THE VALIDITY OF MORPHOLOGICAL FEATURES AND OSTEOLOGICAL MARKERS IN RECONSTRUCTING HABITUAL ACTIVITIES

A DISSERTATION
Presented to the
Faculty of the Graduate School
University of Missouri-Columbia

In Partial Fulfillment
of the Requirements for the Degree

Doctor of Philosophy

---

by
Ahmad Y. Abu Dalou

Dr. Robert A. Benfer, Jr., Dissertation Advisor
Dr. Daniel J.Wescott, Dissertation Co-Advisor

May 2007

The undersigned, appointed by the Dean of the Graduate School, have examined the dissertation entitled

THE VALIDITY OF MORPHOLOGICAL FEATURES AND OSTEOLOGICAL MARKERS IN RECONSTRUCTING HABITUAL ACTIVITIES

Presented by Ahmad Y. Abu Dalou

A candidate for the degree of Doctor of Philosophy

and hereby certify that in their opinion it is worthy of acceptance.

____
Dr. Rober A. Benfer, Jr.

____
Dr. Daniell Wescott

____
Dr. Carol Ward

____
Dr. Raymond Wood

____
Dr. Kay Libbus

ACKNOWLEDGMENTS

First and foremost I would like to thank my advisor and committee chair, Dr. Robert A. Benfer, Jr., who did make this dissertation possible. His knowledge and experience strengthened my education and research skills. I also thank Dr. Daniel J. Wescott, my co-advisor. He provided me with many useful articles and valuable sources of information on biomechanical studies on North American skeletal populations.

I thank Dr. Carol Ward for being generous with her time and knowledge. She was always pointing to essential concepts and raising important questions.

I give great thanks to Dr. Ray Wood who provided me with very useful references on North American Archaeology and Missouri Archaeology.

I also thank Dr. Kay Libbus from Sinclair School of Nursing for her time and valuable Comments. Special thanks are due to Dr. Terrance J. Martin, Curator and Chair of Anthropology, and Dawn Cobb, Illinois State Museum for allowing me to borrow skeletal populations from their institution and temporarily curate them at the Museum Support Center of the University of Missouri-Columbia. Special thanks for the employee of the University of Missouri Museum Support Center. Those materials were essential for my dissertation.

I appreciate so much my colleagues: David McBride and Keith Chan for editing my dissertation. Finally, I strongly thank every member of my family and friends here and in Jordan, who were supportive to me throughout my undergraduate and graduate studies.

ABU DALOU, AHMAD Y., Ph.D., May 2007

THE VALIDITY OF MORPHOLOGICAL FEATURES AND OSTEOLOGICAL MARKERS IN RECONSTRUCTING HABITUAL ACTIVITIES

DISSERTATION SUPERVISOR: ROBERT A. BENFER, JR.

KEY WORDS: biomechanics, anterior femoral curvature (AFC), physical activity, entheses, modeling, remodeling

ABSTRACT

Bony morphological features have been used to reflect biomechanical behavioral patterns among archaeological populations. Of most recent ones is the anterior femoral curvature (AFC). It has been proposed as a valid indicator for mobility and differs by subsistence strategy and sex. This study aimed to investigate how AFC and mobility index vary by subsistence strategy and sex.

It showed that degree of AFC decreased significantly from Woodland to the Mississippian period. People of Woodland, who practiced hunting/gathering or horticulture, displayed greater degree of AFC than the agriculturists of the Mississippian. In addition, anterior femoral curvature showed statistical significant difference by sex. Males, who walked and ran more than females, showed greater degree of femoral curvature than females in both periods.

When variation in anterior femoral curvature by continent was tested, it significantly differed between North Americans and South Americans because of strong genetic differences. For that reason, anterior femoral curvature is good indicator for terrestrial logistic mobility (TLM) among homogenous skeletal population, and reflecting genetic differences between differed genetic groups.

CONTENTS

LIST OF TABLES

CHAPTER TWO

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

CHAPTER SIX

CHAPTER SEVEN

LIST OF FIGURES

CHAPTER ONE

CHAPTER TWO

CHAPTER FOUR

CHAPTER FIVE

CHAPTER SIX

CHAPTER SEVEN

CHAPTER ONE

BIOMECHANICAL MODELS AND INFERENCE OF ACTIVITIES AMONG SKELETAL POPULATIONS

One goal of bioarchaeology is reconstruction of life-ways of past populations from a biomechanical analysis of skeletal remains. One approach to this goal is to test the archaeologically and ethnographically hypothesized habitual behaviors against biological signatures. If validated, these reconstructions can then be applied to a variety of archaeological questions, such as where were the origins of intensive agriculture or whether socioeconomic class differences are identifiable in skeletal signatures. Because people's activities were more closely related to their subsistence practices in the pre-industrial past, anthropologists are able to reconstruct changes in habitual patterns from changes in bone morphology that are associated with a shift from one subsistence practice to another (Bridges, 1991; Wescott, 2006). It is well known that specific physical activities during pre-adult life shape some of the morphological features and leave permanent markers on the skeleton. Unfortunately, the same skeletal marker might result from a variety of causes such as genes and hormonal influences. But the influence of these intervening variables can be diminished by employing a comparative research design, one in which the identification of the same relation between the ethnographically and archaeologically suggested habitual behaviors and the hypothesized skeletal response is studied in a variety of settings and time periods, thereby reducing the risk of misidentification of cause and effect due to more local factors. While some previous research used the biomechanical approach to focus on changes in activity patterns and bone morphology that took place as a result of shifting from hunting and gathering to agriculture, especially in North America (Bridges, 1989, 1991; Larsen et al., 1994; Wescott, 2001, 2006), others investigated the evolutionary trend over a longer period of time (Pearson, 2000; Holt, 2003).

This research has two foci. First, it focuses on bone morphological changes that resulted from shifting from hunting-gathering to agriculture in North America. Secondly, the research explores the differences in bone morphology among Native American populations in South America who practiced farming and those whose subsistence practice mainly was fishing, but who varied by ethnic group. In both cases, the peoples are assumed to have genetic similarity and both groups and their analytical subdivisions by subsistence or ethnic group lived in the same environment. Thus, the present research focuses on a combination of morphological features present in long bones to test hypotheses of their variation as due to specific behavioral activities and mobility by controlling other variables that have also influence on shaping and development of morphological features by studying genetically related or distant populations. Specifically, the indicators proposed here are measures of anterior femoral curvature, its external shape at the midshaft and subtrochantric region, and entheses associated with the femur and tibia.

The biomechanical approach is one in which researchers assume a certain functional model of bone (Ruff, 1992) in order to understand and explain the relation between two variables: bone morphology and stress results from performed activity (Ruff, 1992; Bruns et al., 2002; Weiss, 2004; Eshed et al., 2004). Existing research shows that various morphological features and osteological markers can be explained by mechanical usage, and in some cases specific activities that leave specific signatures on bones. These patterns that result from repeated behavioral activities during life include shape properties of long bones (Benfer, 1990; Wescott, 2006), geometric properties of cortical bone in long bone diaphyses (Ruff and Hayes, 1983; Larsen and Ruff, 1991; Wescott, 2001; Holt, 2003), osteoarthritis (Ortner, 1968; Merbs, 1983), articular surfaces of joints (Ubelaker, 1979; Pechenkina and Benfer, 2002), dimensions of long bones and robusticity (Trinkaus, 1984; Bridges, 1991), femoral neck-shaft angle (Zopac, 1983; Trinkaus, 1993), femoral neck structure (Ven der Meulen, 2000), degree of anterior femoral curvature (Bruns et al., 2002), enthesopathy (Dutour, 1986; Hawkey, 1988; Robb, 1994; Hawkey and Merbs, 1995; Sperduti, 1997: Churchill and Morris, 1998; Steen and Lane, 1998; Weiss, 2003, 2004; Eshad et al., 2004), degenerative joint disease (Sperduti, 1997), Schmorl's node (Sheridan and Steadman, 2003), and trauma (Robb, 1997).

Biomechanical approach is widely used to reconstruct terrestrial logistic mobility (TLM). Terrestrial logistic mobility can be defined as the total distance walked or ran by the individual or the group from place of residence to the field or territory to forage (Wescott, 2006). Biomechanically, TLM can be represented as mobility index. It is the ratio of anteroposterior diameter to mediolateral diameter at femoral midshaft (e.g., Bass, 1995). Studies showed that mobility index differs significantly across archaeological populations with different and known subsistence practices from the archaeological records and ethnographic data (Ruff, 1987, Stock and Pfeiffer, 2001). The mobility index will be further discussed in the next chapter.

Additional biomechanical measures have also been widely used to estimate the TLM. These include cross-sectional geometric properties of femur (Wescott, 2001; Holt, 2006), femoral neck-shaft angle (Trinkaus, 1993; Anderson and Trinkaus, 1998), and anterior femoral curvature (Shackelford and Trinkaus, 2002). So, morphological features have been widely and intensively used to reconstruct TLM and other habitual activities among skeletal populations.

In spite of the wide use of the biomechanical approach to the study of behavioral patterns within the bioarchaeological community, it has been strongly criticized (e.g., Jurmain, 1999; Demes et al., 2001; Lieberman et al., 2004; Zumwalt, 2006)). Jurmain argues that this kind of anthropological research, which attempts to infer activities from skeletal populations, is biased, because skeletal morphological features are multifactorial. In other words, many factors such as genetics (Garen et al., 1964; Ferrari, 2004), hormones (Schuelke et al., 2004), diseases and diet (Bonjour, 2005) have a significant role in determining bone morphology. Two or more of these may interact with each other and result in the final phenotypic pattern displayed by the skeleton.

Jurmain believes it is almost impossible to single out one factor, or partition these factors roles in shaping these bony morphological manifestations, and/or infer behavioral activities. In other words, activity pattern is ambiguous as registered on skeleton micro- and macro-biological features. Jurmain's strong criticism extends beyond using a single indicator and includes the multiple indicators approach. He maintains that the use of a combination of many morphological features to infer specific activity is weak and does not strengthen the degree of precision claimed by some members of bioarchaeological community, because each of these indicators independently is also weak (Jurmain, 1999). Finally, Jurmain urges bioarchaeologists to abandon this methodological approach completely. Arguing from modern studies of experimental biology, Jurmain ignores advantages of studying prehistoric peoples where the range of activities was more limited within a society and ranges of activities among societies were manifestly greater than is the pattern in modern industrial societies.

Experimental biologists that the utilization of the biomechanical model to infer broad habitual activities from cross-sectional geometry has problems. On a Japanese macaque, Demes et al. (2001) showed that the neutral and the bending axes formed an angle ranges from 30º - 40º, not zero. Lieberman et al. (2004) showed that the neutral axes do not lie exactly in the same plane in which the bone is subjected to bending, which affects significantly the value of the calculated SMA_s.

However, it has been argued that the use of multiple indicators does in fact further improve inference (Wilson, 1998), because "confidence in any particular inference will be enhanced when a number of indicators point in the same direction with respect to stress or produce results predicted by one indicator from another" (Benfer, 1990: p. 289); I argue that the comparative approach, in combination with the use of multiple indicators, can be used to test archaeologically and ethnographically hypothesized behavioral models. If, for example, multiple indicators hypothesized to be expected from fishers are found in widely separated prehistoric societies with archaeological signatures of fishermen, it becomes difficult to reject their association with subsistence fishing activities despite the influence of other factors.

This research aims to develop a model of behavioral activities based on ethnographic and archaeological records and test how these are reflected in skeletal remains. Moreover, these ethnographical and archaeological records provide us with valuable information about social stratification, division of labor, age at which individuals engaged in various tasks of subsistence economy, and differences in labor between sexes.

Skeletal markers or morphological features influenced by muscle use are, of course, affected by the expression of genes in particular habitat and in the case of prehistoric humans, especially with particular patterns of subsistence. For example, it is well known that anterior femoral curvature is low among South Americans and African-Americans, presumably as a result of a genetic component (Stewart, 1962; Gilbert, 1976). However, the investigation of the degree of variability within genetically closely related populations is another question of primary interest to bioarchaeology. Since these populations are genetically related, any variability is more likely due to different activity patterns rather than the segregation of genes. It has been long known that American Indians are genetically and morphologically very homogenous for such a widespread population (Stewart, 1973). Studies of both modern and ancient DNA confirm that Native Americans are much more homogenous than are European, Asian, or African populations (Cavalli-Sforza, 2000). Thus, American Indians provide an ideal setting where genetic differences are minimized while at the same time demonstrating a very wide range of subsistence practices and social divisions. Differences in femoral diaphysis shape between North and South American populations permit estimation of the among- group genetic variance component for this characteristic (Singh and Singh, 1972). Different stress during growth and development will in any case affect skeletal indicators, and different but genetically related populations with similar subsistence practices should show similar skeletal responses, while more distant populations might be expected to show differences even with similar subsistence practices.

The development process by which bone remodels and/ or models against repeated stress is complex. However, by selecting skeletal samples in which the activity patterns are well known from the archaeological and ethnographic data (e.g., activities of genetically closely related peoples, some of whom are coastal and others, farmers from inland agricultural villages), it may still be possible to observe the relative importance of development and genetics in the expression of bony response to activities. The influence of habitual activities in prehistoric, reproductively isolated populations, as is typical for prehistoric sedentary peoples, can be assessed. Interpretable variation within such populations by sex, class, or age would provide further evidence for linking behavior to bony response. In prehistoric populations identified by archaeology, variability in behavior among different subsistence groups is probably stronger in influencing bony response than in modern times where activity differences are orders of magnitude less and genetic variability is much greater. For these reasons, criticisms based on modern clinical studies may be exaggerated. Clinically focused studies are unable to consider the range of human behavior and its relative homogeneity in prehistoric societies.

Studies that focus on understanding the relations between bone morphological features and osteological markers on one hand, and functions on the other that are performed mainly before maturity fall into at least two natural groupings based on the kinds of questions that scientists try to answer, and the methodology that is exploited. One group focuses on bioarchaeological questions, to relate ethnographic data and archaeological records on one hand, and the biological evidence on the other. The second group, experimental biology (e.g., Jurmain, 1999) contains studies that aim to test the impact of exercise on bone morphology among smaller organisms that are less affected by gravity, such as birds (Biewener and Bertram, 1993), rats (Tipton et al., 1975; Lanyon et al., 1979; Robling et al., 2000, 2001; Burr et al., 2002; Järvinen et al., 2003), and Japanese macaques (Ruff and Runestad, 1992; Demes et al., 1991, 2001), sheep (Zumwalt, 2005), horses (Biewener, 1983; Fratzl et al., 1995), and pigs (Popwics et al., 2002; Woo et al., 1981), roosters (Rubin and Lanyon, 1984; Matsuda et al., 1986), dogs (Laros et al., 1971; Tipton et al., 1975), rhesus monkeys (Noyes et al., 1974), in the laboratory. The approach is to manipulate and quantify the independent factor, exercise, in terms of time and the amount of resulted strain, and then test its impact on the dependent factor, bone morphology. Since weight and posture are obviously important factors in skeletal development, it is possible that these studies are not very pertinent to understanding human variation.

In spite of the difference in methodology, the clinical and archaeological approaches benefit from each other, but the opportunities for research differ. Clinical studies focus on better controlled biographical and experimental studies whereas bioarchaeology takes advantage of the comparative approach in the study of a much broader range of behavioral activities. One way that bioarchaeological studies can benefit experimental biological studies arises from the opportunity of the former to examine the extremely wide variety of human experiences in the past, so much greater than differences today available to clinical or experimental approaches. By screening a number of indicators, it may be possible to find candidate markers of specific behaviors such as femoral midshaft shape (Larsen and Ruff, 1991; Ruff, 1994, 1999; Wescott, 2001, 2006) and entheses (Dutour, 1986; Sperduti, 1997). From this comparative work in natural laboratories, then, investigators might proceed with studies of experimental animals as well as modern humans toward testing hypotheses and establishing etiologies of markers. Thus, it is proposed that the criticisms of Jurmain (1999), for example, are actually fundamentally flawed, since the direction of research suggested is exactly the opposite of the more productive one in which bioarchaeology finds candidates for experimental investigation rather than vice-versa. This screening by bioarchaeology is more efficient than experimental biology with a research design that includes genetic and environmentally populations. The environmental differences are developed from ethnographic and archaeological findings (Fig.1.1). The present research focuses on a combination of measures of anterior femoral curvature, femoral external shape at the midshaft and subtrochantric region, and entheses of femur and tibia to test hypotheses of their variation as due to specific behavioral activities, by controlling other variables that also have influence on shaping and development of bony morphological features.

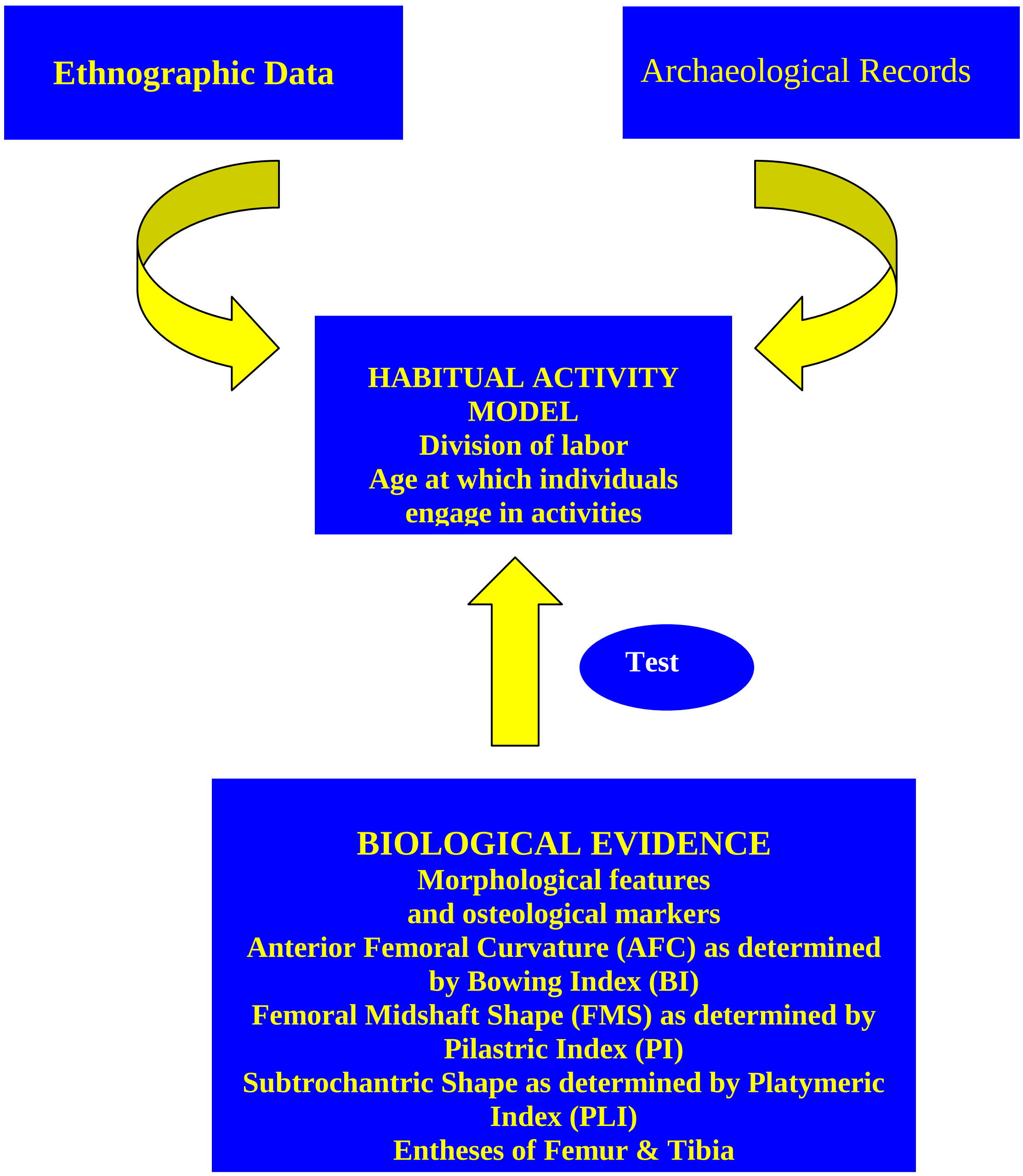

Fig. 1.1. The approach that is used in this research.

1. 1. Research Hypotheses

This bioarchaeological study exploit the biomechanical approach to test how many morphological features of femur and some of the lower limb entheses relate with walking and running hypothesized from subsistence practices. There are many specific hypotheses for this study. These are listed below:

North America

1. Femora of people of Woodland should be more curved femora of people of Mississippian period. This is because Woodland people were more mobile.
2. Femoral midshaft shape (FMS) of people of Woodland should be more elongated in the A-P plane than of people of Mississippian period.
3. Entheses of gluteus maximus other major lower limb muscles of Woodland people should be more developed than of Mississippian people. These muscles are important in running and walking.
4. The degree of anterior femoral curvature and shape of femur at the midshaft and entheses of gluteus maximus and other main muscles should be significantly correlated because both are influenced by walking and running.
5. Significant sexual dimorphism degree should be displayed by these morphological features within each archaeological period. More explicitly, due to the greater division of labor, Missisipian femora should display more sexual dimorphism.

South Americans

To test the following models:

1. **Pechinkina and Delgado's (2006): Coastal (Deformed) vs. highlanders (Un deformed)**

   Highlanders exhibit higher degree of anterior femoral curvature and more elongated femoral cross-sectional shape in (A-P) than (M-L) plane than people who were from the coast.

2. **Rhode's (2006): Fishermen (Deformed) vs. Farmers (Undeformed)**

   Farmers exhibit higher degree of anterior femoral curvature (AFC) than fishermen because of plowing.

   Farmers display more elongated femoral cross-sectional shape at the midshat in the (A-P) than (M-L) than fishers because they walked and ran longer.

Pooled: South Americans and North Americans

1. South Americans display higher degree of anterior femoral curvature than North Americans because of genetic and environmental differences.
2. South Americans exhibit more rounded cross-sectional midshaft femoral shape than North Americans.
3. While South Americans have more elongated femoral diaphysis in (A-P) than (M-L) at the subtrochantric (stenomeric), North Americans are equally shaped in both directions (eurymeric).

CHAPTER TWO

BIOMECHANICAL RESPONSE OF BONE TO BEHAVIOR

This chapter reviews the biological processes that determine the various architectural characteristics of shape, size, density, robusticity, and geometric distribution of bone. I will also review beam theory, which can be used to measure various biomechanical properties of strength of the bone. The adaptive response to mechanical use of bone will be considered from the perspective of Frost's magnitude of strain model as well as the strain rate hypothesis (Robling et al., 2000).

2.1. Functions of Bone

Bone is a biologically, physiologically, and mechanically dynamic structure (Nording and Frankel, 1989). Bone's unique structure enables it to play a crucial role in several mechanical functions, so its structure and function are inseparable. Bone can be divided by metabolic and structural functions (Rosse and Clawson, 1980). These functions include mechanical support, protection of vital tissues, hematopoiesis, and mineral homeostasis, and can also be used to categorize bone function (Martin and Burr, 1989). Another major function is to provide rigid kinematic links for motion (Nordin and Frankel, 1989). Bone does this by providing attachments sites for ligaments, muscles, and tendons for effective locomotion (Rosse and Clawson, 1980; Nordin and Frankel, 1989; Skerry, 2000). Bones thus function as levers (Currey, 1984) and resist gravitational forces. In addition, bones have the ability to resist the impact of mechanical loads that result from performing specific behavioral activities, which otherwise would damage soft organs or tissues, such as heart, lungs, and bone marrow (Skerry, 2000). Bone must be sufficiently strong to resist or repair the occurrence of fatigue fractures or microdamage that may result from repeated imposing of specific loads (Martin and Burr, 1989). It must also resist occasional extreme loads.

The skeletal system houses and protects the brain. Spongy bone between the inner and outer tables of the skull separates dense cortical bone. This architecture maximizes the capability to absorb energy associated with projectile and blunt trauma (Martin and Burr, 1989). Moreover, the protecting role of bone extends to other vital internal organs such as the uterus (Nordin and Frankel, 1989; Skerry, 2000; Wescott, 2001).

Bones are physiologically and metabolically active. They store minerals, especially calcium and phosphorus, but also magnesium, sodium, fluoride, phosphorous, and other elements (Khan et al., 2001; Wescott, 2001). Ninety-nine per cent of calcium available in the human body is stored in the skeletal system (Martin and Burr, 1989). The vertebral column is an especially large reservoir for calcium and phosphate ions and has a central role in their homeostasis (Triffitt, 1980). Calcium ions in particular are necessary for other physiological processes that take place within other body systems, such as clotting of blood, transmission of impulses within the nervous system, and function of the heart. In addition, bones contain the hemopiotic cells and fat (Skerry, 2000). As a result of bone's high metabolic level, the skeletal system stores dangerous heavy metals such as after ingestion, after they are removed from the bloodstream.

2.2. Biomechanics of Bones

It was suggested over a century ago that there is a close relation between bones' morphological features and the functions they perform (Roux, 1881; Wolff, 1892). In other words, bones have some ability to adjust their morphological features of shape, size, density, and geometric distribution in response to the amount and direction of mechanical forces that are imposed on them (Roux 1881; Wolff, 1892). Earlier work by Galileo, the father of mechanics, introduced these kinds of interpretations (Martin, 1999). Wolff and Roux hypothesized that bone is shaped by loads, but he did not develop a model to explain clearly how both function and form are related. Subsequent studies that attempt to develop such models are divided by their methodology into experimental approaches (e.g., Lanyon, 1980; Woo et al., 1981; Hamrick et al., 2000; Demes et al., 2001; Zumwalt, 2006), clinical approaches (e.g., Donaldson et al., 1970), studies of occupational medicine (e.g., Plotkin, 1987), and bioarchaeological investigations of the range of variation available in prehistory (e.g., Ruff and Hayes, 1983; Larsen and Ruff, 1991; Wescott, 2001). But others argued against Wolff' law (e.g., Zumwalt, 2005, 2006). Zumwalt (2006) compared six limb and one masticatory muscle attachment sites between exercised and sedentary female sheep. She assessed these attachments using 3D surface area. Her study showed none of the entheses was influenced by the exercise.

There are many physiological processes that occur within highly vascular living bone, which enables bone to alter its macro- and micro-architectural features to respond to the demands of loads when micro- or macro-damage occurs (Fung, 1993). These processes include modeling and remodeling of bone, which will be discussed later in this chapter. Factors which influence these two processes may include variation in the expression of genes, variation in diet, as well as endocrine levels and biomechanical stresses (Jurmain, 1999; Wescott 2001; Nordström et al., 2005). Body mass, body proportions, habitual postures, and types and levels of behavioral activities can also influence mechanical stresses during activities (Ruff, 1992). How biomechanical loads stimulate modeling and remodeling and how that is reflected on both bone micro- and macro-structural features are the focus of many bioarchaeological studies.

Biomechanical stresses influence both modeling and remodeling of bone. In other words, skeletons have the ability to respond to mechanical stresses, which enables them to perform various functions without failure or micro-damage (Fung, 1993). Bones' functional ability or phenotypic plasticity, in which they adjust to various types of stress, will be discussed in greater detail below. This process begins during the prenatal period, and continues postnatally, through puberty and even later stages of life (Skerry, 2000).

There are many mechanical loads that may be imposed on bone that would result in alterations in external shape, as well as internal distribution of bone around the neutral axis. Bone density may also change in response to mechanical stress. Mechanical stress can be divided into bending, compression, tension, and torsion or twisting, and combinations of stresses (Currey, 1984; Nordin and Frankel, 1989; Skerry, 2000). These mechanical loadings result mainly from the action of muscles attached to skeletal elements (Frost, 1982, 1987, 1997, 1998; Martin and Burr, 1989; Nordin and Frankel, 1989; Ruff, 1992). Body mass is a major factor in the development of muscle attachment areas (Weiss, 2004).

Response to mechanical loads on some limb bones can be treated as similar to the effect of different loadings on beams. Mechanical engineers developed a mathematical model of mechanical relations, beam theory, to calculate the loads placed on relatively homogeneous cylindrical materials.

By treating long bones as if they were hollow, symmetrical tubes, bioarchaeologists are able to adopt beam theory in order to analyze mechanical loads that might be imposed on bone. Specific activities that might produce mechanical forces during habitual activities can be modeled by beam theory.

A long bone, however, is not a homogeneous tube. The heterogeneous properties or structural dissimilarities of long bones make somewhat problematic the direct application of this model in skeletal studies (Nordin and Frankel, 1989). Therefore, an understanding of bone morphology is essential for interpreting the results of such studies.

In addition to the geometrical distribution of compact bone within a diaphysis, shape at the midshaft and subtrochantric region as determined by externally measured dimensions, bone density, curvature, femoral neck-shaft angle, and entheses, or bony response to musculature provide additional indicators for the study of variation in human activity information about stress and behavioral patterns (Ruff, 1987, 1992; Bridges, 1991; Wescott, 2001; Weiss, 2004). These additional indicators may help resolve some of the problems inherent in the use of an overly simplistic geometric model of bones whose complex shape and use are affected by the application of multiple stresses from different muscles and gravity. Should one not observe a strong correlation between muscle development and measures of strength developed from geometry, then further study would be necessary in order to understand the limitations of both methods. However, significant correlations among bone geometry, curvature, and entheses would support the beam theory interpretation. One might expect some agreement and some disagreement, which would point to further research opportunities.

The following terms have to be defined: stress, strain, strength, and rigidity. Stress is the amount of load per unit. Strain is the amount of deformation that is caused by stress. Strength is the ability of bone to resist load. There are different modes of stress. Each will be dicussed in details below.

2.2. 1. Tension

Tension or tensile loading results from stresses that are applied in opposite directions away from the surface of a structure (Fig.2.1a). As a result of this kind of load, linear microstrain occurs when bones lengthen and become narrower. Microscopically, when a magnitude of tensional load is large enough to bring bone to the failure point, tissues are pulled apart at the cement lines and osteons are distorted in shape (Brinckman et al., 2002).

2.2.2. Compression

This mode of load is the opposite of tension. It is characterized by placing a load on the surface of the structure (Fig.2.1b). Bones will tend to strain linearly, which means bone reacts to compression by becoming shorter and wider. At the level of microstructure of bone, osteons will be damaged, when load reaches the failure point.

2.2. 3. Torsion (Twisting)

This mode of mechanical twisting stress is imposed parallel to the structure's surface (Fig.2.1c). The internal structure of bone is strained angularly, not linearly. Moreover, this kind of load may also result when bone is subjected to tension or compression. The amount of this torsional load is proportional to the distance of the outer surface from the central longitudinal neutral axis, the centroid of the bone (Martin and Burr, 1989).

2.2. 4. Bending

This mode of mechanical load causes bone to bend on an axis (Skerry, 2000) (Fig.2.1d). Bone is less able to respond to bending stress than compression, tension, or torsion (Nordin and Frankel, 1989). When bone is subjected to bending load, bending is converted into two modes:

compression and tension. While compression acts on one surface of the neutral axis, tension is exerted on its opposite. The amount of this mechanical loading, as in torsion, is proportional to the distance from the neutral axis. That means its amount is higher and bone gets stronger when bone is added further away from the neutral axis (Fung, 1993). In practice, bone is almost always subjected to more than one force during movement.

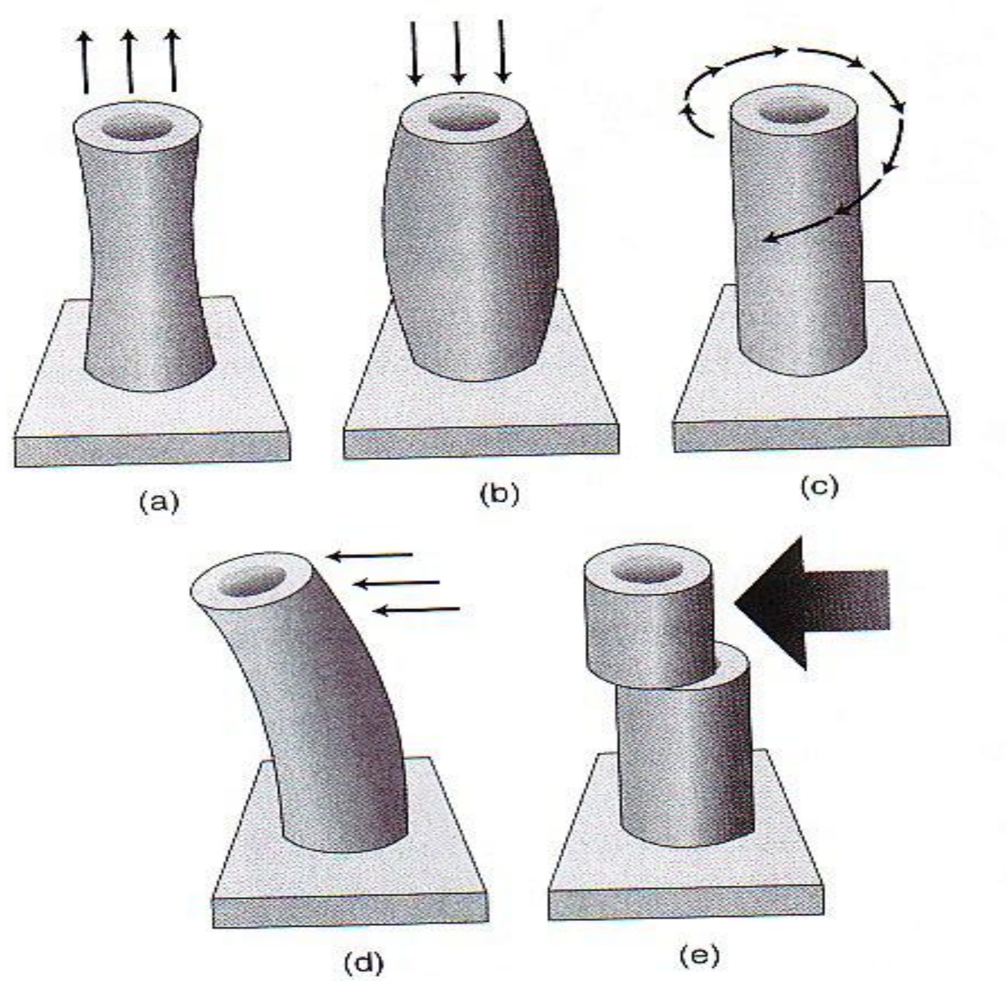

Fig. 2.1.Modes of load imposed on hollow beam: a) tension; b) compression; c) torsion; d) bending; e) shearing (*After Ornter and Putschar, 1981*).

2.3. Biological levels Influenced by Mechanical Loadings:

There are two biological processes responsible for growth, development, maturation, health, maintenance, and strength of a skeleton. These are modeling and remodeling (see Table. 2.1), which are stimulated by the mechano-sensitivity mechanism of bone to mechanical loadings.

2.3.1. Bone Modeling Dynamics

Modeling is defined as the process responsible for modifications of internal and external bone shape and size (Ogden, 1980). Modeling can be divided into two phases: resorption of existing bone by osteoclasts, and formation of new bone by osteoblasts. In long bones, osteoclasts remove bone from the endosteal surface, and osteoblasts add the same amount of bone on the periosteal one. Modeling is very active during early growth, declines with age, and terminates at maturity (Frost, 1980; Ogden, 1980). Frost (1997) mentions that modeling can be stimulated among individuals as old as 30 years when their skeleton is subjected to massive amount of mechanical loading. This process reaches its peak during the adolescent growth spurt. This is a time when nearly 100 per cent of the bone's surface is active (Broadhurst, 2001). Modeling strengthens bone under various kinds of mechanical loadings by increasing length, width, weight, and density, and how bone is distributed geometrically around the neutral axis.

2.3.2. Bone Remodeling Dynamics

This process plays a crucial role in maintaining and reorganizing lamellar bone when it is formed by the final modeling process during growth (Frost, 1980). This process is an ongoing one throughout subsequent human life. It repairs bone that has experienced fatigue fracture or microdamage from the repeated imposing of loads (Frost, 1973) or from a single catastrophic load (Pechenkina and Benfer, 2002). In contrast to modeling, this process does not usually influence length, width, density, weight, or geometric properties of bone and only 20% of bone surface is active at any one time (Broadhurst, 2001). Osteoclasts remove the micro-damaged bone, which is followed by laying down a newly formed bone by the osteoblasts.

The three major phases of remodeling are activation, resorption, and formation (ARF) of bone cells (Robling et al., 2006) can be divided into six phases, which occur in a cycle in which formation always follows resorption on the same bony surface. The stages within these three phases can be further divided into the sequence: activation→ bone resorption→ reversal→ bone formation→ mineralization → and quiescence (Martin and Burr, 1989). The process of remodeling or ARF is responsible for formation of secondary osteons, which are also called bone multicellular units (BMUs), over a period of about four months (Frost, 1997). Remodeling is not uniform within a cross section of femur and tibia of adult individuals (Drapeau and Streeter, 2005).

TABLE. 2.1**.** *The differences between two osteogenic processes: remodeling and modeling (After Frost 1980; Ogden 1980; Broadhurst 2001).*

Activity	**Bone Remodeling**	**Bone Modeling**
Local coupling	Formation and resorption are coupled	Formation and resorption are not coupled
Timing and sequence activity	Cyclical: A[1]-RS[2]-RV[3]-F[4]-M[5]-Q[6]; Formation always follows resorption	Formation and resorption occur continuously in separate bone surfaces, not in the same bony surface.
Extent of surface activity	Only 20% of surfaces are active	100% of surfaces are active
Function	Skeletal maintenance and repair	Gain in skeletal mass increase in bones length, width, and changes in geometric distribution of skeletal material

[1] Activation, [2] Resorption, [3] Reversal, [4] Formation, [5] Mineralization, and [6] Quiescence

2.4. Frost's Magnitude of Strain Theory "Mechanostat"

Since Roux (1881) and Wolff (1892) formulated their general functional adaptation model of bones, many theories have been attempted to explain how bone morphological features and function are specifically related. The most recent ones are Frost's theory (Frost, 1987), the mechanostat, and the frequency of load model (Robling et al., 2000). The mechanostat, in contrast, focuses on the magnitude of load.

In Frost's theory, the magnitude of strain is considered the critical stimulus in stimulating the mechano-sensitivity process of bone, which causes bone to detect and transform mechanical loadings into signals. After receiving appropriate signals, bone responds by modeling and/or remodeling dynamics based on the amount of strain.

Frost (1983a, 1983b, 1983c, 1987, 1988, 1997, 2003) developed his theory, the most recent version of which suggests that, given that the developing skeletal system is homeostatic, it must respond to strain, the response to which activates modeling and/or remodeling to alter the macro- and/or micro-architecture of bone. The mechanostat is similar to a thermostat that is available at home, which responds to temperature signals by switching power "ON" or "OFF".

The mechanostat is comprised of three components. These are (1) bone itself, (2) mechanisms that are responsible for transforming mechanical loadings into specific signals, and (3) other mechanisms. These operate together in order to enable bone to detect signals and determine which of three biological processes: bone growth, modeling, and remodeling, should operate in response to the signals and meet the demands of the mechanical force.

If the load causes a strain that exceeds the minimum effective strain (MES) as measured in microstrains, modeling is activated and results in strengthening bone. This level falls in the range between 800-4000 microstrains. Although modeling traditionally refers to changes during growth, Frost (1997) argues that even in individuals as old as 30 years, large mechanical loadings produced by muscle action, and which exceed MES, are able to stimulate the modeling process, and enable bone to continue to respond to mechanical forces. This means that bone curvature and entheses could continue to be affected in adult life by habitual activities.

The MES value required to turn remodeling “ON” differs from that of modeling. When this value exceeds the remodeling MES value, 50-100 microstrains, bone will be removed and the same amount of new bone will be laid down. But when strain falls below 50 microstrains, remodeling will be switched “OFF.” In the disuse mode, which occurs when a limb is immobilized or strain is below value of minimum strain, the result is increasing bone leading to bone loss.

Frost (1997) argues that the mechanostat provides a biomechanical explanation for why marathon runners have less bone than weight lifters. This explanation is embodied in the premise of the mechanostat theory, that magnitude of load is the most important factor, not rate of repetition, in determining bone size, density, and other morphological features. Weightlifters tend to have big, strong muscles, which impose very large mechanical loadings on bone during practice or competition. Weight lifting results in increased muscle size and strength, and is most effective when practice begins early in life, during years of growth and development. Skeletal muscles convert adenosine triphosphate (ATP) into mechanical loadings sufficient to cause strain that exceeds MES and switches modeling “ON”, which then increases bone mass and strengthens bone. If the same amount of stress is imposed again after the increase in bone mass, the same load will produce a strain value close to the lower limit of MES. For that reason, and as a result of strong and large muscles, weightlifters have large and strong bones.

On the other hand, runners have smaller and weaker muscles than weightlifters. The kinds of activities they perform do not result in large increases in muscle size. When their muscular activities cause a strain that lies within or above the microdamage threshold range, remodeling will be switched on and will repair the microdamages that have taken place. Runners do not increase their bone size and strength by modeling because the amount of mechanical forces imposed on their skeleton does not cause enough value of strain that approaches the range of the modeling threshold.

2.5. Strain Rate Theory

Robling and colleagues, in series of experimental biological studies done on rats (2000, 2001, 2002a, 2002b) argue that, for the much smaller rate, frequency rather than magnitude of load, as implied in the mechanostat theory, is responsible for stimulation of osteogenic response to form bone and strengthen its structure.

Robling et al. (2000) tested the impact of more frequent and shorter bending load trials on bone mass by imposing 360 bending cycles/day delivered in 1,2,3,4, or 6 bouts over the three days of loadings on right tibias of 36 adult female Sprague Dawley rats. Robling et al. concluded that a total of 360 bending cycles are more effective stimulus for bone formation when partitioned into 60 cycles in six trails and/or 90 cycles in four trials interval than they are when imposed in one bout.

