequencies of activity markers and the occupation groups. First, I examined the basic patterns of activity markers to determine if Allen’s fossa and Poirier’s facets are linked to specific behavioral differences related to biomechanics of the hip joint, which might include squatting and walking/running over rough terrain. Table 12 shows the results by sample group, counting all femora that presented with each activity marker. Both Allen’s fossa and Poirier’s facet appear bilaterally in most individuals. Allen’s fossa was present at a much higher frequency in Hamann-Todd females compared to males, but is nearly equal in frequency to males and females in the Schroeder Mounds sample. Allen’s fossa is similar in frequency in both labor groups, but Schroeder Mounds has a much lower frequency. Poirier’s is present in nearly equal frequencies in the labor groups, but is higher in frequency in the Schroeder Mounds sample comparatively. As shown in Table 16, Allen’s fossa occurs in a slightly higher frequency than in Schroeder Mounds. Poirier’s facet occurs at nearly double the rate in the Schroeder Mounds sample.

Table 16 *Proximal Femur Facet Frequencies by Sample.*

Sample	Allen's Fossa	Freq.	Poirier's Facet	Freq.
Hamann-Todd	95	0.66	45	0.31
Schroeder Mounds	24	0.50	28	0.58

Table 17 shows activity markers by sex in each sample. Hamann-Todd males and Schroeder males had a similar frequency of Allen's fossa, while Hamann-Todd females and Schroeder females had a similar frequency of Poirier's facet. Sample comparisons and further sex comparisons are made throughout this section.

Table 17 *Proximal Femur Facet Frequencies by Sex by Sample.*

Sample	Allen's Fossa	Freq.	Poirier's Facet	Freq.
Hamann-Todd Males	85	0.59	39	0.27
Hamann-Todd Females	10	0.83	6	0.50
Schroeder Males	10	0.56	12	0.67
Schroeder Females	14	0.47	16	0.53

Sex differences have been observed in other populations, but are inconsistent as to statistical significance. In the Liushui cemetery nomads, there was a statistically significant sex difference compared to a statistically insignificant difference between males and females in the Neijangyuan cemetery sedentary agriculturalists (Nie et al. 2014). In the study by Lawrence et al. (2018), a total of 6% of individuals from two populations of the same ancestry presented with Poirier's facet, all males. Males may have thus been participating in activities females did not, as found in a similar study by the same author (Lawrence 2017) looking at only one of the two populations from Lawrence et al. (2018). Sex differences varied in statistical significance among the two groups in Lawrence et al. (2018), suggesting they in magnitude between populations, possibly due to behavioral activities or other variables. They suggest one difference is the intensity of agricultural activity in the sample with higher prevalence of Poirier's facet (Lawrence et al. 2018).

Activities and economic systems have been explored as explanations for variable frequencies of Allen's fossa. Nie et al. (2014) investigated their presence in a suspected nomadic population and a suspected sedentary agriculturalist population from China and found that there was a statistically significant difference, with the nomadic population presenting with much higher frequencies. Nie et al. (2014) suggest horse-riding was the habitual activity which led to the difference in activity patterns. However, Berthon (2019) found similar frequencies (0.16 and 0.13) of Allen's fossa when comparing two Hungarian groups, one with evidence of horseback riding and one that lacked evidence of horseback riding. Both Hamann-Todd and Schroeder had a more frequent occurrence of Allen's fossa compared to those reported by Berthon (2019).

In terms of bilaterality of expression, Allen's fossa seems to occur slightly asymmetrically in the current study as well as in other studies as well. Ghosh et al. (2014) found a slightly higher predisposition for Allen's fossa on the right side of dried femora from the Osteology Museum of the Department of Anatomy, Maulana Azad Medical College, New Delhi, India. Rates were 68.6% (n=52) of the left femora and 73.7% (n=56) on the right. Sheridan (2020) found that among the 38% individuals in a monastery repository from the Byzantine period who exhibited with Allen's fossa, there were no statistically significant differences in left and right presentation. Thus, the current samples were typical in expression of the facets in this regard.

Frequencies by sex were also explored. The frequency of the presence of Allen’s fossa on at least one side in Schroeder Mounds males was 0.45, while the female frequency was only slightly larger at 0.50. Hamann-Todd females had a much larger frequency of Allen’s fossa compared to Schroeder. Nie et al. (2014) found males had a statistically higher frequency than females in their nomadic sample. However, there was no statistically significant difference between the sexes in the sedentary agricultural group (Nie et al. 2014). The author does not suggest a reason for these differences.

Due to the low frequency of the trait overall, no comparisons were made in terms of age groups within or between the sample groups in the present study. However, the presence of Allen’s fossa seems to decrease with age according to Angel (1964) and Radi et al. (2013). Radi et al. (2013, Table 5) found a statistically significant decrease in the frequencies of Allen’s fossa from young adults to older adults, although they do not suggest an explanation for this. In addition, Blom (2005, 159) found Allen’s fossa was highly correlated with age (phi=0.414, def=3, p<0.001) in an Andean population, but did not state how they were correlated (i.e., if they decreased or increased with age). These findings could be playing a part in the results of Allen’s fossa frequencies in the Hamann-Todd sample as 45.95% of the sample were older adults. Only five (18.52%) of the Schroeder Mounds individuals were older adults.

Poirier’s facet was investigated for comparisons between the light labor group, heavy labor group, and Schroeder Mounds. The labor groups had similar frequencies of Poirier’s facet, while Schroeder had higher frequencies compared to both groups. Presence of the facet has been associated with particular activities in other studies. Lawrence (2017, 11) states Poirier’s facet develops when the neck of the femur abuts with the acetabular rim, such as sitting cross-legged or during horseback riding. They may also arise from genuflexion such as during kneeling (Sheridan 2020). Lawrence et al. (2018) suggests a combination of Poirier's facet, plaque, and femoroacetabular impingement differences between two Early Christian Period cemetery groups as possibly due to intense activities related to agriculture in the group that presented with a higher frequency of Poirier's facet. Nie et al. (2014) found the facet was statistically significantly higher in frequency in the nomadic group. This suggests differences between the labor groups and Schroeder is unrelated to overall activity levels, but is perhaps related to differences in specific activities. One of these differences may be sitting or postural differences derived from sitting behaviors, as the people of the Hamann-Todd collection were likely utilizing chairs in their daily lives, while the people of Schroeder were utilizing more ground-level objects on which to sit.

In all my samples, Poirier's facet mostly presented as bilateral, but this is not a pattern consistently seen in other populations. Poirier's facet was bilateral in only two of the eight individuals from an Early Christian Period population from Kulubnarti, Nubia (A.D. 550-800) (Lawrence et al. 2018). However, while Buhler and Kirchengast (2022) did not calculate statistics in their study, it appears that Poirier's facet is mostly bilateral in both sexes in the Avar population from early medieval Europe. Presence of Poirier's facet seems to be only slightly higher on the left side (Buhler and Kirchengast 2022). Asymmetrical occurrence of Poirier's facet is thus common, and is not unique of either the Hamann-Todd and Schroeder Mounds collections.

Frequencies of Porier's facet by age were calculated for each labor group (Table 18). Among the light labor group, they decreased greatly from young adult to middle adult, then increased from middle adulthood to older adulthood. In the heavy labor group, frequencies decreased from young adulthood to middle adulthood, then stayed relatively the same from middle to older adults. Schroeder Mounds frequencies were much higher overall, but followed a similar pattern to the heavy labor group; statistical analysis was not conducted for any of my samples due to the low frequencies seen. In other populations, Lawrence et al. (2018, 5), Lawrence (2017, 14), and Buhler and Kirchengast (2022) found Poirier's facet was not associated with age. Lawrence (2017) then suggests Poirier's is not a degenerative trait. This means investigating Poirier's in association with age groups could show generational changes in activity types, as it is associated not with natural aging. This is outside the scope of this study, but may deserve more attention in future studies.