A similar conclusion was reached by others. Burr et al. (2002) concluded also that higher rates of mechanical loadings stimulate the osteogenic response more effectively, even if the duration of these activities is short. Length of the recovery period between the sessions of imposing mechanical loads has also great impact on the level of the osteogenic reaction to load.

In 2001, Robling et al. showed that length of recovery periods between bending cycles are also important for bone to regain its mechano-sensitivity. When recovery periods are longer, endocortical surface histomorphometric measurements for right (loaded) and left (unloaded) tibiae exhibited higher values of bone formation rates, a difference of more than 100%, among the study subsample who were subjected to 8- hour recoveries than those who were subjected to NO and 0.5- hour recovery periods. In addition, results showed that measurement of biomechanical and structural properties of bone among those who were subjected to 14-second recovery periods is higher than those rats who were subjected to 0.5-, 3.5-, or 7- second recovery periods.

In terms of length of the recovery period, Robling et al. concluded that an eight-hour recovery period improves the ability of bone to regain its mechano-sensitivity, although even periods as short as 14 seconds helped. Resting results in strengthened bone resistance under mechanical loadings by enhancing the capability of bone formation. In subsequent research, Burr et al. (2002) concluded that that a 4-8 hour recovery period is enough time for osteogenic cells to regain their sensitivity to external mechanical loadings. It should be noted that rats are much less influenced by gravity than are humans. Compressive forces are much more important, suggesting the size and shape of lower limb should be more influenced than those of the upper limbs for bipedal, large animals such as *Homo sapiens.*

2.6. The Biomechanical Model – Beam Theory

As mentioned above, long bones can be conceptualized as hollow beams, and as a result of that, physical anthropologists borrow this model in order to address many questions of bioarchaeological interest. The goal of these studies is to measure the results of loads that might be imposed on bones. From these data, the parameters of the bony cross-section, we can hypothesize that certain specific activities might have produced these loadings. These hypotheses can be tested if they are predictions for prehistoric populations whose activities can be inferred from the archaeological and ethnographic data. For example, transformation from one economic strategy to another, such as shifting from hunting and gathering to agriculture, can be examined for predicted variation in some of the bone morphological features. Since activities vary in repetition and possibly magnitude of episodic but strong load, responses should vary more widely among prehistoric peoples than among peoples today, and were probably less variable within any one population. Data from skeletons may provide critical tests of hypotheses as to the causes of observed variation in the size and shape of bones.

Cross-sectional geometry has been used to measure hypothesized loadings with archaeological materials. These studies mainly used cross-sections of femur (Wescott, 2001; Holt, 2003) and of humerus (e.g., Rhodes and Knűsel, 2005). However, these methods have been criticized as having inherent problems (Demes et al., 2001; Lieberman et al., 2004). Other anthropological studies use long bones' externally determined midshaft shape (e.g., Wescott, 2005), degree of anterior femoral curvature (Bruns et al., 2002), and entheses (Weiss, 2004; Rhode, 2006), to reconstruct specific activities among prehistoric skeletal populations.

Experimental biologists argue that broad behavioral interpretations based on long bone cross-sectional geometry is problematic, and they emphasize the importance of experimental data on strains, which show how bones behave under actual loadings. Lieberman et al. (2004) measured strain distributions at the midshaft of tibia and metatarsal of sheep running on a treadmill at 1.5 m/sec. Results of this study show that the neutral axis of bending in this quadruped does not pass through the center of the midshaft. In addition, the neutral axes do not lie in the same plane in which the bone is subjected to bending. As a result of mislabeling the neutral axes in calculating various cross-sectional geometric measures for sheep, the calculated values of SMAs ($I_{max.}$) are much higher than of those when the actual axes are used. Study on macaque by Demes et al. (2001) shows that while the neutral axis, which is used to calculate cross-sectional measures, runs mediolaterally, the plane of bending loading runs from anterolateral to posteromedial. Both planes, the neutral and the bending, form an angle between the two with ranges between 30°-$40,^{\circ}$ rather the expected zero degrees. Whether these criticisms from quadrupedal animals apply with any force to the straighter femur of bipedal humans is unclear.

Strength of bone under bending can be also estimated from the shape of long bones at the midshaft (Ruff, 1987; Wescott, 2006). The ability to resist bending can be divided into that which resists bending in the mediolateral direction and that which resists bending in the anterioposterior direct. A ratio is measured of bone strength in the anterioposterior direction (I_x) to its strength in mediolateral direction (I_y) (Bridges, 1989; Ruff, 1987; Larsen and Ruff, 1991; Holt, 2003) is used to measure overall strength. This ratio has been called the mobility index. Ruff and associates found that the I_x / I_y ratio is a good and reliable indicator for mobility. When the mobility index is close to 1.0, bone strength in both planes is the same, as we would expect with low mobility. With low mobility, lower long bones resist compressive forces best when they approach the form of a cylinder, which would result in a ratio of one. A ratio greater than 1.0 indicates that bone strength under bending in the anterioposterior (A-P) direction is higher than M-L, as would result from physical activities such as running and walking for long distances, because the bone has responded to bending stresses by redistributing bone along the A-P direction.

The mobility index has been used by many researchers to test terrestrial logistic mobility and compare it across bioarchaeological populations differing in their subsistence practices (e.g., Ruff, 1987; Wescott, 2006). Ruff (1987) investigated mobility index value among two subsistence groups: hunter-gatherers and horticulturists in North America. His study showed that value of I_x/I_y is greater among the former than among the latter. Morphologically, hunter-gatherers display more elongated femoral midshaft shape in A-P planme than horticulturists.

Although these studies show the importance of research into cross-sectional geometry, I will consider just one indicator in this preliminary investigation.

These properties are obtained when the anterior curvature of femora remains constant. Below, I will show that changes in curvature, which, regardless of mobility, would also affect the distribution of cortical bone at the midshaft. More femoral curvature enables bone to resist bending and torsional forces during walking or running long distances.

In the present study, I will validate the mobility index in hominids by measuring its correlation with femoral curvature. If these results are promising, the curvature and entheses approach can be applied to the full range of indicators available from beam studies of limb bones. Before describing the present approach more fully, it is necessary to consider factors other than habitual activities that can affect any indicator of activity.

2.7. Genetics and Bone Morphology

Genetic components are considered intrinsic factor that contributes to cross-sectional bone morphology. In terms of the amount of compact bone, there exists a significant difference between Americans of European descent and those having an Asian ancestry (Garen et al., 1964). The amount of cortical and cancellous bone is greater in black than white Americans (Han et al., 1996). This significant difference across various ethnic groups may be due to differences in the rate of bone turnover, which may be controlled by genetic components (Garen et al., 1964). Ferrari (2004) stated that heritability explains 80% of variation in bone mass within a studied population. Of course, heritability varies with gene frequency and environmental conditions. In smaller, more inbred populations studied by bioarchaeologists, fixation can occur, enhancing the effect of environmental factors.

It is possible that a genetically controlled portion of variation in bone turnover can have an impact on the development of entheses, sites where muscles attach to bones (Rogers et al., 1997). Moreover, turnover rate might have an impact on cross-sectional geometry of long bones (Jurmain, 1999).

2.7.1. Genetics and Anterior Femoral Curvature (AFC)

Another measure of bone morphology, anterior femoral curvature, may also be influenced by genes. Population variation in femoral curvature exists. Aleš Hrdlička had suggested to T. Dale Stewart that black Americans have straighter femora than white and Native Americans do (Stewart, 1962). Stewart developed a method and measured the degree of anterior femoral curvature among 35 American Indians, 35 white Americans, and 35 black Americans (Stewart, 1962). All the individuals were males. Stewart showed that black American males have the longest femora and the least degree of curvature, white Americans have the shortest femora with intermediate curvature, and American Indians have intermediate femoral length and the greatest amount of curvature. North American Indians' femoral length is intermediate and more curved when contrasted with European femora (Walensky, 1965). Femoral curvature shows variation among Western Hemisphere populations. African-Americans and South Americans have the least curved femora (Walensky, 1965). Femoral curvature has been used forensically to distinguish African Americans from other Americans (Gilbert, 1976; Finnengen, 1978; Ballard and Trudell, 1999).

2.7.2. Genetics and Entheses

Entheses may also be influenced by genetic variation (Wilczak, 1998). In addition, they may be associated with genetic disorders as well as disease and trauma. For example, generalized entheses with calcification of tendons and ligament insertions are prevalent among patients with inherited hypophosphatemic osteomalacia (Polisson et al., 1985). However,

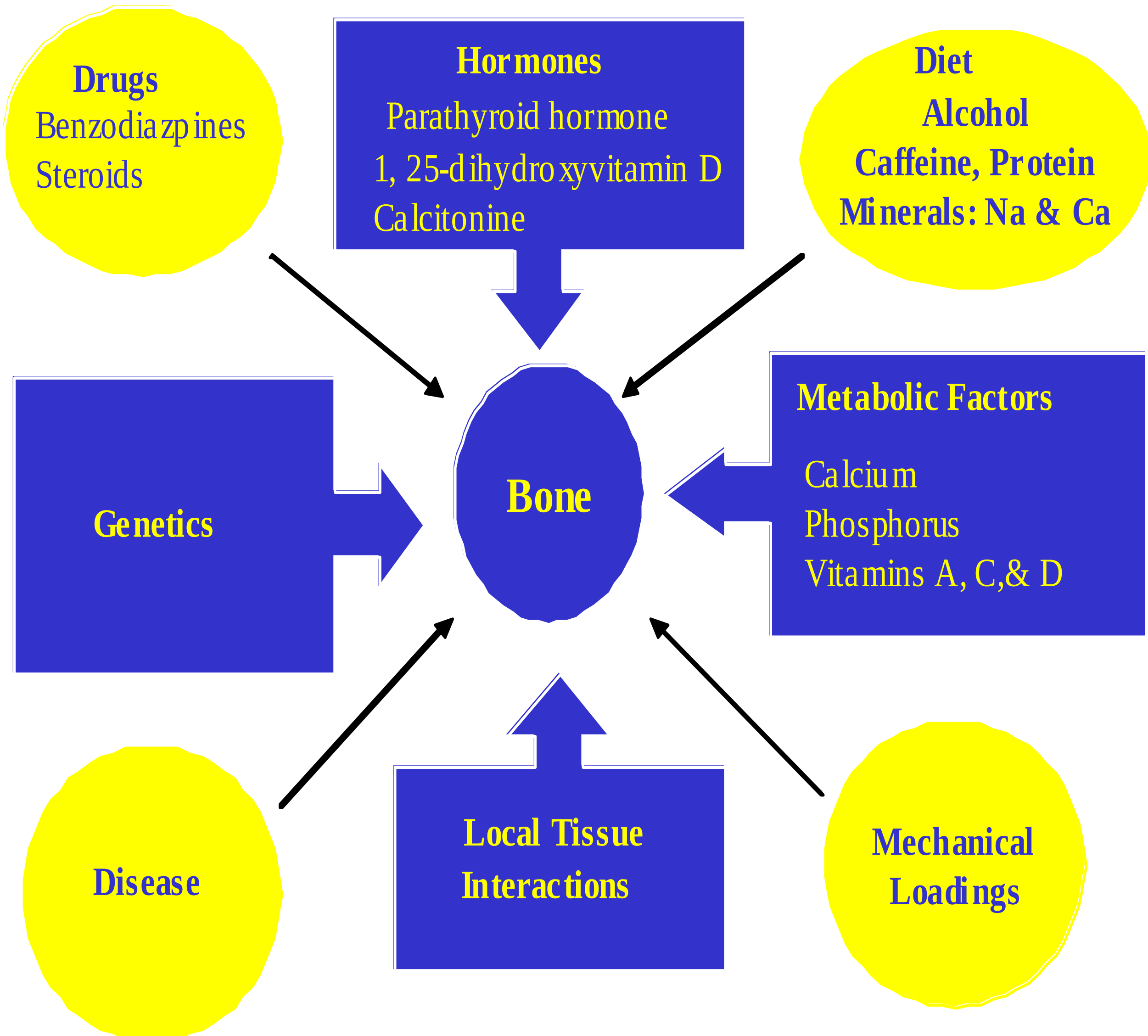

Fig. 2.2. Internal and external factors that influence macro- and micro- morphological features of bone.

genetic diseases are relatively rare. Variation in health and nutrition, especially in prehistory, is likely a much more powerful factor in bone morphology, where skeletal populations are too small to reflect some genetic disorders, which, even if recessive, would be readily removed by selection in more inbred populations.

2.8. Health, Nutrition, and Bone Morphology

Nutrition is considered to have an impact on bone density, mass, and micro- and macro-morphological features (Bonjour, 2005). These nutrients include minerals, vitamins, and protein. Minerals, which play a crucial role in bone structure, and necessary for maintaining purposes, comprises calcium, phosphorus (Ilich et al., 2000), sodium (Khan et al., 2001), magnesium (Ryder et al., 2005), and fluoride. The second nutritional category includes vitamin D, which does influence calcium metabolism. Vitamin D deficiency would be unlikely for peoples whose lives were more outdoors where exposure to the sun was strong. Calcium is considered the most important nutrient for bone growth, maintenance, and strength. Besides health and nutrition, the endocrine system can also affect bone morphology.

2.9. Hormones and Bone Morphology

Hormones, secreted by the endocrine system, regulate bone formation and resorption, which in turn influences bone density, weight, geometric distribution, amount of bone, and ultimately modulate bone macro- and micro-architecture. Influences of parathyroid hormone (PTH), 1, 25-dihdroxyvitamin D_3, and calcitonine (Norman, 1980) on bone formation and resorption are discussed below.

2.9.1. Parathyroid hormone (PTH):

Parathyroid hormone, which is secreted from cells of the parathyroid glands, is considered the most important hormone to have an impact on the skeletal system. This endocrine hormone regulates concentration of calcium and phosphorous in extracellular fluid. Cells of the parathyroid glands are activated and secrete parathyroid hormone when the serum level of calcium falls below the normal range. As a result, parathyroid will bring calcium concentration to the normal range by three physiological complementary processes (Chiras, 2003).

The first physiological process targets the skeletal system that stores the majority of the calcium. PTH acts in order to liberate calcium from the skeleton by activating the osteoclasts, which reabsorb calcium and release it into the bloodstream.

In the second process, PTH indirectly increases the serum level of calcium through Vitamin D. Vitamin D activates the production of calcium-binding protein, which absorbs calcium from the small intestines and releases it into the bloodstream.

While in the first two physiological processes, parathyroid acts to elevate calcium level by mobilizing it from other organs, in the third it elevates calcium level by decreasing the excretion in urine. Parathyroid hormone does that by stimulating the tubular reabsorption of calcium or increasing excreting of phosphate ions in the urine.

2.9.2. 1, 25-dihydroxyvitamin D_3 (Calcitriol)

Calcitriol is 1, 25 –dihydroxyvitamin D_3 or 1, 25 $[OH]_2$ vitamin D_3, the active form of vitamin D (Melvin and Luttge, 1982). Because of the biochemical differences between calcitriol and other vitamins, it is not considered an actual vitamin. Additionally, calcitriol can be obtained by exposure to sunlight and humans and does not require a dietary source. Calcitriol is actually a steriod hormone with many crucial functions (Nussey and Whitehead, 2001). These include a regulatory role in calcium and phosphorus metabolism and processes which affect bone mineralization and growth (e.g., Melvin and Luttge, 1982). To understand its various roles, especially in the skeletal system, it is important to understand vitamin D structure and synthesis.

Vitamin D_3 or cholecalciferol is the result of a process that starts when a precursor molecule, 7-dehydrocholestrol, in skin absorbs sunlight (Melvin and Luttge, 1982). But this form of Vitamin D and D_2 have no biological value in terms of playing a role in bone metabolism or other physiological processes. Because of that, D_3 has to be processed further biologically, in order to become an active hormone (Nusssey and Whitehead, 2001). The process of physiological transformation of $D_{3,}$ which modifies Vitamin D_3 into an active hormone, takes place in the liver and kidneys.

The physiological transformation that occurs in the liver hydroxylates cholecalciferal to 25-hydroxycholecalciferol by enzyme known as 25-hydroxylase
(Nussey and Whitehead, 2001). This step is followed by a second, physiological one that occurs in the kidneys.

In the kidneys, 25-hydroxycholecalciferol (25-hydroxy vitamin D_3) will be transformed into the active form of vitamin D, 1, 25-dihydroxycholecalciferol (1, 25-dihydroxy vitamin D_3). This form of vitamin D is present in all human cells and has many key roles in the body, including a significant role in the differentiation process of most body cells, growth of bone, and metabolism of calcium and phosphorous.

Its role in calcium metabolism is mostly in the intestines, where it facilitates calcium absorption, and the absorption of phosphate and magnesium. So as a hormone, Vitamin D has a crucial role in the initial phase of these minerals, calcium included, metabolism.

Vitamin D performs this function by stimulating the production process of some proteins (Nussey and Whitehead, 2001). These proteins have a marked impact on the process of calcium absorption by the intestinal walls and being transported into the blood stream. Because of that, Vitamin D deficiency has crucial physiological consequences in the human body and the skeletal system in particular.

When serum concentrations falls below the normal range because of poor nutrition, the available Vitamin D will not perform the process of calcium absorption and transportation into the bloodstream efficiently. Vitamin D goes beyond this physiological stage into advanced stage, where it does have significant roles within bone itself. It stimulates the production of osteocalcin, suppresses production of type I collagen, and stimulates the differentiation process of osteoclasts.

2.9.3. Calcitonin

This hormone plays an important role in the metabolism of calcium and phosphorus. It is secreted by specific cells, known as C cells, which are anatomically located in the thyroid glands. Its physiological effect counteracts the parathyroid hormone effect (Gard, 1998). While calcitonin decreases the calcium level in blood stream, PTH increases it. Calcitonin is able to counteract physiological influence of PTH by acting on two anatomical organs: bone and kidneys (Melvin and Luttge, 1982). In the skeletal system, calcitonin inhibits the osteoclasts' mechanism of resorption of bone minerals, calcium and phosphorus in particular. In the renal system, calcitonin prevents kidneys tubules from reabsorbing calcium and phosphorus, which results in elevating the concentration of these minerals in urine. External factors can activate these hormonal processes. These factors can be related to climate, with which bone morphology is known to vary.

2.10. Climate and bone morphology- Cold Climate vs. Warm Climate

Some skeletal morphometric features of Neandertals and early modern humans can be explained in terms of the vigor of biomechanical loads imposed on the skeleton during habitual activities. Pearson (2000) and Weaver (2003) argue totally different scenarios. They interpreted these morphological differences in terms of climatic adaptation.

The premise of their interpretation is mainly based on differences between modern populations living in cold environments and those living in warm environments. While those who live in cold climates tend to have short limbs and wide bodies, warm-climate people tend to be tall with narrow bodies. This pattern of geographic variations (Allen's Rule) in body size and shape was similar among early humans as well (Ruff, 2002). Weaver (2003) argued that the difference between Neandertals' femoral cross-sectional shape and that of near-modern humans can be interpreted as secondary to differences in climate-induced body propositions.

In spite of an emphasis on role of habitual activities in the differences between diaphyseal and epiphyseal robusticity, Pearson (2000) showed that variations in postcranial robusticity among recent humans correlated with climate.

2.11. Age and Bone Formation:

The age at which individuals start to engage in various habitual activities is an important and crucial factor for bone formation. Mechanical loadings result from performing various behavioral activities stimulating bone formation, especially when they are imposed during years of growth. These activities are more effective in stimulate osteogenic formation when performed during periods of rapid growth, when bone is characterized by a domination of periosteal growth rather than endocortical (Jurmain, 1999; Bass et al., 2002). These results in adding bone further away from the central or the neutral axis will strengthen the bone as measured by the formulae presented above.

Age and its impact on bone formation have attracted the attention of many researchers in sports medicine and experimental biology. Jones et al. (1977) tested the influence of age on humeral asymmetry among juvenile tennis players. Their data were analyzed by Trinkaus et al. (1994), who showed that the age at which exercise started was the only factor significantly affecting humeral asymmetry. Moreover, at about 8 years of age, the maximum degree of asymmetry was shown to be reached, and after that, no change occurred in the playing arm.

Bass (2002) tested the effect of mechanical loadings on size and shape of long bones among pre-, peri-, and post-pubertal girl tennis players. Bass showed that the playing arm of the prepubertal group displayed 11-14% greater bone mineral content (BMC) in the dominant arm than in the other, but there was no increase in asymmetry among peri- and postpubertal players, confirming the studies of Trinkaus et al. (1994).

Other studies have shown that bone will also respond to a load from habitual physical activity later in life. Greene et al. (2005) found that 16 year old, female middle distance runners who trained for 8-9 hours per week showed higher cortical bone volume, volumetric cortical, cross-sectional moments of inertia, and bone strength indices in distal tibiae than a 16 year old control group, who trained 2 hours/week.

In addition to bone formation being markedly influenced by age, possibly into adolescence, bone loss also is influenced by age. Mays (2001) showed that bone starts thinning because the amount of bone resorbed endosteally is greater than bone apposed periosteally, after middle age among a male skeletal population from 18-19th century.

The above discussion has shown that there are many possible factors that could influence anterior femoral curvature, and the shape of femoral diaphyses at the midshaft and subtrochatric region, as determined by external dimensions and entheses. A multivariate approach is required to understand them.

2.12. Multiple Indicators (Holistic) Approach

A multiple - indicators approach will be used in this study. This multivariate approach unites many morphological features and osteological markers that will be exploited to test specific hypothesized behaviors. The indicators are anterior femoral curvature, femoral midshaft shape (FMS), shape of femoral diaphysis at the subtrochantric region, and entheses, all adjusted for age and body size. In non-experimental studies, consilience among a variety of at least partially independent indicators is required for confirmation of a hypothesis (Wilson, 1998). These indicators will be used to evaluate the secular trend associated with the transition, mainly, from hunting-gathering to agriculture and differences among ethnic groups that were primarily either fishermen or agriculturists. In addition, these indicators will be used to infer changes in level of terresterial logistic mobility (TLM) among homogeneous archaeological populations that practiced different subsistence economies. After that, the evolutionary trend over a longer period of time, from Neandertals to modern humans, will be discussed using the multiple -indicators approach.

2.12.1. Anterior Femoral Curvature (AFC)

Anterior femoral anterior curvature is a recently suggested indicator of biomechanical stress (Bruns et al., 2002). The femur itself is important in both bioarchaeological and forensic contexts. In the forensic community, while "race" is mostly determined based on the cranium, analysis of anterior femoral curvature is also utilized for the same purpose (Finnegan, 1978). The degree of observed anterior femoral curvature (Stewart, 1962; Walensky, 1965; Gilbert, 1976; Ballard and Trudell, 1999) varies somewhat with the "racial" affinity of an individual.

For this reason, it has been assumed by Stewart (1962), Walensky (1965), and Ballard and Trudell (1999) that femoral curvature is determined largely by ancestry and other factors play only minor roles. On the other hand, it may be that other factors, which influenced the growing bone during childhood and adolescence, also play a crucial role in determining the degree of the curvature, since the childhood experiences of racial groups may have differed substantially in activity, diet, and disease. Cultural differences may be as strong as or stronger than genetic differences.

Singh and Singh (1972) investigated the degree of femoral curvature (Bowing Index) and the location of the maximum curvature, the Position Index (POI), of femora among 140 Indians from Varnasi, India. One hundred two of the study sample were males, the remainder females. Singh and Sing also compared femoral curvature degree and Position Index found in other studies. They showed that femora of Varnasi males are the shortest and have the highest degree of curvature. The femora of Varnasi females were the shortest, most curved, and the maximum point of curvature is located close to the distal end (except for American Indians), while the males are the shortest, most curved, and showed the most distal location of the point. Femora of both Varnasi sexes are close morphologically to those of Inuit. There was no significant sexual dimorphism or bilateral asymmetry in the morphological features in the Varnasi samples.

In contrast to using population variability to explain femoral curvature, as Singh and Singh did in the example presented above, more recent research argues that femoral curvature is also determined by intensity of physical activity within genetically relatively homogeneous populations, in part, in response to mechanical loads during growth and development (Bruns et al., 2002; Shackelford and Trinaus, 2001; 2002).

Bruns et al. (2002) have investigated the curvature of femora among two genetically homogenous Scottish populations, one from the 14^{th} and 15^{th} centuries, and the other from the 20^{th} century. Study shows that femoral curvature in the 20^{th} century is less than that of the medieval population. They ruled out genetics as playing a major role in determining the curvature degree, and assumed that urbanisation with reduced mobility is more important. People in the 20^{th} century were more settled and less mobile, and modern lifestyles produce less curvature. Since the populations are relatively genetically homogeneous and related as ancestral-dependent groups, the influence of genetics has been minimized in their study.

Over a larger time span, Shackelford and Trinkaus (2001, 2002) have investigated the change in femoral curvature from Neandertals to recent humans. They found that there is a decrease in the degree of femoral curvature after the last glacial advance, which may be due to a decrease in mobility. These and other studies used cross-sectional geometry as a proxy for bone strength**.**

2.12.2. Femoral Midshaft Shape (FMS)

Bones strength and/or mechanical properties of bones do not depend on density and composition only, but they depend also on the geometric distribution of the material (Fung, 1993). For that reason, physical activity, as registered in the geometry of long bone diaphyses, and geometry itself, is widely used to reconstruct the physical activity of a bioarchaeological population (Brock and Ruff, 1988; Holt, 2003). Biomechanically, to calculate the level of terrestrial logistic mobility (TLM) that is defined earlier, the mobility index has been widely used by members of the bioarchaeological community (Larsen and Ruff, 1991; Larsen et al., 1994; Ruff, 1994, 1999; Stock and Pfeiffer, 2004; Stock, 2006; Wescott, 2001, 2006). However, much research shows that bone geometry is determined by many factors that interact. These comprise body size, nutrition, genetics, hormonal disturbance, disease, physical activity, and age –related osteoporosis (Bridges, 1989; Trinkaus et al., 1994; Wescott, 2001), and experimental studies on animals show that mechanical forces have an important role in shaping the geometry of bones. In this study, we use femoral midshaft and subtrochantric external shape to characterize archaeological samples by groups with validation possible from observing significant relations with anterior femoral curvature and possibly entheses and external measurements of shape and size. These indicators should also reflect activity patterns, which have been extensively studied by this approach.

Ruff (1987) investigated mobility index values among two subsistence groups: hunter-gatherers and horticulturists in North America. His study showed that value of I_x I_y is greater among the former than among the later. Morphologically, hunter-gatheres displayed more elongated femoral midshaft shape in the A-P plane than horticulturists.

Brock and Ruff (1988) investigated femoral midshaft cross-sectional geometric distributions across three cultural periods in the American Southwest: Early Villages (A.D.500-1150), Abandoments (A.D.1150-1300), and Aggregated Villages (A.D. 1300-1540). The subsistence practices of these cultural periods are huntin–gathering, relocation and adaptation to different environments, and maize agriculture, respectively. Geometric distribution values, especially second moments of area increased temporally between Early Villages and Abandonments, and decreased between Abandonments and Aggregated Villages. The degree of circularity of femoral midshaft, as determined by I_x/I_y, also increased through time from Early Villages to Aggregated in both sexes. Brock and Ruff (1988) inferred that because of changes in activity level. Geometric properties values also indicate that the degree of sexual dimorphism decreases through time as a result of similarity in activity patterns. Finally, this study showed that people of the Abandonments period had least bone density, which may be explained as a result of malnutrition.

Following the pioneering work of Ruff and others, Wescott (2001) studied the geometric properties of humeri and femora among archaeological populations and medicolegal cases. The skeletal populations were from the Great Plains, the Great Basin, the Southwest, the Southeast, and the Texas Gulf Coast of the U.S.A. Although some data were obtained as external dimensions, he also used cross-sectional computed topography (CT) scans to investigate the distribution of bone within the external shape. The results of the study showed that while there was a significant level of homogeneity in both size and shape of humerus and femur of groups from the American Great Plains, the geometry of Northern Plains groups differed significantly from that of Southern Plains groups. Though both practiced the same subsistence, midshaft femoral geometry of the former groups was more platymeric and rounder than in the latter groups. The influence of mobility by riding horses may have been the critical factor. He showed that femora of equestrian groups were larger, more robust, and midshafts were more rounded than non-equestrian groups.

Other researchers use the result of divison of externally measured anterioposterior diameter (A-P) by mediolateral diameter (M-L) to determine the external shape of femur at midshaft (e.g., Wescott, 2006). Externally estimated femoral midshaft shape (FMS) has also been widely used to determine the level of terrestrial logistic mobility (TLM) because it is extremely sensitive to mechanical loads imposed on the femur during various habitual activities such as running, that activate modeling processes that modify bone morphological shape (Ruff, 1987).

Using African material, Stock and Pfeiffer (2001) assessed geometric properties of the clavicle, humerus, femur, tibia, and first metatarsal, and compared them in two skeletal populations, showing how upper and lower limbs varied. Samples came from the southern African Later Stone Age (LSA) and the 19th century indigenous Andaman Islanders (AI). While people of LSA were highly mobile foragers and did not depend on a marine economy, the historic group depended on marine resources, and their terrestrial mobility was restricted. Results of the study showed that while clavicles and humeri are stronger among Andaman Islanders fishermen, femora, tibia, and first metatarsals are stronger among the prehistoric African foragers.

2.12.3. Subtrochantric Shape

In addition to the shape of the femur at the midshaft, as determined by external dimensions, shape at the subtrochantric anatomical region, located directly below lesser trochanter has been intensively used in forensic and bioacrchaological contexts to determine ethnic affiliation of subadults and the level of physical activity within homogenous genetic archaeological population (e.g., Wescott, 2006).

The underlying reason why the shape at the femoral subrochantric region varies across different ethnic groups is explained by many researchers. Wescott (2006) shows that growth and development of the subtrochantric femoral region in the mediolateral (M-L) and anterioposterior (A-P) planes is completed early in life. Over the first 5 years of life, the proximal part of the femoral diaphysis, at the subtrochantric region, grows larger in the mediolateral plane than in the anterioposterior one. After the early childhood growth spurt (after 5 years of age), growth becomes equal in both anatomical growth directions, but does not eventually lead to a significant morphological change at the subtrochantric region. In addition to differences in growth patterns in both anatomical directions, subtrochantric femoral morphology is a highly inheritable genetic trait (Gill, 2001). For these reasons, this morphology has been commonly used with high level of accuracy to discriminate between various ethnic groups in the forensic setting (Gillbert and Gill, 1990; Gill and Rhine, 1990; Wescott, 2006).

Wescott (2006) investigated how subtrochantric femoral shape varies across subadults of Native-American, European-American, and African-American ethnic groups. The results of his study showed that while Native Americans have a platymeric subtrochantric region, European- and African-Americans display a more eurymeric subrochanter.

The same shape variation among adult populations across Native-American, European-American, and African-American has been reported (Wescott 2006). Wescott also reported that Native-American and Polynesian populations display more elongated subtrochanters in the mediolateral plane than European- and African-Americans.

Variation in subtrochantric morphological feature within homogenous populations has also been reportedly due to differences in subsistence economy and geographical variation (e.g., Wescott, 2006)).

In the present research, femoral midshaft and subtrochantric shape will be systematically compared with anterior femoral curvature and lower body activity. Since all of these indicators may respond to childhood and juvenile activity levels, these activities may have influenced the ligamentous attachment of muscles to long bones, so age-adjusted bony response to musculature will also be examined, and will be discussed in Methods and Materials below.

2.13. Entheses or Musculoskeletal markers (MSMs)

The bony responses to muscle activities from tendons and ligaments have been called entheses (Resnick and Niwayama, 1983), enthesopathies (Dutour, 1986; Jurmain, 1999), activity-induced stress markers (Hawkey and Street, 1992), or musculoskeletal stress markers (MSMs) (Hawkey and Merbs, 1995). I will refer to them as entheses. These bony lesions have been known in sporting and occupational medicine to be closely related with hyperactivity of muscles (Dutour, 1986). For that reason, some believe these markers should be informative of physical activity, and they have been widely used to reconstruct specific behavioral activities of bioarchaeological populations, and compare inter- and intra-population variation (Dutour, 1986; Kennedy, 1989; Hawkey and Street, 1992; Churchill and Morris, 1998; Steen and Lane, 1998; Capasso et al., 1998). Others mention that entheses are poor indicators for overall activity, although they may still be good indicators from which to infer specific activities (e.g., Bridges, 1997).

Because of the invisibility of entheses to clinicians, and since they have no serious impact on health, few clinical studies have been done to address various questions related to entheses and their etiology (Jurmain, 1999).

However, their etiology, like the other indicators discussed above, is multifactorial. A variety of systemic factors influence turnover rates of bone. These include the endocrine system and genetic sources of variation. Age, sex, activity level, rheumatic condition, such as spondylorthropathy and diffuse idiopathic skeletal hyperostosis (DISH), and dietary factors are non-systemic factors (Jurmain, 1999; Weiss, 2003, 2004).

Disease may also influence the development of entheses. This is clear from the term “enthesopathies” used by some researchers (e.g., Dutour, 1986), meaning “disorder of the muscular or tendinous attachment to bone” (Dorland, 1994, p. 561). For others, the development of these lesions is not considered pathological and musculoskeletal marker (MSM) is preferred, since the goal is to reconstruct normal activities from the development of specific bony lesions (Steen and Lane, 1998).

Entheses are difficult to use in reconstructing specific activities among skeletal populations (Robb, 1997) and require the solution of a number of associated problems. These include poor correlation with activity in experimental biology, and the lack of a relation between any single enthesis and cross-sectional geometry (Weiss, 2003). This lack could be due to scoring methods. Entheses may be too subjective to be scored and measured to reconstruct activities (Jurmain, 1990; Robb, 1997). But a number of scoring systems have been developed, some of which are less subjective (e.g., Hawkey, 1988; Hawkey and Merbs, 1995). I will use the Hawkey system, which was modified by Rhode (2001, 2006), in this study.

Although other factors may influence the development of entheses, Steen and Lane (1998) found that habitual activities were the strongest influence, and were able to reconstruct daily life among two Alaskan Inuit skeletal populations using entheses on the skull. The results demonstrated that Golovin Bay women used the pterygoid medialis and masseter muscles more than Nunivak women did. Ethnographic data indicated that Nunivak women did not chew skin on a daily basis, which corresponds well with the pattern observed among entheses in the two groups.

In another Inuit study, Hawkey and Merbs (1995) found sexual dimorphism in upper body muscular stress markers associated with marine hunting. The archaeological record is uninformative on this important economic difference, but the patterns correspond well with ethnographic reconstructions of Inuit lifeways. The upper body responds to a different set of stresses than the lower, so stresses are more related to work than locomotion.

Dutour (1986) examined entheses displayed by two Saharan Neolithic groups. The study showed that arms display three types of lesions, which may result from javelin throwing, wood cutting, and archery. Feet display two forms of entheses, one of them on the calcaneum. Sperduti (1997) found entheses on the calcaneus well developed among the population of Lucus Feroniae, a rural town of the Roman Imperial Age. Calcaneal lesions may result from walking and running on hard ground (Dutour, 1986).

Weiss (2003) found that while there is no correlation between any single upper body muscle marker and age, size, sex, and cross-sectional geometries, pooled entheses correlate significantly with age (r = 0.49; P < 0.001), size (r = 0.38; P <0.001), sex (r = 0.40; P < 0.001), and cross-sectional geometries (r = 0.38; P < 0.001). The highest correlation is between the aggregate entheses and age, which means that older individuals display greater bony lesions as the result of usage of their muscles over a long period of time and suggests that correlation for age may be necessary for comparative studies. In another investigation, Weiss (2004) found a similar pattern with pooled lower limb entheses. She found that entheses of muscles of lower limb correlated significantly with age (r = 0.61; P < 0.001), with size of the lower limb (r = 0.52; P < 0.001), and with sex (r = 0.49; P < 0.001). Moreover, entheses of muscles of lower limb differed significantly among the sexes between individuals those categorized as adult (20-30 and 30-40 years) and mature adults (over 40). A strong correlation (r = 0.69) also was found between entheses and age among Italian metal age pastoralists from Pontecagnano (Robb, 1997).

Bridges (1991) investigated the changes in external dimensions of the humerus, as well as other long bones, which accompanied changes in subsistence practices between the Archaic and Mississippian time periods in the Pickwick Basin area of northwestern Alabama. Results of her study showed that the Mississippian agriculturists had longer shafts of long bones, and they were more robust than those of the Archaic hunter-gatherers. While Mississippian men showed the strongest changes in their legs, women also differed between the two periods in both their arms and legs. Bridges concluded that these changes were a result of shifts in activities associated with changes in subsistence practices: Mississippian agriculturists lived a more physically demanding life after the adoption of maize agriculture than the non-agricultural Archaic hunter-gatherers. As a result the of new subsistence strategy, the division of labor shifted. Woman participated in new, strenuous food processing activities within their homes. In particular, increases in robusticity of Mississippians' arms were due to grinding corn. This role for women is known from ethnographic studies. But in another study, in west-central Illinois, the findings were quite different. Bridges et al. (2000) found that humeral strength increased between the Middle and Late Woodland periods, a time in which native seed crops were intensified. But during the Mississippian period, in which maize was adopted, women had less robust humeri. Bridges et al. (2000) suggested that this might be because maize is easier to grind than native hard seeds.

2.14. Gradual Decrease in Habitual Activity from Neandertals to Early Humans

Many biological features of the human skeleton have changed because of transitions from hunting-gathering to agriculture over short periods of time. In contrast to short-term change, many studies have also focused on the evaluation of evolutionary trends that have taken place over a much longer portion of human history, from Neandertals to modern humans. While some of these studies aimed to identify specific evolutionary questions, others aimed to figure out the underlying causes for such change. Both groups exploited various morphological features. These include anterior femoral curvature (Shakelford and Trinkaus, 2002), femoral neck-shaft angle (Trinkaus, 1993), robusticity of postcranial skeleton (Pearson, 2000), shape of femur at midshaft (Weaver, 2003), and femoral cross-sectional geometry (Trinkaus, 1997). Each will be discussed below.

2.14.1. Anterior Femoral Curvature (AFC)

Over a larger time span, Shakelford and Trinkaus (2002) have investigated the change in femoral curvature from Neandertals to recent humans. They found that there is a decrease in the degree of femoral curvature after the last glacial advance, which may be due to a decrease in mobility. These and other studies used cross-sectional geometry as a proxy for bone strength.

2.14.2. Cross-sectional geometry

In addition to anterior femoral curvature, the same trend toward activity reduction was concluded based on cross-sectional geometry of the humerus and femur (Trinkaus, 1997). He showed that some biomechanical measures indicated that loads the humerus was subjected to, declined toward more modern times from Eurasian late archaic, to Early Upper Paleolithic early modern, to Middle Upper Paleolithic humans. Moreover, study showed that measures of strength as calculated from femoral cross-sectional geometry decreased through the Middle Upper Paleolithic.

CHAPTER THREE

ARCHAEOLOGICAL PERIODS AND SITES

This study sample comprises bioarchaeolgical skeletal samples from North America and South America. The North American skeletal sample is divided into hunter-gatherers/horticulturists from the Woodland period, and intensive agriculturists from the Mississippian period. The ones from Woodland are from Elizabeth Mound and Modoc Rock Shelter from Illinois, and those from Mississippian are from Campbell site from Missouri. South American samples are from Villa El Salvador, Perú. Below, I will discuss the Woodland and Mississippian period. In addition, I will discuss the archaeological sites: Elizabeth Mound, Modoc Rock Shelter, Campbell, and Villa El Salvador.

3.1. North America

3.1.1. Woodland Period

Woodland was introduced to the North American archaeological literature in 1930s. This period is dated between ca. 2000 BC and 1000 AD. While there are many cultural traits distinctive to this archaeological period, others from the preceding period, the Archaic, continued into Woodland.

Fagan (1991) mentioned that there were many distinctive cultural traits that prominently marked the beginning of Woodland and differ it significantly from the Archaic period. These include pottery, native plant cultivation and interment under funerary mounds. Each of these will be discussed in more details below.

Fagan (1991) described these pottery containers as being crude, heavy, and took lot of time to make them. As the result of introduction of pottery a significant impact on Woodland people's lifestyle, the “Container Revolution” was introduced by the development of pottery and led to tremendous consequences during the Woodland period (Smith, 1986).

Woodland period can be divided into three subperiods. These are Early, Middle (300 B.C-A.D. 500), and Late Woodland (A.D. 500 – 1000) (e.g., Deel 1996).

Griffin (1978) mentioned that burial mounds of Early Woodland were a more prominent cultural trait after 500 B.C, and therefore most of the archaeological sites of Early Woodland are burial mounds (Fagan 1991). People of Early Woodland buried artifacts and modified bones with their deads.

Middle Woodland extended between 200 B.C and A.D. 500. People adopted a more sedentary lifestyle, depended more on agriculture, and their size increased. But they continued to have some of the cultural traits that were inherited from the Archaic period. They continued to use spears and atlatls. These trends also continued in Late Woodland. But they started to use the bow and arrow instead of spears and atlatls.

3.1.1. A. Elizabeth Mound

The majority of the Woodland skeletal materials used in this study were from Elizabeth Mound. It is located on the west side of the lower Illinois River. Buikstra et al. (1988) mentioned that materials were uncovered from the Middle/Late Archaic, Early Middle Woodland, and Late Woodland periods.

Buikstra et al. (1988) analyzed the Woodland skeletal materials and showed that the Middle Woodland skeletal collection displayed a high incidence of pathology.

3.1.1. B. Modoc Rock Shelter

Modoc Rock Shelter is located to the south and the east of the village of Prairie du Rocher, Illinois by two miles. Ahler (1992) mentioned that the importance of Modoc Rock Shelter to North American archaeology appeared in the late 1940_s. The excavation of this site continued until 1987.

Before 1987, the uncovered archaeological materials enriched archaeologists' understanding about subsistence strategies and technology mainly about Early and Middle Archaic. Most of the Late Archaic was revealed in 1987 excavation.

The skeletal materials used in this study were excavated in 1953 and 1956 by Melvin Fowler and his colleagues (Fowler and Winters, 1956).

3.1.2. Mississippian Period

While this period developed along the Mississippi river and its tributaries between A.D. 900 and 1700, it was more prominently developed between A. D. 1200 and 1500 (e.g., Deel, 1996). The Mississippian period or "The Third Moundbuilding Epoch" is an archaeological period in North America marked significantly by the existence of huge centers, such as Cahokia, which is located on the Mississippi River east of the City of Saint Louis.

Chapman (1980) developed a scheme in which he showed Missouri cultures or subsistence practices and archaeological pre-historical periods (Table 3.1).

TABLE 3.1**.** *Missourian subsistence practices and archaeological periods (After Chapman 1980; Walthall 1990).*

Subsistence Practices	**Time Period**
Early Hunting	Paleo-Indian (12000-8000 B.C)
Hunting-Foraging	Dalton (8000-70000 B.C)
Foraging	Early Archaic (7000-5000 B.C) Middle Archaic (5000-1000 B.C) Late Archaic (3000-1000 B.C)
Prairie-Forest Potter	Early Woodland (1000-500 B.C) Middle Woodland (500 B.C. – A.D. 400) Late Woodland (A.D. 400-900)
Farming	Early Mississippian (A.D. 900-1200) Middle Mississippian (A.D. 1200-1450) Late Mississippian (A.D. 1450-1700)

Others divid Mississippian or “The Third Moundbuilding Epoch” into many subperiods. Schaffer (1992) partioned the Mississippian period as follows: Cahokia (A.D. 700-1250), Major Spanish Invasions (A.D. 1513-1543), Poscontact Survivals (A.D. 1550-1731), and French Defeat Natchez (A.D 1731).

However, whatever the division is, there are many cultural traits that generally distinguish this period from the ones preceded it. These are building of huge mounds, manufacturing shell-tempered pottery, and planting maize intensively (O’Brien 1996).

3.1.2. A. Campbell Site

This archaeological site is located east of the town of Cooter. The archaeological work at Campbell started in January of 1954 and continued into 1968. All skeletal materials were uncovered by Leo Anderson and his wife, Mary Ellen.

Cole (1965) mentioned that Ellen and her husband unearthed a total of 218 human skeletons from the Mississippian period at Campbell. Of these, 144 skeletons were transported to and curated at the Museum Support Center of the University of Missouri-Columbia, and there is no clue about the destination of the rest (O'Brien, 1994).

O'Brien (1994) considered Campbell skeletal materials as the most complete skeletal collection in the State of Missouri. Moreover, it is the largest skeletal collection from the Mississippian period from the west of the Mississippi river.

Holland (1991, 1994) did a thorough study on the skeletal collection from Pemiscot Bayou, Campbell included. He aimed to understand population dynamics and health status among maize agriculturists living in the Late Mississippian period. His study showed there were only two cases of tuberculosis, and generally health was good based on some of paleodemographic parameters. Male and female age at death was in the late late $30_{s.}$ Mortality level reached its peak between 25 and 35 years of age among males. On the other hand, mortality rate among females increased at 20 years of age, and showed a significant increase between 30 and 35 years of age.

3.2. South America

3.2.1. Villa El Salvador

This is an Early Intermediate period cemetery on the central coast of Perú. It is a part of the lower Lurin Valley in the Sechura Desert, south of Lima. This cemetery dated to the Early

Intermediate period. The excavation of this cemetery started in 1977 by Stothert and Ravines (Stothert, 1980). The materials used in this study were uncovered in 1992 and 1994 by Delgado.

CHAPTER FOUR

MATERIALS AND METHODS

4.1. Materials

This study sample comprises skeletal samples from North and South America. The North American skeletal sample is divided into two subsamples: 65 skeletons are from the Woodland Period, and 50 are from the Mississippian Period.

TABLE 4.1. *Distribution of Pooled North American skeletal sample by period and sex.*

	Value Label	N
Period	Mississippian	17
	Woodland	35
Sex	Female	32
	Male	20

The Woodland period skeletal population is combined from Elizabeth Mound (Buikstra et al., 1988) and Modoc Rock Shelter (Fowler et al., 1956). The Mississippian Period skeletal sample is from the Campbell site (O'Brien and Holland, 1994).

The first skeletal sample is curated at the Illinois State Museum, and was borrowed and temporarily curated at the University of Missouri-Columbia (UMC) Museum Support Center during the period of data collection. The Campbell site materials are curated permanently at the UMC Museum Support Center. The North American sample distribution by sex is presented in Table 4.1.

The South American skeletal remains comprise 59 skeletons that were studied in Lima, Perú by Matthew Rhode. They are from the Early Intermediate site of Villa El Salvador (Rhode, 2006). Their distribution by sex is presented in Table 4.2.

TABLE 4.2. *Distribution of South American skeletal sample by cranial deformation type and sex.*

	Value Label	N
Cranial Deformation Type	Undeformed	16
	Deformed	27
Sex	Male	21
	Female	22

TABLE 4.3. *Sample composition by sex, for North American archaeological periods and sites.*

Period	Archaeological Site	Sample	
		♀	♂
Woodland	Elizabeth Mound	23	11
Woodland	Modoc Rock Shelter	7	5
Mississippian	Campbell site	16	8
TOTAL		46	24

TABLE 4.4. *Sample composition* by sex for South American archaeological *period and site.*

Period	**Archaeological Site**	**Sample** ♀	♂
Early Intermediate	Villa El Salvador (VES)	28	31

TABLE 4.5. *Sample composition by age, for North Americans and South Americans.*

	North Americans	**South Americans**
Estimated age	Number of Individuals	Number of Individuals
20-29	20	15
30-39	32	24
40-49	17	17
50-59	3	2
Total	72	58

TABLE 4.6. *Distribution of pooled skeletal samples by continent and sex.*

	Value Label	**N**
Continent	North America	52
	South America	53
Sex	Female	57
	Male	48

Sex was estimated from pelvic traits (Krogman, 1962), cranial traits (Krogman, 1962; Rhine, 1990; France, 1998), and post-cranial morphology. Age was estimated from closure of epiphyseal plates (White and Folkens, 2000), morphology of auricular surface of illium (Lovejoy et al., 1985), morphology of the pubic symphysis surface (Todd, 1920; Todd and Lyon, 1924; Todd and Lyon 1925a: 1925b: 1925c), and morphology of the sternal rib (Bennett, 1993).

Each vertebra was assessed for lipping and presence or absence of Schmorl's node as indicators of excessive stress. Tibiae were assessed for periostitial lesions, since disease can change bony response to stress. All long bone articular surfaces were examined for osteo-arthritic reaction, which was scored according to White and Folkens (2000).

4.2. METHODS

Linear measurements were used for femur (Tables 4.3). In addition, measurements of anterior femoral curvature have been modified and developed for this research. Finally, entheses, which sample most of muscle insertions of femur and tibia have been scored (Table 4.4). Methods used to collect data are discussed in more detail below.

4.2.1. Femoral Linear Measurements

Femoral linear external measurements are maximum length (ML), maximum diameter of the head (MFH), mediolateral (MLS) and anterioposterior (APS) diameters, circumference at the midshaft, and mediolateral (MLD) and anterioposterior subtrochantric diameters (APD). These measurements were also taken according to Bass (1995).

TABLE 4.7. *External femoral measurements, following Buikstra and Ubelaker (1994).*

Measurement	**Instrument**
1. Maximum Length (ML)	Osteometric board
2. Maximum diameter of the head (MFH)	Sliding caliper
3. Mediolateral diameter at the midshaft (MLS)	Sliding caliper
4. Anteroposterior diameter at the midshaft (APS)	Sliding caliper
5. Mediolateral at the subtrochanter (MLD)	Sliding caliper
6. Anteroposterior at the subtrochanter (APD)	Sliding caliper

TABLE 4.8. *External femoral measurements descriptions, following Buikstra and Ubelaker (1994).*

(ML)[1]: "Distance from the most superior point on the head of the femur to the most inferior point on the distal condoyles (Buikstra and Ubelaker, 1994; 82).

(MFH)[2]: "The maximum diameter of the femur head, wherever it occurs" (Buikstra and Ubelaker, 1994; 82).

(MLS)[3]: "Distance between the medial and lateral surfaces at midshaft, measured perpendicular to the anterior-posterior" (NO. 66 in Buikstra and Ubelaker, 1994; 83).

(APS)[4]: "Distance between anterior and posterior surfaces measured approximately at the midpoint of the diaphysis at the highest elevation of linea aspera" (Buikstra and Ubelaker, 1994; 83).

Circumference at the Midshaft: "Circumference measured at the level of the midshaft diameters" (NO. 66 and 67 in Buikstra and Ubelaker, 1994; 83)

(MLD)[5]: "Distance between medial and lateral surfaces of the proximal end of the diaphysis at the point of its greatest lateral expansion below the base of the lesser trochanter (Buikstra and Ubelaker, 1994; 82).

(APD)[6]: "Distance between anterior and posterior surfaces at the proximal end of the diaphysis, measured perpendicular to the mediolateral diameter" (Buikstra and Ubelaker,1994; 82).

---

[1] Maximum Length, [2] Maximum Diameter of the Head, [3] Mediolateral Diameter at the Midshaft, [4] Anteroposterior Diameter at the Midshaft, [5] Mediolateral Diameter at the Subtrochanter, [6] Anteroposterior Diameter at the Subtrochanter.

In addition to standard measurements, the following are modified and developed for the present study.

4.2.2. Anterior Femoral Curvature (AFC)

Stewart's method, developed in 1962 and revised in 1972 by Singh and Singh, is used to measure anterior femoral curvature (AFC), according to the following procedure (See figs., 4.1to 4.8).

First, maximum length was taken using the osteometric board as described above. The femur placed on its posterior surface. The distal and proximal low points were marked (Figs.

4.1, 4.2& 4.3, 4.4): I marked the distal one and take its height, then insert a wooden wedge to bring the proximal end to the same level as the distal end. A sliding caliper was moved along the shaft to locate the point of the greatest curvature (Fig. 4.5). With the bone is in that position, diphyseal length was taken with spreading calipers (Fig. 4.7). The distance between the point of the greatest curvature and low proximal point and the upper length of diaphysis were measured by spreading caliper (Fig. 4.8).

From these measurements the following indices were calculated:

POI: Position Iindex (relative position of the point of maximum curvature)

= upper length of diaphysis ×100 / diaphyseal length

BI: Bowing Index (relative curvature) = maximum curvature –low distal

Point (LDP) x 100 / diaphyseal length

4.2.3. Pilastric Index: Femoral Midshaft Shape (FMS)

PI: Pilastric Index = Anteroposteroir diameter at femoral midshaft (APS)/

Mediolateral diameter at midshaft (MLS)

4.2.4. Platymeric Index: Subtrochantric Shape

PLI= Platymeric Index (Subtrochantric Shape) =

(Subtrochantric anteroposterior diameter (APD) X 100) /

Subtrochantric mediolateral diameter (MLD)

Fig. 4.1. Determining low distal point (LDP) of femur. The lowest point close to the epiphyseal line.

.

Fig. 4.2. Marking low distal point (LDP) by a pencil.

Fig. 4.3. Determining low proximal point (LPP). This point is located directly below lesser trochanter on the medial surface of the femur.

Fig. 4. 4. Marking low proximal point (LPP) by a pencil.

Fig. 4.5. Finding maximum curvature along femoral diaphysis.

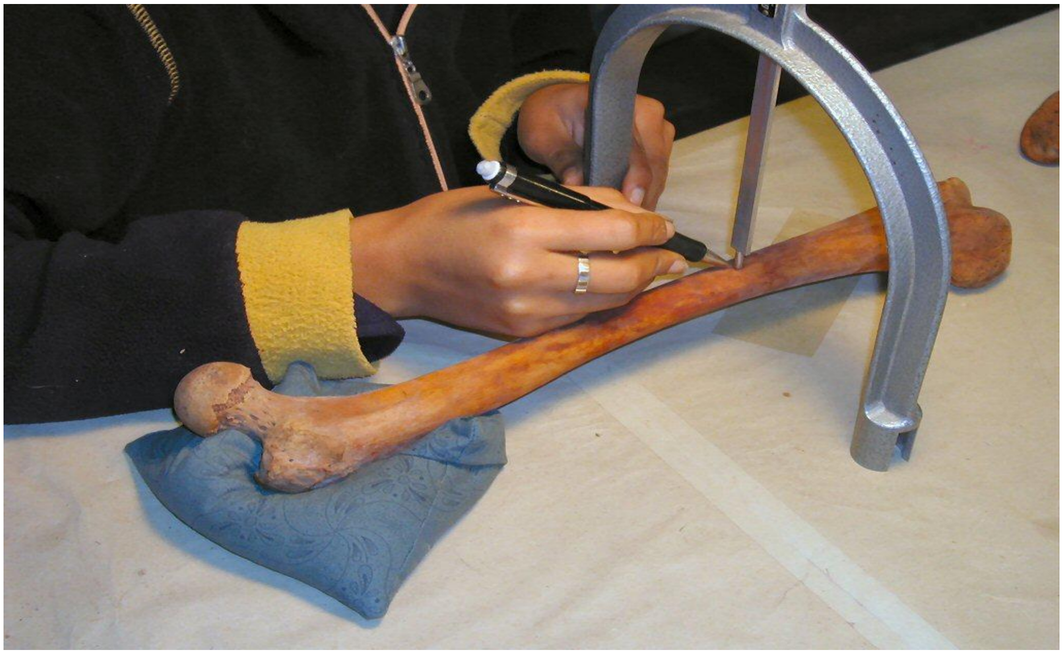

Fig. 4.6. Marking the maximum curvature position by a pencil.

Fig. 4.7. Measuring length of the femoral diaphysis. It is the distance between LDP and LPP, which are determined as in Figs. 4.2 & 4.4, respectively.

Fig. 4.8. Measuring femoral lower diaphyseal length; this measurement proceeds from the LDP which is located close to anterior auricular surface point (as in Fig. 4.3) and maximum curvature (Fig. 4.5).

TABLE 4.9. *Femoral indices calculated in the study.*

Bone	Index
FEMUR	**BI** = (maximum curvature – low distal point (LDP)) X 100/ diaphyseal length[1] **POI** = upper length of diaphysis X 100 / diaphyseal length[1] **PI or FMS** = anterioposterior diameter at the midshaft (APS) / mediolateral diameter at the midshaft (MLS)[2] **PLI** = subtrochanter anterioposterior diameter (APD) X 100 / subtrochantric mediolateral diameter (MLD)[2]

[1] Stewart (1962); Singh and Singh (1972)
[2] Bass (1995)

4.2.5. Entheses of Femur and Tibia

Hawkey's scoring system (1987) was used to score entheses on the upper skeletal extremities, and as modified by Rhode (Rhode, 2003, 2006). These muscle markers were scored as a 0-6 rank-order scale for femur and tibia. These are divided into two habitual marker categories: robusticity marker (RM); ridges, crest, and stress lesions (SL); furrows, grooves. Below, I will show what each score means morphologically:

0 = absence of expression (normal/smooth)

1 = robusticity grade 1 (RM1) (faint/smooth)

2 = robusticity grade 2 (RM2) (moderate)

3 = robusticity grade 3 (RM3) (strong)

4 = stress lesion grade 1 (SL1) (faint/trace)

5 = stress lesion grade 2 (SL2) (moderate)

6 = stress lesion grade 3 (SL3) (strong)

This system was used to score lower limb entheses. Table 4.9 shows the name of each muscle site for which its attachment has been scored.

TABLE 4.10. *Sites for which muscle insertions and origin entheses are scored in femur and tibia.*

	Muscle	Origin and attacment	Function
Femoral Sites			
	Gluteus medius:Origin	Origin: crests of hip bone Insertion: side of the femur	Abduction the leg
	Obturator externus	Origin: rami of the pubis and inferior ramus of the ischium Insertion: Posteromedial surface of greater trochanter of femur	Rotation the thigh laterally at the hip joint
	Gluteus maximus (GM)	Origin: hip bone crests Insertion: rear of the femur	Extension the hip
	Psoas major, Illiacus	Origin: bodies and transverse processes of L1-L5 Insertion: lesser trochanter	Flexion the hip
	Gastrocenmius, Medial Head	Origin: posterior surface of medial condyle of femur Insertion: middle 1/3 of the posterior surface of calcaneus	Plantar flexion
Tibial Sites			
	Tibial tuberosity	Bony structure	
	Soleus	Origin: posterior surface of the fibular head proximal third of fibular diaphysis middle diaphyseal part of the medial border of the tibia Insertion:	Plantar flexion with the knee bent

Entheses of the muscles of lower limb shown in table (4.9) were scored because some of them have a crucial role in biomechanics of walking and running. Liberman et al. (2006) showed on human subjects that gluteus maximus has distinctive role in running. Gluteus medius abducts the leg.

4.2.6. Statistical Methods

4.2.6. A. Normal Distribution

All femoral indices and entheses scores were tested for normal distribution. Values of skewness and kurtosis were calculated for all of them. Whenever the skewness and kurtosis values of any of these dependent variables fall within the range of ± 2 SE, it is considered normally distributed, otherwise it is not.

4.2.6. B. Natural Logarithm Transformation

All entheses were scored according to 0-6 ordinal scale. These were transformed into natural logarithm plus one. After this transformation, all were tested for being normal distribution by calculating values of skewness and kurtosis. If the calculated value is between – 2 SE and +2 SE, the dependent factor will be considered normally distributed, if falls outside this range, it will be statistically, considered normally undistributed.

4.2.6. C. General Linear Model (GLM)

General Linear Model (GLM) will be used to test the impact of independent variable(s) on dependent variable(s), when the latter were normally distributed. Among North Americans, the impact of period, sex, and period and sex on mean values of femoral indices and entheses will be tested. GLM will be used test the influence of deformation, sex, and deformation and sex on the same variables. Finally and among pooled skeletal samples, the effect of continent, sex, and continent and sex on calculated values of femoral indices and entheses of lower limb will be examined.

CHAPTER FIVE: RESULTS AND DISCUSSION

NORTH AMERICAN SKELETAL SAMPLE

FEMORAL INDICES

It is necessary to understand femoral indices in terms of the muscles that produced the curvature. I will do this by correlating them with femoral and tibial entheses. However, before this discussion, it is important to establish the sample size and shape of distribution of the indices and entheses, neither of which would necessarily be expected to arise from a normal distribution.

Normal Distribution

Tests for normality are shown in Table 5.1, while Position and Bowing Indices are negatively skewed, Pilastric and Platymeric Indices are positively skewed. All femoral indices are similarly platykurtic. But, because absolute values of skewness of all femoral indices fall within the expected range (± 2SE), the distributions of each do not depart significantly from normal. Kurtosis also does not significantly depart from mesokurtic.

Since values do not vary from chance expectations of having been from a normal distribution, the data are considered acceptable for parametric statistical analysis.

TABLE 5.1. *Descriptive Statistics of femoral indices for pooled North American skeletal sample.*

	Mean	SD	Skewness		Kurtosis	
Dependent Variable	**Statistic**	**Statistic**	**Statistic**	**SE**	**Statistic**	**SE**
Mean of POI of L & R Femora	49.83	4.03	-.00	.33	-.60	.65
Mean of BI of L & R Femora	3.88	.74	-.14	.33	-.18	.65
Mean of PI or FMS of L & R Femora	1.10	.080	.16	.31	-.73	.61
Mean of PLI of L & R Femora	91.67	7.78	.28	.31	-.13	.61

5.2 LOWER LIMB ENTHESES

Entheses, the bony anatomical regions where muscles and/or ligaments attach, were scored on a 0-6 scale. These scores were transformed into natural logarithm of the enthesis + 1 to achieve normal distribution. Even after transformation, some of these were skewed significantly from normal distribution or depart prominently from mesokurtic, or both.

Table 5.2 shows the absolute values of skewness and kurtosis of each femoral and tibial entheses. For those that are normally distributed, correlation among age and these entheses was tested using Pearson's Product Moment correlation (r). But, for those that are not normally distributed or/and significantly moved from mesokurtic, association was examined by Spearman's rank-order correlation coefficient (r_s). Entheses were also correlated with femoral indices to examine the association between muscles and bony morphological features; the remainder was analyzed with a standard Pearson (r).

Correlations among indices were used to determine whether age and any of femoral indices is significantly correlated with another. Results show that age does not correlate significantly with any of these indices. This is probably because the femora reached their adult shape in adolescence mainly by modeling process. The only correlation among the indices is between Pilastric Index and Platymeric Index is low but significant (r = 0.24; P = 0.03) (See Table 5.3). When femoral midshaft shape grows more elongated anterioposteriorly, there is a very slight trend for subtrochantric shape to grow also anterioposteriorly. This weakness of this correlation can be explained in terms of the shape of the subtrochnatric region being mostly determined during the first five years of age (e.g., Wescott, 2006), but modeling processes continue to determine femoral shape at the midshaft and does not end till adulthood (Frost, 1980; Ogden, 1980).

Table 5.4 presents results of correlations among age and entheses of the femur and tibia. Correlation between age and tibial tuberosity approaches closely level of significance (r = 0.27; P = 0.06), correlation with gluteus medius enthesis closely approaches level of significance (r = 0.24; P = 0.08). Many of these entheses correlate with each other. The gluteus medius enthesis significantly correlates with that of gastrocnemius (r = 0.39; P = 0.02) and with the tibial tubersosity (r = 0.40; P = 0.01). In addition to its correlation with gluteus medius enthesis, gastrocnemius correlates significantly also with the tibial tuberosity (r = 0.45; P = 0.01) and soleus (r = 0.36, P = 0.04). Tibial tuberosity correlates with soleus also (r = 0.39; P = 0.02). Finally, obturator externus significantly correlates with squatting facet (r_s = 0.35; P = 0.02). Gluteus maximus correlates significantly with soleus (r_s = 0.47; P = 0.00).

Some of the femoral indices also correlate significantly with lower limb entheses. Results of these correlations are presented in Table 5.5. The Position Index, correlates negatively with gluteus medius (r = -0.30; P = 0.04). The Bowing Index significantly correlates with soleus and gluteus maximus. These results are (r = 0.30; P = 0.05) for the correlation between Bowing Index and soleus, and (r_s = 0.43; P = 0.00) for the correlation between Bowing Index and gluteus maximus. These significant associations with the Bowing Index can be explained that anterior femoral curvature and soleus all involve in the biomechanics of walking. Soleus has an important role in standing and walking, and if it is not consistently pulled, the body will fall forward. But gluteus maximus which is anatomically located in the trunk and of its functions to keep the trunk in the erect posture, and its activity increases with speed during running (Lieberman et al., 2006). Finally, there is a statistically significant correlation between Platymeric Index and gluteus medius (r = 0.28; P = 0.05). Because femoral proximal diaphysis is shaped early, during the first five years of age (e.g., Wescott, 2006), this weak positive correlation between this bony region and gluteus medius, might happen during childhood, period of developing gait.

From theses results, we can see that the indices are related to growth of a few major muscles. Their pattern suggests that we can understand Bowing Index as due to greater exertion registered in the soleus and gluteus maximus muscles, Position Index in the gluteus medius, and Platymeric Index on gluteus medius.

When I tested the correlation between maximum diameter of femoral head with femoral indices, I found that it correlates significantly with Bowing Index (r = .53; P = .000) and femoral midshaft shape (FMS) or Pilastric Index (r = .30; P =.033). In addition, correlation between maximum length of femur was correlated with the same femoral indices. It correlates significantly with Bowing Index (r = .323; P = .02) and femoral midshaft shape (FMS) or Pilastric Index (r = .45; P < .01).

TABLE 5.2**.** *Descriptive statistics of femoral and tibial entheses of pooled North American skeletal sample.*

	N	Mean		SD	Skewness		Kurtosis	
Dependent Variable	**Statistic**	**Statistic**	**SE**	**Statistic**	**Statistic**	**SE**	**Statistic**	**SE**
Log. of Mean of Glut. Med. of L & R Femora	55	.53	.05	.37	-.42	.32	-1.16	.63
Log. of Mean of Obtur.Extern. of L & R Femora	57	.03	.02	.17	5.60	.32	31.72	.62
Log. of Mean of Glut. Max. of L & R Femora	59	.91	.04	.29	-.83	.31	1.36	.61
Log. of Mean of Psoas Maj. of L & R Femora	54	.32	.05	.36	.33	.33	-1.75	.64
Log. of Mean Gastrocn. (Medial Head) of L & R Femora	36	.61	.07	.41	-.28	.393	-1.08	.77
Log. of Tibial Tubero. of L & R Tibiae	53	.75	.07	.46	-.51	.33	-.84	.64
Log. of Mean of Soleus of L & R Tibiae	57	.78	.05	.39	-.62	.32	-.35	.62
Log. of Mean of Squatting Facet of L & R Tibiae	55	.06	.03	.25	4.92	.32	26.63	.63

TABLE 5.3. *Pearson's correlations among age and femoral indices o f pooled North American skeletal sample.*

		Mean of POI of L & R Femora	**Mean of BI of L & R Femora**	**Mean of PI or FMS of L & R Femora**	**Mean of PLI of L & R Femora**
Age	Pearson Correlation	.01	-.01	.03	.00
	Sig. (1-tailed)	.47	.48	.43	.49
	N	52	52	59	60
Mean of POI of L & R Femora	Pearson Correlation		.17	-.01	.04
	Sig. (1-tailed)		.11	.47	.39
	N		52	52	52
Mean of BI of L & R Femora	Pearson Correlation			.07	.01
	Sig. (1-tailed)			.32	.49
	N			52	52
Mean of PI or FMS of L & R Femora	Pearson Correlation				**.24**
	Sig. (1-tailed)				.03
	N				59

TABLE 5.4. *Correlations among age and femoral and tibial entheses of pooled North American skeletal sample.*

		Log. of Mean of Glut. Med. of L & R Femora	**Log. of Mean of Obtur. Extern. of L & R Femora**	**Log. of Mean of Glut. Max. of L & R Femora**	**Log. of Mean of Psoas Maj. of L & R Femora**	**Log. of Mean Gastrocn. (Medial Head) of L & R Femora**	**Log. of Tibial Tubero. of L & R Tibiae**	**Log. of Mean of Soleus of L & R Tibiae**	**Log. of Mean of Squatting Facet of L & R Tibiae**
Age	Correlation Coefficient	.24	.06	.15	-.07	.18	.27	.18	.05
	Sig. (2-tailed)	.08[a]	.64[b]	.26[b]	.63[b]	.31[a]	.06[a]	.184[a]	.70[b]
	N	55	57	59	54	36	53	57	55
Log. Of Mean of Glut. Med. of L & R Femora	Correlation Coefficient		.05	**.27**	.22	**.39**	**.38**	.11	.01
	Sig. (2-tailed)		.73[b]	.05[b]	.13[b]	.02[a]	.01[a]	.44[a]	.97[b]
	N		53	55	50	34	45	48	47
Log. of Mean of Obtur. Extern. of L & R Femora	Correlation Coefficient			.03	.08	.18	-.19	-.13	**.35**
	Sig. (2-tailed)			.85[b]	.55[b]	.31[a]	.21[a]	.38[a]	.02[b]
	N			57	54	35	47	50	49
Log. of Mean of Glut. Max. of L & R Femora	Correlation Coefficient				.24	**.35**	**.40**	**.47**	-.26
	Sig. (2-tailed)				.08[b]	.03[a]	.01[a]	.00[b]	.07[b]
	N				54	36	48	51	50
Log. of Mean of Psoas Maj. of L & R Femora	Correlation Coefficient					**.66**	**.45**	**.35**	-.28
	Sig. (2-tailed)					.00[a]	.00[a]	.015[a]	.06[b]
	N					32	45	47	46
Log. of Mean Gastrocn. (Medial Head) of L & R Femora	Correlation Coefficient						**.45**	**.36**	-.25
	Sig. (2-tailed)						.01[a]	.04[a]	.17[b]
	N						31	33	33
Log. of Tibial Tubero. of L & R Tibiae	Correlation Coefficient							**.36**	-.18
	Sig. (2-tailed)							.01[a]	.21[b]
	N							52	52
Log. of Mean of Soleus of L & R Tibiae	Correlation Coefficient								-.22
	Sig. (2-tailed)								.11[b]
	N								55

[a] These Probability Values were Obtained From Pearson's Formula
[b] These Probability Values were Obtained From Spearman's Formula

TABLE 5.5. *Correlations between femoral and tibial entheses and femoral indices of pooled North American skeletal sample.*

		Log. of Mean of Glut. Med. of L & R Femora	**Log. of Mean of Obtur. Extern. of L & R Femora**	**Log. of Mean of Glut. Max. of L & R Femora**	**Log. of Mean of Psoas Maj. of L & R Femora**	**Log. of Mean Gastrocn. (Medial Head) of L & R Femora**	**Log. of Tibial Tuberosity of L & R Tibiae**	**Log. of Mean of Soleus of L & R Tibiae**	**Log. of Mean of Squatting Facet of L & R Tibiae**
Mean of POI of L & R Femora	Correlation coefficient	**-.30**	.07	-.04	-.16	.05	-.16	.10	-.03
	Sig. (2-tailed)	.04[a]	.66[b]	.80[b]	.28[b]	.79[a]	.32[a]	.50[a]	.87[b]
	N	46	47	49	45	32	41	44	43
Mean of BI of L & R Femora	Correlation coefficient	.02	.02	**.43**	-.03	.24	.26	**.30**	-.11
	Sig. (2-tailed)	.88[a]	.89[b]	.00[b]	.86[b]	.19[a]	.10[a]	.05[a]	.50[b]
	N	46	47	49	45	32	41	44	43
Mean of PI or FMS of L & R Femora	Correlation coefficient	**.28**	.16	.08	.01	.16	.12	.02	.19
	Sig. (2-tailed)	.05[a]	.24[b]	.58[b]	.92[b]	.36[a]	.42[a]	.88[a]	.20[b]
	N	53	54	56	51	36	48	51	50
Mean of PLI of L & R Femora	Correlation coefficient	-.12	.18	.21	.04	.14	-.01	.11	-.16
	Sig. (2-tailed)	.41[a]	.19[b]	.12[b]	.77[b]	.41[a]	.93[a]	.42[a]	.27[b]
	N	54	55	57	52	36	48	51	50

[a] These Probability values were Obtained From Pearson's Formula
[b] These Probability Values were Obtained From Spearman's Formula

PERIOD: Trend of Change From Woodland to Mississippian

Table 5.6 shows mean values of femoral indices of left and right femora of North American skeletal sample by period. Differences in mean values of femoral indices among North American skeletal samples by period, support the hypothesis that Woodland skeletal samples display slightly higher mean of Bowing Index than the sample of Mississipian.When the six indices (three left and three rights) are converted to factor scores, the first factor, that for the Bowing Index, does differ significantly by period (*P* = 0.046, analysis not presented). For that reason, I will accept this difference between the mean as statistically significant. There is no statistically significant difference in mean values of Position Index (F = 0.12; df = 1; P = 0.73), cross-sectional femoral midshaft shape (FMS) (F = 0.95; df =1; P = 0.33), or Platymeric Index (F = 0.26; df = 1; P = 0.62). See Table 5.7 for these results. Table 5.8 shows mean values of lower limb enthesis scores by period. None of the lower limb enthesis scores vary significantly by period (Table 5.9). Below, I will discuss results of these indices in the same order shown in Table 5.6.

Position Index: Anatomical Location of the Maximum Curvature

Table 5.6 shows mean values of Position Index of left and right femora of Woodland and Mississippian skeletal samples. As shown in Table 5.7, there are no significant differences in the mean value of the Position Index of left and right femora by period.

TABLE 5.6. *Mean values of femoral indices of left and right femora of pooled North American skeletal sample by period.*

				95% Confidence Interval	
Dependent Variable	**Period**	**Mean**	**SE**	**Lower Bound**	**Upper Bound**
Mean of POI of L & R Femora	Mississippian	49.68	1.04	47.60	51.77
	Woodland	50.12	.71	48.70	51.54
Mean of BI of L & R Femora	Mississippian	3.75	.15	3.46	4.05
	Woodland	4.09	.10	3.89	4.29
Mean of PI or FMS of L & R Femora	Mississippian	1.10	.02	1.06	1.14
	Woodland	1.12	.01	1.09	1.15
Mean of PLI of L & R Femora	Mississippian	91.53	1.87	87.78	95.30
	Woodland	92.68	1.27	90.12	95.23

TABLE 5.7. *Results of GLM of effect of period, sex and period and sex on femoral indices of pooled North American skeletal sample.*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Period	Mean of POI of L & R Femora	2.01	1	2.01	0.12	0.73
	Mean of BI of L & R Femora	1.24	1	1.24	3.73	**0.06**
	Mean of PI or FMS of L & R Femora	0.01	1	0.01	0.95	0.33
	Mean of PLI of L & R Femora	13.81	1	13.81	0.26	0.62
Sex	Mean of POI of L & R Femora	14.29	1	14.29	0.85	0.36
	Mean of BI of L & R Femora	8.71	1	8.71	26.12	**0.00**
	Mean of PI or FMS of L & R Femora	0.03	1	0.03	5.36	**0.03**
	Mean of PLI of L & R Femora	0.20	1	0.20	0.00	0.95
Period*Sex	Mean of POI of L & R Femora	2.46	1	2.46	0.18	0.70
	Mean of BI of L & R Femora	0.01	1	0.01	0.03	0.86
	Mean of PI or FMS of L & R Femora	5.81 E-005	1	5.81E-005	0.010	0.92
	Mean of PLI of L & R Femora	18.19	1	18.19	0.34	0.57

TABLE 5.8. *Mean Values of femoral and tibial entheses of Pooled North American skeletal sample by period.*

Dependent Variable	Period	Mean	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
Log. of Mean of Glut. Med. of L & R Femora	Woodland	.56	.09	.39	.74
	Mississippian	.75[a]	.26	.22	1.29
Log. of Mean of Obtur. Extern. of L & R Femora	Woodland	.06	.03	-.01	.12
	Mississippian	-1.89E-018[a]	.09	-.19	.19
Log. of Mean of Glut. Max. of L & R Femora	Woodland	1.07	.06	.94	1.19
	Mississippian	1.01[a]	.19	.63	1.39
Log. of Mean of Psoas Maj. of L & R Femora	Woodland	.41	.09	.23	.59
	Mississippian	.35[a]	.26	-.20	.89
Log. of Mean Gastrocn. (Medial Head) of L & R Femora	Woodland	.61	.10	.40	.82
	Mississippian	.41[a]	.30	-.22	1.04
Log. of Tibial Tubero. of L & R Tibiae	Woodland	.92	.10	.72	1.12
	Mississippian	1.09[a]	.29	.49	1.68
Log. of Mean of Soleus of L & R Tibiae	Woodland	.91	.09	.73	1.09
	Mississippian	.62[a]	.26	.08	1.16
Log. of Mean of Squatting Facet of L & R Tibiae	Woodland	.02	.03	-.05	.09
	Mississippian	8.15E-020[a]	.10	-.21	.21

[a] Based on modified population marginal mean.

TABLE 5.9. *Results of GLM of effect of period, sex, and period and sex on femoral and tibial entheses of pooled North American skeletal sample.*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Period	**Log. of Mean of Glut. Med. of L & R Femora**	.09	1	.09	.68	.42
	Log. of Mean of Obtur. Extern. of L & R Femora	.00	1	.00	.00	1.00
	Log. of Mean of Glut.Max.of L & R Femora	.01	1	.01	.14	.71
	Log. of Mean of Psoas Maj. of L & R Femora	.02	1	.02	.12	.73
	Log. of Mean Gastrocn. (Medial Head) of L & R Femora	.03	1	.03	.14	.71
	Log. of Tibial Tubero. of L & R Tibiae	.14	1	.14	.83	.37
	Log. of Mean of Soleus of L & R Tibiae	.03	1	.03	.20	.66
	Log. of Mean of Squatting Facet of L & R Tibiae	.00	1	.00	.14	.72
Sex	**Log. of Mean of Glut. Med. of L & R Femora**	.02	1	.02	.16	.69
	Log. of Mean of Obtur. Extern. of L & R Femora	.06	1	.06	3.45	.08
	Log. of Mean of Glut. Max.of L & R Femora	.31	1	.31	4.56	**.04**
	Log. of Mean of Poas Maj. of L & R Femora	.022	1	.022	.16	.70
	Log. of Mean Gastrocn. (Medial Head) of L & R Femora	.13	1	.13	.706	.409
	Log. of Tibial Tubero. of L & R Tibiae	.22	1	.22	1.3	.26
	Log. of Mean of Soleus of L & R Tibiae	.55	1	.55	4.05	**.06**
	Log. of Mean of Squatting Facet of L & R Tibiae	.01	1	.01	.34	.57

The Position Index is used to determine the anatomical location of the most curved point along the femoral diaphysis. Singh and Singh (1972) report these differences as influenced mostly by gene frequency differences among the populations. Moreover, it should be established during the early years of growth. This process starts in uterus and continues over the first five years of childhood. Variation in mechanical loads associated with gait is probably negligible in the early years. Significant differences in activity level that affect the amount and/or the frequency of load imposed on the femur happen later, and would be most influential during adolescence, when growth is most rapid. In any case, the location of the most curved point is not significantly influenced by biomechanical loads first experienced during adolescence and that may have varied between Woodland and Mississippian children. In other words, Position Index displays minimum degree of phenotypic plasticity and does not respond as strongly to differences in level of mobility as Bowing Index, which shows a higher degree of plasticity. However, the Position Index does correlates negatively with gluteus medius enthesis (r = -0.30; P = 0.04); thus, point of maximum curvature closer most to the midshaft is associated with development of the gluteus medius. Since the primary function of the gluteus medius is hip abduction, moving legs laterally from the body, we can associate this with biomechanics of walking, running and carrying heavy loads.

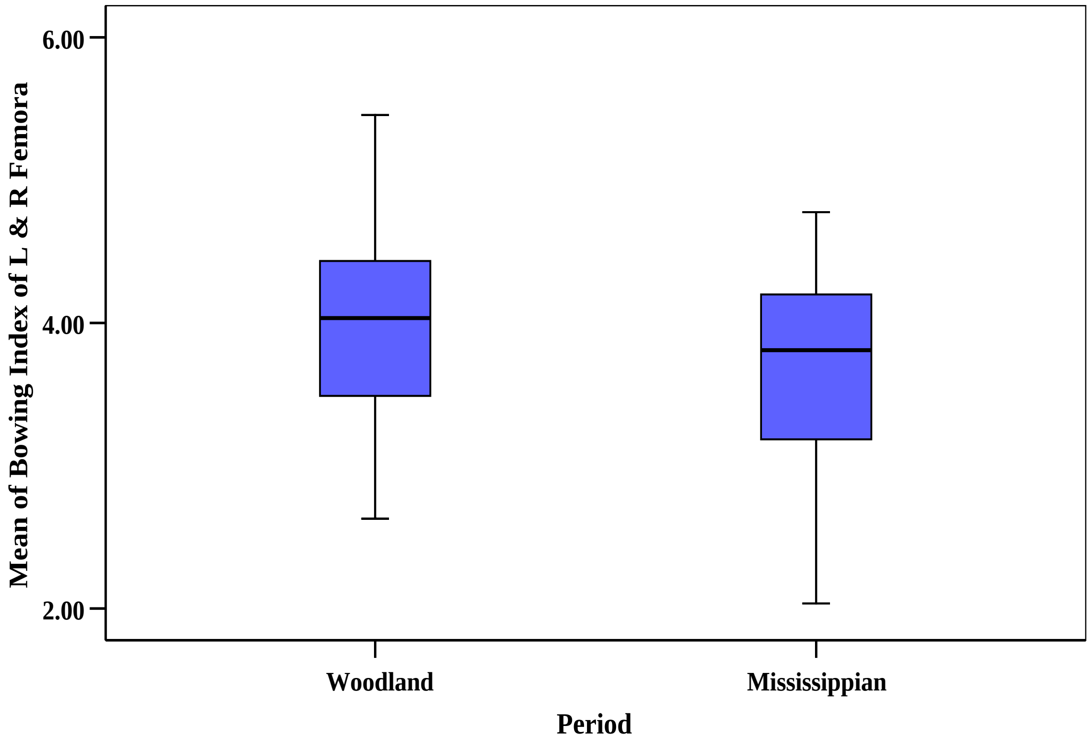

Fig. 5.1. Mean values of Bowing Index of left and right femora of pooled North American skeletal sample by period (*F*= 3.73; with 1 df; *P* = 0.06; *P* = 0.046 with factor analysis).

Bowing Index: Anterior Femoral Curvature (AFC)

The results show that differences in the degree of anterior femoral curvature are almost significant (*F* = 1.244; df = 1; *P* = 0.06; *P* = 0.046 with factor analysis). As shown in Table 5.6, the Woodland skeletal sample displays higher mean value of Bowing Index than Mississippian sample when pooled over sex. In addition, Woodland people display higher scores of obturator externus and gluteus maximus than of Mississippian's. Of these muscles, gluteus maximus positively correlates with Bowing Index (r_s = 0.43; P = 0.00). Although the soleus enthesis does not show significant difference by period, it correlates significantly with degree of anterior femoral curvature (r = 0.30; P = 0.05). This significant correlation between the degree of anterior femoral curvature and a major muscle of the lower part of lower limb shows how bony morphological features and muscles respond to biomechanical load. Soleus has a prominent role in biomechanics of standing, walking, and running. Its pulling action maintains the body in erect posture; otherwise the body will fall forward.