Table 18 *Proximal Femur Facet Frequencies by Age and Activity Level.*

Sample Group	**Age Group**	**Allen's Fossa**	**Freq.**	**Poirier's Facet**	**Freq.**
Hamann-Todd Light Labor	**YA**	14	0.70	12	0.60
	MA	19	0.79	3	0.13
	OA	20	0.57	10	0.30
Hamann-Todd Heavy Labor	**YA**	2	0.33	4	0.67
	MA	14	0.47	7	0.23
	OA	26	0.81	9	0.28
Schroeder Mounds	**YA**	13	0.59	17	0.77
	MA	11	0.69	7	0.44
	OA	0	0.00	4	0.40

Next, I explored differences between the proximal femur angles and presence or absence of activity markers among the labor groups and Schroeder using a Chi-square test. In order to do so, I determined how many individuals had an angle above or below the mean in addition to presence or absence of the given activity marker (Tables 19 and Table 20). In the only significant finding, Allen's fossa was found to be statistically related to bicondylar angle in the light labor group. Statistically significant p-values were mainly in the bicondylar angle groups, with NSA being statistically significant only in the Schroeder Mounds group for NSA and Allen's fossa. Most likely these isolated associations are not indicative of a meaningful relationship between the variables involved.

Table 19 *Chi-Square Testing of Presence/Absence of Allen's Fossa with Angle Values Above and Below Mean.*

	FNV	**p-value**	**BA**	**p-value**	**NSA**	**p-value**
Hamann-Todd Light Labor	N.S	0.65	Sig.	0.02	N.S.	0.5
Hamann-Todd Heavy Labor	N.S.	0.54	N.S.	0.89	N.S.	0.45
Schroeder	N.S.	0.84	N.S.	0.2	Sig.	0.002

Table 20 *Chi-Square Testing of Presence/Absence of Allen's Fossa with Angle Values Above and Below Mean.*

	FNV	**p-value**	**BA**	**p-value**	**NSA**	**p-value**
Hamann-Todd Light Labor	N.S.	0.32	N.S.	0.68	N.S.	0.63
Hamann-Todd Heavy Labor	N.S.	0.49	Sig.	0.02	N.S.	0.62
Schroeder	N.S.	0.29	Sig.	0.08	N.S.	0.92

Efficacy of Hamann-Todd as a Model

In order to answer research questions posed in this thesis, the Hamann-Todd collection, especially with its individuals of known occupations, was used as a model to explore the effects of activity on the proximal femur; the patterns seen would then be used to compare with data from individuals recovered at Schroeder Mounds to establish the level of activity and possibly add to the information of subsistence-settlement data for the site. However, the light labor and heavy labor groups of Hamann-Todd sample did not show any statistically significant differences or even just consistent patterns in expected directions for the means and/or frequencies of the proximal femur angles or activity markers observed.

Only two significant findings appeared in the data when I investigated the presence or absence of each activity marker to an angle above or below the mean for each individual in each group (Table 15 and Table 16). BA and Allen’s fossa in the light labor group were statistically significantly different, and BA and Poirier’s facet in the heavy labor group were statistically significantly different. As there is no consistency except that both are BA, it may be that each is an independent variable (activity marker and BA) and can be explained by the coincidence of the presence of the activity markers, and the fact that all people in the study were assumed to have a normal bipedal locomotor ability. This contributes to the inconsistencies of the model and casts doubt on a true pattern of labor intensity shown by the presence of these statistically significant results.

Several interpretations might be drawn from these findings. The inconsistencies in my statistical values are possibly due to too many confounding factors unrelated to physical labor also affecting the variables; these include childhood activity levels (Anderson and Trinkaus 1998; Yadav et al. 2021), sleeping positions (Korukonda et al. 2017), habitual sitting postures (Korukonda et al. 2017), and habitual medial or lateral positioning or repetitive motion of the hip (Korukonda et al. 2017; Yadav et al. 2021). Thus, the proximal femur morphology is simply too complex to be an easily interpreted indicator of activity. Activity levels fluctuate over time, with socioeconomic status among populations, between cultures, and with individual preferences such as postural habits or sleeping positions; all of these factors can potentially have an effect on overall population means. This results in variables unaccounted for within comparisons of populational data, as I have done.

Other explanations might involve the research design used. One primary concern could be the classification and then use of the high and low activity occupation in the Hamann-Todd series. A variety of jobs was included in each of the two categories, and it is possible that the distinction in level of activities was not sufficiently discrete. It is also very possible that individuals switched jobs during the course of their lifetimes. Unfortunately, only one job is listed on the census data per individual.

However, one clear pattern did emerge. The labor groups did not significantly differ in their values for FNV and NSA, yet Schroeder Mounds significantly differed from both labor groups for these variables. While the model did not necessarily work as the labor groups did not show a statistically significant difference, this is still an interesting and important point. Postural differences and other activity differences may play a part in this difference. Unfortunately, given the present literature and the lack of patterns in correlations in this study, there is little to draw on to link traits such as angle of the femur to presence or absence of activity markers like Poirier’s facet and Allen’s fossa. However, it is likely there is some relationship due to interpretations made by Korukonda et al. (2017), Buhler and Kirchengast (2022), Lawrence et al. (2018), and others who state activities play an important role in the morphology of the proximal femur.

The goal of this study was to establish activity levels, and perhaps suggest specific behaviors associated with the people of Schroeder Mounds. In order to do so, I attempted to create a model utilizing Hamann-Todd. While the model did not produce the statistical differences I expected, I did find data to explore. While this data is not consistent in suggesting activity levels for Schroeder, it is worth expounding on possible causes of these inconsistencies. The inconsistencies of activity level data and subsistence practices will be discussed further in the next chapter.

CHAPTER VI – DISCUSSION AND CONCLUSIONS

This research had two primary goals. The first was to explore the patterns of proximal femur morphology in two very distinct populations, one from the Schroeder Mounds, a prehistoric Illinois, and one from the Hamann-Todd collection, a collection from the early-to-mid 1900s U.S. The other goal was then to utilize the patterns seen in the Hamann-Todd collection in order to investigate the intensity of subsistence labor performed by the Schroeder Mounds people.

Discussion of Hypotheses and Study Results

It has been established that people with non-agricultural subsistence patterns did not always participate in the high level of intense labor that was previously assumed of all prehistoric peoples (Lee 1969; Sahlins 1972; Ogilvie and Hilton 2011; Sparacello et al. 2011). Both Ogilvie and Hilton (2011) and Bridges et al. (2000) found that male and female foragers had less humeral strength than farmers, with female farmers showing the highest humeral loading stress. This change in upper arm bone strength was due to the manual labor differences. Female farmers would have cleared, prepared, and maintained crops, all of which are tasks requiring more strength over longer periods of time, as compared to forager females who would have dug roots and tended to smaller crops (Ogilvie and Hilton 2011). Male farmers compared to foragers saw a decrease in right humeral strength, perhaps related to the transition from using an atlatl to using a bow and arrow (Bridges et al. 2000).

Utilizing this same framework of comparison, I sought to investigate the activity levels of the Schroeder Mounds population to assess their subsistence-settlement pattern by collecting data on proximal femur angles (FNV, BA, and NSA) and two activity markers (Allen’s fossa and Poirier’s facet). As bicondylar angle has been shown to be associated with bipedalism and was not statistically significantly related to FNV or NSA values, I focus on the proximal femur angles of FNV and NSA in the following sections. In addition, I consider patterns seen in Allen’s fossa and Poirier’s facet. Overall, this chapter addresses contextualization of my findings, in the process assessing limitations of my study, establishing future research, and expounding on my contributions to the literature.