Morphologically, the sample of the earlier period expresses more anteriorly curved femora than later sample. This is an expected secular trend as strongly expressed by decreasing degree of anterior femoral curvature from Woodland to Mississippian period. Archaeologically known Woodland was a very mobile society that shows more anteriorly curved femur and bigger obturator externus and gluteus maximus than people of Mississippian who adopted more sedentary lifestyle. Because its vital role mainly in biomechanics of running, gluteus maximus is more developed among Woodland people, who had to run after the prey.

Societies practiced more hunting-gathering in the Early Woodland and horticulture later in the same period. However, the sample was too small to investigate morphological changes within the Woodland. Individuals who lived during Middle or Late Woodland were more physically active and engaged in more strenuous activities such as walking and running than those who lived during the Mississippian. Their physically active lifestyle could have resulted in more anteriorly curved femur, which would be stronger under bending force than a straight femur of those lived more sedentary and less strenuous lifestyle in Mississippian. Biomechanically, this physically strenuous lifestyle resulted in enough load and/or rate of load imposed on femur to stimulate osteogenic or mechanostat processes that modified the degree of femoral curvature and masked similarities in the expressed degree of curvature that might result from similar genetic components.

Results of this research agree with previous research aimed to assessing variation in the level of activity within and reconstruct temporal secular trends between archaeologically and genetically homogenous populations with different subsistence practices and activities. Some of these studies introduced degree of anterior femoral curvature as a valid measure to reconstruct terrestrial logistic mobility change trend over short period (e.g., Bruns et al., 2002). Shackelford and Trinkaus (2001, 2002) have investigated the change in femoral curvature from Neandertals to recent humans.

When they controlled for genetics, Bruns et al. showed a trend of strongly decreasing level of activity over time among Scottish population using degree of anterior femoral curvature, which was significantly less among more sedentary 20th century population.

The same pattern was exhibited in another study: Shackelford and Trinkaus (2001, 2002) found significant decrease in degree of anterior femoral curvature after the last glacial advance, which might be due to a decrease in mobility.

Pilastric Index: Femoral Midshaft Shape (FMS)

Another indicator used in this investigation to measure the morphological secular trend between genetically homogenous populations is cross-sectional shape at the midshaft of femur. Femoral midshaft shape (FMS) as determined externally by linear measurements in the anteriorposterior (A-P) plane and mediolateral (M-L) plane has been intensively used by many researchers as a valid measure of activity level. Those who exhibit elongated cross-sectional femoral midshaft shape in anterioposterior direction femora should be stronger under bending load than is more a symmetrical. In this study, femoral midshaft shape (FMS) or Pilastric Index, like Bowing Index, is found to be significantly positively correlated with gluteus medius (r = 0.28; P = 0.05)

The trend from Woodland to Mississippian in femoral midshaft shape is similar, but not significant as the one displayed by degree of anterior femoral curvature. As shown in Table 5.6, Woodland skeletal sample does exhibit higher mean value of Pilastric index than the one exhibited by Mississippian skeletal sample. However, cross-sectional femoral midshaft shape does not vary across periods (F = 0.01; df = 1; P = 0.33). Subtrochantric shape also shows no significant differences across periods.

Platymeric Index: Subtrochantric Shape

Another femoral index that does not vary significantly across periods is subtrochantric cross-sectional shape. The Platymeric Index used to determine shape of femoral proximal diaphysis at the subtrochantric region. This shape is estimated as the ratio of anterioposterior (A-P) direction divided by the product of (100 multiplied by mediolateral (M-L) plane) (Bass, 1995). It has been previously reported that shape of this region significantly varies across genetically differed human populations. The Platymeric Index is not associated significantly with development of any muscle. That might due to the fact that this bony region is established morphologically during the first five years of life, while entheses of muscles continue to respond to and interact with biomechanical load over longer period of time.

Table 5.8 shows mean values of lower limb entheses by period. None of them varies significantly by period (Table 5.9).

SEX: Sexual Dimorphism Degree in North America

Differences in mean values of femoral indices are also investigated between sexes among North American skeletal sample. Results show Bowing Index and cross-sectional femoral midshaft shape are highly sexually dimorphic: Position Index and Platymeric Index are not. These statistically significant results for Bowing Index are (F = 26.12; df = 1; P = 0.00), and (F = 5.36; df= 1; P = 0.03) for Pilastric Index. Position Index and Platymeric Index are not significant (Table 5.8). Table 5.9 shows mean values of femoral indices of left and right femora of North American skeletal sample by sex. I will discuss findings of each index separately.

Position Index: Anatomical Location of the Maximum Curvature

As shown in Table 5.10, the mean value of Position Index of males of North American skeletal sample is higher than for females. Morphologically that can be interpreted while the most curved point of anterior femoral curvature is located on the average more proximally than of males, whose Position Index located anatomically below the midshaft. But the difference in mean values of Position Index between males and females is not statistically significant. In other words, no significant sexual dimorphism is found.

TABLE 5.10. *Mean values of femoral indices of left and right femora of pooled North American skeletal sample by sex.*

				95% Confidence Interval	
Dependent Variable	**Sex**	**Mean**	**SE**	**Lower Bound**	**Upper Bound**
Mean of POI of L & R Femora	Female	49.32	.76	47.79	50.85
	Male	50.48	1.00	48.47	52.49
Mean of BI of L & R Femora	Female	3.47	.11	3.25	3.69
	Male	4.37	.14	4.09	4.69
Mean of PI or FMS of L & R Femora	Female	1.08	.01	1.05	1.109
	Male	1.13	.02	1.09	1.17
Mean of PLI of L & R Femora	Female	92.18	1.37	89.42	94.93
	Male	92.04	1.80	88.43	95.65

However, a possible problem with pooling sexes across periods might arise from the fact that the sample differs in percent of sexes across periods. There are 17 females and 7 males (33%) in the Mississippian period and 30 females, and 18 males (37.5%) in the Woodland period. However, these results are not statistically significantly different ($\chi^2 = 0.49$; df =1; $P = 0.48$).

Bowing Index: Anterior Femoral Curvature (AFC)

For mean values of Bowing Index of males and females of North American skeletal sample see Table 5.10. Males' skeletons have significantly higher Bowing Index than females do (F = 8.71; df= 1; P = 0.00). Males also show significantly bigger gluteus maximus and soleus entheses. (F = 4.56; df = 1; P = 0.04, F = 4.05; df = 1; P = 0.06) for gluteus maximus and soleus, respectively (Table 5.9). Both significantly correlate with the Bowing Index. These correlations are (r_s = 0.43; P = 0.00) between Bowing Index and gluteus maximus and (r = 0.30; P = 0.047) between Bowing Index and soleus. In other words, Woodland people developed more anteriorly curved femur, which would be stronger under and more able to resist mainly bending loading resulted from walking and running and bigger gluteus maximus and soleus that engage in biomechanics of walking and running. As discussed above, the sex ratio difference between periods is not significant.

Variation in degree of anterior femoral curvature morphological features in North American skeletal sample by sex, can be explained as different activity level by sex, due to specialization of work roles. Male children experienced more biomechanical stress from mobility than did female children. In other words, femoral curvature, biomechanically, shows a high level of phenotypic plasticity and responds strongly to differences in activity level by sex. This tested model of activity by sex agrees with the one reconstructed by ethnographic analogy.

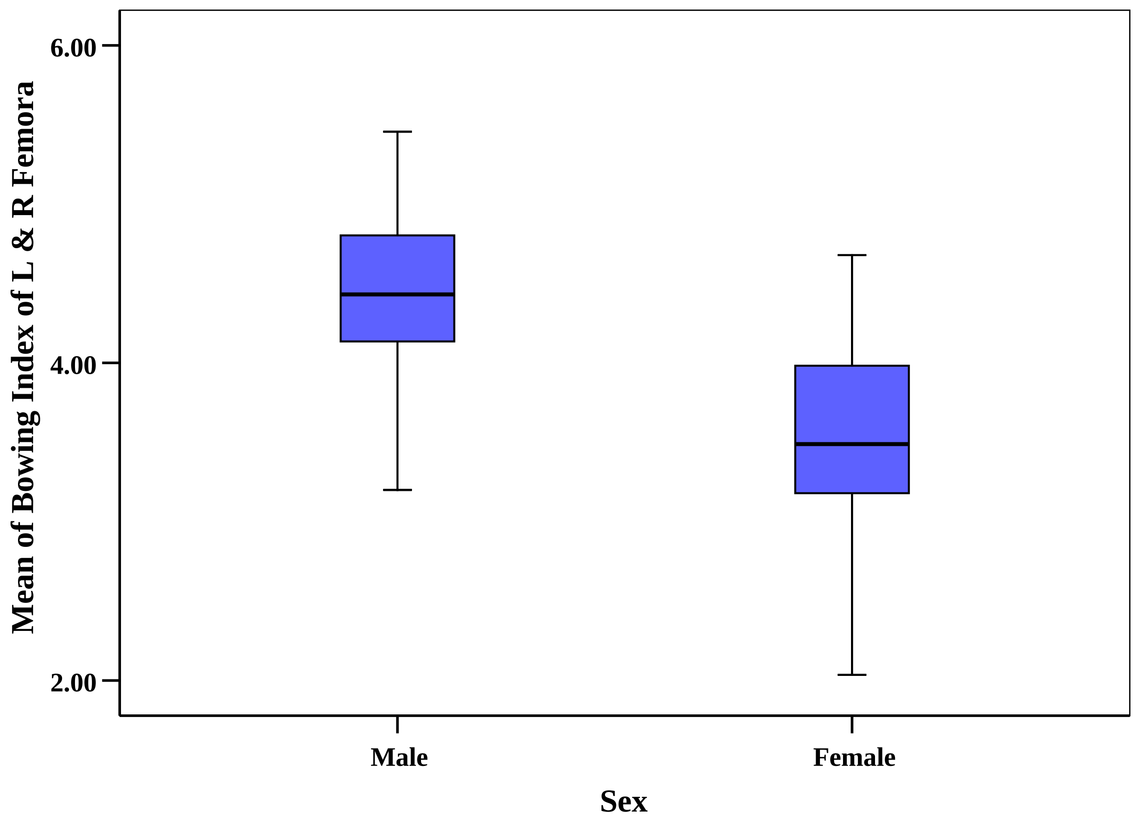

Fig. 5.2. Mean values of Bowing Index of left and right femora of pooled North American skeletal sample by sex (*F* = 26.12; with 1 df; *P* = 0.00).

According to model of activity constructed from ethnographic analogy, male children of both periods, Woodland and Mississippian, have more physically active lifestyle, in which they walked and ran, females, who were more sedentary and engaged in less walking and running. For that reason, the femora of males were subjected to high amounts of and more frequent bending loads from walking and running. The magnitude was great enough to stimulate osteogenic or mechanostatic processes that modified the degree of anterior curvature and midshaft cross-sectional shape of femur to produce differences that were retained in adults of each sex. These processes developed more anteriorly curved femora in males, which were stronger and better able to resist bending force than straighter femora.

Pilastric Index: Femoral Midshaft Shape (FMS)

Males exhibit significantly higher mean values of Pilastric Index of left and right femora than females (Table 5.10). These findings are (F= 5.36; df = 1; P = 0.03) (Table 5.7). Morphologically, males display significantly more elongated cross-sectional femoral midshaft shape in the (A-P) direction than females. In terms of biomechanics, the male femur would be stronger under bending stress and in its ability to resist bending force in the (A-P) than the (M-L) direction.

These external dimensions do not reflect the actual distribution of compact bone; it is possible that a study of this distribution using cross-sectional geometry would produce different results. However, the Pilastric Index differences are confirmed by cross-sectional femoral midshaft geometry studies across sexes.

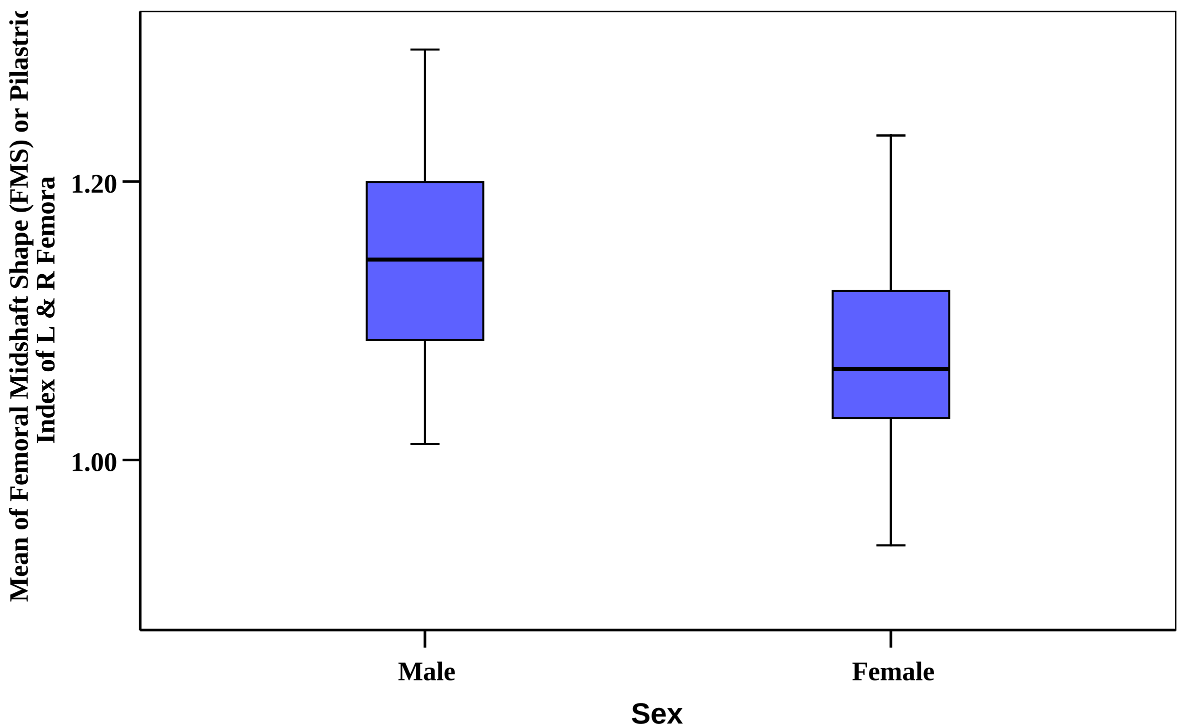

Fig. 5.3. Mean values of femoral midshaft shape (FMS) or Pilastric Index of left and right femora of pooled North American sample by sex ($F = 5.36$; with 1 df; $P = 0.03$).

Both cross-sectional femoral midshaft shape and anterior femoral curvature show that men from a pooled Mississippian/Woodland sample walked and ran more than women, who must have lived a more sedentary lifestyle and engaged in less walking and running. For that reason, femora of males were biomechanically must have been subjected to higher amount of and/or more frequent bending loading resulted from walking and running than females' femora. This bending loading was enough to stimulate osteogenic or mechanostat process that modified cross-sectional femoral midshaft shape. This process developed more elongated cross-sectional shape in (A-P) direction of the midshaft of femur, which its functional ability to resist bending force in (A-P) higher than in (M-L) direction. While cross-sectional shape of femur at the midshaft shows significant degree of phenotypic plasticity, cross-sectional shape at the subtrochantric region of the same bone does not.

Platymeric Index: Subtrochantric Shape

As shown in Table 5.10, both sexes show mean values of the Platymeric Index that fall in the range of being rounded subtrochantric region shape (eurymeric). Results show that there is no significant difference in mean values of the Platymeric Index or subtrochantric shape between males and females (F = 0.20; df = 1; P = 0.95) (Table 5.7). Both sexes are similar in shape of their femoral proximal diaphysis. Activity differences modeled by ethnographic analogy were not registered on the shape of the femoral proximal diaphysis, which shows the least amount of plasticity to mechanical loads.

This level of similarity in shape of this bony region between males and females of North American skeletal sample could be due to it being less affected by curvature of the bone than the midshaft.

It has been intensively reported by previous researchers that morphology of subtrochantric bony region is determined by genetics and shapely established early in human life (e.g., Miller, 1994; Wescott, 2006). Because of that, differences in activity level and subsistence tasks between males and females in both periods, which mostly happened after years of childhood, activated modeling processes that adjusted, but not significantly, the shape of early equally established in both growth directions proximal diaphysis of femur.

Native American populations are genetically highly homogenous (Cavalli-Sforza, 2000). Moreover, developmentally, the subtrochnatric region shape is mostly determined in years of childhood, while variation in level of activity and mechanical loading take place later. It may be that the only mechanical load that can modify shape in this region is the one associated with developing gait. Mechanical load differences between sexes, resulting from gait are negligible.

TABLE 5.11. *Mean values of femoral and tibial entheses of pooled North American skeletal sample by sex.*

Dependent Variable	**Sex**	**Mean**	**SE**	**95% Confidence Interval**	
				Lower Bound	**Upper Bound**
Log. of Mean of Glut. Med. of L & R Femora	Male	.60[a]	.15	.29	.91
	Female	.64	.14	.36	.92
Log. of Mean of Obtur. Extern. of L & R Femora	Male	.12[a]	.05	.00	.23
	Female	-3.98E-018	.05	-.10	.10
Log. of Mean of Glut. Max. of L & R Femora	Male	1.20[a]	.11	.98	1.42
	Female	.97	.10	.77	1.17
Log. of Mean of Psoas Maj. of L & R Femora	Male	.37[a]	.15	.06	.69
	Female	.40	.14	.11	.68
Log. of Mean Gastrocn. (Medial Head) of L & R Femora	Male	.70[a]	.18	.33	1.06
	Female	.47	.16	.13	.80
Log. of Tibial Tubero. of L & R Tibiae	Male	1.03[a]	.17	.69	1.37
	Female	.95	.15	.63	1.26
Log. of Mean of Soleus of L & R Tibiae	Male	1.09[a]	.15	.78	1.40
	Female	.68	.14	.40	.96
Log. of Mean of Squatting Facet of L & R Tibiae	Male	8.13E-020[a]	.06	-.12	.12
	Female	.02	.05	-.09	.13

[a] Based on modified population marginal mean.

III. PERIOD AND SEX MODEL

Mean values of femoral indices by period are presented in Table 5.12, grouped by sex. Mean values of lower limb entheses for each periodare presented in table 5.13, by sex. The interaction of period and sex, for mean values of femoral indices in the North American skeletal sample is not statistically significant. Results are shown in Table 5.7. In addition, none of the lower limb muscle scores shows significant variation by period and sex (Table 5.9). But when sexual dimorphism was separately assessed for each period, populations of both periods show significant degree of sexual dimorphism in some of femoral indices, as expected. Sexual dimorphism in each period will be discussed below. First, I will discuss it among bioarchaeological population of Woodland, and second among Mississippian skeletal sample.

TABLE 5.12. *Mean values of femoral indices of pooled North American skeletal sample by period and sex.*

Dependent Variable	Period	Sex	Mean	SE	95% Confidence Interval	
					Lower Bound	**Upper Bound**
Mean of POI of L & R Femora	Mississippian	Female	49.34	1.23	46.86	51.82
		Male	50.02	1.67	46.67	53.38
	Woodland	Female	49.30	.89	47.50	51.09
		Male	50.94	1.09	48.74	53.14
Mean of BI of L & R Femora	Mississippian	Female	3.29	.174	2.93	3.63
		Male	4.219	.236	3.75	4.69
	Woodland	Female	3.66	.126	3.40	3.91
		Male	4.529	.154	4.22	4.84
Mean of PI or FMS of L & R Femora	Mississippian	Female	1.07	.023	1.02	1.11
		Male	1.12	.031	1.06	1.19
	Woodland	Female	1.09	.016	1.06	1.13
		Male	1.14	.020	1.10	1.19
Mean of PLI of L & R Femora	Mississippian	Female	90.96	2.22	86.49	95.41
		Male	92.12	3.01	86.08	98.17
	Woodland	Female	93.40	1.61	90.17	96.64
		Male	91.96	1.97	87.99	95.9

TABLE 5.13. *Mean values of femoral and tibial entheses of pooled North American skeletal sample by period and sex.*

Dependent Variable	Period	Sex	Mean	SE	95% Confidence Interval	
					Lower Bound	Upper Bound
Log. of Mean of Glut. Med. of L & R Femora	Woodland	Male	.60	.15	.29	.91
		Female	.52	.09	.35	.71
	Mississippian	Male	.[a]	.	.	.
		Female	.75	.26	.22	1.287
Log. of Mean of Obtur. Extern. of L & R Femora	Woodland	Male	.12	.05	.00	.23
		Female	-6.07E-018	.03	-.06	.06
	Mississippian	Male	.[a]	.	.	.
		Female	-1.89E-018	.09	-.19	.19
Log. of Mean of Glut. Max. of L & R Femora	Woodland	Male	1.20	.11	.98	1.42
		Female	.94	.06	.81	1.06
	Mississippian	Male	.[a]	.	.	.
		Female	1.01	.19	.63	1.39
Log. of Mean of Psoas Maj. of L & R Femora	Woodland	Male	.37	.15	.06	.69
		Female	.44	.09	.26	.63
	Mississippian	Male	.[a]	.	.	.
		Female	.35	.27	-.20	.90
Log. of Mean Gastrocn. (Medial Head) of L & R Femora	Woodland	Male	.70	.18	.33	1.06
		Female	.53	.10	.32	.74
	Mississippian	Male	.[a]	.	.	.
		Female	.41	.30	-.22	1.04
Log. of Tibial Tubero. of L & R Tibiae	Woodland	Male	1.03	.17	.69	1.37
		Female	.81	.10	.61	1.01
	Mississippian	Male	.[a]	.	.	.
		Female	1.09	.29	.49	1.68
Log. of Mean of Soleus of L & R Tibiae	Woodland	Male	1.09	.15	.78	1.40
		Female	.74	.09	.56	.92
	Mississippian	Male	.[a]	.	.	.
		Female	.62	.26	.08	1.16
Log. of Mean of Squatting Facet of L & R Tibiae	Woodland	Male	8.13E-020	.06	-.12	.12
		Female	.04	.03	-.03	.11
	Mississippian	Male	.[a]	.	.	.
		Female	8.15E-020	.10	-.21	.21

[a] This level combination of factors is not observed, thus the corresponding population marginal mean is not estimable.

The lower limb has shown correlations of the Bowing Index with two major muscle entheses, showing the Bowing Index related to activity. Sexual dimorphism is strong, but differences among the archaeological periods are slight.

SEX DIFFERENCES IN EACH ARCHAEOLOGICAL PERIOD

SEXUAL DIMORPHISM AMONG WOODLAND SKELETAL SAMPLE

Absolute values of skewness and kurtosis of femoral indices of Woodland skeletal sample are in Table 5.14. All are normally distributed and do not depart significantly from mesokurtic. Femoral and tibial skewness and kurtosis absolute values are shown in Table 5.15. Even after they were transformed into natural logarithm, some of them still significantly depart from normal distribution or/and mesokurtic. So, in those cases, I used the Spearman's rank-order correlation coefficient. Correlations among age and these entheses are presented in Table 5.16.

TABLE 5. 14. *Descriptive statistics of femoral indices of Woodland skeletal sample.*

	N	Mean		SD	Skewness		Kurtosis	
Dependent Variable	**Statistic**	**Statistic**	**SE**	**Statistic**	**Statistic**	**SE**	**Statistic**	**SE**
Mean of POI of L & R Femora	35	49.95	.60	3.54	-.19	.40	.15	.78
Mean of BI of L & R Femora	35	4.01	.12	.68	.18	.40	-.41	.78
Mean of PI or FMS of L & R Femora	41	1.11	.013	.083	.19	.37	-.82	.72
Mean of PLI of L & R Femora	42	91.94	1.33	8.61	.24	.37	-.38	.72

TABLE 5. 15. *Descriptive statistics of femoral and tibial entheses of Woodland skeletal sample.*

	N	Mean		SD	Skewness		Kurtosis	
Dependent Variable	**Statistic**	**Statistic**	**SE**	**Statistic**	**Statistic**	**SE**	**Statistic**	**SE**
Log. Of Mean of Glut. Med. of L & R Femora	39	.50	.07	.40	-.16	.38	-1.50	.74
Log. of Mean of Obtu. Extern. of L & R Femora	40	.04	.03	.20	4.64	.37	21.59	.73
Log. of Mean of Glut. Max. of L & R Femora	41	.94	.05	.32	-1.15	.37	1.87	.72
Log. of Mean of Psoas Maj. of L & R Femora	37	.35	.06	.37	.18	.39	-1.82	.76
Log. of Mean Gastrocn. (Medial Head) of L & R Femora	30	.58	.08	.41	-.08	.43	-1.07	.83
Log. of Tibial Tubero. of L & R Tibiae	37	.82	.07	.42	-.70	.39	-.22	.76
Log. of Mean of Soleus of L & R and Tibiae	38	.83	.06	.40	-.76	.38	-.08	.75
Log. of Mean of Squatting Facet of L & R Tibiae	38	.09	.05	.30	4.03	.38	17.74	.75

TABLE 5.16**.** *Correlations among age and femoral and tibial entheses of Woodland skeletal sample.*

		Log. of Mean of Glut. Med. of L & R Femora	**Log. of Mean of Obtu. Extern. of L & R Femora**	**Log. of Mean of Glut. Max. of L & R Femora**	**Log. of Mean of Psoas Maj. of L & R Femora**	**Log. of Mean Gastrocn. (Medial Head) of L & R Femora**	**Log. of Tibial Tubero. of L & R Tibiae**	**Log. of Mean of Soleus of L & R and Tibiae**	**Log. of Mean of Squatting Facet of L & R Tibiae**
Age	Correlation Coefficient	.20	.18	.11	-.05	.21	-.03	**.35**	-.11
	Sig. (2-tailed)	.23[b]	.26[b]	.51[b]	.78[b]	.28[a]	.86[a]	.03[a]	.53[b]
	N	39	40	41	37	30	37	38	38
Log. of Mean of Glut. Med. of L & R Femora	Correlation Coefficient		.09	.29	.27	**.40**	**.40**	.14	.04
	Sig. (2-tailed)		.59[b]	.07[b]	.12[b]	.03[a]	.02[a]	.42[a]	.81[b]
	N		38	39	35	30	34	35	35
Log. of Mean of Obtu. Extern. of L & R Femora	Correlation Coefficient			-.00	.09	.21	-.24	-.17	**.34**
	Sig. (2-tailed)			.99[b]	.63[b]	.27[a]	.17[a]	.34[a]	.04[b]
	N			40	37	29	35	36	36
Log. of Mean of Glut. Max. of L & R Femora	Correlation Coefficient				.22	**.45**	**.48**	**.42**	**-.33**
	Sig. (2-tailed)				.19[b]	.01[a]	.00[a]	.01[a]	.05[b]
	N				37	30	35	36	36
Log. of Mean of Psoas Maj. of L & R Femora	Correlation Coefficient					**.60**	**.39**	**.31**	**-.36**
	Sig. (2-tailed)					.00[a]	.02[a]	.08[a]	.04[b]
	N					26	33	33	33
Log. of Mean Gastrocn. (Medial Head) of L & R Femora	Correlation Coefficient						**.49**	**.41**	-.27
	Sig. (2-tailed)						.01[a]	.03[a]	.17[b]
	N						26	27	27
Log. of Tibial Tubero. of L & R Tibiae	Correlation Coefficient							.28	-.27
	Sig. (2-tailed)							.10[a]	.11[b]
	N							36	36
Log. of Mean of Soleus of L & R and Tibiae	Correlation Coefficient								-.30
	Sig. (2-tailed)								.07[b]
	N								38

[a]These Probability Values were Obtained From Pearson's Formula
[b]These Probability Values were Obtained From Spearman's Formula

TABLE 5.17. *Correlations between femoral and tibial entheses and femoral indices of Woodland skeletal sample.*

		Log. of Mean of Glut. Med. of L & R Femora	**Log. of Mean of Obtu. Extern. of L & R Femora**	**Log. of Mean of Glut. Max. of L & R Femora**	**Log. of Mean of Psoas Maj. of L & R Femora**	**Log. of Mean Gastrocn. (Medial Head) of L & R Femora**	**Log. of Tibial Tubero. of L & R Tibiae**	**Log. of Mean of Soleus of L & R and Tibiae**	**Log. of Mean of Squatting Facet of L & R Tibiae**
Mean of POI of L & R Femora	Correlation Coefficient	-.22	.06	-.03	-.20	-.21	.02	.04	-.05
	Sig. (2-tailed)	.24[b]	.76[b]	.89[b]	.29[b]	.32[a]	.91[a]	.86[a]	.80[b]
	N	31	33	33	31	25	28	29	29
Mean of BI of L & R Femora	Correlation Coefficient	.15	-.02	**.40**	.05	.25	**.51**	.36	-.13
	Sig. (2-tailed)	.42[b]	.92[b]	.02[b]	.80[b]	.22[a]	.01[a]	.06[a]	.50[b]
	N	31	33	33	31	25	28	29	29
Mean of PI or FMS of L & R Femora	Correlation Coefficient	.23	.19	.15	.07	.07	.08	.25	-.17
	Sig. (2-tailed)	.18[b]	.27[b]	.37[b]	.68[b]	.73[a]	.65[a]	.16[a]	.35[b]
	N	36	37	38	34	30	33	34	34
Mean of PLI of L & R Femora	Correlation Coefficient	-.24	-.06	.22	.23	.16	.06	.22	-.32
	Sig. (2-tailed)	.15[b]	.71[b]	.19[b]	.19[b]	.41[a]	.74[a]	.21[a]	.06[b]
	N	37	38	39	35	30	34	35	35

[a] These Probability Values were Obtained From Pearson's Formula
[b] These Probability Values were obtained From Spearman's Formula

TABLE 5.18. *Pearson's correlations among age and femoral indices of Woodland skeletal sample.*

		Mean of POI of L & R Femora	**Mean of BI of L & R Femora**	**Mean of PI or FMS of L & R Femora**	**Mean of PLI of L & R Femora**
Age	Pearson Correlation	-.07	-.00	.08	-.08
	Sig. (2-tailed)	.67	.10	.61	.63
	N	35	35	41	42
Mean of POI of L & R Femora	Pearson Correlation		.11	.00	-.01
	Sig. (2-tailed)		.54	.99	.95
	N		35	35	35
Mean of BI of L & R Femora	Pearson Correlation			.14	-.05
	Sig. (2-tailed)			.41	.76
	N			35	35
Mean of PI or FMS of L & R Femora	Pearson Correlation				.29
	Sig. (2-tailed)				.06
	N				41

Position Index: Anatomical Location of the Maximum Curvature

Table 5.19 shows mean values of the Position Index for males and females of the Woodland skeletal sample. Males display higher mean values than of females. Morphologically, males' most curved point is distal to the midshaft, females' is proximally to the midshaft. Statistically, the difference between male and female mean values of Position Index is not significant (t = -1.360; df = 33; P = 0.18) (Table 5.20).

Bowing Index: Anterior Femoral Curvature (AFC)

As shown in Table 5.19, males have higher mean value of Bowing Index than females do. Results show that the difference in Bowing Index is highly significant (t = -4.75; df = 33; P = 0.00). Mean values of lower limb entheses are presented in Table (5.21). Males of Woodland also have significantly higher score of gluteus maximus and soleus entheses than females of Woodland. Results of GLM are (F = 4.31; df = 1; P = 0.05) and (F = 4.55; df = 1; P = 0.05) for these entheses, respectively (Table 5.22). These also correlate with degree of femoral curvature. While the correlation between Bowing Index and gluteus maximus is significant (r_s = 0.40; P =0.02), it is almost significant with soleus (r = 0.36; P = 0.06). These correlations of the degree of anterior femoral curvature with entheses of gluteus maximus and soleus are results of all are involved in biomechanics of standing, walking, and running.

TABLE 5. 19. *Mean values of femoral indices of Woodland skeletal sample by sex.*

Dependent Variable	Sex	Mean	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
Mean of POI of L & R Femora	Female	49.30	.76	47.74	50.85
	Male	50.94	.94	49.04	52.84
Mean of BI of L & R Femora	Female	3.66	.12	3.42	3.89
	Male	4.53	.14	4.24	4.82
Mean of PI or FMS of L & R Femora	Female	1.09	.02	1.06	1.13
	Male	1.14	.02	1.10	1.19
Mean of PLI of L & R Femora	Female	93.40	1.75	89.84	96.97
	Male	91.96	2.15	87.59	96.32

TABLE 5.20. *Results of t-test of differences between mean values of femoral indices of left and right femora of males and females of Woodland skeletal sample.*

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
Dependent Variable		**F**	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**Lower**	**Upper**
Mean of POI of L & R Femora	Equal variances assumed	.07	.79	-1.36	33	.18	-1.64	1.21	-4.10	.81
Mean of BI of L & R Femur	Equal variances assumed	.03	.87	-4.75	33	**.00**	-.87	.18	-1.25	-.50
Mean of PI or FMS of L & R Femora	Equal variances assumed	.27	.61	-2.51	39	**.02**	-.06	.03	-.12	-.01
Mean of PLI of L & R Femora	Equal variances assumed	2.38	.13	-.05	40	.96	-.13	2.81	-5.81	5.54

TABLE 5.21. *Mean values of femoral and tibial entheses of Woodland skeletal sample by sex.*

Dependent Variable	Sex	Mean	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
Log. of Mean of Glut. Med. of L & R Femora	Male	.60	.16	.27	.92
	Female	.54	.09	.34	.73
Log. of Mean of Obtu. Extern. of L & R Femora	Male	.12	.06	-.00	.23
	Female	-2.44E-018	.03	-.07	.07
Log. of Mean of Glut. Max. of L & R Femora	Male	1.20	.11	.97	1.43
	Female	.93	.07	.79	1.07
Log. of Mean of Psoas Maj. of L & R Femora	Male	.37	.15	.06	.69
	Female	.43	.09	.24	.62
Log. of Mean Gastrocn. (Medial Head) of L & R Femora	Male	.70	.18	.33	1.06
	Female	.51	.10	.29	.72
Log. of Tibial Tubero. of L & R Tibiae	Male	1.03	.17	.68	1.38
	Female	.79	.10	.58	.10
Log. of Mean of Soleus of L & R and Tibiae	Male	1.09	.15	.78	1.39
	Female	.72	.09	.54	.90
Log. of Mean of Squatting Facet of L & R Tibiae	Male	6.94E-018	.06	-.13	.13
	Female	.04	.04	-.03	.12

TABLE 5.22. *Results of GLM of effect of sex on femoral and tibial entheses of Woodland skeletal sample.*

	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Sex	**Log. of Mean of Glut. Med. of L & R Femora**	.02	1	.02	.12	.74
	Log. of Mean of Obtu. Extern. of L & R Femora	.06	1	.06	3.10	.09
	Log. of Mean of Glut. Max. of L & R Femora	.32	1	.32	4.31	**.05**
	Log. of Mean of Poas Maj. of L & R Femora	.01	1	.01	.10	.76
	Log. of Mean Gastrocn. (Medial Head) of L & R Femora	.16	1	.16	.85	.37
	Log. of Tibial Tubero. of L & R Tibiae	.26	1	.26	1.52	.23
	Log. of Mean of Soleus of L & R and Tibiae	.59	1	.59	4.55	**.05**
	Log. of Mean of Squatting Facet of L & R Tibiae	.01	1	.01	.34	.57

Archaeologically activity model shows that men in Woodland were more physically active than females. This model is strongly supported by the biological evidence, in which men exhibit more curved anteriorly femora than females. Biomechanically, males of Woodland walked and ran more than females. Because of that, they developed higher degree of anterior femoral curvature to resist bending force

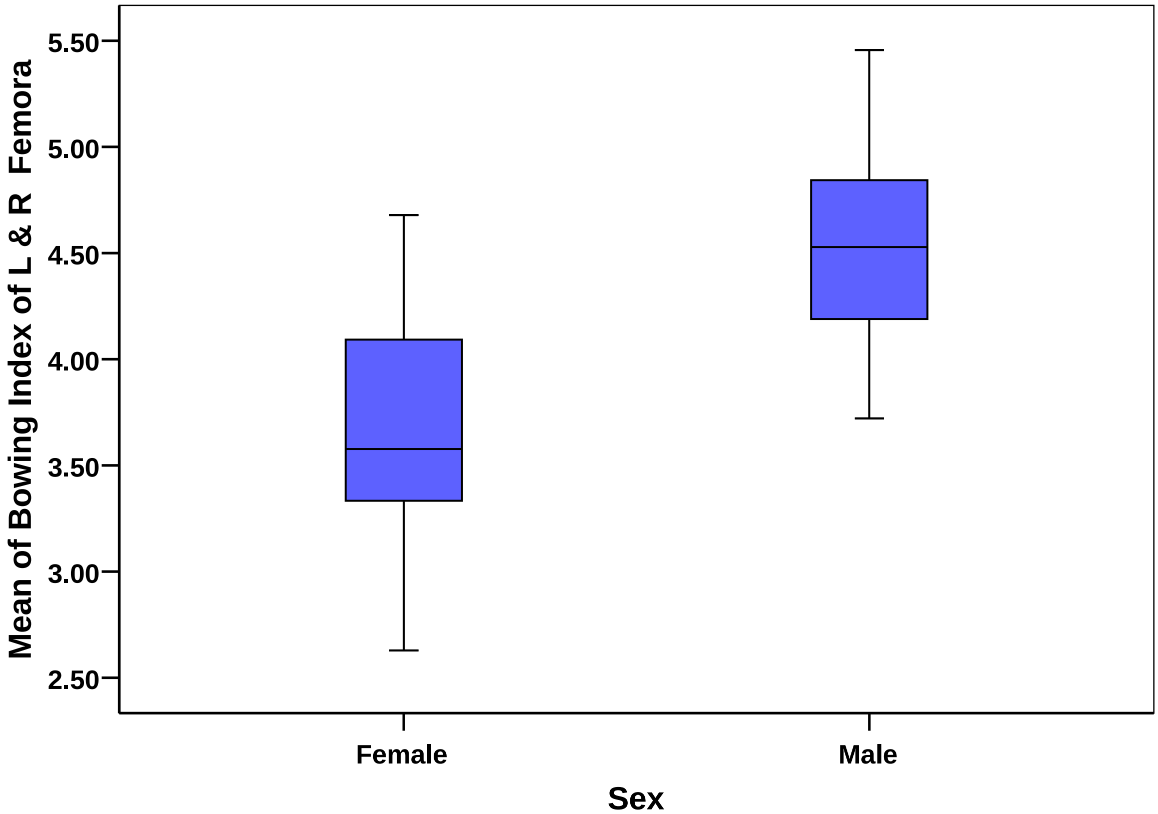

Fig. 5.4. Mean values of Bowing Index left and right femora of Woodland skeletal sample by sex (t = -4.75; with 33 df; P = 0.00).

Pilastric Index: Femoral Midshaft Shape (FMS)

As shown in Table 5.19, males have higher mean value of Pilastric Index than of females'. Morphologically, men display a more elongated cross-sectional femoral midshaft shape in the (A-P) plane than women. This difference in femoral midshaft shape between men and women is statistically significant. These results are (t = - 2.56; df = 39; P = 0.02) (Table 5.20).

As mentioned above and according to archaeologically reconstructed model of activity, men in Woodland were more active physically than women, who adopted more sedentary lifestyle. As a result of that, men developed an anteriorposteriorly elongated femoral cross-section at midshaft, which would be stronger under bending force than one circular in section. Bending force results mostly from walking and running, which were performed more by men of Woodland.

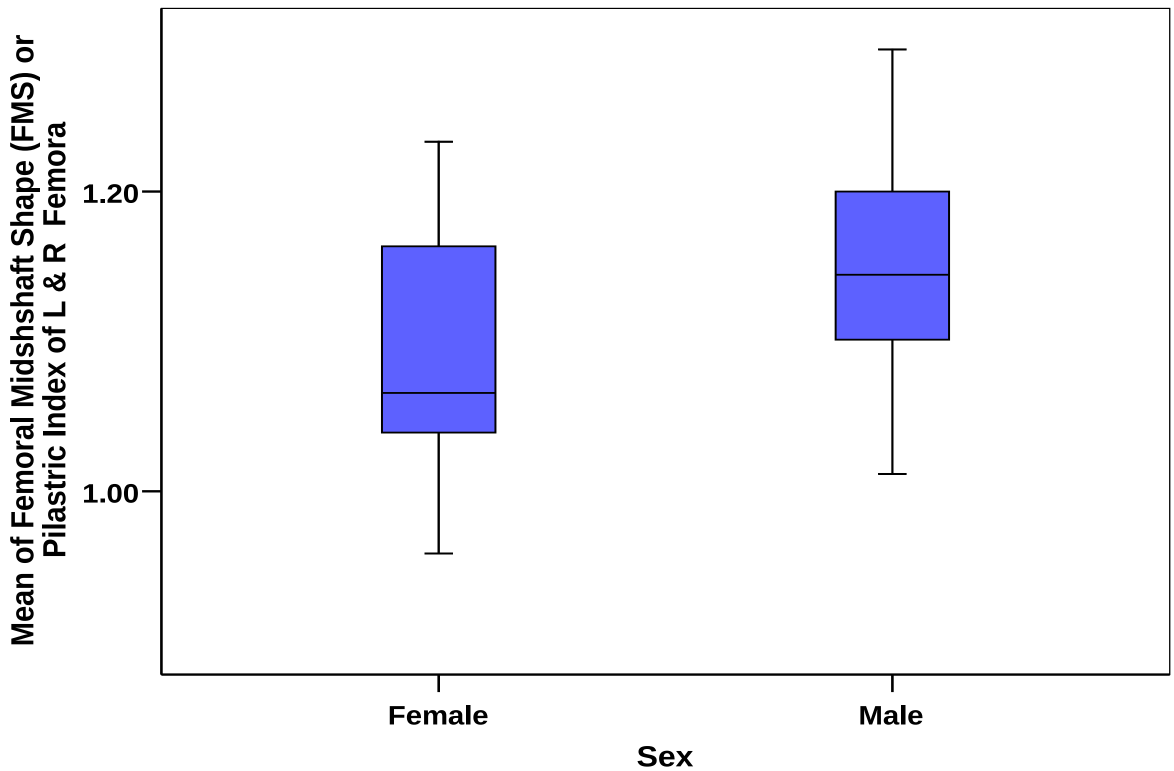

Fig. 5.5.Mean values of femoral midshaft shape (FMS) or Pilastric Index of Woodland skeletal sample by sex (t = -2.56; df = 29; P = 0.02).

Platymeric Index: Subtrochantric Shape

Table 5.19 shows mean values of Platymeric Index of Woodland males and females. Males and females lived in Woodland period do not significantly differ in external shape of proximal femoral diaphysis (t = -.05; df = 40; P = 0.96) (Table 5.20). Both sexes have a similar, eurymeric subtrochantric cross-section. This region is not strongly influenced by differences in activity level between sexes, because it is strongly determined by genetics and its shape is mostly established during the first 5 years of age (Gill, 2001; Wescott, 2006). So, any difference in amount and/or rate of mechanical loads imposed on lower limb that happened latter in the life course between sexes, activated osteogenic or mechanostat process that adjusted, but not strongly, early shaped morphology of this region.

SEXUAL DIMORPHISM AMONG MISSISSIPPIAN SKELETAL SAMPLE

FEMORAL INDICES

Table 5.23 shows absolute values of skewness and kurtosis of femoral indices of Mississippian skeletal sample. None of them departs significantly from normal distribution or mesokurtic.

LOWER LIMB ENTHESES

These were transformed into natural logarithm to achieve normal distribution. As shown in Table 5.24, while some of them still skewed significantly and/or departs from mesokurtic even after the transformation, others are normally distributed and have mesokurtic.

As shown in Table 5.25 no significant correlation among age and femoral indices of Mississippian skeletal sample. When correlation among age and lower limb entheses was examined, none of them significantly with age, but of them two correlate significantly. These are gluteus medius and gastrocnemius (r_s = 1.0; P = very low (can not be estimated) (Table 5.25).

Correlation of these entheses with femoral indices was tested. As shown in Table (5.26), none of them significantly correlates with any of the femoral indices.

TABLE 5.23. *Descriptive statistics of femoral indices of Mississippian skeletal sample.*

	N	Mean		SD	Skewness		Kurtosis	
Dependent Variable	**Statistic**	**Statistic**	**SE**	**Statistic**	**Statistic**	**SE**	**Statistic**	**SE**
Mean of POI of L & R Femora	17	49.58	1.21	5.00	.23	.55	-1.35	1.06
Mean of BI of L & R Femora	17	3.61	.192	.80	-.34	.55	-.67	1.06
Mean of PI or FMS of L & R Femora	18	1.09	.02	.08	-.06	.54	-.70	1.04
Mean of PLI of L & R Femora	18	91.03	1.30	5.51	-.01	.54	-1.22	1.04

TABLE 5.24. *Descriptive statistics of femoral and tibial entheses of Mississpippian skeletal sample.*

	N	Mean		SD	Skewness		Kurtosis	
Dependent Variable	**Statistic**	**Statistic**	**SE**	**Statistic**	**Statistic**	**SE**	**Statistic**	**SE**
Log. of Mean of Glut. Med. of L & R Femora	15	.64	.07	.28	-1.57	.58	2.93	1.12
Log. of Mean of Glut. Max. of L & R Femora	17	.83	.05	.22	.33	.55	-.49	1.06
Log. of Mean of Psoas Maj. of L & R Femora	16	.23	.09	.36	.98	.56	-1.04	1.09
Log. of Mean Gastrocn. (Medial Head) of L & R Femora	5	.75	.19	.43	-1.91	.91	3.97	2.00
Log. of Tibial Tubero. of L & R Tibiae	15	.54	.13	.50	.10	.58	-1.40	1.12
Log. of Mean of Soleus of L & R Tibiae	18	.66	.08	.36	-.54	.54	-.58	1.04

TABLE 5.25. *Correlations among age and femoral and tibial entheses of Mississippian skeletal sample.*

		Log. of Mean of Glut. Med. of L & R Femora	**Log. of Mean of Glut. Max. of L & R Femora**	**Log. of Mean of Psoas Maj. of L & R Femora**	**Log. of Mean Gastrocn. (Medial Head) of L & R Femora**	**Log. of Tibial Tubero. of L & R Tibiae**	**Log. of Mean of Soleus of L & R Tibiae**
Age	Pearson Correlation	.30	.07	.09	-.70	.22	-.01
	Sig. (2-tailed)	.28[b]	.80[a]	.75[a]	.19[b]	.44[a]	.97[a]
	N	15	17	16	5	15	18
Log. of Mean of Glut. Med. of L & R Femora	Pearson Correlation		.38	.42	**1.00**	.60	.32
	Sig. (2-tailed)		.16[a]	.13[a]	.[b]	.07[a]	.32[a]
	N		15	14	3	10	12
Log. of Mean of Glut. Max. of L & R Femora	Pearson Correlation			.19	-.50	.00	.43
	Sig. (2-tailed)			.49[a]	.39[b]	.10[a]	.13[a]
	N			16	5	12	14
Log. of Mean of Psoas Maj. of L & R Femora	Pearson Correlation				.58	.53	.38
	Sig. (2-tailed)				.31[b]	.10[a]	.21[a]
	N				5	11	13
Log. of Mean Gastrocn. (Medial Head) of L & R Femora	Pearson Correlation					-.15	-.01
	Sig. (2-tailed)					.85[a]	.99[a]
	N					4	5
Log. of Tibial Tubero. of L & R Tibiae	Pearson Correlation						.44
	Sig. (2-tailed)						.11[a]
	N						15

[a] These Probability Values were Obtained From Pearson's Formula
[b] These Probability Values were Obtained From Spearman's Formula

TABLE 5.26. *Correlations between femoral and tibial entheses and femoral indices of Mississippian skeletal sample.*

		Log. of Mean of Glut. Max. of L & R Femora	**Log. of Mean of Psoas Maj. of L & R Femora**	**Log. of Tibial Tubero. of L & R Tibiae**	**Log. of Mean of Soleus of L & R Tibiae**	**Log. of Mean of Glut. Med. of L & R Femora**	**Log. of Mean Gastrocn. (Medial Head) of L & R Femora**
Mean of POI of L & R Femora	Correlation Coefficent	-.26	-.11	-.32	-.10	-.31	.63
	Sig. (2-tailed)	.33[a]	.69[a]	.33[a]	.74[a]	.27[b]	.37[b]
	N	16	15	11	13	14	4
Mean of BI of L & R Femora	Correlation coefficient	.29	-.23	-.26	-.11	-.19	.63
	Sig. (2-tailed)	.28[a]	.40[a]	.43[a]	.73[a]	.52[b]	.37[b]
	N	16	15	11	13	14	4
Mean of PI or FMS of L & R Femora	Correlation coefficient	-.38	.06	.05	-.23	-.10	.56
	Sig. (2-tailed)	.14[a]	.83[a]	.88[a]	.44[a]	.72[b]	.32[b]
	N	17	16	12	14	15	5
Mean of PLI of L & R Femora	Correlation coefficient	.08	-.32	-.39	.28	-.24	-.21
	Sig. (2-tailed)	.77[a]	.22[a]	.21[a]	.34[a]	.40[b]	.74[b]
	N	17	16	12	14	15	5

[a]These Probability Values were Obtained From Pearson's Formula
[b]These Probability Values were Obtained From Spearman's Formula

TABLE 5. 27. *Pearson's correlations among age and femoral indices of Mississippian skeletal sample.*

		Mean of POI of L & R Femora	**Mean of BI of L & R Femora**	**Mean of PI or FMS of L & R Femora**	**Mean of PLI of L & R Femora**
Age	Pearson Correlation	.13	-.17	-.22	.31
	Sig. (2-tailed)	.62	.50	.38	.22
	N	17	17	18	18
Mean of POI of L & R Femora	Pearson Correlation		.25	-.05	.14
	Sig. (2-tailed)		.34	.86	.59
	N		17	17	17
Mean of BI of L & R Femora	Pearson Correlation			-.18	.07
	Sig. (2-tailed)			.48	.80
	N			17	17
Mean of PI or FMS of L & R Femora	Pearson Correlation				.03
	Sig. (2-tailed)				.92
	N				18

Position Index: Anatomical Location of the Maximum Curvature

Table 5.28 shows mean values of Position Index of Mississippian males and females of. Difference in this index across sexes is not statistically significant (*t* =-0.26; df = 15; *P* = 0.80) (Table 5.29). It shows no phenotypic plasticity as Position Index of Woodland skeletal sample. But, femoral curvature does**,** as in the Woodland sample.

Bowing Index: Anterior Femoral Curvature (AFC)

Femoral curvature of Mississippian displays significant level of phenotypic plasticity as skeletal sample of Woodland. As shown in Table 5.28, males of Mississippian skeletal sample exhibits higher mean value for the Bowing Index than females do. Morphologically, the male femur is more curved anteriorly than of females. As shown in Table 5.29, difference in the amount of femoral anterior curvature by sex of Mississippian is extremely significant (*t* = -2.78; df = 15; *P* = 0.01). The division of labor by sex that was related to mobility was more pronounced in Mississippian times than in Woodland.

TABLE 5.28. *Mean values of femoral indices of Mississippian skeletal sample by sex.*

Dependent Variable	Sex	N	Mean	SD	Std. Error Mean
Mean of POI of L & R Femora	Female	11	49.34	5.17	1.56
	Male	6	50.03	5.12	2.09
Mean of BI of L & R Femora	Female	11	3.28	.71	.21
	Male	6	4.22	.57	.23
Mean of PI or FMS of L & R Femora	Female	12	1.07	.07	.021
	Male	6	1.12	.07	.03
Mean of PLI of L & R Femora	Female	12	90.49	4.91	1.42
	Male	6	92.12	6.95	2.84

TABLE 5.29. *Results of t-test of differences between mean values of femoral indices of left and right femora of males and females of Mississippian skeletal sample.*

		Levene's Test for Equality of Variances		t-test for Equality of Means						
Dependent Variable		**F**	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	Upper
Mean of POI of L & R Femora	Equal variances assumed	.10	.76	-.26	15	.80	-.68	2.62	-6.26	4.90
Mean of BI of L & R Femora	Equal variances assumed	.68	.42	-2.78	15	**.01**	-.94	.34	-1.66	-.22
Mean of PI or FMS of L & R Femora	Equal variances assumed	.01	.91	-1.53	16	.15	-.06	.04	-.13	.02
Mean of PLI of L & R Femora	Equal variances assumed	1.08	.31	-.58	16	.57	-1.64	2.81	-7.60	4.32

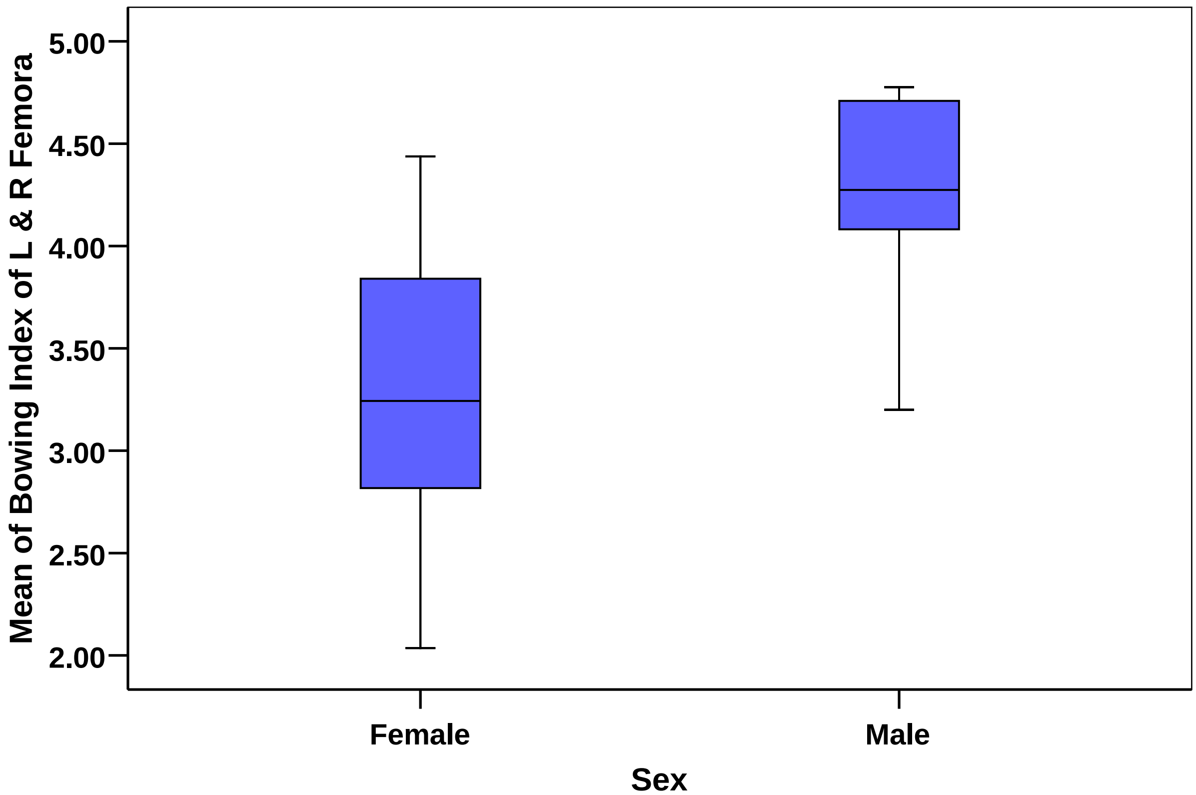

Fig. 5.6. Mean values of Bowing Index of left and right femora of Mississippian skeletal sample by sex (t = -2.78; with 15 df; P = 0.01).

Anterior femoral curvature responded strongly to differences in activity model between males and females. This indicates that men were engaged in more strenuous activities such as walking and running, than females. As the results of that, men of Mississippian skeletal sample femur responded significantly mainly to the amount or frequency of bending stress that resulted from walking and running, and developed more anterior curvature. This difference is slightly greater in the Mississippian time (mean difference between the sexes of 0.94 compared to 0.87 for Woodland. Had the difference been found statistically significant, it would have suggested that division of labor by gender was greater in the more agriculturally intensive Mississippian than the earlier Woodland period. However, at best, the trend is suggestive.

Pilastric Index: Femoral Midshaft Shape (FMS)

Table 5.28 shows that Mississippian men have a higher mean value of the Pilastric Index than Mississippian females. Morphologically and similar to the trend displayed in the Woodland skeletal sample, the cross-sectional femoral midshaft shape (FMS) of men is more elongated in the (A-P) direction than females do. But, the differences, although in the same direction, do not rise to the level of significance. Table 5.30 shows that the difference between mean values of the Pilastric Index across sexes of Mississippian is not significant, but approaches significance at t = -1.53; df = 16; P = 0.15.

Platymeric Index: Subtrochantric Shape

Like the Platymeric Index of Woodland skeletal sample, the Platymeric Index of Mississippian does not show significant degree of sexual dimorphism. As shown in Table 5.28 men exhibit more elongated (A-P) subtrochantric shape than women do, but the difference is statistically insignificant (t = -0.58; df = 16; P = 0.62) for Position Index and Platymeric Index, respectively. In other words, this shape of femoral proximal diaphysis displays the least phenotypic plasticity, presumably because it is mostly determined early in the course of human life (Miller, 1994; Wescott, 2006).

Overall, the pattern of sex differences in the Bowing Index among the Mississippian sample is similar to that displayed by the Woodland sample. According to the model, males were more physically active in Mississippian agricultural societies than females. Men walked and ran between their households and agricultural fields, as well as in other activities, such as hunting or warfare. Differences in degree of anterior femoral curvature as expressed in the Bowing Index between sexes support the hypothesis.

TABLE 5. 30. *Mean values of femoral and tibial entheses of Mississippian skeletal sample by sex.*

Dependent Variable	Sex	Mean	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
Log. of Mean of Glut. Med. of L & R Femora	Male	.52	.12	.25	.80
	Female	.74	.10	.50	.99
Log. of Mean of Obtur. Extern. of L & R Femora	Male	.00	.00	.00	.00
	Female	.00	.00	.00	.00
Log. of Mean of Glut. Max. of L & R Femora	Male	.87	.10	.63	1.12
	Female	.90	.09	.68	1.12
Log. of Mean of Psoas Maj. of L & R Femora	Male	.00	.12	-.28	.28
	Female	.14	.11	-.11	.39
Log. of Tibial Tubero. of L & R Tibiae	Male	.35	.22	-.17	.86
	Female	.71	.19	.25	1.17
Log. of Mean of Soleus of L & R Tibiae	Male	.62	.12	.33	.91
	Female	.61	.11	.34	.87
Log. of Mean of Squatting Facet of L & R Tibiae	Male	.00	.00	.00	.00
	Female	.00	.00	.00	.00

TABLE 5.31. *Results of GLM of effect of sex on lower limb entheses on mean values of Femoral and tibial entheses of Mississippian skeletal sample.*

Source	**Dependent Variable**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Sex	**Log. of Mean of Glut. Med. of L & R Femora**	.11	1	.11	2.00	.20
	Log. of Mean of Glut. Max. of L & R Femora	.00	1	.00	.04	.86
	Log. of Mean of Psoas Maj. of L & R Femora	.04	1	.04	.78	.41
	Log. of Tibial Tubero. of L & R Tibiae	.30	1	.30	1.56	.25
	Log. of Mean of Soleus of L & R Tibiae	.00	1	.00	.01	.93

CHAPTER SEX: RESULTS AND DISCUSSION

SOUTH AMERICAN SKELETAL SAMPLE

FEMORAL INDICES

These indices will better be understood with anlaysis of entheses of muscles inserted or originated from femur and tibia. Differences among South American skeletal samples are defined in terms of ethnic groups as indicated by cranial deformation and sex (Pechenkina and Delgado, 2006).

Normal Distribution

Each femoral index also was tested for normal distribution before proceeding further in the statistical analysis. Table 6.1 shows skewness and kurtosis of femoral indices of South American skeletal sample. All femoral indices are positively skewed. In terms of kurtosis, while Position and Bowing Indices are platykurtic, Pilastric and Platymeric Indices are leptokurtic. However, none of them is significantly skewed or departs highly from mesokurtic.

LOWER LIMB ENTHESES

All enthesis scores were transformed to natural logarithm to more closely achieve normal distribution. All were tested for normal distribution. Table 6.2 shows absolute values of skewness and kurtosis of femoral and tibial transformed entheses of South American skeletal sample. While some are normally distributed and/or do not depart significantly from mesokurtic, others are not normally distributed and/or significantly depart from being mesokurtic. In that case, Spearman's (r_s), the correlation among ranks was used.

Table 6.3 shows correlation coefficients among age and all femoral and tibial entheses. While none of them correlates significantly with age, many of them correlate significantly with each other. Gluteus medius significantly positively correlates with soleus (r = 0.63; P = 0.00), gluteus maximus (r_s = 0.43; P = 0.00), and with obturator externus (r_s = 0.39; P = 0.00).

Psoas major significantly correlates with gluteus maximus (r_s = 0.40l; P = 0.00). Soleus correlates significantly with four other muscles. While it correlates negatively with gastrocnemius (r_s = - 0.28; P = 0.04), it positively correlates with gluteus maximus (r_s = 0.42; P = 0.00), with tibial tuberosity (r_s = 0.39; P = 0.00), and with obturator externus (r_s = 0.28; P = 0.04). When these were correlated with femoral indices, the only significant correlation is between psoas major and Platymeric Index (r = 0.54; P = 0.00). Because subtrochantric region is shaped during the first five years of age, and psoas major attaches to that region anatomically and has a crucial role in biomechanics of gait, this correlation, most likely, happens early in life.

Correlation was also used to examine the relation among age and femoral indices.
None is significant. The only two indices, that were significantly correlated were the Position Index and Bowing Index (r = - .51; P = 0.00). Morphologically, the Position Index moves proximally, as the degree of anterior femoral curvature increases.

When I tested the correlation between head diameter of left and right femora and maximum length of left and right femora with femoral indices, I found that mean of head diameter of left and right femora significantly correlated with the mean of Bowing Index of both left and right femora (r = 0.47; df = 46; P = 0.00). In addition, maximum diameter head of left and right femora significantly correlated with the Pilastric Index of left and right femora (r = 0.36;df = 49; P = 0.01). Thus, bone mass probably increases with curvature, both as response to mobility stresses. Supporting the hypothesis of bone mass increasing with the Bowing Index, the maximum length of left and right femora are significantly correlated with the mean of Pilastric Index of left and right femora ($r = 0.47$; df = 56; $P = 0.00$).

TABLE 6.1. *Descriptive statistics of femoral indices of pooled South American skeletal sample.*

	N	Mean		SD	Skewness		Kurtosis	
Dependent Variable	**Statistic**	**Statistic**	**SE**	**Statistic**	**Statistic**	**SE**	**Statistic**	**SE**
Mean of POI of L & R Femora	45	53.41	.64	4.31	.07	.35	-.81	.70
Mean of BI of L & R Femora	45	4.22	.12	.78	.29	.35	-.04	.70
Mean of PI or FMS of L & R Femora	44	1.06	.01	.08	.56	.36	.48	.70
Mean of PLI of L & R Femora	44	104.29	1.41	9.32	-.31	.36	.76	.70

TABLE 6.2. *Descriptive statistics of femoral and tibial entheses of pooled South American skeletal sample.*

	N	Mean		SD	Skewness		Kurtosis	
Dependent Variable	**Statistic**	**Statistic**	**SE**	**Statistic**	**Statistic**	**SE**	**Statistic**	**SE**
Log. of Glut. Med. of L & R Femora	54	.34	.05	.38	.60	.33	-1.07	.64
Log. of Obtur. Extern. of L & R Femora	58	.38	.05	.36	.21	.31	-1.42	.62
Log. of Glut. Max. of L & R Femora	57	.74	.05	.38	-.96	.32	-.13	.62
Log. of Mean of Psoas Maj. of L & R Femora	53	.66	.04	.32	-.43	.33	-.51	.64
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	56	.14	.04	.30	2.17	.32	3.94	.63
Log. of Mean of Tibial Tuberosity of L & R Tibiae	53	.27	.05	.34	.67	.33	-1.16	.64
Log. of Mean of Soleus of L & R Tibiae	56	.55	.05	.41	-.10	.32	-1.05	.63
Log. of Mean of Squatting Facet of L & R Tibiae	49	.25	.05	.34	.81	.34	-1.01	.67

TABLE 6.3. *Correlations among age and femoral and tibial entheses of pooled South American skeletal sample.*

		Log. of Glut. Med. of L & R Femora	Log. of Mean of Psoas Maj. of L & R Femora	Log. of Mean of Soleus of L & R Tibiae	Log. of Obtur. Extern. of L & R Femora	Log. of Glut. Max. of L & R Femora	Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	Log. of Mean of Tibial Tubero. of L & R Tibiae	Log. of Mean of Squatting Facet of L & R Tibiae
Age	Correlation coefficient	.01	-.11	.13	.09	.18	.16	.17	-.01
	Sig. (2-tailed)	.93[a]	.42[a]	.33[a]	.52[b]	.18[b]	.23[b]	.23[b]	.97[b]
	N	54	53	56	58	57	56	53	49
Log. of Glut. Med. of L & R Femora	Correlation coefficient		.18	**.63**	**.39**	**.43**	-.11	.21	.18
	Sig. (2-tailed)		.21[a]	.00[a]	.00[b]	.00[b]	.46[b]	.14[b]	.23[b]
	N		50	54	54	54	53	51	47
Log. of Mean of Psoas Maj. of L & R Femora	Correlation coefficient			.14	-.06	**.40**	.00	.15	.10
	Sig. (2-tailed)			.33[a]	.68[b]	.00[b]	.99[b]	.30[b]	.53[b]
	N			52	53	53	52	49	45
Log. of Mean of Soleus of L & R Tibiae	Correlation coefficient				**.28**	**.42**	**-.28**	**.39**	.22
	Sig. (2-tailed)				.04[b]	.00[b]	.04[b]	.00[b]	.12[b]
	N				56	56	55	53	49
Log. of Obtur. Extern. of L & R Femora	Correlation coefficient					.17	-.05	-.14	-.01
	Sig. (2-tailed)					.20[b]	.71[b]	.31[b]	.92[b]
	N					57	56	53	49
Log. of Glut. Max. of L & R Femora	Correlation coefficient						-.08	-.02	-.08
	Sig. (2-tailed)						.54[b]	.86[b]	.58[b]
	N						56	53	49
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	Correlation coefficient							-.01	-.22
	Sig. (2-tailed)							.94[b]	.13[b]
	N							53	48
Log. of Mean of Tibial Tubero. of L & R Tibiae	Correlation coefficient								.06
	Sig. (2-tailed)								.70[b]
	N								46

[a] These Probability Values were Obtained From Pearson's Formula
[b] These Probability Values were Obtained From Spearman's Formula

TABLE 6.4. *Correlations between femoral and tibial entheses and femoral indices of pooled South American skeletal sample.*

		Log. of Glut. Med. of L & R Femora	**Log. of Obtur. Extern. of L & R Femora**	**Log. of Glut. Max. of L & R Femora**	**Log. of Mean of Psoas Maj. of L & R Femora**	**Log. of Mean of Gastrocn. (Medial Head) of L & R Femora**	**Log. of Mean of Tibial Tubero. of L & R Tibiae**	**Log. of Mean of Soleus of L & R Tibiae**	**Log. of Mean of Squatting Facet of L & R Tibiae**
Mean of POI of L & R Femora	Correlation coefficient	.03	.10	-.01	-.08	-.10	.00	.06	.07
	Sig. (2-tailed)	.86[a]	.51[b]	.94[a]	.61[a]	.53[b]	.98[a]	.69[a]	.68[b]
	N	41	45	44	40	43	41	43	38
Mean of BI of L & R Femora	Correlation coefficient	-.03	-.28	-.03	.09	.11	.06	.03	-.04
	Sig. (2-tailed)	.86[a]	.06[b]	.85[b]	.60[a]	.47[b]	.73[a]	.85[a]	.80[b]
	N	41	45	44	40	43	41	43	38
Mean of PI or FMS of L & R Femora	Correlation coefficient	.22	.12	.23	.18	-.09	.12	.18	-.16
	Sig. (2-tailed)	.17[a]	.44[b]	.14[b]	.28[a]	.58[b]	.47[a]	.24[a]	.35[b]
	N	41	44	44	40	43	41	43	38
Mean of PLI of L & R Femora	Correlation coefficient	.13	.23	-.03	**.54**	.14	-.14	.08	-.05
	Sig. (2-tailed)	.41[a]	.14[b]	.83[b]	.00[a]	.36[b]	.40[a]	.60[a]	.78[b]
	N	41	44	44	40	43	41	43	38

[a]These Probability Values were Obtained From Pearson's Formula
[b] These Probability Values were obtained From Spearman's Formula

TABLE 6.5. *Pearson's correlations among age and femoral indices of pooled South American skeletal sample.*

		Mean of POI of L & R Femora	**Mean of BI of L & R Femora**	**Mean of PI or FMS of L & R Femora**	**Mean of PLI of L & R Femora**
Age	Pearson Correlation	-.04	.03	.14	-.02
	Sig. (2-tailed)	.80	.83	.35	.88
	N	45	45	44	44
Mean of POI of L & R Femora	Pearson Correlation		**-.51**	-.20	.01
	Sig. (2-tailed)		.00	.20	.97
	N		45	43	43
Mean of BI of L & R Femora	Pearson Correlation			.19	-.10
	Sig. (2-tailed)			.22	.53
	N			43	43
Mean of PI or FMS of L & R Femora	Pearson Correlation				.22
	Sig. (2-tailed)				.15
	N				44

CRANIAL DEFORMATION TYPE

Table 6.6 shows mean values of femoral indices by deformation type. Results of GLM show no significant differences in mean value of any femoral index between deformed and undeformed skeletal samples (Table 6.7). This could be because the two groups are genetically and behaviorally similar, but these contradict results of Pechenkina and Delgado (2006) hypothesis that one type is from the Andes. They are also negative for the fishing-agricultural ethnic group hypothesis of Rhode (2006), since some differences in mobility would be expected. Table 6.8 shows mean values of femoral and tibial entheses of South American skeletal sample by cranial deformation type. No significant relation with of cranial deformation is indicated (Table 6.9). Tibial tuberosity is larger among those are cranially undeformed than those are cranially deformed (Table 6.8). It closely approaches level of significance (F = 3.18; df =1; P = 0.086) (Table 6.9).

TABLE 6.6. *Mean values of femoral indices of left and right femora of South American skeletal sample by cranial deformation type.*

Dependent Variable	**Cranial Deformation Type**	**Mean**	**SE**	**95% Confidence Interval**	
				Lower Bound	**Upper Bound**
Mean of POI L & R Femora	Undeformed	54.52	1.09	52.33	56.72
	Deformed	53.05	.82	51.40	54.70
Mean of BI of L & R Femora	Undeformed	4.13	.19	3.75	4.51
	Deformed	4.27	.14	3.98	4.55
Mean of PI or FMS of L & R Femora	Undeformed	1.06	.02	1.02	1.10
	Deformed	1.05	.02	1.02	1.08
Mean of PLI of L & R Femora	Undeformed	102.06	2.41	97.20	106.93
	Deformed	104.79	1.80	101.15	108.44

TABLE 6.7. *Results of GLM of effect of cranial deformation type, sex, and cranial deformation type and sex on femoral indices of South American skeletal sample.*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Deformation Type	Mean of POI of L & R Femora	20.97	1	20.97	1.18	0.28
	Mean of BI of L & R Femora	0.19	1	0.19	0.19	0.56
	Mean of PI or FMS of L & R Femora	0.00	1	0.00	0.04	0.85
	Mean of PLI of L & R Femora	71.56	1	71.56	0.83	0.37
Sex	Mean of POI of L & R Femora	56.53	1	56.53	3.19	**0.01**
	Mean of BI of L & R Femora	1.54	1	1.54	2.89	0.10
	Mean of PI or FMS of L & R Femora	0.02	1	0.02	2.69	0.11
	Mean of PLI of L & R Femora	11.62	1	11.62	0.13	0.72
Deformation* Sex	Mean of POI of L & R Femora	6.20	1	6.20	1.01	0.35
	Mean of BI of L & R Femora	0.81	1	0.81	3.12	**0.06**
	Mean of PI or FMS of L & R Femora	0.00	1	0.00	0.03	0.87
	Mean of PLI of L & R Femora	22.59	1	22.59	0.26	0.61

TABLE 6.8. *Mean values of femoral and tibial entheses of pooled South American skeletal sample by cranial deformation type.*

Dependent Variable	Cranial Deformation	Mean	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
Log. of Glut. Med. of L & R Femora	Undeformed	.25	.11	.02	.48
	Deformed	.29	.08	.12	.46
Log. of Obtur. Exter. of L & R Femora	Undeformed	.29	.10	.08	.49
	Deformed	.32	.08	.17	.48
Log. of Glut. Max. of L & R Femora	Undeformed	.81	.12	.57	1.05
	Deformed	.68	.09	.50	.86
Log. of Mean of Psoas Maj. of L & R Femora	Undeformed	.70	.10	.50	.90
	Deformed	.64	.07	.49	.79
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	Undeformed	.17	.10	-.05	.38
	Deformed	.18	.08	.02	.33
Log. of Mean of Tibial Tubero. of L & R Tibiae	Undeformed	.47	.11	.25	.69
	Deformed	.24	.08	.07	.40
Log. of Mean of Soleus of L & R Tibiae	Undeformed	.57	.14	.29	.86
	Deformed	.49	.10	.28	.71
Log. of Mean of Squatting Facet of L & R Tibiae	Undeformed	.19	.07	.03	.34
	Deformed	.05	.06	-.06	.17

TABLE 6.9. *Results of GLM of effect of cranial deformation type, sex, and cranial deformation type and sex on mean values of femoral and tibial entheses of pooled South American skeletal sample.*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Cranial Deformation	**Log. of Glut. Med. of L & R Femora**	.01	1	.01	.09	.77
	Log. of Obtur. Exter. of L & R Femora	.01	1	.01	.09	.77
	Log. of Glut. Max. of L & R Femora	.12	1	.12	.79	.38
	Log. of Mean of Psoas Maj. of L & R Femora	.03	1	.03	.25	.62
	Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	.00	1	.00	.00	.952
	Log. of Mean of Tibial Tubero. of L & R Tibiae	.40	1	.40	3.177	.09
	Log. of Mean of Soleus of L & R Tibiae	.04	1	.04	.20	.66
	Log. of Mean of Squatting Facet of L & R Tibiae	.12	1	.12	2.02	.17
Sex	**Log. of Glut. Med. of L & R Femora**	.05	1	.05	.38	.54
	Log. of Obtur. Exter. of L & R Femora	.03	1	.03	.31	.59
	Log. of Glut. Max. of L & R Femora	.08	1	.08	.55	.47
	Log. of Mean of Psoas Maj. of L & R Femora	.05	1	.05	.50	.49
	Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	.01	1	.01	.06	.81
	Log. of Mean of Tibial Tubero. of L & R Tibiae	.07	1	.07	.54	.47
	Log. of Mean of Soleus of L & R Tibiae	.03	1	.03	.14	.71
	Log. of Mean of Squatting Facet of L & R Tibiae	.01	1	.01	.16	.69
Cranial Deformation and Sex	**Log. of Glut. Med. of L & R Femora**	.06	1	.05	.40	.53
	Log. of Obtur. Exter. of L & R Femora	2.31E-005	1	2.31E-005	.00	.99
	Log. of Glut. Max. of L & R Femora	.03	1	.03	.18	.67
	Log. of Mean of Psoas Maj. of L & R Femora	9.47E-005	1	9.47E-005	.00	.98
	Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	.01	1	.01	.04	.84
	Log. of Mean of Tibial Tubero. of L & R Tibiae	.00	1	.00	.01	.91
	Log. of Mean of Soleus of L & R Tibiae	.04	1	.04	.20	.66
	Log. of Mean of Squatting Facet of L & R Tibiae	.02	1	.02	.36	.55

SEX

Table 6.10 shows mean values of femoral indices of the South American skeletal sample by sex. The only index that significantly varies by sex is the Position Index. In addition, none of the lower limb entheses shows significant differences by sex. See Tables 6.11 and 6.12 for mean values of femoral and tibial entheses and results of GLM, respectively.

Position Index: Anatomical Location of the Maximum Curvature

Table 6.8 shows that these results are highly significant (F = 3.19; df = 1; P = 0.01). Females display higher mean value of Position Index than males. Morphologically, the most curved point is distal to the midshaft among females, but closer to midshaft among males.

TABLE 6. 10. *Mean values of femoral indices of pooled South American skeletal sample by sex.*

Dependent Variable	Sex	Mean	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
Mean of POI of L & R Femora	Male	52.54	.89	50.74	54.34
	Female	54.51	.91	52.67	56.35
Mean of BI of L & R Femora	Male	4.42	.16	4.10	4.73
	Female	3.97	.16	3.64	4.29
Mean of PI or FMS of L & R Femora	Male	1.08	.02	1.04	1.11
	Female	1.03	.02	.10	1.07
Mean of PLI of L & R Femora	Male	104.03	1.96	100.07	107.99
	Female	103.79	2.01	99.74	107.85

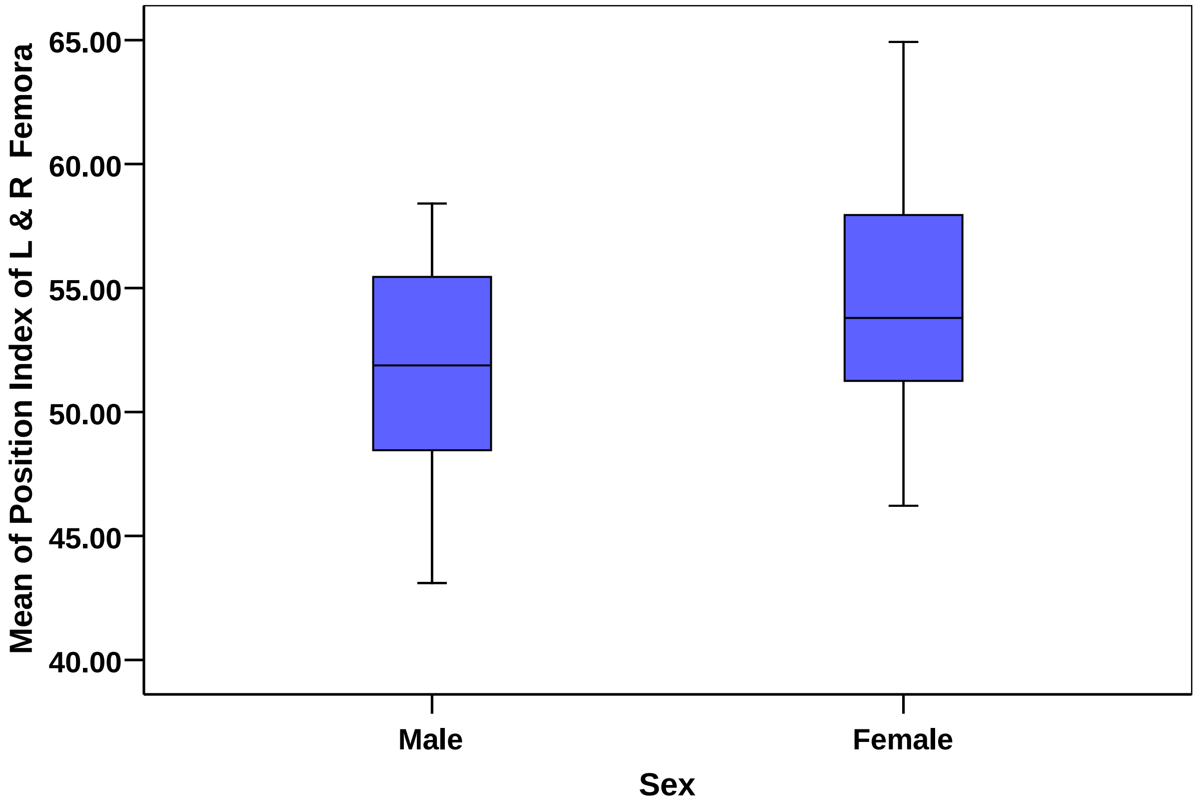

Fig. 6.1. Mean values of Position Index of left and right femora of pooled South American skeletal sample by sex (F = 3.19; df = 1; P = 0.01).

TABLE 6.11. *Mean values of femoral and tibial entheses of pooled South American skeletal sample by sex.*

Dependent Variable	Sex	Mean	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
Log. of Glut. Med. of L & R Femora	Male	.31	.10	.11	.51
	Female	.23	.10	.02	.43
Log. of Obtur. Exter. of L & R Femora	Male	.27	.09	.09	.45
	Female	.34	.09	.16	.52
Log. of Glut. Max. of L & R Femora	Male	.80	.10	.59	1.01
	Female	.69	.12	.48	.91
Log. of Mean of Psoas Maj. of L & R Femora	Male	.71	.08	.54	.88
	Female	.63	.09	.45	.80
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	Male	.19	.09	.00	.37
	Female	.16	.10	-.03	.35
Log. of Mean of Tibial Tubero. of L & R Tibiae	Male	.40	.09	.21	.59
	Female	.31	.10	.11	.50
Log. of Mean of Soleus of L & R Tibiae	Male	.50	.12	.25	.75
	Female	.57	.12	.31	.82
Log. of Mean of Squatting Facet of L & R Tibiae	Male	.14	.06	.01	.27
	Female	.10	.07	-.03	.24

Bowing Index: Anterior Femoral Curvature (AFC)

Results show that mean differences in bowing index between males and females of the South American skeletal sample pooled over cranial deformation approaches significance (F = 2.89; df = 1; P = 0.10). As expected, males have slightly greater degree of anterior femoral curvature than females.

Pilastric Index: Femoral Midshaft Shape (FMS)

Males display a more elongated femoral shape at the midshaft in the anterioposterior plane than females. But the difference is not statistically significant (F = 2.69; df = 1; P = 0.11) (Table 6.7).

Platymeric Index: Subtrochantric Shape

There is no differences in subtrochantric shape ($F = 0.13$; df = 1; $P = 0.72$) (Table 6.7).

CRANIAL DEFORMATION AND SEX MODEL

Table 6.13 shows mean values of all femoral indices of South American skeletal sample by deformation type and sex. In the overall model to test the impact of the interaction of deformation type and sex, as represented in Table 6.8, the only statistically significant impact is on mean values of Bowing Index. These results closely approach significance ($F = 3.12$; df = 1; $P = 0.06$). I will discuss each index separately.

Position Index: Anatomical Location of the Maximum Curvature

Table 6.12, shows that mean of Position Index is higher among undeformed than deformed South American skeletal sample, difference in degree of sexual dimorphism that is not statistically significant across samples (Table 6.7).