Hypotheses Tested

Four hypotheses were tested within this research. My first hypothesis was: A higher frequency of Allen’s fossa and Poirier’s facet in the Schroeder Mounds group compared to Hamann-Todd. My research showed very little difference between the two groups for Allen’s fossa frequencies. However, Poirier’s facet showed a near double frequency in the Schroeder Mounds group compared to Hamann-Todd. This could be explained by behavioral differences such as squatting during rest or work that Hamann-Todd individuals did not participate in, but Schroeder Mounds individuals did.

My second hypothesis was: FNV would be lower in the heavy labor group due to mechanical stress on the femoral neck. My research did not find this hypothesis to be supported. FNV was fairly close between the two labor groups. However, Schroeder Mounds was statistically significantly different from both labor groups. Again, this could be explained by behavioral differences between the two groups which affected proximal femur morphology, resulting in FNV differences.

My third hypothesis was: BA would be similar to each other between Hamann-Todd and Schroeder Mounds. My research supported this finding. Each group fell within normal reported ranges, showing BA was not affected by behavioral factors.

My fourth hypothesis was: NSA would be lower in the heavy labor group compared to the light labor group; Schroeder Mounds would have an NSA mean similar to the heavy labor group, but possibly lower. There were no statistically significant differences between the labor groups. Additionally, my research found the exact opposite of what was hypothesized for Schroeder Mounds.

My research did not support any of my hypotheses except that BA would be similar in Schroeder and Hamann-Todd. While this may seem to suggest the proximal femur would not be a good indicator of subsistence-settlement and postural behaviors, the results did show differences, just not those expected.

Contextualizing the Data

This research has recently become timelier to assess given new findings that have emerged concerning subsistence practices at Schroeder Mounds. Previous archaeological evidence has suggested that the Schroeder Mounds individuals were agriculturalists with more labor intensive activities based on skeletal data such as musculoskeletal markers of the humerus, foot trauma, and rib osteoarthritis suggesting load carrying with tump lines (Nicosia et al. 2016; Dobbins 2018; Smith and Woollen 2020; Keeling 2019); however, other data suggested they were actually forager-horticulturalists, such as the lack of tuberculosis, which is more often seen in Mississippianized groups with their higher population densities (Mosher et al. 2013), dental health (Specht 1995); and lack of maize in the stable isotope analysis conducted on the sample in 2020 (Illinois State

Archaeological Survey 2019). However, the lack of tuberculosis does not necessarily disqualify a population from partaking in maize agriculture (Buikstra and Cook 1978). As Schroeder dates to the time in Illinois when maize was in the region, but not intensively cultivated or eaten regularly (VanDerwarker et al. 2013), it is highly likely Schroeder was indeed horticultural.

While my hypothesis was the Schroeder Mounds people would follow trends established by the model created from Hamann-Todd, there was the possibility that the Schroeder Mounds people would not align with either extreme of the model, but instead fall outside the expected values established by the Hamann-Todd model. Schroeder Mounds has been posited to be more sedentary than expected of a hinterland group due to the abundance of available aquatic fauna (Kolb 1982; Mosher et al. 2013). Utilizing Hamann-Todd as a model, I sought to explore these possibilities. Trends in the data such as lower FNV in the heavy labor group to reflect a higher level of activity would then create a comparable pattern to compare to Schroeder. Even if individuals at Schroeder Mounds presented with lower values than the heavy labor group this would signal a general trend of high activity and low FNV. However, the opposite was found. My hypothesis that heavier load bearing would decrease FNV may not be as straight-forward as I had assumed. Posturing behavior may then be a more likely explanation for the differences between Hamann-Todd and Schroeder Mounds.

FNV in the Schroeder Mounds population was statistically significantly different from both labor groups, but in the opposite direction anticipated, still suggesting activity differences possibly hold the key to these differences. Data suggests squatting behaviors may be at work in creating this high mean of FNV in the Schroeder Mounds population compared to Hamann-Todd (Jain et al. 2003; Zalawadia et al. 2010; Korukonda et al. 2017). This could explain the unexpected result and the significant difference between the two populations. Hamann-Todd presumably did not have to squat to take a resting position, but would have utilized chairs. As the adults of Schroeder Mounds were found by Smith and Woollen (2020) to possess a high percentage (73%) of squatting facets on the tibia and talus, my findings are supported. No statistically significant sex differences were found by Smith and Woollen (2020), which was also seen in my data for FNV of the two squatting markers (Allen's fossa and Poirier's facet) which also supports the idea that few sex differences in physical behaviors existed in the cultural group of Schroeder Mounds. Likewise, the statistical significance of Allen's fossa and Poirier's facet were not significant by sex in the Hamann-Todd sample. All this suggests it is not the level of intensity of activity influencing FNV, but the specific activities that may be associated such as squatting or sitting on a chair rather than closer to the ground.

The other statistically significant differences were seen in values for NSA. They were much higher than expected in the Schroeder Mounds group compared to the Hamann-Todd population overall, which was also shown to be a statistically significant difference. NSA was expected to be lower in the Schroeder Mounds group as they were presumed to be more nomadic than the more sedentary Hamann-Todd group. Schroeder Mounds was perhaps more sedentary than expected. A high level of sedentism was suggested by the levels of treponemal disease (13.2%-15.1%) in the adult population sampled (N=53) by Mosher et al. (2016), which is typically a condition seen in groups with greater population density. While this does not explain the difference between Schroeder Mounds and Hamann-Todd, this could be due in part to the possibility workers were moving around a lot during their jobs, walking over rough terrain, or traveling from job to job. There was a slightly lower NSA mean in the heavy labor group. As suggested by Gilligan et al. (2013) and Anderson and Trinkaus (2017), more sedentary groups tend to have a higher NSA value. The possibly unstable nature of the heavy labor group members' jobs compared to the light labor group could explain this difference within the Hamann-Todd sample, which would still make their behaviors similar to Schroeder Mounds. Schroeder Mounds was still statistically significantly different from the heavy labor group. This would further support the idea that specific activities are more to blame than activity levels for these differences.

Study Limitations

An obviously limited number of studies in the literature, especially concerning FNV and NSA, was a deciding factor in undertaking this project due to suggestions by multiple authors within the limited literature that activity played an important role in activity related to FNV (Khamanarong et al. 2014; Korukonda et al. 2017; Debnath et al. 2018) and NSA indicated settlement patterns and activity levels (Anderson and Trinkaus 1998; Gilligan et al. 2013). Additionally, a recent study conducted by Ausel and Cook (2023) found statistically significant differences in FNV values between horticulturalists (Late Woodland period) and agriculturalists (Mississippian period) in the Lower Illinois River Valley. However, the small number of studies created a limitation in assessing the context of my results. This led to a dearth of clear explanations for my results, especially since there is a lack of research examining both proximal femur and activity marker data. Thus, my study pioneered the possibility for this avenue of exploration.

Sample size played a key factor in the overall limitations of my research. Only six females were present in the Hamann-Todd group due to the limitations of the reported census data, i.e., females did not have many reported jobs. If they did, they had jobs related to light labor occupations such as secretarial work or teaching. Small sample size was also an issue in Schroeder Mounds. Complete, or nearly complete, femora were needed to take all measurements required for this study, and this was especially a challenge with the population, despite the relatively high level of preservation. Fewer than half of the more than 70 adults in the Schroeder Mounds mortuary group were able to meet these criteria. Most issues arose from the outer cortical bone being damaged from taphonomic processes in areas critical for the methods employed in this study.