TABLE 6.12. *Mean values of femoral indices of left and right femora of pooled South American skeletal sample by cranial deformation type and sex.*

Dependent Variable	Cranial Deformation Type	Sex	Mean	SE	95% Confidence Interval	
					Lower Bound	**Upper Bound**
Mean of POI of L & R Femora	Undeformed	Female	56.14	1.72	52.66	59.61
		Male	52.91	1.33	50.22	55.60
	Deformed	Female	53.86	1.09	51.66	56.05
		Male	52.23	1.22	49.78	54.69
Mean of BI of L & R Femora	Undeformed	Female	4.07	.30	3.47	4.68
		Male	4.18	.23	3.72	4.65
	Deformed	Female	3.92	.19	3.54	4.30
		Male	4.61	.21	4.19	5.04
Mean of PI or FMS of L & R Femora	Undeformed	Female	1.04	.03	.97	1.11
		Male	1.08	.03	1.03	1.13
	Deformed	Female	1.03	.02	.99	1.07
		Male	1.08	.02	1.03	1.12
Mean of PLI of L & R Femora	Undeformed	Female	100.75	3.80	93.05	108.44
		Male	103.38	2.95	97.42	109.34
	Deformed	Female	105.01	2.41	100.15	109.88
		Male	104.58	2.69	99.14	110.02

TABLE 6. 13. *Mean values of femoral and tibial entheses of pooled South American skeletal sample by cranial deformation type and sex.*

Dependent Variable	Cranial Deformation	Sex	Mean	SE	95% Confidence Interval	
					Lower Bound	Upper Bound
Log. of Glut. Med. of L & R Femora	Undeformed	Male	.34	.15	.03	.65
		Female	.16	.17	-.18	.50
	Deformed	Male	.29	.12	.04	.54
		Female	.29	.11	.06	.52
Log. of Obtur. Exter. of L & R Femora	Undeformed	Male	.25	.14	-.03	.53
		Female	.32	.15	.02	.63
	Deformed	Male	.29	.11	.06	.52
		Female	.36	.10	.15	.56
Log. of Glut. Max. of L & R Femora	Undeformed	Male	.90	.16	.57	1.22
		Female	.73	.17	.37	1.08
	Deformed	Male	.70	.13	.44	.97
		Female	.66	.12	.42	.90
Log. of Mean of Psoas Maj. of L & R Femora	Undeformed	Male	.74	.13	.48	1.00
		Female	.66	.14	.37	.95
	Deformed	Male	.68	.11	.47	.90
		Female	.60	.10	.40	.79
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	Undeformed	Male	.20	.14	-.09	.48
		Female	.14	.15	-.18	.45
	Deformed	Male	.18	.11	-.06	.41
		Female	.18	.10	-.04	.39
Log. of Mean of Tibial Tubero. of L & R Tibiae	Undeformed	Male	.53	.14	.23	.83
		Female	.42	.16	.09	.74
	Deformed	Male	.28	.12	.03	.52
		Female	.20	.11	-.03	.41
Log. of Mean of Soleus of L & R Tibiae	Undeformed	Male	.50	.19	.12	.89
		Female	.64	.21	.22	1.07
	Deformed	Male	.50	.15	.19	.82
		Female	.49	.14	.20	.78
Log. of Mean of Squatting Facet of L & R Tibiae	Undeformed	Male	.23	.10	.03	.44
		Female	.14	.11	-.09	.36
	Deformed	Male	.05	.08	-.12	.21
		Female	.06	.07	-.09	.21

Bowing Index: Anterior Femoral Curvature (AFC)

As shown in Table 6.12, difference in mean values of Bowing Index between males and females among deformed is greater than the difference between males and females among undeformed South American skeletal sample. Difference in degree of sexual dimorphism displayed by the Bowing Index across two populations is almost statistically significant (F = 3.12; df =1; P = 0.06). While sexual dimorphism displayed by anterior femoral curvature is almost significant (t =-1.91; df = 26; P = 0.07) among cranially deformed sample, it is not among undeformed sample (t = -0.31; df =14; P = 0.76). If the deformed group were coastal in origin (Pechenkena and Delgado 2006) or fishermen (Rhode 2006), then the unusually bowed femora among deformed males might be related to subsistence differences among males. As will be discussed below, the tibial tuberosity also shows an interaction with female deformed having unusually small expressions, again, possibly a difference in activities. Delgado (personal communication) suspects that some of the deformed individuals might be weavers. They would have presumably have had less bowed femora (in fact, the least of the categories) and less strong expression of entheses at the tibial tuberosity.

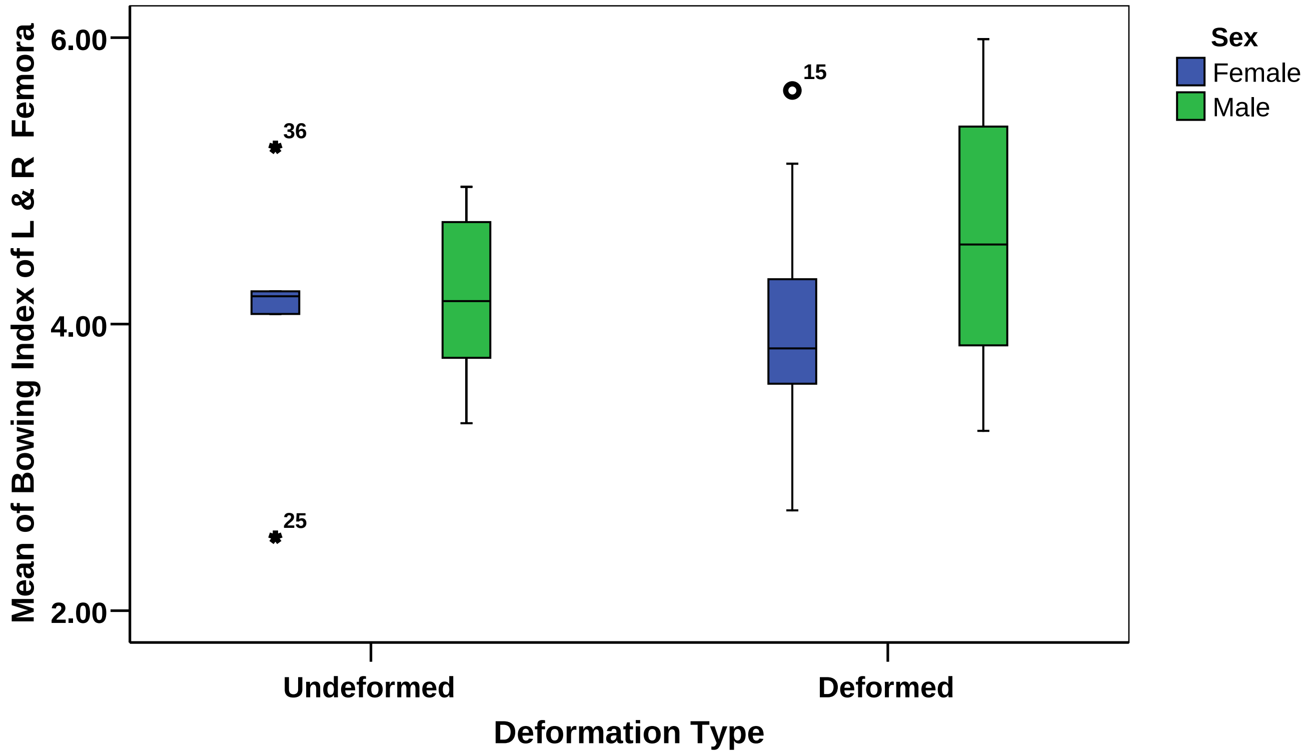

Fig. 6.2. Mean values of Bowing Index of left and right femora of pooled South American skeletal sample by cranial deformation type and sex (F = 3.12; df =1; P = 0.06).

Pilastric Index: Femoral Midshaft Shape (FMS)

There is no significant statistical difference in degree of sexual dimorphism displayed by femoral midshaft shape (FMS) (F = 0.03; df = 1; P = 0.87).

Platymeric Index: Subtrochantric Shape

As shown in Table 6.8, there is no statistically significant interaction effect of cranial deformation type and sex on mean values of the Platymeric Index**.**

Table 6.14 shows mean values of femoral and tibial of pooled South American sample by cranial deformation and sex. None of these vary significantly by cranial deformation and sex (Table 6.10).

SEXUAL DIMORPHISM AMONG CRANIALLY DEFORMED SAMPLE

FEMORAL INDICES

Skewness and kurtosis values of each femoral index were calculated and are presented in Table 6.14. None of the femoral indices is significantly skewed or departs from mesokurtic.

LOWER LIMB ENTHESES

All femoral and tibial entheses were tested for skewness and kurtosis. Table 6.15 shows absolute values of each entheses of the lower limb.

None of femoral and tibial entheses are significantly correlated with age. Gluteus medius positively correlates with two muscles. These are soleus (r = 0.40; P = 0.05) and psoas major (r = 0.39; P = 0.04) (Table 6.16). Psoas major only correlates significantly with Platymeric Index (r = 0.64; P = 0.00) (Table 6.17). There is a significant statistical negative correlation between Position Index and Bowing Index (r = - 0.50; P = 0.01) (Table 6.18). When a femur develops a higher degree of anterior curvature, the anatomical position of the most curved point moves proximally, toward the midshaft.

TABLE 6.14. *Descriptive statistics of femoral indices of cranially deformed South American skeletal sample.*

Dependent Variable	N	Mean		SD	Skewness		Kurtosis	
	Statistic	Statistic	SE	Statistic	Statistic	SE	Statistic	SE
Mean of POI of L & R Femora	29	53.01	.82	4.40	.36	.43	-.81	.85
Mean of BI of L & R Femora	29	4.26	.15	.83	.50	.43	-.46	.85
Mean of PI or FMS of L & R Femora	28	1.05	.02	.08	.42	.44	-.29	.86
Mean of PLI of L & R Femora	28	105.38	2.07	10.94	-.54	.44	.31	.86

TABLE 6. 15. *Descriptive statistics of femoral and tibial entheses of cranially deformed South American skeletal sample.*

Dependent Variable	N	Mean		SD	Skewness		Kurtosis	
	Statistic	Statistic	SE	Statistic	Statistic	SE	Statistic	SE
Log. of Mean of Glut. Med. of L & R Femora	28	.28	.07	.34	.89	.44	-.42	.86
Log. of Mean of Obtur. Extern. of L & R Femora	30	.41	.07	.36	.13	.43	-1.33	.83
Log. of Mean of Glut. Max. of L & R Femora	29	.68	.08	.40	-.66	.43	-.77	.85
Log. of Mean of Psoas Maj. of L & R Femora	26	.62	.07	.34	-.43	.46	-.81	.89
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	28	.13	.05	.26	2.46	.44	6.79	.86
Log. of Mean of Tibial Tubero. of L & R Tibiae	27	.24	.06	.32	.75	.45	-1.09	.87
Log. of Mean of Soleus of L & R Tibiae	29	.57	.08	.42	.02	.43	-.93	.85
Log. of Squatting Facet of L & R Tibiae	26	.18	.06	.32	1.57	.46	1.32	.89

TABLE 6.16. *Correlations among age and femoral and tibial entheses of cranially deformed South American skeletal Sample.*

		Log. of Mean of Glut. Med. of L & R Femora	**Log. of Mean of Obtur. Extern. of L & R Femora**	**Log. of Mean of Glut. Max. of L & R Femora**	**Log. of Mean of Psoas Maj. of L & R Femora**	**Log. of Mean of Gastrocn. (Medial Head) of L & R Femora**	**Log. of Mean of Tibial Tubero. of L & R Tibiae**	**Log. of Mean of Soleus of L & R Tibiae**	**Log. of Squatting Facet of L & R Tibiae**
Age	Correlation Coefficient	.14	.07	.03	.30	-.03	.01	.17	.35
	Sig. (2-tailed)	.49[b]	.73[a]	.86[a]	.11[a]	.90[b]	.95[a]	.40[a]	.08[b]
	N	28	30	30	29	26	28	27	26
Log. of Mean of Glut. Med. of L & R Femora	Correlation Coefficient		.19	.20	**.39**	.08	.03	**.40**	-.12
	Sig. (2-tailed)		.33[a]	.32[a]	.04[a]	.72[b]	.90[a]	.05[a]	.57[b]
	N		28	28	28	25	27	26	25
Log. of Mean of Obtur. Extern. of L & R Femora	Correlation Coefficient				.23	-.17	-.03	-.29	.03
	Sig. (2-tailed)				.22[a]	.42[b]	.88[a]	.14[a]	.89[b]
	N				29	26	28	27	26
Log. of Mean of Glut. Max. of L & R Femora	Correlation Coefficient					.34	.11	.09	-.37
	Sig. (2-tailed)					.09[b]	.59[a]	.68[a]	.07[b]
	N					26	28	27	26
Log. of Mean of Psoas Maj. of L & R Femora	Correlation Coefficient						.24	.07	-.09
	Sig. (2-tailed)						.26[a]	.74[a]	.69[b]
	N						25	24	23
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	Correlation Coefficient							.05	-.34
	Sig. (2-tailed)							.82[a]	.09[b]
	N							27	25
Log. of Mean of Tibial Tubero. of L & R Tibiae	Correlation Coefficient								.02
	Sig. (2-tailed)								.91[b]
	N								24
Log. of Mean of Soleus of L & R Tibiae	Correlation Coefficient								.16
	Sig. (2-tailed)								.44[b]
	N								26

[a] These Probability Values were Obtained From Pearson's Formula
[b] These Probability Values were Obtained From Spearman's Formula

TABLE 6. 17. *Correlations between femoral indices and femoral and tibial entheses of cranially deformed South American skeletal sample.*

		Log. of Mean of Glut. Med. of L & R Femora	**Log. of Mean of Obtur. Extern. of L & R Femora**	**Log. of Mean of Glut. Max. of L & R Femora**	**Log. of Mean of Psoas Maj. of L & R Femora**	**Log. of Mean of Gastrocn. (Medial Head) of L & R Femora**	**Log. of Mean of Tibial Tubero. of L & R Tibiae**	**Log. of Mean of Soleus of L & R Tibiae**	**Log. of Squatting Facet of L & R Tibiae**
Mean of POI of L & R Femora	Correlation Coefficient	.01	.03	-.10	-.07	-.20	.02	.00	.07
	Sig. (2-tailed)	.94[b]	.86[a]	.63[a]	.73[a]	.33[b]	.91[a]	.99[a]	.74[b]
	N	27	29	28	25	27	26	28	25
Mean of BI of L & R Femora	Correlation Coefficient	.07	-.29	.04	.21	.15	.15	-.04	-.08
	Sig. (2-tailed)	.73[b]	.13[a]	.84[a]	.32[a]	.46[b]	.46[a]	.86[a]	.72[b]
	N	27	29	28	25	27	26	28	25
Mean of PI or FMS of L & R Femora	Correlation Coefficient	.13	-.00	.09	.20	.07	.10	.05	-.19
	Sig. (2-tailed)	.51[b]	.99[a]	.65[a]	.33[a]	.75[b]	.63[a]	.81[a]	.38[b]
	N	27	28	28	25	27	26	28	25
Mean of PLI of L & R Femora	Correlation Coefficient	.05	.08	.00	**.64**	.17	-.12	.07	-.07
	Sig. (2-tailed)	.80[b]	.69[a]	.99[a]	.00[a]	.40[b]	.55[a]	.72[a]	.73[b]
	N	27	28	28	25	27	26	28	25

[a] These Probability Values were Obtained From Pearson's Formula
[b] These Probability Values were Obtained From Spearman's Formula

TABLE 6.18. *Pearson's correlations among age and femoral indices of cranially deformed South American skeletal sample.*

		Mean of POI of L & R Femora	**Mean of BI of L & R Femora**	**Mean of PI or FMS of L & R Femora**	**Mean of PLI of L & R Femora**
Age	Pearson Correlation	.05	-.09	.06	.04
	Sig. (2-tailed)	.78	.65	.78	.86
	N	29	29	28	28
Mean of POI of L & R Femora	Pearson Correlation		**-.50**	-.32	-.09
	Sig. (2-tailed)		.01	.11	.65
	N		29	27	27
Mean of BI of L & R Femora	Pearson Correlation			.21	-.08
	Sig. (2-tailed)			.29	.68
	N			27	27
Mean of PI or FMS of L & R Femora	Pearson Correlation				.24
	Sig. (2-tailed)				.22
	N				28

Table 6.19 represents mean values of each femoral index of males and females of the cranially deformed South American skeletal sample. Results of t-test are shown in Table 6.20. I will discuss each finding separately.

Position Index: Anatomical Location of the Maximum Curvature

As shown in Table 6.19, females have a higher mean Position Index than males, but the difference statistically not significant ($t = 0.67$; df = 26; $P = 0.51$) (Table 6.20).

TABLE 6.19. *Mean values of femoral indices of left and right femora of cranially deformed South American skeletal sample by sex.*

Dependent Variable	Sex	N	Mean	SD	Std. Error Mean
Mean of POI of L & R Femora	Female	16	53.38	4.71	1.18
	Male	12	52.23	4.14	1.20
Mean of BI of L & R Femora	Female	16	4.03	.72	.180
	Male	12	4.612	.90	.26
Mean of PI or FMS of L & R Femora	Female	16	1.03	.06	.02
	Male	12	1.08	.10	.03
Mean of PLI of L & R Femora	Female	16	105.98	13.41	3.35
	Male	12	104.58	6.89	1.99

Bowing Index: Anterior Femoral Curvature (AFC)

Males have higher mean value of Bowing Index than females. Morphologically males display more anteriorly curved femora than females. The difference among the cranially deformed South American skeletal sample approaches statistical significance (t = - 1.91; df = 26; P = 0.07) (Table 6.20). However, the differences are much less than expressed among Mississippians. This is possibly due to the lower curvature of South American femora compared with North America, perhaps it is surprising to find any sexual dimorphism at all.

Pilastric Index: Femoral Midshaft Shape (FMS)

As shown in Table 6.20, males have higher mean value of Pilastric Index than females, but statistically the difference is not significant (t = -1.46; df = 26; P = 0.156) (Table 6.20)).

Platymeric Index: Subtrochantric Shape

Females display higher mean value of Platymeric Index than males, but this difference is not significant statistically (t = 0.33; df = 26; P = 0.74) (Table 6.20).

Table 6. 22 shows mean values of lower limb entheses by sex. As with the femoral indices, none of these entheses varies significantly across sexes of cranially deformed South American skeletal sample (Table 6.22).

TABLE 6.20. *Results of t-test of differences between mean values of femoral indices of males and females of cranially deformed South American skeletal sample.*

		Levene's Test for Equality of Variances		t-test for Equality of Means						
Dependent Variable		**F**	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
Mean of POI of L & R Femora	Equal variances assumed	.03	.86	.67	26	.51	1.15	1.71	-2.37	4.66
Mean of BI of L & R Femora	Equal variances assumed	1.55	.23	-1.91	26	.07	-.58	.31	-1.21	.05
Mean of PI or FMS of L & R Femora	Equal variances assumed	3.07	.09	-1.46	26	.16	-.05	.03	-.11	.02
Mean of PLI of L & R Femora	Equal variances assumed	3.76	.06	.33	26	.74	1.40	4.25	-7.33	10.14

TABLE 6.21. *Mean values of femoral and tibial entheses of cranially deformed South American skeletal sample.*

Dependent Variable	Sex	Mean	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
Log. of Mean of Glut. Med. of L & R Femora	Male	.29	.13	.02	.56
	Female	.29	.12	.05	.54
Log. of Mean of Obtur. Extern. of L & R Femora	Male	.29	.10	.07	.51
	Female	.36	.09	.16	.56
Log. of Mean of Glut. Max. of L & R Femora	Male	.70	.14	.41	.99
	Female	.66	.13	.39	.92
Log. of Mean of Psoas Maj. of L & R Femora	Male	.68	.11	.45	.91
	Female	.60	.10	.39	.80
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	Male	.18	.10	-.03	.39
	Female	.17	.09	-.02	.36
Log. of Mean of Tibial Tubero. of L & R Tibiae	Male	.28	.11	.05	.50
	Female	.19	.10	-.01	.40
Log. of Mean of Soleus of L & R Tibiae	Male	.50	.16	.16	.84
	Female	.49	.15	.19	.79
Log. of Squatting Facet of L & R Tibiae	Male	.05	.06	-.08	.17
	Female	.06	.05	-.05	.18

TABLE 6.22. *Results of GLM of effect of sex on femoral and tibial entheses of cranially deformed South American skeletal sample.*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Sex	**Log. of Mean of Glut. Med. of L & R Femora**	1.99E-005	1	1.99E-005	.00	.99
	Log. of Mean of Obtur. Extern. of L & R Femora	.02	1	.02	.23	.64
	Log. of Mean of Glut. Max. of L & R Femora	.01	1	.01	.06	.81
	Log. of Mean of Psoas Maj. of L & R Femora	.04	1	.04	.35	.56
	Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	6.00E-005	1	6.00E-005	.00	.98
	Log. of Mean of Tibial Tubero. of L & R Tibiae	.03	1	.03	.33	.57
	Log. of Mean of Soleus of L & R Tibiae	.00	1	.00	.00	.96
	Log. of Squatting Facet of L & R Tibiae	.00	1	.00	.05	.83

SEXUAL DIMORPHISM AMONG CRANIALLY UNDEFORMED SAMPLE

FEMORAL INDICES

Values of skewness and kurtosis of all these femoral indices are shown in Table 6.23. While none of them is skewed significantly, femoral midshaft shape (FMS) or Pilastric Index does depart significantly from mesokurtic.

FEMORAL AND TIBIAL ENTHESESE

All femoral and tibial entheses of cranially undeformed South American skeletal sample were tested for skewness and kurtosis after were transformed into natural logarithm to achieve a more normal distribution. Table 6.24 presents values of skewness and kurtosis of each lower limb entheses included in the study. While some are still not normally distributed and/or depart significantly from mesokurtic, even after natural logarithm transformation, others achieve normal distribution and are mesokurtic.

TABLE 6. 23. *Descriptive statistics of femoral indices of cranially undeformed South American skeletal sample.*

Dependent Variable	N	Mean		SD	Skewness		Kurtosis	
	Statistic	**Statistic**	**SE**	**Statistic**	**Statistic**	**SE**	**Statistic**	**SE**
Mean of POI of L & R Femora	16	54.12	1.05	4.19	-.51	.57	.10	1.09
Mean of BI of L & R Femora	16	4.14	.17	.68	-.66	.56	1.09	1.09
Mean of PI or FMS of L & R Femora	16	1.06	.02	.08	1.05	.56	3.22	1.09
Mean of PLI of L & R Femora	16	102.39	1.32	5.26	-.42	.56	-.27	1.09

TABLE 6. 24. *Descriptive statistics of femoral and tibial entheses of cranially undeformed South American skeletal sample.*

	N	Mean		SD	Skewness		Kurtosis	
Dependent Variable	**Statistic**	**Statistic**	**SE**	**Statistic**	**Statistic**	**SE**	**Statistic**	**SE**
Log. of Mean of Glut. Med. of L & R Femora	14	.37	.10	.37	.26	.60	-1.61	1.15
Log. of Mean of Obtur. Extern. of L & R Femora	16	.34	.09	.35	.27	.56	-1.73	1.09
Log. of Mean of Glut. Max. of L & R Femora	16	.86	.07	.30	-1.62	.56	3.64	1.09
Log. of Mean of Psoas Maj. of L & R Femora	15	.70	.07	.26	-.13	.58	-.43	1.12
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	16	.12	.08	.33	2.85	.56	7.67	1.09
Log. of Mean of Tibial Tubero. of L & R Tibiae	15	.44	.10	.39	-.16	.58	-1.60	1.12
Log. of Mean of Soleus of L & R Tibiae	15	.64	.10	.38	-.85	.58	-.37	1.12
Log. of Mean of Squatting Facet of L & R Tibiae	13	.21	.09	.33	.95	.62	-1.34	1.19

Table 6.25 shows that none of the femoral and tibial entheses significantly correlates with age. But many of them significantly correlate with each other. Soleus correlates with many other muscles. While it significantly correlates positively with gluteus medius and gluteus maximus, it negatively correlates with gastrocnemius. These results of correlation are (r = 0.71; P = 0.01) between soleus and gluteus medius, (r = .53; P = 0.04) between soleus and gluteus maximus, and (r = - .67; P = .01) between soleus and gastrocnemius. The last correlation among lower limb entheses are between gluteus maximus and gestrocnemius (r_s = - .50; P = .05). This pattern is different from that observed with Mississippian, where fewer significant correlations were observed. When correlation of these entheses with femoral indices was tested, the only one significant is between soleus and femoral midshaft shape (FMS) (r_s = .55; P = .04) (Table 6.26). Surprisingly, the gastrocnemius does not correlate with the soleus. The deeper muscle, the soleus, is most active when knee is bent, as when picking up objects. Finally, correlation among age and also among femoral indices was examined. These results are presented in Table (6.28). The only significant correlation is between Bowing Index and Position Index (r = - .53; P = .04). Morphologically when anterior femoral curvature grows higher, the most curved point anatomically positioned closer to the midshaft.

TABLE 6. 25. *Correlations among age and femoral and tibial entheses of cranially undeformed South American skeletal sample.*

		Log. of Mean of Glut. Med. of L & R Femora	**Log. of Mean of Obtur. Extern. of L & R Femora**	**Log. of Mean of Glut. Max. of L & R Femora**	**Log. of Mean of Psoas Maj. of L & R Femora**	**Log. of Mean of Gastrocn. (Medial Head) of L & R Femora**	**Log. of Mean of Tibial Tubero. of L & R Tibiae**	**Log. of Mean of Soleus of L & R Tibiae**	**Log. of Mean of Squatting Facet of L & R Tibiae**
Age	Correlation coefficient	-.16	-.19	.06	-.32	.34	.05	.04	-.08
	Sig. (2-tailed)	.59[a]	.48[a]	.84[b]	.25[a]	.20[b]	.87[a]	.89[a]	.79[a]
	N	14	16	16	15	16	15	15	13
Log. of Mean of Glut. Med. of L & R Femora	Correlation coefficient		.45	.11	-.07	-.43	-.07	**.71**	.46
	Sig. (2-tailed)		.11[a]	.71[b]	.82[a]	.13[b]	.81[a]	.01[a]	.13[a]
	N		14	14	13	14	14	14	12
Log. of Mean of Obtur. Extern. of L & R Femora	Correlation coefficient			-.06	-.10	-.39	-.20	.40	.00
	Sig. (2-tailed)			.82[b]	.74[a]	.13[b]	.48[a]	.14[a]	1.00[a]
	N			16	15	16	15	15	13
Log. of Mean of Glut. Max. of L & R Femora	Correlation coefficient				.23	**-.50**	-.19	**.53**	.20
	Sig. (2-tailed)				.40[a]	.05[b]	.50[a]	.04[a]	.52[a]
	N				15	16	15	15	13
Log. of Mean of Psoas Maj. of L & R Femora	Correlation coefficient					-.37	.48	-.17	-.07
	Sig. (2-tailed)					.17[b]	.08[a]	.57[a]	.83[a]
	N					15	14	14	12
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	Correlation coefficient						-.19	**-.67**	-.27
	Sig. (2-tailed)						.50[a]	.01[a]	.37[a]
	N						15	15	13
Log. of Mean of Tibial Tubero. of L & R Tibiae	Correlation coefficient							-.03	.42
	Sig. (2-tailed)							.91[a]	.16[a]
	N							15	13
Log. of Mean of Soleus of L & R Tibiae	Correlation coefficient								.49
	Sig. (2-tailed)								.09[a]
	N								13

[a] These Probability Values were Obtained From Pearson's Formula
[b] These Probability Values were Obtained From Spearman's Formula

TABLE 6. 26. *Correlations between femoral and tibial entheses and femoral indices of cranially undeformed South American skeletal sample.*

		Log. of Mean of Glut. Med. of L & R Femora	**Log. of Mean of Obtur. Extern. of L & R Femora**	**Log. of Mean of Glut. Max. of L & R Femora**	**Log. of Mean of Psoas Maj. of L & R Femora**	**Log. of Mean of Gastrocn. (Medial Head) of L & R Femora**	**Log. of Mean of Tibial Tubero. of L & R Tibiae**	**Log. of Mean of Soleus of L & R Tibiae**	**Log. of Mean of Squatting Facet of L & R Tibiae**
Mean of POI of L & R Femora	Correlation coefficient	-.02	.32	.07	-.16	-.06	-.13	.17	.08
	Sig. (2-tailed)	.94[a]	.23[a]	.79[b]	.56[a]	.81[b]	.64[a]	.55[a]	.78[a]
	N	14	16	16	15	16	15	15	13
Mean of BI of L & R Femora	Correlation coefficient	-.03	-.07	.11	-.21	-.17	-.06	.20	-.06
	Sig. (2-tailed)	.92[a]	.80[a]	.68[b]	.46[a]	.54[b]	.84[a]	.47[a]	.84[a]
	N	14	16	16	15	16	15	15	13
Mean of PI or FMS of L & R Femora	Correlation coefficient	.39	.34	.35	.17	-.41	.17	**.55**	-.05
	Sig. (2-tailed)	.17[b]	.19[b]	.19[b]	.56[b]	.12[b]	.56[b]	.04[b]	.89[b]
	N	14	16	16	15	16	15	15	13
Mean of PLI of L & R Femora	Correlation coefficient	.44	.49	.14	.25	-.10	.01	.21	.00
	Sig. (2-tailed)	.12[a]	.06[a]	.60[b]	.37[a]	.71[b]	.97[a]	.45[a]	1.00[a]
	N	14	16	16	15	16	15	15	13

[a] These Probability Values were Obtained From Pearson's Formula
[b] These Probability Values were Obtained From Spearman's Formula

TABLE 6. 27. *Correlations among age and femoral indices of cranially undeformed South American skeletal sample.*

		Mean of POI of L & R Femora	**Mean of BI of L & R Femora**	**Mean of PI or FMS of L & R Femora**	**Mean of PLI of L & R Femora**
Age	Correlation coefficient	-.23	.30	.31	-.17
	Sig. (2-tailed)	.39[a]	.26[a]	.24[b]	.53[a]
	N	16	16	16	16
Mean of POI of L & R Femora	Correlation coefficient		**-.53**	.14	.44
	Sig. (2-tailed)		.04[a]	.60[b]	.09[a]
	N		16	16	16
Mean of BI of L & R Femora	Correlation coefficient			.08	-.23
	Sig. (2-tailed)			.77[b]	.40[a]
	N			16	16
Mean of PI or FMS of L & R Femora	Correlation coefficient				.12
	Sig. (2-tailed)				.66[b]
	N				16

[a] These Probability Values were Obtained From Pearson's Formula
[b] These Probability Values were Obtained From Spearman's Formula

Position Index: Anatomical Location of the Maximum Curvature

Though males display higher mean value of Position Index than of females (Table 6.28), this difference is statistically not significant (*F* = 2.44; df = 1; *P* = 0.141) (Table 6.29).

TABLE 6. 28. *Mean values of femoral indices of left and right femora of cranially undeformed South American skeletal sample by sex.*

Dependent Variable	Sex	N	Mean	SD	Std. Error Mean
Mean of POI of L & R Femora	Female	6	56.14	3.53	1.44
	Male	10	52.91	4.24	1.34
Mean of BI of L & R Femora	Female	6	4.07	.88	.36
	Male	10	4.18	.57	.18
Mean of PI or FMS of L & R Femora	Female	6	1.04	.07	.03
	Male	10	1.08	.08	.03
Mean of PLI of L & R Femora	Female	6	100.75	8.00	3.27
	Male	10	103.38	2.76	.87

Bowing Index: Anterior Femoral Curvature (AFC)

There is no significant difference in the degree of anterior femoral curvature by sex among the cranially undeformed sample (*F* = 0.09; df = 1; *P* = 0.76). This is a surprising result and one quite at variance with the North American samples.

Pilastric Index: Femoral Midshaft Shape (FMS)

There is also no interaction by sex and cranial deformation group**.** Femoral midshaft shape (FMS) does not significantly vary across sexes in the cranially undeformed South American sample (*F* = 0.94; df = 1; *P* = .35).

Platymeric Index: Subtrochantric Shape

Males display a higher mean value of Platymeric Index than females do, but statistically the difference is not significant (F = 0.94; df = 1; P = .35).

TABLE 6. 29. *Results of GLM of effect of sex on mean values of femoral indices of cranially undeformed South American skeletal sample.*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Sex	**Mean of POI of L & R Femora**	39.14	1	39.14	2.44	.14
	Mean of BI of L & R Femora	.05	1	.05	.09	.76
	Mean of PI or FMS of L & R Femora	.01	1	.01	.94	.35
	Mean of PLI of L & R Femora	26.02	1	26.02	.94	.35

Table 6.30 shows mean values of lower limb entheses of cranially undeformed South American skeletal sample by sex. None of these significantly varies by sex (Table 6.31).

TABLE 6. 30. *Mean values of femoral and tibial entheses of cranially undeformed South American skeletal sample by sex.*

Dependent Variable	Sex	Mean	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
Log. of Mean of Glut. Med. of L & R Femora	Female	.16	.15	-.18	.50
	Male	.34	.14	.03	.64
Log. of Mean of Obtur. Extern. of L & R Femora	Female	.32	.17	-.05	.70
	Male	.25	.15	-.09	.59
Log. of Mean of Glut. Max. of L & R Femora	Female	.73	.15	.39	1.06
	Male	.90	.14	.59	1.20
Log. of Mean of Psoas Maj. of L & R Femora	Female	.66	.13	.37	.95
	Male	.74	.12	.47	1.01
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	Female	.14	.19	-.28	.56
	Male	.20	.17	-.19	.58
Log. of Mean of Tibial Tubero. of L & R Tibiae	Female	.42	.19	-.00	.84
	Male	.53	.17	.15	.91
Log. of Mean of Soleus of L & R Tibiae	Female	.64	.19	.22	1.07
	Male	.50	.17	.12	.89
Log. of Mean of Squatting Facet of L & R Tibiae	Female	.14	.15	-.20	.48
	Male	.23	.14	-.08	.54

TABLE 6.31. *Results of GLM of effect of sex on mean values of femoral and tibial entheses of cranially undeformed South American skeletal sample.*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Sex	Log. of Mean of Glut. Med. of L & R Femora	.08	1	.08	.74	.41
	Log. of Mean of Obtur. Extern. of L & R Femora	.01	1	.01	.10	.76
	Log. of Mean of Glut. Max. of L & R Femora	.08	1	.08	.73	.42
	Log. of Mean of Psoas Maj. of L & R Femora	.02	1	.02	.21	.66
	Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	.01	1	.01	.05	.82
	Log. of Mean of Tibial Tubero. of L & R Tibiae	.04	1	.04	.21	.66
	Log. of Mean of Soleus of L & R Tibiae	.06	1	.06	.32	.59
	Log. of Mean of Squatting Facet of L & R Tibiae	.02	1	.02	.21	.66

CHAPTER SEVEN: RESULTS AND DISCUSSION

POOLED NORTH AND SOUTH AMERICAN SKELETAL SAMPLES

Since some of the patterns found varied by continent, here I present a more complete analysis of the variability by continent and sex.

Normal Distribution

Skewness and kurtosis of femoral indices of North American skeletal sample are shown in Table 7.1. Distribution of all femoral indices is positively skewed. In addition, all are similarly platykurtic. But none are significantly non-normally distributed, or depart significantly from mesokurtic.

TABLE 7.1. *Descriptive statistics of femoral indices of pooled skeletal samples.*

	N	Mean	SD	Skewness		Kurtosis	
Dependent Variable	**Statistic**	**Statistic**	**Statistic**	**Statistic**	**SE**	**Statistic**	**SE**
Mean of POI of L & R Femur	108	51.56	4.69	.22	.23	-.23	.46
Mean of BI of L & R Femur	108	4.08	.77	.07	.23	-.03	.46
Mean of PI or FMS of L & R Femora	113	1.08	.08	.38	.23	-.36	.45
Mean of PLI of L & R Femora	114	97.61	10.36	.13	.23	-.43	.45

7.2. LOWER LIMB ENTHESES

Lower limb entheses were tested for normal distribution and kurtosis after were transformed into natural logarithm. Table 7.2 shows absolute values of skewness and kurtosis of these entheses. While some are not normally distributed and/or deviates significantly from being a mesokurtic, even after the transformations, others achieve normal distribution and mesokurtic**.**

Table 7.3 shows that none of the lower limb entheses significantly correlates with age. Many of them significantly correlate with each other. This may be due to the larger sample size or may be an artifact of correlation groups whose means may differ enough and influence correlation. Gluteus medius significantly positively correlated with gluteus maximus (r_s = .38; P = .00), with gastrocnemius (r_s = .23; P = .03), with tibial tuberosity (r_s = .35; P = .00), and with soleus (r_s = .41; P = .00).

While it significantly positively correlated with psoas major (r_s = .23; P =.017) and squatting facet (r_s = .24; P = .02), obturator externus significantly negatively correlated with tibial tuberosity (r_s = - .40; P = .00).

Gluteus maximus is significantly positively correlated with psoas major (r_s = .19; P = .05), with gastrocnemius (r_s = .25; P = .02), with tibial tuberosity (r_s = .28; P = .00), and with soleus (r_s = .47; P = .00), it is negatively correlated with squatting facet (r_s = - .23; P = .02).

Gastrocnemius correlates positively with tibial tuberosity (r_s = .49; P = .00) and negatively with squatting facet (r_s = - .38; P = .00).

Tibial tuberosity correlates positively with soleus (r_s = .45; P = .00) and negatively with squatting facet (r_s = -.22; P = .03).

TABLE 7.2. *Descriptive statistics of femoral and tibial entheses of pooled skeletal samples.*

Dependent Variable	N	Mean	SD	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	SE	Statistic	SE
Log. Mean of Glut. Med. of L & R Femora	109	.44	.39	.07	.23	-1.46	.46
Log. of Mean of Obtur. Exter. of L & R Femora	115	.21	.33	1.22	.23	-.00	.45
Log. of Mean of Glut. Max. of L & R Femora	116	.83	.35	-1.02	.23	.72	.45
Log. of Mean of Psoas Maj. of L & R Femora	107	.49	.38	-.13	.23	-1.37	.46
Log. of Mean Gastrocn. (Medial Head) of L & R Femora	92	.32	.41	.83	.25	-.78	.50
Log. of Tibial Tubero. of L & R Tibiae	106	.51	.47	.23	.24	-1.28	.47
Log. of Mean of Soleus of L & R Tibiae	113	.67	.41	-.34	.23	-.88	.45
Log. of Mean of Squatting Facet of L & R Tibiae	104	.15	.31	2.13	.24	4.60	.47

TABLE 7.3. *Correlations among age and femoral and tibial entheses of pooled skeletal samples.*

		Log. of Mean of Glut. Med. of L & R Femora	**Log. of Mean of Obtur. Exter. of L & R Femora**	**Log. of Mean of Glut. Max. of L & R Femora**	**Log. of Mean of Psoas Maj. of L & R Femora**	**Log. of Mean of Gastrocn. (Medial Head) of L & R Femora**	**Log. of Mean Tibial Tubero. of L & R Tibiae**	**Log. of Mean of Soleus of L & R Tibiae**	**Log. of Mean of Squatting Facet of L & R Tibiae**
Age	Correlation Coefficient	.12	.03	.16	-.11	.18	.17	.16	-.01
	Sig. (2-tailed)	.20[b]	.75[b]	.08[b]	.24[b]	.09[b]	.08[b]	.10[a]	.96[b]
	N	109	115	116	107	92	106	113	104
Log. of Mean of Glut. Med. of L & R Femora	Correlation Coefficient		.07	**.38**	.05	**.23**	**.35**	**.41**	.01
	Sig. (2-tailed)		.45[b]	.00[b]	.61[b]	.03[b]	.00[b]	.00[b]	.90[b]
	N		107	109	100	87	96	102	94
Log. of Mean of Obtur. Exter. of L & R Femora	Correlation Coefficient			-.04	**.23**	-.30	**-.39**	-.04	**.24**
	Sig. (2-tailed)			.70[b]	.02[b]	.00[b]	.00[b]	.72[b]	.02[b]
	N			114	107	91	100	106	98
Log. of Mean of Glut. Max. of L & R Femora	Correlation Coefficient				**.19**	**.25**	**.28**	**.47**	**-.23**
	Sig. (2-tailed)				.05[b]	.02[b]	.00[b]	.00[b]	.02[b]
	N				107	92	101	107	99
Log. of Mean of Psoas Maj. of L & R Femora	Correlation Coefficient					.07	.01	.09	.08
	Sig. (2-tailed)					.53[b]	.96[b]	.40[b]	.45[b]
	N					84	94	99	91
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	Correlation Coefficient						**.49**	.16	**-.38**
	Sig. (2-tailed)						.00[b]	.13[b]	.00[b]
	N						84	88	81
Log. of Mean Tibial Tubero. of L & R Tibiae	Correlation Coefficient							**.45**	**-.22**
	Sig. (2-tailed)							.00[b]	.03[b]
	N							105	98
Log. of Mean of Soleus of L & R Tibiae	Correlation Coefficient								-.07
	Sig. (2-tailed)								.46[b]
	N								104

[a] These Probability Values were Obtained From Pearson's Formula
[b] These Probability Values were Obtained From Spearman's Formula

Correlation of these entheses with femoral indices was tested also (Table 7.4). Position Index is positively correlated with obturator externus (r_s = .24; P = .01) and squatting facet (r_s = .25; P = .02). It correlates negatively with gluteus medius (r_s = -.25, p = .01), with gastrocnemius (r_s = -.23; P = .03), and with tibial tuberosity (r_s = -.24; P = .02). Femoral midshaft shape (FMS) or Pilastric Index is positively correlated with gluteus medius (r_s = .26; P = .01), with gastrocnemius (r_s = .21; P = .05), and with tibial tuberosity (r_s = .25; P = .02).

Platymeric Index is positively correlated with obturator externus (r_s = .45; P = .00), with psoas major (r_s = .46; P = .00), and with squatting facet (r_s = .22; P = .03). It negatively correlates with gastrocnemius (r_s = - .32; P = .00) and with tibial tuberosity (r_s = - 42; P = .00).

Table 7.5 shows results of Pearson's correlation among age and femoral indices of pooled skeletal sample. None of theses is significantly correlated with age. Position Index is positively correlated with Platymeric Index (r = .25; P = .01) and negatively with femoral midshaft shape (FMS) (r = - .22; P = .01). That the Bowing Index does not correlate significantly with any muscle marking suggests that when pooled, the data no longer reflect the functional relations among muscle and bony response to muscle through entheses development and anterior curvature. As will be shown below, there is a significant continent and sex interaction which makes pooled data less interpretable.

TABLE 7.4. *Correlations between femoral indices and femoral and tibial entheses of pooled skeletal samples.*

		Log. of Mean of Glut. Med. of L & R Femora	**Log. of Mean of Obtur. Exter. of L & R Femora**	**Log. of Mean of Glut. Max. of L & R Femora**	**Log. of Mean of Psoas Maj. of L & R Femora**	**Log. of Mean of Gastrocn. (Medial Head) of L & R Femora**	**Log. of Mean Tibial Tubero. of L & R Tibiae**	**Log. of Mean of Soleus of L & R Tibiae**	**Log. of Mean of Squatting Facet of L & R Tibiae**
Mean of POI of L & R Femora	Correlation Coefficient	**-.25**	**.24**	-.11	.14	**-.23**	**-.24**	-.01	**.25**
	Sig. (2-tailed)	.01[b]	.01[b]	.28[b]	.17[b]	.03[b]	.02[b]	.95[a]	.02[b]
	N	98	103	104	96	86	93	98	90
Mean of BI of L & R Femora	Correlation Coefficient	-.03	.07	.17	.17	-.00	-.04	.05	.02
	Sig. (2-tailed)	.76[b]	.46[b]	.09[b]	.10[b]	.70[b]	.70[b]	.60[a]	.84[b]
	N	98	103	104	96	86	93	98	90
Mean of PI or FMS of L & R Femora	Correlation Coefficient	**.26**	-.09	.16	-.03	**.21**	**.25**	.11	-.15
	Sig. (2-tailed)	.01[b]	.37[b]	.09[b]	.76[b]	.05[b]	.02[b]	.26[a]	.15[b]
	N	104	108	110	101	89	99	104	96
Mean of PLI of L & R Femora	Correlation Coefficient	-.14	**.45**	-.04	**.46**	**-.32**	**-.42**	-.06	**.22**
	Sig. (2-tailed)	.17[b]	.00[b]	.66[b]	.00[b]	.00[b]	.00[b]	.57[a]	.03[b]
	N	105	109	111	102	89	99	104	96

[a] These Probability Values were Obtained From Pearson's Formula
[b] These Probability Values were Obtained From Spearman's Formula

TABLE 7.5. *Pearson's correlations among age and femoral indices of the pooled skeletal samples.*

		Mean of POI of L & R Femur	**Mean of BI of L & R Femur**	**Mean of PI or FMS of L & R Femora**	**Mean of PLI of L & R Femora**
Age	Pearson Correlation	.04	.07	.06	-.03
	Sig. (1-tailed)	.35	.28	.27	.39
	N	108	108	113	114
Mean of POI of L & R Femur	Pearson Correlation		.00	**-.22**	**.25**
	Sig. (1-tailed)		.48	.01	.01
	N		108	105	105
Mean of BI of L & R Femur	Pearson Correlation			.05	.12
	Sig. (1-tailed)			.31	.11
	N			105	105
Mean of PI or FMS of L & R Femora	Pearson Correlation				-0.00
	Sig. (1-tailed)				.49
	N				113
	Pearson Correlation				

CONTINENT

Table shows 7.6 shows mean values of femoral indices of pooled skeletal sample by continent. Results show that there are significant statistical differences across continents in mean values of Position Index, Bowing Index, Pilastric Index, and Platymeric Index as expected. This significant interaction with sex makes interpretation of pooled values across sexes or across continents not easily interpretable and requires further examination of one factor within each of the subgroups of the other. Results of GLM of impact of continent, sex, continent and sex on mean values of femoral indices of pooled skeletal population are represented in table 7.7. I will discuss differences in each femoral index by continent.

Position Index: Anatomical Location of the Maximum Curvature

Results show that there is a strong difference in mean values of Position Index between North America and South American skeletal samples (F = 292.30; df =1; P = 0.00). Mean values of Position Index of both skeletal samples are shown in Table 7.6. South American mean value of Position Index is significantly higher that of North American skeletal sample. While the North American most curved point is located above, but close to the midshaft, it is located below the midshaft, toward the distal end of the diaphysis among South American skeletal sample.

The Position Index is used to determine the anatomical position of the most curved anatomical point along the diaphysis of femur has been reported that it varies significantly across genetically differed human populations (Singh and Singh 1972).

TABLE 7.6. *Mean values of femoral indices of pooled skeletal samples by continent.*

Dependent Variable	Continent	Mean	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
Mean of POI of L & R Femora	North America	49.99	.61	48.78	51.20
	South America	53.38	.59	52.21	54.54
Mean of BI of L & R Femora	North America	3.98	.10	3.79	4.17
	South America	4.26	.09	4.07	4.44
Mean of PI or FMS of L & R Femora	North America	1.11	.01	1.09	1.13
	South America	1.06	.01	1.03	1.08
Mean of PLI of L & R Femora	North America	92.28	1.14	90.02	94.54
	South America	103.93	1.10	101.75	106.11

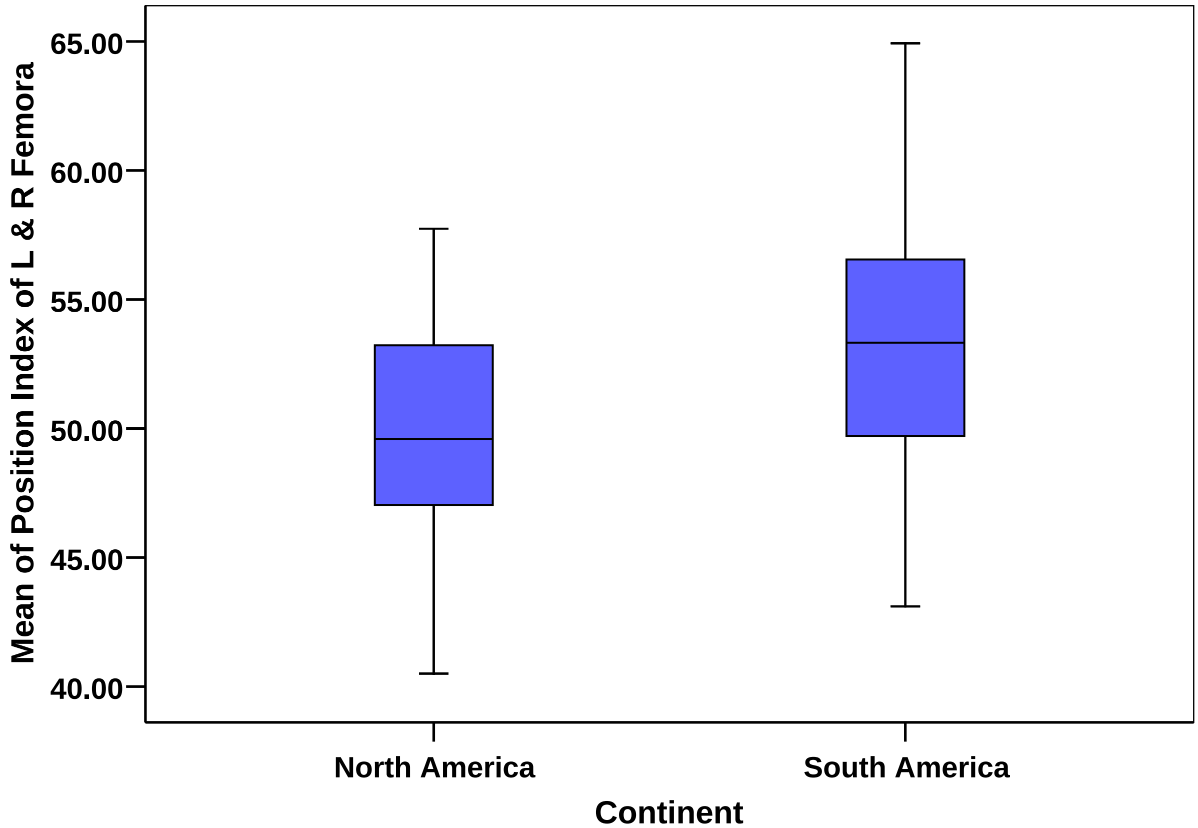

Fig. 7.1. Mean values of Position Index of left and right femora of pooled skeletal samples by continent (F = 15.95; df = 1; P = 0.00).

TABLE 7. 7. *Results of GLM of effect of continent, sex, and continent and sex on mean values of femoral indices of pooled skeletal samples.*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Continent	Mean of POI of L & R Femora	292.30	1	292.30	15.95	**0.00**
	Mean of BI of L & R Femora	1.93	1	1.93	4.27	**0.04**
	Mean of PI or FMS of L & R Femora	0.08	1	0.08	14.04	**0.00**
	Mean of PLI of L & R Femora	3458.63	1	3458.63	54.16	**0.00**
Sex	Mean of POI of L & R Femora	14.06	1	14.06	0.77	0.38
	Mean of BI of L & R Femora	8.96	1	8.96	19.84	**0.00**
	Mean of PI or FMS of L & R Femora	0.06	1	0.06	9.44	**0.00**
	Mean of PLI of L & R Femora	9.30	1	9.30	0.15	0.70
Continent and Sex	Mean of POI of L & R Femora	111.65	1	111.65	6.09	**0.02**
	Mean of BI of L & R Femora	2.55	1	2.55	5.63	**0.02**
	Mean of PI or FMS of L & R Femora	0.00	1	0.00	0.20	0.65
	Mean of PLI of L & R Femora	0.06	1	0.06	0.00	0.98

Bowing Index: Anterior Femoral Curvature (AFC)

Mean values of the Bowing Index of pooled skeletal samples by continent are represented in Table 7.6. Results show that South American sample exhibits significantly higher mean value of Bowing Index than of North Americans (F = 1.93; df = 1; P = 0.04) (Table 7.7).

These results strongly agree with findings of previous research that showed femoral curvature level differs significantly across ethnic groups. Because of that, curvature is one of morphological features of the femur that has been used in the forensic settings to determine race. Historically, Aleš Hrdlička noted that degree of femoral curvature varies across human populations. His student, Stewart investigated degree of variation of anterior femoral curvature across human populations (Stewart, 1962). His research showed that African-Americans have the longest and least curved femora, and European- Americans have the shortest and intermediately curved femora, American Indians have intermediate length and most curved femur (Stewart 1962). Walensky (1965) showed results similar to of Stewart's, that North American Indians exhibited higher degree of anterior femoral curvature than Europeans.

The differences in anterior femoral curvature across continents can be explained genetically rather that biomechanically.

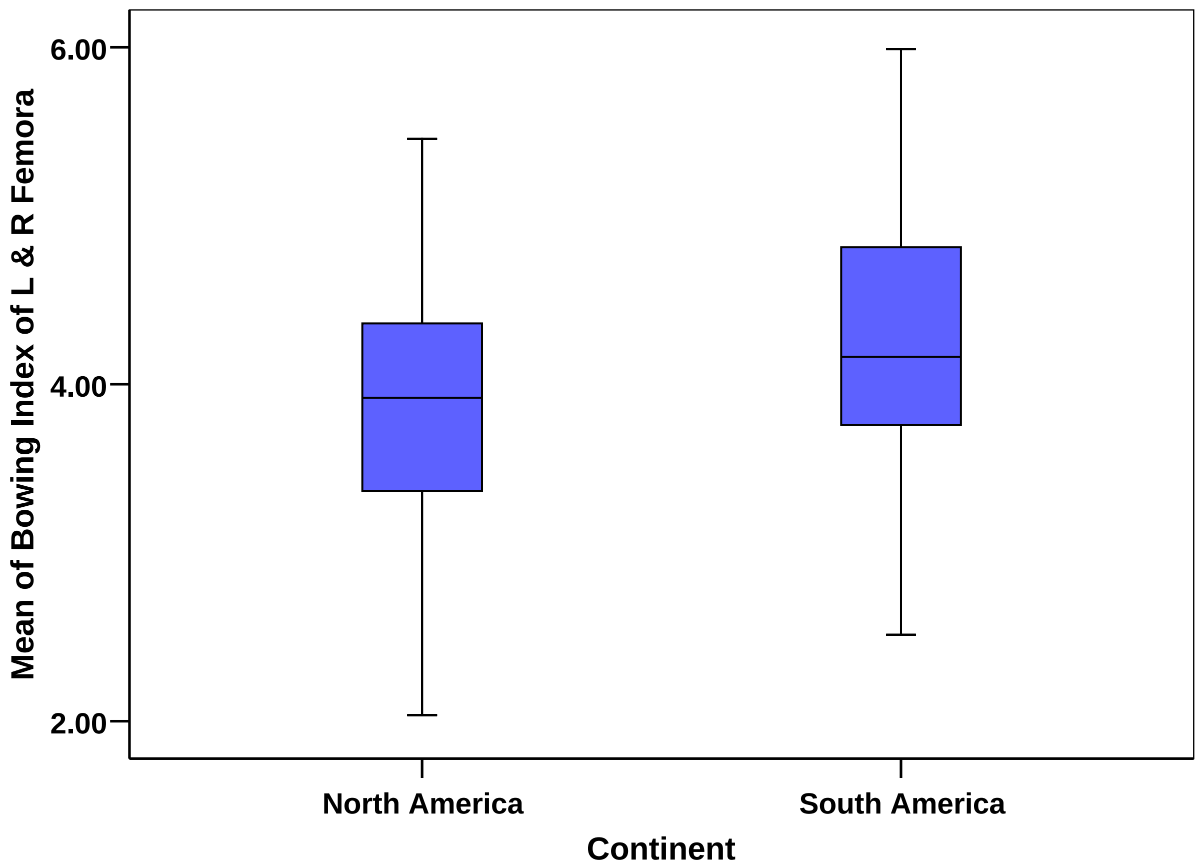

Fig. 7.2. Mean values of Bowing Index of left and right femora of pooled skeletal samples by continent (*F* = 4.27; df = 1; *P* = 0.04).

Pilastric Index or Femoral Midshaft Shape (FMS)

The Pilastric Index or cross-sectional femoral midshaft shape also shows significant difference across continents. As shown in Table 7.6, mean value of Pilastric Index of North American skeletal sample is higher than of South Americans. Results show that this difference in mean values of Pilastric Index statistically is extremely significant (*F* = 14.044; df = 1; *P* = 0.00) (Table 7.7). In terms of bony morphology, North American skeletal sample exhibits significantly more elongated cross-sectional midshaft femoral shape in (A-P) plane than South

American sample, who exhibits a more rounded one. This is mainly because of genetic and environmental differences.

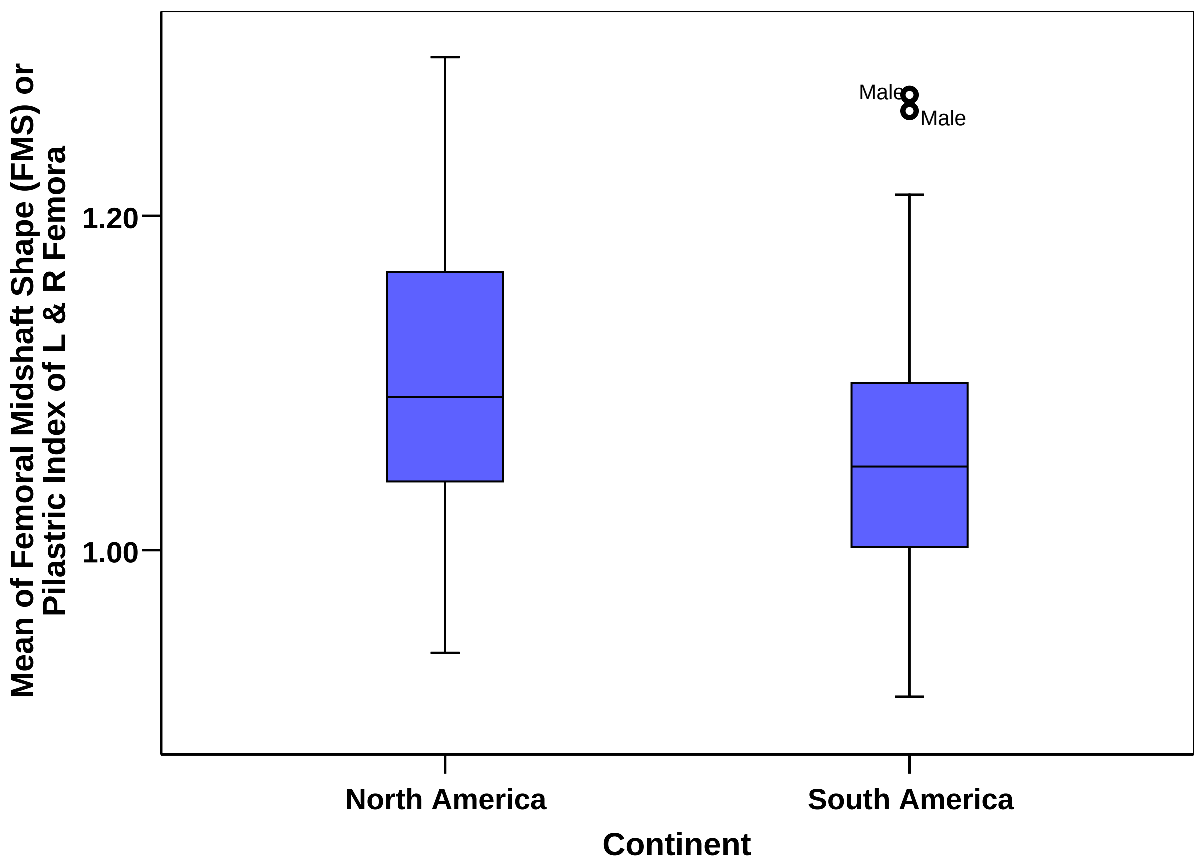

Fig. 7.3. Mean values of femoral midshaft shape (FMS) or Pilastric Index of left and right femora of pooled skeletal samples by continent (F = 14.04; df = 1; P = 0.00).

Platymeric Index: Subtrochantric Shape

Finally, Platymeric Index shows a high degree of variation across continents (F = 3458.63; df = 1; P = 0.00) (See Table 7.7). As shown in Table 7.6, South American skeletal sample displays higher mean value of Platymeric Index than North American skeletal sample does.

Morphologically, the proximal femoral diaphysis is elongated in (A-P) direction than (M-L) plane (stenomeric) among South Americans and equally shaped in both directions among North Americans (eurymeric).

It has been intensively reported in previous studies that morphology of this bony region is determined by genetics and shape established early in life (Wescott, 2006). For that reason, morphologically, this region significantly differs across human populations and is used in forensic anthropology to estimate ethnic affiliation. Wescott (2005) found that while the femur is broadly shaped in mediolateral direction among Native Americans and Polynesians, femoral proximal diaphysis is shaped equally in both among Black and White Americans.

Difference in the subtrochantric region external morphology across continents can be explained as differences in genetic components and bony circumferential growth. Variation in rate and amount of load imposed on human skeleton happens later in life and does not strongly influence earlier established and varied subtrochantric shape. Thus, the differences across populations mask phenotypic bony variation between North American and South American skeletal populations.

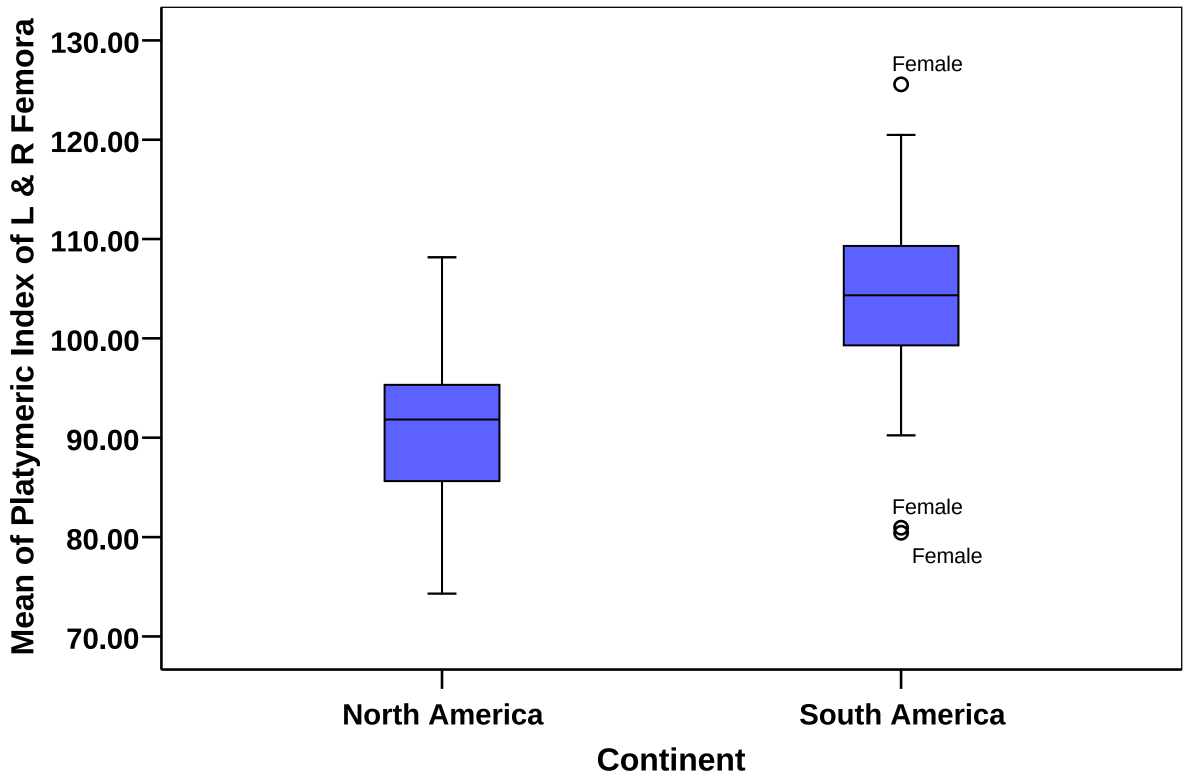

Fig. 7.4. Mean values of Platymeric Index of left and right femora of pooled skeletal samples by continent (F = 54.16; df = 1; P = 0.00).

Table 7.8 shows mean values of lower limb entheses of pooled skeletal sample by continent. All results are statistically significant (Table 7.9). While gluteus medius, gluteus maximus, gastrocnemius, tibial tuberosity, soleus are significantly bigger among North

Americans, obturator externus, psoas major, and squatting facet are significantly bigger among South American skeletal sample.

TABLE 7. 8. *Mean values of femoral and tibial entheses of pooled skeletal samples by continent.*

Dependent Variable	Continent	Mean	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
Log. of Mean of Glut. Med. of L & R Femora	North America	.57	.09	.40	.75
	South America	.31	.06	.19	.43
Log. of Mean of Obtur. Exter. of L & R Femora	North America	.06	.06	-.07	.19
	South America	.31	.04	.22	.40
Log. of Mean of Glut. Max. of L & R Femora	North America	1.07	.08	.91	1.23
	South America	.75	.05	.64	.85
Log. of Mean of Psoas Maj. of L & R Femora	North America	.40	.08	.25	.56
	South America	.66	.05	.56	.77
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	North America	.60	.09	.44	.77
	South America	.16	.06	.05	.28
Log. of Mean Tibial Tubero. of L & R Tibiae	North America	.93	.09	.76	1.11
	South America	.27	.06	.15	.39
Log. of Mean of Soleus of L & R Tibiae	North America	.91	.09	.72	1.10
	South America	.51	.06	.38	.63
Log. of Mean of Squatting Facet of L & R Tibiae	North America	.02	.06	-.10	.13
	South America	.17	.04	.10	.25

TABLE 7.9. *Results of GLM of effect of continent, sex and continent and sex on mean values of femoral and tibial entheses of pooled skeletal samples.*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Continent	**Log. of Mean of Glut. Med. of L & R Femora**	.86	1	.86	6.06	**.02**
	Log. of Mean of Obtur. Exter. of L & R Femora	.80	1	.80	10.59	**.00**
	Log. of Mean of Glut. Max. of L & R Femora	1.33	1	1.33	11.78	**.00**
	Log. of Mean of Psoas Maj. of L & R Femora	.86	1	.86	7.44	**.01**
	Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	2.46	1	2.46	18.59	**.00**
	Log. of Mean Tibial Tubero. of L & R Tibiae	5.52	1	5.52	39.90	**.00**
	Log. of Mean of Soleus of L & R Tibiae	2.03	1	2.03	12.37	**.00**
	Log. of Mean of Squatting Facet of L & R Tibiae	.31	1	.31	4.99	**.03**
Sex	**Log. of Mean of Glut. Med. of L & R Femora**	.05	1	.05	.341	.56
	Log. of Mean of Obtur. Exter. of L & R Femora	.02	1	.02	.23	.63
	Log. of Mean of Glut. Max. of L & R Femora	.32	1	.32	2.817	.10
	Log. of Mean of Psoas Maj. of L & R Femora	.00	1	.00	.02	.89
	Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	.12	1	.12	.89	.35
	Log. of Mean Tibial Tubero. of L & R Tibiae	.22	1	.22	1.62	.21
	Log. of Mean of Soleus of L & R Tibiae	.28	1	.28	1.68	.20
	Log. of Mean of Squatting Facet of L & R Tibiae	.00	1	.00	.00	.97
Continent and Sex	**Log. of Mean of Glut. Med. of L & R Femora**	.00	1	.00	.02	.88
	Log. of Mean of Obtur. Exter. of L & R Femora	.08	1	.08	1.03	.31
	Log. of Mean of Glut. Max. of L & R Femora	.12	1	.12	1.06	.31
	Log. of Mean of Psoas Maj. of L & R Femora	.03	1	.03	.241	.63
	Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	.09	1	.09	.70	.41
	Log. of Mean Tibial Tubero. of L & R Tibiae	.05	1	.05	.33	.57
	Log. of Mean of Soleus of L & R Tibiae	.58	1	.58	3.51	.07
	Log. of Mean of Squatting Facet of L & R Tibiae	.02	1	.02	.29	.60

SEX

Differences in femoral indices of pooled skeletal sample were also investigated by sex. These will be discussed in more details below. Table 7.10 shows mean values of femoral indices of pooled skeletal sample.

Position Index: Anatomical Location of the Maximum Curvature

As shown in Table 7.10, females have higher mean value of Position Index than males, but the difference is statistically not significant (F = 0.77; df = 1; P = 0.38) (Table 7.7).

Bowing Index: Anterior Femoral Curvature (AFC)

As shown in Table 7.10, males have higher mean value of Bowing Index than females do. This difference is statistically extremely significant (F = 19.84; df = 1; P = 0.00) (Table 7.7). Morphologically, males have more anteriorly curved femur than females do, even when pooled across continents.

TABLE 7.10. *Mean values of femoral indices of pooled skeletal samples by sex.*

Dependent Variable	Sex	Mean	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
Mean of POI of L & R Femora	Male	51.31	.63	50.07	52.55
	Female	52.05	.57	50.92	53.19
Mean of BI of L & R Femora	Male	4.42	.10	4.22	4.61
	Female	3.82	.09	3.65	4.00
Mean of PI or FMS of L & R Femora	Male	1.11	.01	1.08	1.13
	Female	1.06	.01	1.04	1.08
Mean of PLI of L & R Femora	Male	97.81	1.17	95.49	100.13
	Female	98.41	1.07	96.30	100.53

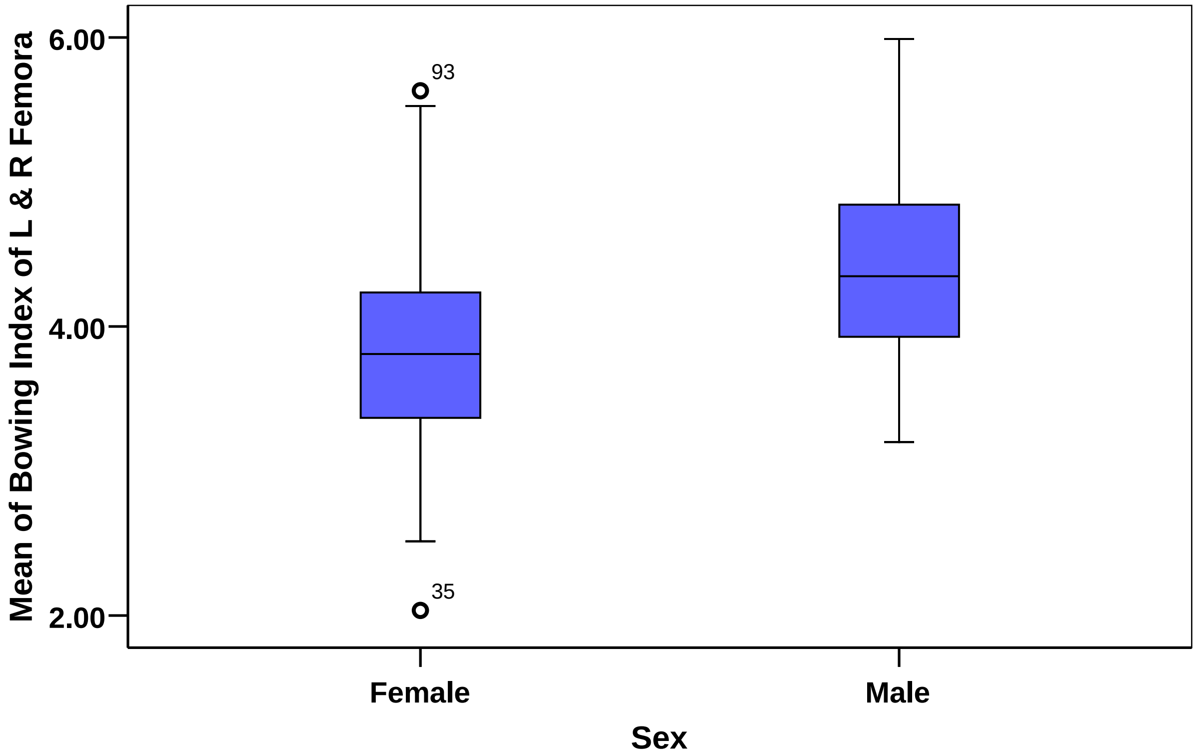

Fig. 7.5 Mean values of Bowing Index of left and right femora of pooled skeletal samples by sex (F = 19.84; df =1; P = 0.00).

Pilastric Index: Femoral Midshaft Shape (FMS)

As shown in Table 7.10, males exhibit higher mean value of Pilastric Index than females do. This difference statistically is extremely significant (F = 9.44; df = 1; P = 0.00) (Table 7.7). Morphologically, males have more elongated femoral shape at the midshaft in the anterioposterior direction than females do, indicating greater strength in resisting bending during walking.

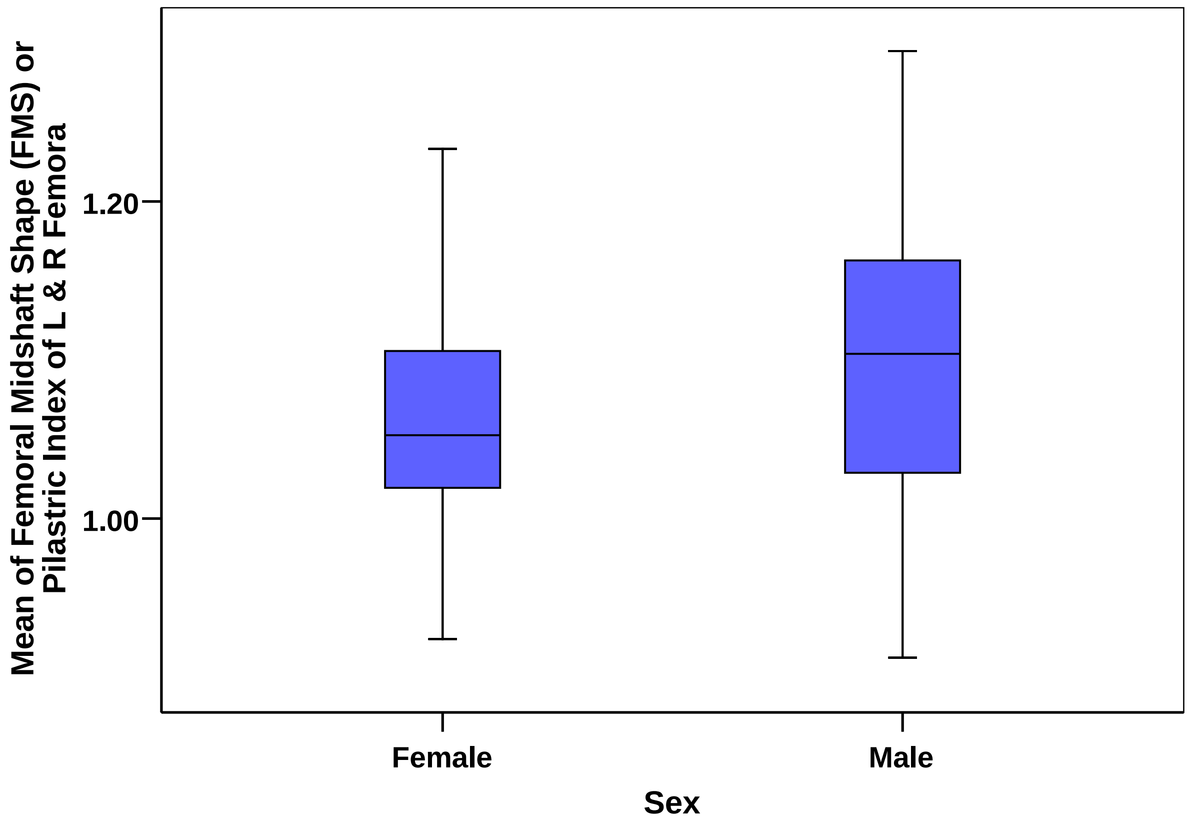

Fig. 7. 6. Mean values of femoral midshaft shape (FMS) or Pilastric Index of left and right femora of pooled skeletal samples by sex (F = 9.44; df =1; P = 0.00).

Platymeric Index: Subtrochantric Shape

As shown in Table 7.10, while females display subtrochantric shape closer to circular than males do, statistically the difference is not significant ($F = 0.15$; df = 1; $P = 0.70$).

All mean values of lower limb entheses of pooled skeletal sample by sex are shown in Table 7.11. As shown in Table 7.9, none of these significantly varies by sex. The only is closely approaching level of significance is gluteus maximus ($F = 2.82$; df = 1; $P = 0.10$). Males display higher score of entheses of gluteus maximus than females do, as would be expected.

TABLE 7.11. *Mean values of femoral and tibial entheses of pooled skeletal samples by sex.*

Dependent Variable	Sex	Mean	SE	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Log. of Mean of Glut. Med. of L & R Femora	Male	.48	.09	.30	.65
	Female	.41	.06	.29	.54
Log. of Mean of Obtur. Exter. of L & R Femora	Male	.20	.06	.08	.33
	Female	.17	.05	.08	.26
Log. of Mean of Glut. Max. of L & R Femora	Male	.99	.08	.83	1.14
	Female	.83	.06	.72	.94
Log. of Mean of Psoas Maj. of L & R Femora	Male	.53	.08	.37	.68
	Female	.54	.06	.43	.65
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	Male	.43	.08	.26	.60
	Female	.34	.06	.22	.45
Log. of Mean Tibial Tubero. of L & R Tibiae	Male	.67	.09	.50	.84
	Female	.54	.06	.41	.66
Log. of Mean of Soleus of L & R Tibiae	Male	.78	.10	.60	.97
	Female	.63	.07	.50	.76
Log. of Mean of Squatting Facet of L & R Tibiae	Male	.10	.06	-.02	.21
	Female	.09	.04	.01	.18

CONTINENT AND SEX MODEL

Table 7.12 shows mean values of femoral indices of pooled skeletal sample by continent and sex. While the results of Position Index and Bowing Index in the overall model for continent and sex are statistically significant, those of Pilastric Index and Platymeric Index are not (Table 7.7). Degree of sexual dimorphism displayed by the Position Index and Bowing Index in North America significantly varies from differences in these indices among the South American skeletal sample.

TABLE 7.12. *Mean values of femoral indices of pooled skeletal samples by continent and sex.*

Dependent Variable	Continent	Sex	Mean	SE	95% Confidence Interval	
					Lower Bound	**Upper Bound**
Mean of POI of L & R Femora	North America	Female	49.31	.76	47.81	50.81
		Male	50.66	.96	48.76	52.56
	South America	Female	54.79	.86	53.09	56.49
		Male	51.95	.81	50.35	53.56
Mean of BI of L & R Femora	North America	Female	3.53	.12	3.30	3.76
		Male	4.44	.15	4.14	4.73
	South America	Female	4.12	.13	3.85	4.39
		Male	4.40	.13	4.14	4.65
Mean of PI or FMS of L & R Femora	North America	Female	1.09	.01	1.06	1.11
		Male	1.14	.02	1.10	1.17
	South America	Female	1.04	.02	1.00	1.07
		Male	1.07	.02	1.05	1.10
Mean of PLI of L & R Femora	North America	Female	92.56	1.41	89.76	95.36
		Male	92.01	1.79	88.46	95.55
	South America	Female	104.26	1.60	101.09	107.43
		Male	103.61	1.51	100.61	106.60

Table 7.13 shows mean values of femoral and tibial entheses of pooled skeletal sample by continent and sex. As shown in Table 7.9, none of these significantly differs by continent and sex. But the only that closely approaches level of significance is soleus (F = 3.51; df = 1; P = 0.07). While males have higher entheses score than females in North America, paradoxically, females exhibit higher score than males in South American archaeological sample. This is a surprising result and one that requires further investigation.

TABLE 7.13. *Mean values of femoral and tibial entheses of pooled skeletal samples by continent and sex.*

Dependent Variable	Continent	Sex	Mean	SE	95% Confidence Interval	
					Lower Bound	**Upper Bound**
Log. of Mean of Glut. Med. of L & R Femora	North America	Male	.60	.15	.29	.91
		Female	.55	.08	.38	.72
	South America	Male	.35	.08	.19	.51
		Female	.27	.09	.10	.45
Log. of Mean of Obtur. Exter. of L & R Femora	North America	Male	.12	.11	-.11	.34
		Female	.00	.06	-.12	.12
	South America	Male	.29	.06	.17	.41
		Female	.33	.07	.20	.46
Log. of Mean of Glut. Max. of L & R Femora	North America	Male	1.20	.14	.92	1.47
		Female	.94	.08	.79	1.09
	South America	Male	.78	.07	.63	.92
		Female	.71	.08	.56	.87
Log. of Mean of Psoas Maj. of L & R Femora	North America	Male	.37	.14	.10	.65
		Female	.43	.08	.28	.59
	South America	Male	.68	.07	.54	.83
		Female	.65	.08	.49	.81
Log. of Mean of Gastrocn. (Medial Head) of L & R Femora	North America	Male	.70	.15	.40	.99
		Female	.51	.08	.35	.68
	South America	Male	.17	.08	.01	.32
		Female	.16	.09	-.01	.33
Log. of Mean Tibial Tubero. of L & R Tibiae	North America	Male	1.03	.15	.73	1.33
		Female	.84	.08	.67	1.00
	South America	Male	.31	.08	.15	.47
		Female	.23	.09	.06	.41
Log. of Mean of Soleus of L & R Tibiae	North America	Male	1.09	.17	.76	1.42
		Female	.73	.09	.55	.91
	South America	Male	.47	.09	.30	.65
		Female	.54	.10	.35	.73
Log. of Mean of Squatting Facet of L & R Tibiae	North America	Male	.00	.10	-.20	.20
		Female	.04	.06	-.08	.15
	South America	Male	.20	.05	.09	.30
		Female	.15	.06	.04	.27

Position Index: Anatomical Location of the Maximum Curvature

The level of variation in mean values of Position Index between males and females in North America differs significantly from that of South America ($F = 6.45$; df = 1; $P = 0.01$). Table 7.13 shows that females display lower mean values of the Position Index than males in North America, but they are higher than males among South American skeletal sample. In addition, level of sexual dimorphism in South America is greater than of North America. Results of t-test for sexual dimorphism in North America are ($t = 1.21$; df = 50; $P = 0.23$), and for South America are ($t = -2.16$; df = 54; $P = 0.04$). These differences in sexual dimorphism across continents are also seen in the Bowing Index.

Bowing Index: Anterior femoral Curvature (AFC)

As shown in Table 7.13, the difference between mean values of Bowing Index between males and females in North America is greater than of the one exhibited by sexes of South America. This difference is statistically significant ($F = 5.33$; df = 1; $P = 0.02$) (See Table 7.8). Morphologically, variation in the degree of femoral curvature between sexes among North American skeletal sample is much higher than exhibited among South American skeletal sample. While difference in mean values of degree of anterior femoral curvature is very small and not statistically significant in South America ($t = 1.08$; df = 54; $P= 0.29$), femoral curvature is highly sexually dimorphic in North American skeletal sample ($t = 5.02$; df = 50; $P = 0.00$).