Contributions of Research

This study sought to create a model to which values from populations of unknown activity levels might be compared. Although the model did not work as intended, my research showed that such a model might still work in future studies utilizing a larger sample or different ancestry group, proximal femur angle and activity marker data is still important to collect. FMV and NSA especially offer the possibility of showing how activity and subsistence-settlement differences between populations.

This study contributes valuable data for hip replacements and femoral neck reconstructive surgeries, as it is important to establish populational differences, especially in FNV (Khamanarong et al. 2014; Debnath et al. 2016; Korukonda et al. 2017). In addition, establishing normal ranges of values like FNV allows for clinical assessments of abnormal values related to diseases (Debnath et al. 2016). Diseases such as Perthes disease, cerebral palsy, and congenital deformities like genu vara and genu valga are characterized by abnormal FNV of the proximal femur (Debnath et al. 2016). This research contributes more data to this body of literature for a Native American ancestry group and white American population.

Additionally, skeletal data on past populations, especially those lacking archaeological data for interpretations such as Schroeder Mounds, is key to understanding past people's way of life. The lack of archaeological data for Schroeder Mounds and the surrounding area does not mean all is lost in the interpretation of past people in the area. In fact, bioarchaeology has been shown to play a key role in contributing to contexts where a lack of material culture could be seen as a detriment. While it is always helpful to have material culture, a wide variety of information can be gathered without it, such as my study with has contributed to a better understanding of postural differences between more modern groups and pre-contact groups.

Recommended Future Studies

In future studies, femoroacetabular osteoarthritis could be recorded to explore the relationship between proximal femur angles and osteoarthritis (Debnath et al. 2016). Not merely its presence or absence should be recorded, but the position, the over size and depth of the affected area. Effects of proximal angles of the femur and therefore the relationship of the femoral head to the acetabulum have been suggested as a factor in the development of hip arthritis in older adults (Debnath et al. 2016). Medical research on the subject of proximal femur angles is most concerned with hip replacement surgeries and femoroacetabular impingement. However, a focus on the development of osteoarthritis and an individual's proximal femur angles could help doctors with preventative care measures for their patients. Additionally, bioarchaeologists could factor in the proximal femur morphology in studies related to data collection on osteoarthritis, as hip osteoarthritis may be caused by an angle such as FNV and be unrelated to activities like walking (Gulan et al. 2000), activity pattern differences between and among populations (Khamanarong et al. 2013; Korukonda et al. 2017), body mass (Ejnisman et al. 2013), and age (Cibulka 2004).

Other ancestries should also be considered in future studies of proximal femur morphology. This study takes one step towards that goal. However, many populations are left out of the literature. For example, people of African and Native American ancestry were not often considered in the literature. People of all populations and ancestries all over the world need hip replacements. Establishing more averages and performing statistical analysis on more populations would give doctors more data to apply to patient care.

Utilizing more historic groups like I did in this study could also help to establish a better baseline for which to compare pre-contact populations. By establishing labor groups like I did, they can be utilized as a model to compare change over time between groups of people of similar ancestry. For example, more studies focusing on modern Indian populations could help establish a model to compare prehistoric Indian populations to explore labor division and load stresses on the body. Especially as the methods employed in this study are non-destructive and easily executed, they are able to be utilized on virtually any sample. More prehistoric analysis creates a better body of literature by which to compare others, offering more data to assist in reconstructing past narratives.

Conclusions

This research attempted to create a model by which other populations could be compared to establish activity levels. Expected patterns for FNV, BA, NSA, Allen’s fossa, and Poirier’s facet were not identified in this study. However, the statistical significance of FNV and NSA reveal they are possibly good indicators of subsistence-settlement and postural practices. FNV and NSA are therefore worthy of exploration in future studies as activity related markers. This study has also contributed comparative data for future research concerning proximal femur angles and activity markers like Allen’s fossa and Poirier’s facet. Future studies may be able to factor in more variables and add more data for statistical analysis. In addition, this study shows how bioarchaeology can assist in interpreting past lifeways by examining larger cultural trends regionally, even when little to no material culture is available.

REFERENCES CITED

Anderson, John Y., and Erik Trinkaus. 1998. “Patterns of Sexual, Bilateral and Interpopulational Variation in Human Femoral Neck-shaft Angles.” *Journal of Anatomy* 192, no. 2 (February): 279-285. doi: 10.1046/j.1469-7580.1998.19220279.

Armelagos, George J. 2003. “Bioarchaeology as Anthropology.” *Archaeological Papers of the American Anthropological Association* 13, no. 1: 27-40. doi: 10.1525/ap3a.2003.13.1.27.

Atwell, Karen A. 1994. “Analysis of Burial Patterns.” In *The Kuhlman Mound Group and Late Woodland Mortuary Behavior in the Mississippi River Valley of West-Central Illinois*. Edited by Karen A. Atwell and Michael D. Conner. Kampsville Archaeological Center Research Series, no. 9: 208-237.

Ausel, Erica L., and Della Cook. 2023. “Insights from Bone and Lives Lived: Sitting Posture and Femoral Morphology in the Lower Illinois River Valley at the Klunk (AD 600-800) and Schild (AD 700-1250) Sites.” Abstract. Paper presented at the Paleopathology Association Hybrid Conference Program Meeting, June 2, Denver.

Berthon, William, Balazs Tihanyi, Luca Kis, Laszlo Revesz, Helene Coqueugniot, Olivier Dutour, and Gyorgy Palfi. 2018. “Horse Riding and the Shape of the Acetabulum: Insights from the Bioarchaeological Analysis of Early Hungarian Mounted Arches.” *International Journal of Osteoarchaeology* 29, no. 1 (October): 117-126.

Blom, Deborah E. 2005. “A Bioarchaeological Approach to Tiwanaku Group Dynamics.” In *Us and Them*, 153-182. Edited by David Berreby. Chicago: The University of Chicago Press.

Boncal, Sarah A., and Maria Ostendorf Smith. 2013 “Comprehensive Paleopathological Analysis of the Cervical Vertebrae from the Schroeder Mounds Site of Woodland Period Illinois.” Poster presented at the Midwest Bioarchaeology and Forensic Anthropology Association Meeting, Columbus.

Bonneau, Noemie, Paul-Antoine Libourel, Caroline Simonis, Laurent Puymerali, Michel Baylac, Christine Tardieu, and Olivier Gagey. 2012. “A Three-Dimensional Axis for the Study of Femoral Neck Orientation.” *Journal of Anatomy* 221, no. 5 (September): 465-476.

Bridges, Patricia, John H. Blitz, Martin C. Solano. 2000. “Changes in Long Bone Diaphyseal Strength with Horticultural Intensification in West-Central Illinois.” *American Journal of Physical Anthropology* 112, no. 2 (June): 217-238. doi: 10.1002/(SICI)1096-8644(2000)112:2<217::AID-AJPA8>3.0.CO;2-E.

Buikstra, Jane E., and Della C. Cook. 1978. “Pre-Columbian Tuberculosis: An Epidemiological Approach.” *Medical College of Virginia Quarterly* 14, no. 1: 32-44. https://scholarscompass.vcu.edu/cgi/viewcontent.cgi?article=1541&context=mcvq.

Buhler, Birgit, and Sylvia Kirchengast. 2022. “A Life on Horseback? Prevalence and Correlation of Metric and Non-metric Traits of the “Horse-Riding Syndrome” in an Avar Population (7th-8th century AD) in Eastern Austria.” *Anthropological Review* 85, no. 3: 821-831. https://doi.org/10.18778/1898-6773.85.3.05.

Child, Stephanie L., and Libby W. Cowgill. 2017. “Femoral Neck-Shaft Angle and Climate-Induced Body Proportions.” *American Journal of Physical Anthropology* 164, no. 4 (September): 720-735. doi: 10.1002/ajpa.23311.

Cibulka, Michael T. 2004. “Determination and Significance of Femoral Neck Anteversion.” *Physical Therapy* 84, no. 6 (June): 550-558. 10.2519/jospt.2004.34.8.461.

Corruccini, Robert S. 1974. “An Examination of the Meaning of Cranial Discrete Traits for Human Skeletal Biological Studies.” *American Journal of Physical Anthropology* 40, no. 3 (May): 210-234. https:/10.1002/ajpa.1330400315.

Danion, Frederic, Mireille Bonnard, and Jean Pailhous. 1997. “Intentional On-Line Control of Propulsive Forces in Human Gait.” *Experimental Brain Research* 116, no. 3 (November): 525-538. doi: 10.1007/PL00005781.

de la Cova, Carlina. 2010. “Cultural Patterns of Trauma among 19th-Century-Born Males in Cadaver Collections.” *American Anthropologist* 112, no 4 (April-June): 295-303. doi: 10.1111/j.1548: 1433.2010.01278.x

Debnath, Moulik, Sudipto Konar, Plyali Kundu, and Madhumita Debnath. 2016. “Study of Femoral Neck Anteversion and its Correlations in Bengali Population.” *International Journal of Anatomy, Radiology, and Surgery* 5, no. 1 (January-March). https://ijars.net/article_fulltext.asp?issn=0973-709x&year=2016&month=January&volume=5&issue=1&page=1&id=2090.

Dewar, Genevieve, and Susan Pfeiffer. 2004. “Postural Behavior of Later Stone Age People in South Africa.” *The South African Archaeological Bulletin* 59, no. 180 (December): 52-58. https://www.researchgate.net/profile/Susan-Pfeiffer/publication/270132882_Postural_Behaviour_of_Later_Stone_Age_People_in_South_Africa/links/5714e09908ae4e2fdba17155/Postural-Behaviour-of-Later-Stone-Age-People-in-South-Africa.pdf?origin=publication_detail.

Djukic, Ksenija, Petar Milenkovic, Petar Milovanovic, Milos Dakic, and Marija Djuric. 2014. "The Increased Femoral Neck Anteversion in Medieval Cemetery of Pecenjevce. Aetiology and Differential Diagnosis in Archaeological Context." *Chungara* 46, no. 2 (September): 295-303. https://www.jstor.org/stable/24588288.

Dobbins, Paige. "Working Women: Agricultural Intensification, Osteoarthritis in Females, and Subadult Health in Illinois Woodland and Mississippian Mortuary Contexts." Master's thesis, Illinois State University.

Dunlap, Knox, A. R. Shands Jr., Lucius C. Hollister Jr., J. Stuart Gaul Jr., and Harold A. Streit. 1953. "A New Method for Determination of Torsion of the Femur." *Journal of Bone Joint Surgery of America* 35, no. 2 (April): 289-311.

Durchholz, Aaron. 2017. "Candy Corn: Subsistence Strategy and Dental Decay at the West-Central Illinois Schroeder Mounds (11HE177) Site." Paper presented at the Midwest Bioarchaeology & Forensic Anthropology Association Conference, October 17, Milwaukee.

Ejnisman, Leandro, Marc J. Philippon, Pisit Lertwanich, Andrew T. Pennock, Mackenzie M. Herog, Karen K. Briggs, and Charles P. Ho. 2013. "Relationship Between Femoral Anteversion and Findings in Hips With Femoroacetabular Impingement." *Orthopedics* 36, no. 3 (March): e293-e300.

Emerson, Thomas E., Dale L. McElrath, and Andrew C. Fortier. 2000. *Late Woodland Societies: Traditions and Transformation across the Midcontinent*. Lincoln: The University of Nebraska Press.

Finnegan, Michael. 1978. "Non-Metric Variation of the Infracranial Skeleton." *Journal of Anatomy* 125, no. 1: 23-37. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1235564/pdf/janat00359-0029.pdf

Fraser, Jim, and Robin Williams. 2013. *Handbook of Forensic Science: Chapter 6*. London: Routledge.

Fuentes, Augustin. 2010. "The New Biological Anthropology: Bringing Washburn's New Physical Anthropology Into 2010 and Beyond—The 2008 AAPA Luncheon Lecture." *Yearbook of Physical Anthropology* 53: 2-12. doi: 10.1002/ajpa.21438.

Galbraith, Robert T., Robert H. Gelberman, Paul C. Hajek, Lori A. Baker, David J. Sartoris, George T. Rab, Mark Cohen, and Paul P. Griffin. 1987. "Obesity and Decreased Femoral Anteversion in Adolescence." *Journal of Orthopaedic Research* 5, no. 4: 523-528. https://doi.org/10.1002/jor.1100050407.

Garner, Cynthia. 1994. “Kuhlman Demography and Disease in Comparative Perspective.” In *The Kuhlman Mound Group and Late Woodland Mortuary Behavior in the Mississippi River Valley of West-Central Illinois*,180-207. Edited by Karen A. Atwell and Michael D. Conner. Kampsville Archaeological Center Research Series, no. 9.

Ghosh, S., M. Sethi, and N. Vasudeva. 2014 “Bony Impression on Caput and Neck of Human Femora in Indian Population.” *Journal of Surgical Academia* 4, no. 1: 5-9. http://journalarticle.ukm.my/7681/1/02._Ghosh_S_et_al_%285-9%29.pdf.

Gillespie, Robert J., Ari D. Levine, Steven J. Fitzgerald, Jensen G. Kolaczko, Marlene DeMaio, Randall E. Marcus, and Daniel R. Cooperman. 2011. “Gender Differences in the Anatomy of the Distal Femur.” *The Bone & Joint Journal* 95-B, no. 3 (March): 357-363. doi: 10.1302/0301-620X-9383.24708.

Gilligan, Ian, and David Bulbeck. 2007. “Environment and Morphology in Australian Aborigines: A Re-Analysis of the Birdsdell Database.” *Environmental Science* 134, no. 1 (June): 75-91. https://doi.org/10.10002/ajpa.20640.

Gilligan, Ian, Supichya Chandraphak, and Pasuk Mahakkanukrauh. 2013. “Femoral Neck-Shaft Angle in Humans: Variation Relating to Climate, Clothing, Lifestyle, Sex, Age and Side*.” Journal of Anatomy* 223, no. 2 (August): 133-151. doi: 10.1111/joa.12073.

Green, William. 1993. “A Prehistoric Frontier in the Prairie Peninsula: Late Woodland Upland Settlement and Subsistence Patterns.” In Highways to the Past: Essays on Illinois Archaeology in Honor of Charles J. Bareis. Edited by Thomas E. Emerson, Andrew C. Fortier, and Dale L. McElrath. *Illinois Archaeology* 5: 201-214.

Green, William, and David J. Nolan. 2000. “Late Woodland Peoples in West-Central Illinois.” In *Late Woodland Societies: Tradition and Transformation across the Midcontinent*, 345-386. Edited by Thomas E. Emerson, Dale L. McElrath, and Andrew C. Fortier. Lincoln: University of Nebraska Press.

Gudiera, Kenneth J., Timothy M. Ganey, Claire R. Keneally and John Ogden. 1994. “The Embryology of Lower-Extremity Torsion.” *Clinical Orthopaedics and Related Research* 302, no. 1 (May): 17-21.

Gulan, Gordan, Damir Matovinocic, Boris Nemec, Dusan Rubinic, and Jagoda Ravlic-Gulan. 2000. “Femoral Neck Anteversion: Values, Development, Measurement, Common Problems.” *Collegium Antropologocum* 24, no. 2 (December): 521-527. https://hrcak.srce.hr/file/26576.

Heiple, Kingsbury G., and C. Owen Lovejoy. 1971. “The Distal Femoral Anatomy of Australopithecus.” *American Journal of Physical Anthropology* 35, no 1. (July): 75-84.

Hedman, Kristen M., and Thomas E. Emerson. 2008. “The Luthy Alps Site: AMS Dates, Stable Isotopes, and Maize Consumption in the Central Illinois River Valley at the Late Woodland-Mississippian Interface.” *Illinois Archaeology* 20: 48-84. https://www.researchgate.net/profile/Thomas-Emerson-3/publication/303258385_The_luthy_alps_site_AMS_dates_stable_isotopes_and_maize_consumption_in_the_Central_Illinois_River_Valley_at_the_Late_Woodland-Mississippian_interface/links/5744e81308ae298602f75d93/The-luthy-alps-site-AMS-dates-stable-isotopes-and-maize-consumption-in-the-Central-Illinois-River-Valley-at-the-Late-Woodland-Mississippian-interface.pdf.

Hernandez-de Sosa, Nerea, Georgios Athanasiadis, Jorge Malouf, and Ana M. Laiz. 2016. “Genetic Contribution of Femoral Neck Bone Geometry to the Risk of Developing Osteoporosis: A Family-Based Study.” *PLoS ONE* 11, no. 5. doi: 10.1371/journal.pone.0154833.

Hitzemann, Nicole J. 1997. “Regional Osteoarthritis Patterns: An Examination of Late Woodland Trends in West-Central Illinois.” Master’s thesis, Northern Illinois University.

Hogervorst, Tom, and Evie. E. Vereecke. 2014. “Evolution of the Human Hip. Part 1: The Osseous Framework.” *Journal of Hip Preservation Surgery* 1, no. 2 (October): 39-45. https://doi.org/10.1093/jhps/hnu013.

Hunt, Kevin D., Sarah E. Dunevant, Ryan M. Yohler, and Kristian J. Carlson. 2021. “Femoral Bicondylar Angles among Dry-Habitat Chimpanzees (*Pan troglodytes schweinfurthii*) Resemble Those of Humans: Implications for Knee Function, Australopith Sexual Dimorphism, and the Evolution of Bipedalism*.” Journal of Anthropological Research* 77, no. 3 (August): 303-337. doi: 10.1086/715398.

Jain, Anil K., Aditya Maheshwari, M.P. Singh, and Subha Nath. 2005. “Femoral Neck Anteversion: A Comprehensive Indian Study.” *Indian Journal of Orthopaedics* 39, no. 3: 137-144. http://dx.doi.org/10.4103/0019-5413.36685.

Jiang, Nan, Lin Peng, Mohammed Al-Qwbani, Guo-Ping Xie, Qin-Meng Yang, Yu Chai, Qing Zhang, and Bin Yu. 2015. “Femoral Version, Neck-Shaft Angle, and Acetabular Anteversion in Chinese Han Population: A Retrospective Analysis of 466 Healthy Adults.” *Medicine (Baltimore)* 94, no. 21 (May): e891. doi: 10.1097/MD.0000000000000891.

Jin, Sangeun, Ryan McCulloch, and Gary Mirka. 2009. “Biomechanical Evolution of Postures Assumed When Harvesting from Bush Crops.” *International Journal of Industrial Ergonomics* 39, no. 2: 347-352. doi: 10.1016/j.ergon.2008.07.005.

Keeling, Brian A. 2019. “Frequency of Costovertebral and Costotransverse Osteoarthritis in the Schroeder Mounds Site.” *Field Notes: A Journal of Collegiate Anthropology* 10, no. 1: 44-73. https://dc.uwm.edu/cgi/viewcontent.cgi?article=1111&context=fieldnotes.

Khamanarong, Kimaporn, Wiphawi Hipkaeo, Piyawan Chatuparisute, Surachai Sae-Jung, and Kaewjai Tepsutamarat. 2014. “Version of Femoral Neck: A Cadaveric Dried Bone Study.” *International Journal of Morphology* 32, no. 2: 464-468. http://dx.doi.org/10.4067/S0717-95022014000200015.

Kharbuja, Rabita, Rashmi Manjushree Adhikari, and Anupama Shrestha. 2018. “Bicondylar Angle and Its Relation with Length and Neck Length of Human Femur.” *Journal of Lumbini Medical College* 6, no. 1 (January-June): 17-20. doi: 10.22502/jmlc.v6i1.176.Epud.

Kingsley, Paul C., and K.L. Olmsted. 1948. “A Study to Determine the Angle of Anteversion of the Neck of the Femur.” *The Journal of Bone and Joint Surgery* 30A, no. 3 (July): 745-751. https://doi.org/10.2106/00004623-194830030-00021.

Kolb, Michael. 1982. “The Schroeder Mounds Site: A Preliminary Analysis from a Spatial Perspective.” Master’s thesis, University of Wisconsin, Milwaukee.

Korukonda, Sushma, Jami Sagar Prusti, and Purna Chandra Maharana. 2017. “A Study on Femoral Anteversion in Adult Dry Femora of South Indian Population.” *Journal of Evidence Based Medicine and Healthcare* 4, no. 4 (January): 178-182. DOI: 10.18410/jebmh/2017/35.

Kuo, Tony Y., John G. Skedros, and Roy D. Bloebaum. 1997. “Comparison of Human, Primate, and Canine Femora: Implications for Biomaterials Testing in Total Hip Replacement.” *Journal of Biomedical Materials Research* 40 (February): 475-489. https://teambone.com/wp-content/uploads/2014/07/17.-Kuo-et-al.-1998.-Comparison-of-human-primates-and-canine-femora.pdf.

Langford, Donna K. Snyder. 1999. “Indications of Health Status in Two Late Woodland Sites in West Central Illinois.” Master’s thesis, Northern Illinois University.

Lawrence, Austin B. 2017. *Hips Don’t Lie: Implications for the Functional Morphology of the Hip in Bioarchaeological Activity Reconstruction and the Evolution of Hominin Locomotion*. Honors thesis, University of Colorado, Boulder.

Lawrence, Austin B., Paul A. Sandberg, Dennis P. Van Gerven, and Matt Sponheimer. 2018. “Evidence for Differences in Activity Between Socioeconomic Groups at Kulubnarti, Nubia (550-800 CE), From Osseous Modifications of the Proximal Femur.” *International Journal of Osteoarchaeology* 28, no. 6 (August): 735-744.

Lee, Richard Borshay. 1969. “Eating Christmas in the Kalahari.” *Natural History*: 1-4. http://people.morrisville.edu/~reymers/readings/ANTH101/EatingChristmas-Lee.pdf.

Lerner, Shereen. 1984. “Defining Prehistoric Frontiers: A Methodological Approach.” In *Exploring the Limits: Frontiers and Boundaries in Prehistory*. Edited by Suzanne P. De Atley and Frank J. Findlow, 67-80. Oxford: B.A.R. International Series No. 223.

Litrenta, Jody M., and Benjamin G. Domb. 2018. “Normative Data on Femoral Version.” *Journal of Hip Preservation Surgery* 5, no. 4: 1-15. doi: 10.1093/jhps/hny048.

Lynn, Scott K., and Guillermo J. Noffal. 2012. “Lower Extremity Biomechanics During a Regular and Counterbalanced Squat.” *The Journal of Strength & Conditioning Research* 26, no. 9: 2417-2425. doi: 10.1519/JSC.0b013e31823f8c2d.

Macho, Gabriele A. 1991. “Anthropological Evaluation of Left-Right Differences in the Femur of Southern African Populations.” *Anthropologischer Anzeiger* 49, no. 3 (September): 207-216. doi: 10.1127/anthranz/49/1991/207.

Maheshwari, Aditya V., Michael P. Zlowodzki, Gautam Siram, Anil K. Jain. 2010. “Femoral Neck Anteversion, Acetabular Anteversion and Combined Anteversion in the Normal Indian Adult Population: A Computed Tomographic Study.” *Indian Journal of Orthopaedics* 44, no. 3 (July): 277-281. doi: 10.4103/0019-5413.65156.

Maruyama, Masaaki, Judy R. Feinberg, William N. Capello, and James A. D’Antonio. 2001. “The Frank Stinchfield Award: Morphological Features of the Acetabulum and Femur: Anteversion Angle and Implant Positioning.” *Clinical Orthopaedics and Related Research* 393: 52-65.

Medlej, Bahaa, Haim Cohen, Gali Dar, Smadar Peleg, Janan Abbas, Youssef Msharawi, Israel Hershkovitz, and Hila May. 2021. “Defects of the Femoral Head-Neck Junction: A New Method of Classification and Observed Frequency in Hamann-Todd Skeletal Collection.” *International Journal of Osteoarchaeology* 31, no. 5 (May): 801-808. https://doi.org/10.1002/oa.2991.

Meltzer, David J. 2011. *Lewis Roberts Binford: 1931-2011*. Washington D.C.: National Academy of Science.

Mensforth, Robert P., and Bruce M. Latimer. 1989. “Hamann-Todd Collection Aging Studies: Osteoporosis Fracture Syndrome.” *American Journal of Physical Anthropology* 80, no. 4 (December): 461-479. doi: 10.1002/ajpa.1330800406.

Molleson, Theya, and Joel Blondiaux. 1994. “Riders’ Bones from Kish, Iraq.” *Cambridge Journal of Archaeology* 4, no. 2 (October): 312-316. doi: 10.1017/S095977430000113 1X.

Moore, Keith L., Arthur F. Dalley, and Anne M. R. Agur. *Clinically Oriented Anatomy*. Philadelphia: Wolters Kluwer.

Mosher, Germane M., Maria O. Smith, Jessica L. Albrecht, and V. P. Salaka. 2013. “Treponemal Disease, Tuberculosis and Subsistence-Settlement Pattern in the Late Woodland Period West-Central Illinois.” *International Journal of Osteoarchaeology* 25, no. 5 (August): 776-787. https://doi.org/10.1002.oa.2344.

Murphy, Stephen, Sheldon Simon, Peter Kijewski, Robert H. Wilkinson, and N. Thorne Griscom. 1987. “Femoral Anteversion.” *Journal of Bone and Joint Surgery of America* 69, no.8 (October): 1169-1176.

Neidich, Deborah L., and Maria O. Smith. 2016. “Major Questions about Teres Minor: The Pattern of Reactive Changes in a Pre-Columbian Human Skeletal Sample From Illinois.” *Field Notes: A Journal of Collegiate Anthropology* 8, no. 1 (June): 70-85. https://d1wqtxts1xzle7.cloudfront.net/47287740/Neidich_Smith-FN-2016-libre.pdf?1468734101=&response-content-disposition=attachment%3B+filename%3DNeidich_and_Smith_2016_Major_Questions_a.pdf&Expires=1685775755&Signature=OJax82imSFvouN5N1uYawm~duykp6qA8TAJCeLR0-NI4xQO1LuLZGFoT-O8MDGYDtUjhXIMCqQBdVLAjh25bRu~8Glmbq1Z~PQRp5L~RgVpkP~V6uEG3FeTDF8SxnKAhauX8sxhvbEQgyHoKlBg12GxXB1K-JiRXcvOBX7oPWWWDIhu32MSoGfNoVu-Ln4IULDVj3176K0goZGHIB7ckGzxtjOPGWJyqRKLLK6~5EVrcHQB6AA1HOF1WrHUioYAyJOgJS0YGqa86jsVn3HhQbb1SDbB~a43fAoc~053qYVLkovoD-mX2DNPOmgL0jbNR76EBsM-~ZuwiO1VPkanlew__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA.

Nelson, Kassandra. 2011. “Behavior Patterns in Florida’s Middle Archaic: Activity Inducing Articular Facets from the Gauthier (8BR-193) Mortuary Complex”. Master’s thesis, Florida Atlantic University.

Nicosia, Christopher, Jessica R. Dorsz, and Maria Ostendorf Smith. 2016. “Subadult Growth Stunting at Schroeder Mounds (11He177): A Late Woodland Sample from Illinois.” *Field Notes: A Journal of Collegiate Anthropology* 8, no. 7: 104-121. https://www.academia.edu/27032856/Nicosia_Dorsz_and_Smith_2016_Subadult_Growth_Stunting_at_Schroeder_Mounds_11He177_A_Late_Woodland_Sample_from_Illinois.

Nie, Zhongzhi, Xu Zhang, Minghui Wang, Ying Nie, Dongya Yang, Hong Zhu, and Xinhua Wu. 2014. "Preliminary Investigations of Habitual Stress on Femora from Two Economically Different Archaeological Populations in China." Abstract. *American Journal of Physical Anthropology* 153: 195. https://researchonline.jcu.edu.au/33225/1/Newton%20and%20Domett%202014%20AAPA%20Abstract.pdf.

Ogilvie, Marsha D., and Charles E. Hilton. 2011. "Cross-Sectional Geometry in the Humeri of Foragers and Farmers from the Prehispanic American Southwest: Exploring Patterns in the Sexual Division of Labor." *American Journal of Physical Anthropology* 144, no. 1: 11-21. doi: 10.1002/ajpa.21362.

Parker, Kathryn E. 1996. "Plant Remains from Archaeological Investigations at the Shaw Site (11-OG-188) on the Middle Rock River, Northern Illinois." Master's thesis, Northern Illinois University.

Pitt, Michael J., Anna R. Graham, Jeff H. Shipman, and Walter Birkby. 1982. "Herniation Pit of the Femoral Neck." *Clinical Orthopaedics and Related Research* 32, no. 1 (June): 130-142. https://www.ajronline.org/doi/pdf/10.2214/ajr.138.6.1115.

Purcell, Maureen W. 2013. *Sex Differences in the Femur and Acetabulum: Biomechanical Analysis with Forensic Significance*. Master's thesis, Texas State University.

Radi, Nico, Valentina Mariotti, Alessandro Riga, Stefania Zampetti, Chiari Villa, and M. Giovanna Belcastro. 2013. "Variation of the Anterior Aspect of the Femoral Head-Neck Junction in a Modern Human Identified Skeletal Collection." *American Journal of Physical Anthropology* 152, no. 2 (September): 261-272.

Radin, Eric L., and Igor L. Paul. 1974. "The Biomechanics of Congenital Dislocated Hip and Their Treatment." *Clinical Orthopaedics and Related Research,* 98 (January): 32-38.

Rowe, Paul, Adam Koller, and Sandeep Sharma. 2023. *Physiology, Bone Remodeling*. National Library of Medicine: National Center for Biotechnology Information. https://www.ncbi.nlm.nih.gov/books/NBK499863/.

Ruff, Christopher B. 2018. "Biomechanical Analysis of Archaeological Human Skeletons." In *Biological Anthropology of the Human Skeleton,* 189-224. Edited by M. Anne Katzenberg and Anne L. Grauer. Oxford: John Wiley & Sons.

Sahlins, Marshall. 1972. "The Original Affluent Society." In *Stone Age Economics,* 85-89. New York: Aldine.

Schmeltzpfenning, Timo, and Torsten Brauner. 2013. "Foot Biomechanics and Gait." *Handbook of Footwear Design and Manufacture* 1, no. 1: 27-48.

Shah, Meet Paresh. n.d. "A Study of the Bicondylar Angle in the Gujarat Region." *Semantic Scholar*. https://www.semanticscholar.org/paper/A-Study-Of-The-Femoral-Bicondylar-Angle-In-The-Shah/dfc9ee96729ea3d0f47777f496cd64c001006b28.

Sharma, Raj Laxmi, Suresh Ku Sharma, Massarat Jehan, and Anil Sastya. 2014. "Sexual Dimorphism of the Femoral Bicondylar Angle in Gwalior, Madhya Pradesh Region." *International Journal of Healthcare and Biomedical Research* 2, no. 4 (July): 38-45. http://ijhbr.com/pdf/38-45.pdf.

Shefelbine, Sandra J., Christine Tardieu, and Dennis R. Carter. 2002. "Development of the Femoral Bicondylar Angle in Hominid Bipedalism." *Bone* 30, no. 5 (June): 765-770. doi:10.1016/S8756-3282(02)00700-7.

Simon, Mary L. 2000. "Regional Variations in Plant Use Strategies in the Midwest During the Late Woodland." In *Late Woodland Societies: Tradition and Transformation across the Midcontinent,* 37-76. Edited by T.E. Emerson, D.L. McElrath, and A.C. Fortier. Lincoln: University of Nebraska Press.

Smith, Maria Ostendorf, Katie J. Kurtenbach, and Jacqueline C. Vermaat. 2016. "Linear Enamel Hypoplasia in Schroeder Mounds (11HE177): A Late Woodland Period Site in Illinois." *International Journal of Paleopathology* 14, (September): 10-23. doi: 10.1016/j.ijpp.2016.04.005.

Smith, Maria Ostendorf, and Katharine C. Woollen. 2020. "Tibiotalar and Metatarsophalangeal Squatting Facets in a Late Woodland Period Context in West-Central Illinois." *Bioarchaeology International* 4, no. 1: 57-74. doi: 10.5744/bi.2020.1003.

Souza, Anne D., Vrindi H. Ankolekar, S. Padmashali, Anusuya Das, Antony Sylvan D. Souza, and Mamatha Hosapatna, M. 2015. "Femoral Neck Anteversion and Neck Shaft Angles: Determination and their Clinical Implications in Fetuses of Different Gestational Ages." *Malaysian Orthopaedic Journal* 9, no. 2 (July): 33-36. doi:10.2519/jospt.2009.2996.

Sparacello, V.S., O.M. Pearson, A. Coppa, and D. Marchi. 2011. "Changes in Skeletal Robusticity in an Iron Age Agropastoral Group: The Samnites from the Alfedena Necropolis (Abruzzo, Central Italy)." *American Journal of Physical Anthropology* 144, no. 1 (August): 119-130. doi: 10.1002/ajpa.22650.

Specht, William J. 1995. "Dental Health as an Indicator of Subsistence Patter and Cultural Affiliation: The Schroeder Mound Burials". Doctoral Dissertation, Southern Illinois University, Carbondale.

Tardieu, Christine, and Erik Trinkaus. 1994. “Early Ontogeny of the Human Femoral Bicondylar Angle.” *American Journal of Physical Anthropology* 95, no. 2 (October): 183-195.

Tavares, Joao O. 2012. “Differentiating Subluxation from Developmental Dislocation of the Hip.” *Orthopedic Reviews (Pavia)* 4, no. 1 (January). doi: 10.4081/or.2012.e7.

Tayton, Edward. 2007. “Femoral Anteversion: A Necessary Angle or an Evolutionary Vestige?” *Journal of Bone and Joint Surgery* 89, no. 10 (October): 1283-1288. doi:10.1302/0301620X.89B10.19435.

Trinkaus, Erik. 1976. “The Evolution of the Hominid Femoral Diaphysis During the Upper Pleistocene in Europe and the Near East.” *Zeitschrift fur Morphologie und Anthropologie* 67, no. 3: 291-319.

Ubelaker, Douglas H. 1974. *Reconstruction of Demographic Profiles from Ossuary Skeletal Samples: A Case Study from the Tidewater Potomac*. Washington: Smithsonian Institution Press.

Ubelaker, Douglas H. 1979. “Skeletal Evidence for Kneeling in Prehistoric Ecuador.” *American Journal of Physical Anthropology* 51, no 4: 679-686. https://doi.org/10.1002/ajpa.1330510417.

Waxenbaum, Erin B., and Michala K. Stock. 2016. “Variation in the Human Bicondylar Angle.” *American Journal of Physical Anthropology* 160, no. 2 (March): 334-340. https://doi.org/10.1002/ajpa.22972.

Weiss, Elizabeth. 2017. *Reading the Bones: Activity, Biology, and Culture.* Gainesville: University Press of Florida.

Wilk, Elizabeth E. 2014. “Lower Limb Posturing Behavior in Western Tennessee: An Analysis of Knee and Ankle Pressure Facets”. Master’s thesis, University of Indianapolis

Wilson, Diane, and Timothy K. Perttula. 2013. “Reconstructing the Paleodiet of the Caddo through Stable Isotopes.” *American Antiquity* 78, no. 4 (September): 702–723.

Witte, Hartmut, Holger Preuschoft, and Stefan Recknagel. 1991. “Human Body Proportions Explained on the Basis of Biomechanical Principles.” *Zeitschrift fur Morphologie und Anthropologie* 87, no. 3 (April): 407-423. https://www.jstor.org/stable/25757327.

Woollen, Katherine C., and Maria Ostendorf Smith. 2017. “Adult Food and Ankle Trauma at Schroeder Mounds (11He177): A Late Woodland Period Site in Illinois.” *Field Notes: A Journal of Collegiate Anthropology* 9, no. 1 (June): 32-52. https://dc.uwm.edu/cgi/viewcontent.cgi?article=1058&context=fieldnotes.

Yadav, Priti, Marta Pena Fernandez, and Elena M. Gutierrez-Farewik. 2021. “Influence of Loading Direction Due to Physical Activity on Proximal Femoral Growth Tendency.” *Medical Engineering and Physics* 90, (April): 83-91. https://doi.org/10.1016/j.medengphy.2021.02.008.

Yerkes, Richard W. 2005. “Bone Chemistry, Body Parts, and Growth Marks: Evaluating Ohio Hopewell and Cahokia Mississippian Seasonality, Subsistence, Ritual, and Feasting.” *American Antiquity* 70, no. 2: 241–65. doi: 10.2307/40035703.

Yin, Yingchao, Ruipeng Zhang, Lin Jin, Shilun Li, Zhiyong Hou, and Yingze Zhang. 2018. “The Hip Morphology Changes with Ageing in Asian Population.” *BioMedical Research International*, (September): 1-6. https://doi.org/10.1155/2018/1507979.

Yoshioka, Yuki, Derek V. Cooke. 1987. “Femoral Anteversion: Assessment Based of Function Axes.” *Journal of Orthopaedic Research* 5, no. 1: 86-91. doi: 10.1002/jor.1100050111.

Zaghloul, Ahmed, and Mohamed Mohsen Elalfy. 2019. “Hip Joint: Embryology, Anatomy and Biomechanics.” *Biomedical Journal of Scientific & Technical Research* 12, no. 3 (December): 9304-9318. doi: 10.26717/BJSTR.2018.12.002267.

Zalawadia, Ankur, Srushti Ruparelia, Shaival Shah, Dhara Parekh, Sureshbhai P. Rathod, and Samir V. Patel. 2010. “Study of Femoral Neck Anteversion of Adult Dry Femora in Gujarat Region.” *National Journal of Integrated Research in Medicine,* 1, no. 3: 1-5. https://njirm.pbworks.com/f/4femoral_neck_antiversion.pdf.