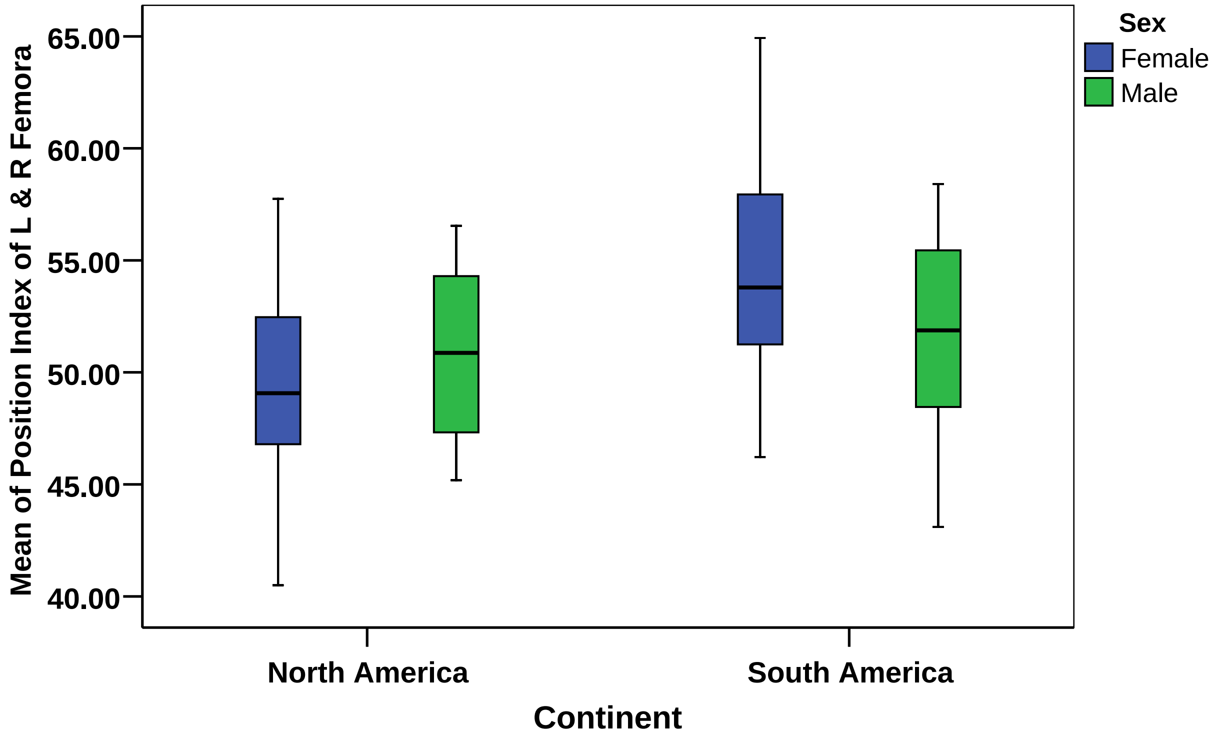

Fig. 7.7. Mean values of Position Index of left and right femora of pooled skeletal samples by continent and sex (F = 6.09; df = 1; P = 0.02).

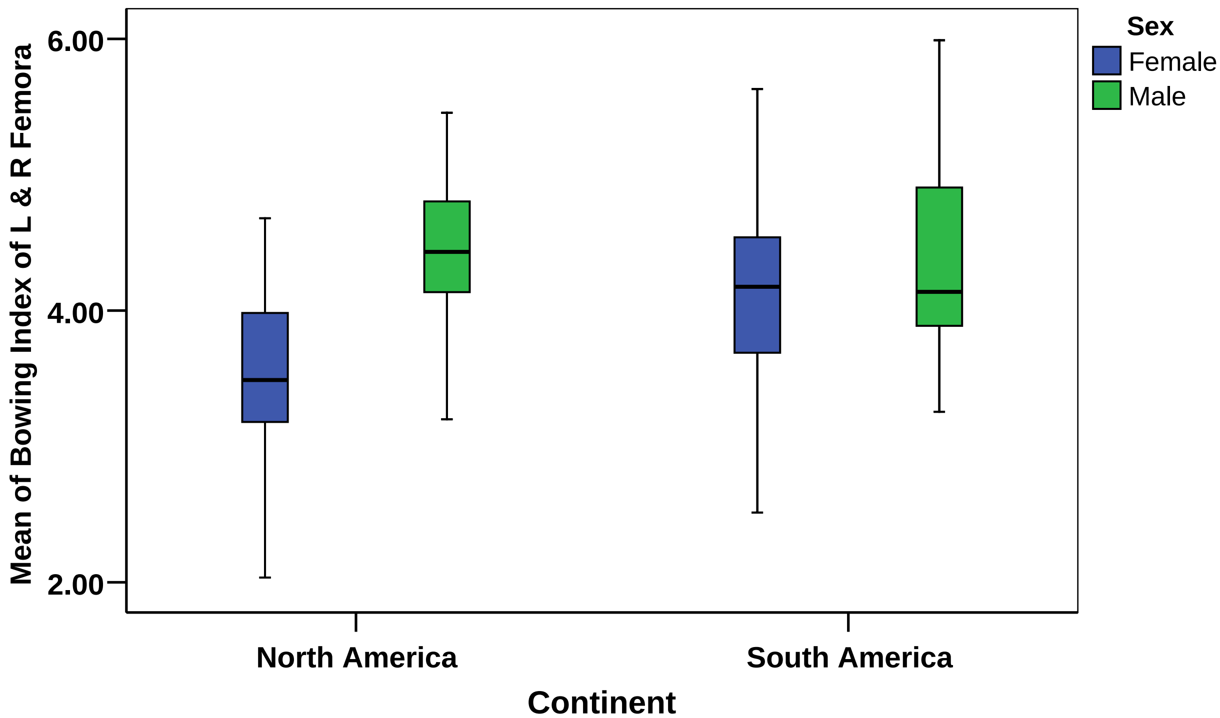

Fig. 7.8. Mean values of Bowing Index of left and right femora of pooled skeletal samples by continent and sex (F = 5.63; df = 1; P = 0.02).

Pilastric Index: Femoral Midshaft Shape (FMS)

Table 7.13 shows mean values of Pilastric Index of pooled skeletal sample by continent and sex. Results show that differences in mean values of Pilastric Index in the overall model for continent and sex are not statistically significant. These are (F = 0.61; df = 1; P = 0.44) (Table 7.8).

When degree of sexual dimorphism examined in both continents separately, results show while South American sample displays degree of sexual dimorphism in Pilastric Index that approaches level of significance (t = 1.83; df = 52; P = 0.07), North American skeletal sample exhibits highly significant degree of sexual dimorphism (t = 3.14; df = 57; P = 0.00) .

Platymeric Index: Subtrochantric Shape

Mean values of femoral indices by period and sex are represented in Table 7.13. Results show that differences in mean values of Platymeric Index in the overall model for continent and sex are not significant. These results are (F = 4.16; df =1; P = 0.85) and represented in Table (7.8).

Sexual dimorphism degree is investigated for each continent separately. Results show that Platymeric Index of both continents skeletal sample does not display significant sexual dimorphism. These results are (t = 0.53; df = 52; P = 0.60) for South American skeletal sample and (t = 0.22; df = 58; P = 0.83).

Table 7.14 shows mean values of lower limb entheses of pooled skeletal sample by continent and sex. The interaction between continent and sex has no significant effect on mean value of any of these entheses (Table 7.10). The only one closely approaches level of significance is soleus (F = 3.51; df = 1; P = .07).

The large differences shown in the indicators of activity across the continents must have both genetic and environmental component. The most surprising result was that the South American femora from the Villa El Salvador, unlike most other collections, is more curved than the North American femora. Secondly, the pattern of tighter correlations among the entheses in South America may be explained by the fact that all of the material came from a single site, so patterns were not obscured by mixing different activity patterns as possibly happened when North American sites were pooled by period.

Since the pattern of males having greater Bowing Index than females was found in both continents and since the Bowing Index was significantly correlated with the response of some muscles, it is validated as an indicator of childhood activity level and kind.

CHAPTER EIGHT

CONCLUSION AND RECOMMENDATION

Bony morphological features have been used to reflect adolescence behavioural patterns among the bioarchaeological skeletal populations. Anterior femoral curvature has been validated as an indicator of mobility. It varies significantly by subsistence strategy and sex.

This study showed that the degree of anterior curvature varied significantly among homogeneous genetically North American skeletal samples who practiced different subsistence practices. The degree of femoral curvature showed statically significant decrease from Woodland to the Mississippian. Morphologically, the Woodland people who practiced hunting gathering/horticulture had more curved anterior femora than of people of the Mississippian who practiced intensive maize agriculture.

Moreover, the degree of anterior curvature differed significantly by sex. Males exhibited more curved anteriorly femora than females in both North American archaeological periods reflecting the difference in walking and running. Males displayed greater degree of anterior femoral curvature than females.

Femoral anterior curvature also correlated significantly with some entheses of the major muscles that involve in the biomechanics of walking and running, indicating how muscular actions and osteogenic response interacted with each other and response to biomechanical load.

Femoral anterior curvature (Bowing Index), Position Index, femoral midshaft shape (FMS) or Pilastric Index, subtrochantric shape (Platymeric Index) showed statistical significant variation by continent. All of these differed between South American and North American skeletal samples because of the genetics differences.

This bony morphological feature, anterior femoral curvature, has three distinctive methodological features. It is cheap, easy, and non-invasive method. I recommend that future research uses femoral anterior curvature and test its correlation with cross-sectional geometry. Moreover bilateral asymmetry in anterior femoral curvature has to be tested.

LITERATURE CITED

Anderson JY, Trinkaus E. 1998. Patterns of sexual, bilateral and interpopulational variation in human femoral neck-shaft angles J Anat 192: 279-285.

Arnaud SB, Schneider VS, Morey-Holton E. 1986. Effects of inactivity on bone and calcium metabolism. In: Sandler H, Vernikos J, editors. Inactivity: Physiological effects. Orelando: Academic Press Inc. p 49-72.

Bailit HL, Workman PL, Niswander JD, Maclean CJ. 1970. Dental asymmetry as an indicator of genetic and environmental conditions in human populations. Hum Biol 42: 626-638.

Ballard ME, Trudell MB.1999. Anterior femoral curvature revisited: race assessment from the femur. J For Sci 44: 1108.

Bass SL, Saxon L, Daly RM, Turner CH, Robling AG, Seeman E, Stuckey S.2002. The effect of mechanical loading on the size and shape of bone in pre-, peri-, and postpubertal girls: a study in tennis players. J Bone Miner Res 17: 2274-2280.

Bass WM.1995. Human osteology. A laboratory and field manual. 4th ed. Columbia: Missouri Archaeological Society.

Benfer RA, Benfer AN.1981. Automatic classification of inspectional categories: multivariate theories of archaeological data. Am Antiq 46:381-396.

Benfer RA. Jr.1990. The preceramic period site of Paloma, Perú: bioindications of improving adaptation to sendentism. Lat Am Antiq 1: 284-318.

Benfer RA 1995. Multiple linear discriminant function, multidimensional scaling and individual pathways for developing knowledge based system. In: Xiong FL, Lee JK, Mizoguchi R, editors. Proceedings of PACES ’95. Beijing: Publishing House of Electronics Industry. p 464-466.

Bennett KA .1993. A field guide for human skeletal identification 2nd edition Springfield: Charles Thomas Publisher.

Bertram JEA, Biewener AA.1992. Allometry and curvature in the long bones of quadrupedal mammals. J Zool (London) 226: 455-467.

Biewener AA, Thomason J, Goodship A, and Lanyon LE. 1983. Bone stress in the horse forelimb during locomotion at different gaits: a comparison of two experimental methods 16: 565-76.

Biewener AA .1991.Musculoskeletal design in relation to body size. J Biomech 24 Suppl 1: 19 - 29.

Biewener AA, Bertram JEA. 1994. Structural response of growing bone to exercise and disuse. J Appl Physiol 76: 946-955.

Biewener AA, Bertram JEA. 1993. Mechanical loading and bone growth in *vivo*. In Hall BK, editors. Bone growth b. Nova Scotia: CRC Press. p. 1-36.

Bonjour JP. 2005. Dietary protein: an essential nutrient for bone health. J Am Coll Nutr 24: 526S-536S.

Bridges PS. 1989. Changes in activity with the shift to agriculture in the Southeastern United States. Curr Anthropol 30: 385-394.

Brickley M. 2002. An investigation of historical and archaeological evidence for age-related bone loss and osteoporosis. Int J Osteoarchaeol 12: 364-371.

Bridges PS.1991. Skeletal evidence of changes in subsistence activities between the Archaic and Mississippian time periods in Northwestern Alabama. In: Powell ML, Bridges PS, Mires AMW, editors. What mean these bones?: studies in southeastern bioarchaeology. Tuscaloosa and London: The University of Alabama Press. p 89-101.

Bridges PS, Blitz JH, Solano MC. 2000. Changes in long bone diaphyseal strength with horticultural intensification in west-central Illinois. Am J Phys Anthropol 112: 217-238.

Brinckmann P, Frobin W, Leivseth G. 2002. Musculoskeletal biomechanics. New York, NY: Thieme Medical Publishing.

Broadhurst CL. 2001. Polyunsaturated fatty acids (PUFA) for bone growth and repair. Nutrition Science News.

Brock SL, Ruff CB. 1988. Diachronic patterns of change in structural properties of the femur in the prehistoric American Southwest. Am J Phys Anthropol 75: 113-127.

Brues AM. 1977. People and races. New York: Macmillan.

Bruns W, Bruce M, Prescott G, Maffulli N. 2002. Temporal trends in femoral curvature and length in medieval and modern Scotland. Am J Phys Anthropol 119: 224-230.

Buikstra JE, Ubelaker DH. 1994. Standards for data collection from human skeletal r remains. Research series, no. 44. Fayetteville: Arkansas Archaeological Survey.

Burr DB, Robling AG, Turner CH. 2002. Effects of biomechanical stress on bones in animals. Bone 30: 781-786.

Capasso L, Kennedy KAR, Wilczak CA. 1999. Atlas of occupational markers on human remains. Teramo: Edigrafital S.P.A.

Carter DR 1982. The relationship between in vivo strains and cortical bone remodeling. Crit Rev Biomed Eng 8: 1-28.

Cavalli-Sforza LL. 2000. Genes, peoples and languages. Berkeley: University of California Press.

Chan K. 2003. Harris lines and bending rigidity. M.A thesis. University of Missouri-Columbia, Columbia, MO.

Chapman N. 1998. Evidence for Spanish influence on activity induced musculoskeletal stress markers at Pecos Pueblo. Int J Osteoarch 7: 497-506.

Chiras DD. 2003. Human body system: structure, function, and environment. Sudbury, MA: Jones and Bartlett Publishers.

Churchill SE, and Morris AG. 1998. Muscle marking morphology and labor intensity in pre-historic Khoisan foragers. Int J Osteoarch 8:390-411.

Crawford MH. 1998. The origins of Native Americans: evidence from anthropological genetics. Cambridge: Cambridge University Press.

Curry JD. 1984. The mechanical adaptations of bones. New Jersey: Princeton University Press.

Darwin C. 1859. On the origin of species by means of natural selection, 1st ed.

Dawson-Hughes B. 2003. Calcium and protein in bone health. Proc Nutr Soc 62 : 505-509.

Deel J. 1996. Missouri's Mississippian legacy. Preservation Issues 6: 1-4.

Demes B, Jungers WL, Selpien K. 1991. Body size, locomotion, and long bone cross-sectional geometry in indriid primates. Am J Phys Anthropol 86: 537-547.

Demes B, Qin YX, Stern JT Jr., Larson SG, Rubin CT. 2001. Patterns of strain in the macaque tibia during functional activity. Am J Phys Anthropol 116: 257-265

Dlamini N, Morris AG. 2005. An investigation of the frequency of squatting facets in Later Stone Age foragers from South Africa. Int J Osteoarchaeol 15: 371-376.

Donaldson JE, Hulley SD, Vogel JM, Hattner RS, Byers JH, McMillan DE. 1970. Effect of prolonged bed rest on bone mineral. Metabolism 19: 1071-1084.

Drapeau MSM, Streeter MA. 2005. Modeling and remodeling responses to normal loading in the human lower limb. Am J Phys Anthropol 129: 403-409.

Drusini AG, Bredariol S, Carrara N, Bonati MR. 2000. Cortical bone dynamics and age-related osteopenia in a Longobard archaeological sample from three graveyards of the Veneto region (Northeast Italy). Int J Osteoarchaeol 10: 268-279.

Dutour O. 1986. Enthesopathies (lesions of muscular insertion) as indicators of activities of neolithic Saharan populations. Am J Phys Anthropol 71: 221-224.

Eshed V, Gopher A, Galili E, Hershkovitz I. 2004. Musculoskeletal stress markers in Natufian hunter-gatherers and Neolithic farmers in the Levant: The upper limb. Am J Phys Anthropol 123: 303-315.

Feik SA, Thomas CDL, Bruns L, Clement JG. 2000. Regional variations in cortical modeling in the femoral mid-shaft: sex and age differences. Am J Phys Anthropol 112: 191-205.

Ferrari S. 2004. Genetics, Nutrition, and bone health. In: Holick MF, Bess DH, editors. Nutrition and bone health. p 19-42.

Finnengen M. 1978. Non-metric variation of the infracranial skeleton. J Anat 125: 23-37.

France DL. 1998. Observational and metric analysis of sex in the skeleton. In: Reichs, KJ, ed. Forensic osteology. Advances in the identification of human remains. 2nd ed. Springfield, IL: Charles C Thomas.

Fratzl P, Schreiber S, Boyde A. 1995. Characterization of bone mineral crystals in horse radius by small-angle X-ray scattering. Calcif Tissue Int 58: 341-346.

Frost HM. 1980. Skeletal physiology and bone remodeling. In: Urist MR, editor. Fundamental and clinical physiology. Philadelphia, PA: JB Lippincott Company. p 201-241.

Frost HM. 1982. Mechanical determinants of bone modeling. Metab Bone Dis Relat Res 4: 217-229.

Frost HM 1983a. A determinant of bone architecture. The minimum effective strain. Clin Orthop Relat Res 175: 286-292.

Frost HM. 1983b. The skeletal intermediary organization. Metab Bone Dis Relat Res 4 : 281-290.

Frost HM. 1983c.The regional acceleratory phenomeneon: a review. Henry Ford Hosp Med J 31: 3-9.

Frost HM. 1987. Bone "mass" and the "mechanostat": a proposal. Anat Rec 219: 1-9.

Frost HM. 1988. Vital biomechanics: proposed general concepts for skeletal adaptations to mechanical usage. Calcif Tissue Int 42: 145-156.

Frost HM. 1997. Why do marathon runners have less bone than weightlifters? A vital-biomechanical view and explanation. Bone 20: 183-189.

Frost HM. 2003. Bone's mechanostat: a 2003 update. Anat Rec A Discov Mol Cell Evol Biol 275A 1:1081-1101.

Fung YC. 1993. Biomechanics: mechanical properties of living tissues. 2nd ed. New York: Springer- Verlag.

Gard PR. 1998. Human endocrinology. London: Tylor and Francis Ltd.

Garen SM, Pao E, Ruhl M. 1964. Compact bone in Chinese and Japanese. Science 143: 1439-1440.

Gilbert BM.1976. Anterior femoral curvature: its probable basis and utility as criterion of racial assessment. Am J Phys Anthropol 45: 601-604.

Gordon JE, Swenning TA, Burd TA, Szymanski DA, Schoenecker PL. 2003. Radiographic changes after lateral transtrochantric intermedullary nail placement in children. J Bone J Surg 85: 1295-1301.

Greene DA, Naughton GA, Briody JN, Kemp A, Woodhead H, Corrigan L. 2005. Bone strength index in adolescent girls: does physical activity make a difference? Br J Sports Med 39: 622-627.

Han ZH, Palniktar S, Rao DS, Nelson D, Parfitt AM. 1996. Effect of ethnicity and age or menopause on the structure and geometry of iliac bone. J Bone Miner Res 11 : 1967-1975.

Hannan MT, Tucker KL, Dawson-Hughes B, Cupples LA, Felson DT, Kiel DP. 2000. Effect of dietary protein on bone loss in elderly men and women: the Framingham osteoporosis study. J Bone Miner Res 15: 2504-2512.

Harrington M, Cashman, and Kevin D. 2003. High salt intake appears to increase bone resorption in postmenopausal women but high potassium intake ameliorates these adverse effects. Nutrition Reviews.

Hawkey DE. 1988. Use of upper extremity enthesopathies to indicate habitual activity patterns. M.A. Thesis. Arizona State University.

Hawkey DE, Street SR. 1992. Activity-induced stress markers in prehistoric human remains from the eastern Aleutian Islands (abstract). Am J of Phys Anthropol; Supplement 14: 89.

Hawkey DE, Merbs CF. 1995. Activity-induced musculoskeletal stress markers (MSM) and subsistence strategy changes among ancient Hudson Bay Eskimos. Int J Osteoarch 5: 324-338.

Hogan HA, Groves JA, Sampson HW. 1999. Long-term alcohol consumption in the rat affects femur cross-sectional geometry and bone tissue material properties. Alcohol Clin Exp Res 23: 1825-33.

Holland TD.1991 An archaeological and biological analysis of the Campbell site. PhD Dissertation. Department of Anthropology, University of Missouri-Columbia.

Holland TD.1994. Skeletal analysis. In O'Brien MJ, editor. Cat monsters and head pots the archaeology of Missouri's Pemiscot bayou Columbia: University of Missouri Press, p 307-347

Holiday TW. 1997. Postcranial evidence of cold adaptation in European Neandertals. Am J Phys Anthropol 104: 245-258.

Holiday TW. 1997. Body proportions in Late Pleistocene Europe and modern human origins. J Hum Evol 32: 423-447.

Holt BM. 2003. Mobility in upper Paleolithic and Mesolithic Europe: evidence from the lower limb. Am J Phys Anthropol 122: 200-215.

Holt BM, Benfer RA. 2000. Estimating missing data: an iterative regression approach. J Hum Evol 39: 289-296.

Ilich JZ, Kerstetter JE. 2000. Nutrition in bone health revisited: a story beyond calcium. J Am Coll Nutr 19: 715-737.

Järvinen TL, Pajamäki I, Sievänen H, Vuohelainen T, Tuukkanen J, Järvinen M, and

Kannus P. 2003. Femoral neck response to exercise and subsequent deconditioning in young and adult rats. J Bone Miner Res 18: 1292-1299.

Jones HH, Priest JD, Hayes WC, Tichenor CC, Nagel DA. 1977. Humeral hypertrophy in response to exercise. J Bone Joint Surg, U.S.A 59: 204-208.

Jurmain R. 1999. Stories from the skeleton: behavioral reconstruction in human osteology. Studies of bone geometry: the shape of things to come? Australia: Gordon and Breach Publishers.

Kachigan SK. 1986. Statistical analysis: an interdisciplinary introduction to univariate and multivariate methods. New York: Radius press.

Kaga M, Takahashi K, Ishihara T, Suzuki H, Tanaka H, Seino Y, and Makino H. 2004. Bone assessment of female long-distance runners. J Bone Miner Metab 22 : 509-513.

Kelly PJ, Hopper JL, Macaskill GT, Pocock NA, Sambrook PN, Eisman JA. 1991. Genetic factors in bone turnover. J Clin Endocrinol Metab 72: 808-813.

Kennedy KAR. 1998. Markers of occupational stress: conspectus and prognosis research. Int J Osteoarchaeol 8: 305-310.

Kerstetter JE, Mitnick ME, Gundberg CM, Caseria DM, Ellison AF, Carpenter TO, Insogna KL.1999. Changes in bone turnover in young women consuming different levels of dietary protein. J Clin Endocrinol Metab 84: 1052-1055.

Khan K, Mckay H, Kannus PA, Bailey DA, Wark J, Bennell K. 2001. Physical activity and bone health. Human Kinetics Publishers, Inc.

Krogman WM, Iscan MY. 1986. The human skeleton in forensic medicine. Springfield, IL: Charles C Thomas.

Lanyon LE, and Baggott DG.1976.Mechanical function as an influence on the structure and form of bone. J. Bone Joint Surg 58B: 436-443.

Lanyon LE, Magee PT, Baggott DG. 1979. The relationship of functional stress and strain to the process of bone remodeling. An experimental study of the sheep radius. J Biomechan 12: 593-600.

Lanyon LE.1980. The influence of function on the development of bone curvature. An experimental study on the rate tibia. J Zool (London) 192: 457-466.

Lanyon LE and Rubin CT.1985. Functional adaptation in skeletal structures. Vertebrate Morphology. In Hildebrand M, Bramble DM, Liem KF and Wake DB, editors. Functional vertebrate morphology Cambridge: Belknap Press (Harvard

University Press). p 1-25.

Lanyon LE .1996. Using functional loading to influence bone mass and architecture: Objectives, mechanisms, and relationship with estrogen of the mechanically adaptive process in bone. Bone Supp. 18: 37S-43S.

Laros GS, Tipton CM, and Cooper RR. 1971. Influence of physical activity on ligament insertions in the knees of dogs. J Bone Joint Surg 53A: 275-285.

Larsen CS, Ruff C. 1991. Biomechanical adaptation and behavior on the prehistoric Georgia coast. In: Powell ML, Bridges PS, Mires AMW, editors. What Mean these Bones? studies in southeastern bioarchaeology. Tuscaloosa: The University of Alabama Press. p 102-113.

Larsen CS, Ruff CB, Kelly RL. 1994. Structural analysis of the Stillwater postcranial human remains: behavioral implications of articular joint pathology and long bone diaphyseal morphology. In: Larsen CS, Kelly RL, editors. Bioarchaeology of the Stillwater Marsh: Prehistoric human adaptation in the Western Great Basin. Anthropological Papers of the American Museum of Natural History, no.77, p 107-133.

Larsen CS, Kelly RL, Ruff CB, Schoeninger MJ, Hutchinson DL. 1996. Biobehavioral adaptations in the western Great Basin. In: Reitz EJ, Newson LA Scudder SJ, editors. Case studies in environmental archaeology New York: Plenum Press, p 149-174.

Larsen CS. 1997. Bioarchaeology: interpreting behavior from the human skeleton. Cambridge, Massachusetts: Cambridge University Press.

Larsen CS.2000. Skeletons in our closet. Princeton: Princeton University Press.

Ledger M, Hotzhausen LM, Constant D, Morris AG. 2000. Biomedical beam analysis of long bones from a late 18th century slave cemetery in Cape Town, South Africa. Am J Phys Anthropol 112: 207-216.

Lieberman DE, Pearson OM, Polk JD, Demes B, Crompton AW. 2003. Optimization of bone growth and remodeling in response to loading in tapered mammalian limbs. J Exp Biol 206: 3125-3138.

Lieberman DE, Polk JD, Demes B. 2004. Predicting long bone loading from cross-sectional geometry. Am J Phys Anthropol 123: 156-171.

Lieberman DE, Raichlen DA, Pontzer H, Bramble, DM, and Cutright-Smith E. 2006. The human gluteus maximus and its role in running. J Exp Biol 209: 2143-2155.

Looker AC. 2002. The skeleton, race, and ethnicity. J Clin Endocrinol Metab 87

: 3047-3050.

Lovejoy CO, Cohn MJ, White TD. 1999. Morphological analysis of the mammalian postcranium: a development perspective. Proc Natl Acad Sci U.S.A. 96: 13247-13252.

Luckas JR. 2003. Skeletal variation among Mesolithic people of the Ganga Plains: new evidence habitual activity and adaptation to climate. Asian perspectives 42 : 329-351.

Manly BFJ. 2001. Randomization, bootstrap, and monte carlo methods in biology. 2nd ed. London: Chapman and Hall.

Martin RB. 1993. Aging and strength of bone as a structural material. Calcif Tissue Int 53: 834-840.

Martin RB, Burr DB, Sharkey NA. 1989. Skeletal tissue mechanics. New York: Springer-Verlag.

Martin RB. 1999. A genealogy of biomechanics. Presidential lecture presented at the 23rd Annual Conference of the American Society of Biomechanics. Pittsburgh: University of Pittsburgh.

Mays S, Lees B, Stevenson JC. 1998. Age-dependent bone loss in the femur in a medieval population. Int J Osteoarchaeol 8: 97-106.

Mays S. 2001. Effects of age and occupation on cortical bone in a group of 18th –19th century British men. Am J Phys Anthropol 116: 34-44.

McBride DG, Dietz MJ, Vennemeyer MT, Meadosr SA, Furbee NL, Benfer RA 2001. Bootstrap methods for sex determination from the os coxae using the ID3 Algorithm. J Forensic Sci 46: 427-431.

Medeiros DM, Plattner A, Jennings D, Stoecker B. 2002. Bone morphology, strength, and density are compromised in iron-deficient rats and exacerbated by calcium restriction. J Nutr 132: 3135-3141.

Melvin FJ, Luttge WG. 1982. Human Endocrinology: an interactive text. New York: Elsevier Biomedical.

Merbs CF. 1983. Patterns of activity-induced pathology in a Canadian Inuit population. Mercury Series. Paper No. 119. National Museum of Man. Ottawa: Archaeological Survey of Canada.

Molnar P. 2006. Tracing prehistoric activities: musculoskeletal stress marker analysis of a stone-age population on the island of Gotland in the Baltic sea. Am

J Phys Anthropol 129:12-23.

Moore RJ, Fazzalari NL, Manthey BA, Vernon-Roberts B. 1994. The relationship between head –neck-shaft angle calcar width, articular cartilage thickness of bone volume in arhrosis of the hip. Oxford Journals 33: 432-436.

Mastuda JJ, Zernicke RF, Vailas RF, Pedrini VA, Pedrini-Mille A, Maynard JA. 1986. Structural and mechanical adaptation of immature bone to strenuous exercise. J Appl Physiol 60: 2028.

Nelson DA, Barondess DA, Hendrix SL, Beck TJ. 2000. Cross-sectional geometry bone strength, and bone mass in the proximal femur in African-American and White postmenopausal women. J Bone Min Res 15: 1992-1997.

Nelson DA, Megyesi MS. 2004. Sex and ethnic differences in bone architecture. Current Osteoporosis Reports 2: 65-69.

Nordin M, Frankel VH. 1989. Basic biomechanics of the musculoskeletal system. 2nd ed. London: Lea and Febiger. p 3-29.

Nordström A, Olsson T, Nordström P. 2005. Bone gained from physical activity and lost through detraining: a longitudinal study in young males. Osteoporosis Int 16: 835-841.

Norman AW.1980. Bone and the vitamin D. endocrine system. In: Urist MR, editor. Fundamental and clinical bone physiology. Philadelphia, PA: JB Lippincott Company, p 242-267.

Noyes FR, Torvike PJ, Hyde WB, Delucas JL . 1974. Biomechanics of ligament failure. J Bone Joint Surg, 60A: 1406-1418.

O'Brien MJ, Holland T. 1994. Campbell. In O'Brien MJ, editor. Cat monsters and head pots: the archaeology of Missouri Pemiscot bayou Columbia: University of Missouri Press, p 195-260

O'Brien MJ. 1996. Paradigms of the past: the story of Missouri archaeology. Columbia: University of Missouri Press.

O'Brien MJ, Wood WR. 1998. The prehistory of Missouri. Columbia: University of Missouri Press.

Ogata K, Goldsand. 1979. .A simple biplanar method of measuring femoral anterversion and neck-shaft angle. J Bone J Surg 61: 846-851.

Ogden JA. 1980. Chondro-osseous development and growth. In: Urist MR, editor. Fundamental and clinical bone physiology. Philadelphia, PA: JB Lippincott

Company, p 108-171.

Ortner DJ. 1968. Description and classification of degenerative bone changes in the distal joint surfaces of the humerus. Am J Phys Anthropol 28: 139-155.

Ortner DJ, Putschar WGJ. 1981. Identification of pathological conditions in human skeletal Remains. Smithsonian contributions to anthropology 28. Washington, DC: Smithsonian Institution Press.

Pearson OM. 2000. Activity, climate, and postcranial robusticity: implications for modern human origins and scenarios of adaptive change. Curr Anthropol 41: 569-607.

Pearson OM, Lieberman DE. 2004. The aging of Wolf's "Law": ontogeny and responses to mechanical loading in cortical bone. Yearb of Phys Anthropol 47: 63-99.

Pechenkina EA, Benfer RA. 2002. The role of occlusal stress and gingival infection in the formation of exostosis on mandible and maxilla from Neolithic China. Homo 53: 112-150.

Pechenkina EA, Delgado M. 2006. Dimensions of health and social structure in the Early Intermediate period cemetery at Villa El Salvador, Peru. Am J Phys Anthropol 131: 218-235.

Peterson J. 1998. The Natufian hunting conundurm: spears, atlatls, or bows? Musculoskeletal and armature evidence. Int J Osteoarchaeol 8 : 378-389.

Plotkin EL. 1987. The static biomechanical examination and its importance in occupational Medicine. Clin Podiatr Med Surg 4: 653-69.

Polisson RP, Martinez S, Koury M, Harrel RM, Lyles KW, Friedman N, Harrelson JM, Reisner E, Drezner MK. 1985. Calcification of entheses associated with X-linked hypophosphatemic osteomalacia. N Eng J of Med 313: 1-6.

Popowics TE, Zhu Z, Herring SW. 2002. Mechanical properties of the periosteum in the pig, Sus Scrofa. Arch Oral Biol 47: 733-41.

Preuschoft H.1973. Functional anatomy of the upper extremity. In: Bourne GH, editor. The chimpanzees Basel: Karger. p 34-120.

Promislow JH, Goodman-Gruen D, Slymen DJ, Barrett-Conner E. 2002. Protein consumption and bone mineral density in the elderly: the rancho bernardo study. Am

J Epidemiol 155: 636-644.

Purkait R, Chandra H. 1993. Anterior femoral curvature: a study on sex difference. J Ind Acad Forensic Med 32: 1-11.

Purkait R, Chandra H. 2002. Sexual dimorphism in femora: An Indian study. Forensic Science Communications 4:

Resnick D, Niwayama G. 1983. Entheses and enthesopathy: Anatomical, pathological, and radiological correlation. Radiology 146: 1-9.

Reitz EJ. 2003. Resource use through time at Paloma, Perú. Bulletin of the Florida Museum of Natural History 44: 65-80.

Rhine S. 1990. Non-metric skull racing. In: Gill, GW, and Rhine JS, eds. Skeletal attribution of race: methods for forensic anthropology. Anthropological papers 4, Maxwell Museum of Anthropology, Albuquerque, NM.

Rhode M.2003. Enthesis scoring system. Unpublished system.

Rhode M. 2006. Habitual subsistence practices among prehistoric Andeans: Fishers and Farmers. PhD Dissertation. University of Missouri-Columbia.

Rhodes JA, Knűsel CJ. 2005. Activity-related skeletal change in medieval humeri: cross-sectional and architectural alterations. Am J Phy Anthropol 128 : 536-546.

Roux W.1881. Der kampf der teile im organismus. Leizig: Engelmann.

Robb J. 1994. Skeletal signs of activity in the Italian Metal Ages: methodological and interpretive notes. Hum Evol 9: 215-229.

Robb JE. 1998. The interpretation of skeletal muscle sites: a statistical approach. Int J Osteoarchaeol 8: 363-377.

Robling AG, Burr DB, Turner CH. 2000. Partitioning a daily mechanical stimulus into a discrete loading bout optimizes the osteogenic response to loading. J Bone Miner Res 15: 1596-1602.

Robling AG, Burr DB, Turner CH.2001. Recovery periods restore mechanosensitivity to dynamically loaded bone. J Exp Biol 204: 3389-3399.

Robling AG, Hinant FM, Burr DB, Turner CH. 2002a. Improved of bone structure and strength after long-term mechanical loading is greatest if the loading is separated into short bouts. J Bone Miner Res 17: 1545-1554.

Robling AG, Hinant FM, Burr DB, Turner CH. 2002b. Shorter, more frequent mechanical loading sessions enhance bone mass. Med Sci Sports Exerc 34: 196-202.

Robling AG, Castillo AB, Turner CH. 2006. Biomechanical and molecular regulation of bone remodeling. Annu Rev Biomed Eng 8: 455-498.

Rogers J, Shepstone L, Dieppe P.1997. Bone formers: osteophyte and enthesophyte formation are positively associated. Ann Rheum Dis 56: 85-90.

Rubin CT, Lanyon LE. 1984. Regulation of bone formation by applied dynamic loads. J Bone Joint Surg, 66A: 397-402.

Ruff CB, Jones HH.1981. Bilateral asymmetry in cortical bone of the humerus and tibia-sex and age factors. Hum Biol 53: 69-86.

Ruff CB, Hayes WC. 1983a. Cross-sectional geometry of the Pecos Pueblo femora and tibiae -a biomechanical investigation. I. Methods and general patterns of variation. Am J Phy Anthropol 60: 359-381.

Ruff CB, Hayes WC. 1984. Bone mineral content in lower limb. Relationship to cross-sectional geometry. J Bone Joint Surg 66: 1024-1031.

Ruff CB, Larsen CS, Hayes WC. 1984. Structural changes in femur with the transition to agriculture on the Georgia coast. Am J Phys Anthropol 64: 125-136.

Ruff CB. 1987. Sexual dimorphism in human lower limb bone structure: Relationship to subsistence strategy and sexual division of labor. J. Hum Evol 16: 396-416.

Ruff CB.1992. Biomechanical analyses of archaeological human skeletal samples. In: Saunders SR, Katzenberg MA, editors. Skeletal biology of past peoples New York: Alan R. Liss, p 41-62.

Ruff CB. 1994. Morphological adaptation to climate in modern fossil hominids. Yearb of Phys Anthrop 37: 65-107.

Ruff CB. 1999. Skeletal structure and behavioral patterns of prehistoric Great Basin populations. In: Hemphill BE, Larsen CS, editors. Prehistoric Lifeways in the Great Basin Wetlands: bioarchaeoloical reconstruction and interpretation. Salt Lake City: University of Utah Press.

Ruff CB. 2000a. Body size, body shape, and long bone strength in modern humans. J

Hum Evol 38: 269-290.

Ruff CB. 2000b. Body mass prediction from skeletal frame size in elite athletes. Am J Phys Anthropol 113: 507-517.

Ruff CB. 2002. Variation in human body size and shape. Ann Rev of Anthropol 31: 211-232.

Ruff CB. 2005. Mechanical determinants of bone form: insights from skeletal remains. J Musculoskeletal Neuronal Interact five: 202-212.

Ruff CB, Holt B, Trinkaus E. 2006. Who's afraid of the big bad Wolf?: "Wolf's Law" and bone functional adaptation. Am J Phys Anthropl 129: 484-498.

Ruff CB and Runestad JA. 1992. Primate limb bone structural adaptation. Ann Rev Anthropol 21: 407-433.

Ryder KM, Shorr RI, Bush AJ, Kritchesky SB, Harris T, Stone K, Cauley J, and Tylavsky FA. 2005. Magnesium intake from food and supplements is associated with bone mineral density in healthy older subjects. J Am Geriatr Soc 53: 1875- 80.

Schuelke M, Wagner KR, Stolz LE, Hubner C, Riebel T, Komen W, Braun T, Tobin JF, Lee SJ. 2004. Myostatin mutation associated with gross muscle hypertrophy in a child. New Eng J M 350: 2682-2688.

Seeman E. 1998. Growth in bone mass and size-are racial and gender differences bone mineral density more apparent than real? J Clin Endocrinol Metab 83: 1414-1419.

Shackelford LL, Trinkaus E. 2001. Late Pleistocene human anterior femoral curvature. Am J Phys Anthropol 32 (Suppl.): 135-135 [Abstract].

Shackelford LL, Trinkaus E. 2002. Late Pleistocene human femoral diaphyseal curvature. Am J Phys Anthropol 118: 359-370.

Singh SP, Singh S. 1972. A study of anterior femoral curvature in Indian subjects. Acta Anat. (Basel). 83: 416-425.

Skedros JG, Hunt KJ, Bloebaum RD. 2004. Relationships of loading history and structural and material characteristics of bone: development of the mule deer calcaneus. J of Morphology 259: 281-307.

Skerry T.2000. Biomechanical influences on skeletal growth and development. In: O'Higgins P, Cohn M, editors. Development, growth, and evolution: implications for the study of the hominid skeleton. London: Academic Press. p 30-39.

Sperduti A. 1997. Life conditions of a Roman imperial age population: occupational stress Markers and working activities in Lucus Feroniae (Rome, 1st –2nd cent. AD). Hum Evol 12: 253-267.

Steen S, Lane R.1998. Evaluation of habitual activities among two Alaskan Eskimo populations based on musculoskeletal stress markers. Int J Osteoarchaeol 8: 341-353.

Stewart TD.1962. Anterior femoral curvature: its utility for race identification. Hum Biol 34 (1): 49-62.

Stirland AJ.1993. Asymmetry and activity-related change in the male humerus. Int J Osteoarchaeol 2: 105-113.

Stock J, Pfeiffer S. 2001. Linking structural variability in long bone diaphysis to habitual behaviors: Foragers from the Southern African Later Stone Age and the Andaman Islands. Am J Phys Anthropol 115: 337-348.

Stock JT, Pfeiffer SK. 2004. Long bone robustcity and subsistence behaviour among Later Stone Age foragers of the forest and fynbos biomes of South Africa. J Arch Sc 31: 999-1013.

Stock JT. 2006. Hunter-gatherer postcranial robusticity relative to patterns of mobility, climatic adaptation, and selection for tissue economy. Am J Phys Anthropol 131: 194-204.

Swartz SM.1991. Strain analysis as a tool for functional morphology. Am Zool 31: 655-669.

Taaffe DR, Lang TF, Fuerst T, Cauley JA, Nevitt MC, Harris TB. 2003. Sex- and race-related differences in cross-sectional geometry and bone density of the femoral mid-shaft in older adults. Ann Hum Biol 30: 329-346.

Tipton CM, Matthes RD, Maynard JA, Carey RA. 1975. The influence of physical activity on ligaments and tendons. Med Sci Sports 7: 165-175.

Todd TW. 1920. Age changes in the pubic bone: I, the male white pubis. Am J Phys Anthropol 3: 285- 334.

Todd TW, Lyon DW. 1924. Endocranial suture closure: its progess and age relationship. Part I, adult males of white stock. Am J Phys Anthropol 7: 325-384.

Todd TW, Lyon DW. 1925a. Cranial suture closure: its progess and age relationship. Part II, ectocranial closure in adult males of white stock. Am J Phys Anthropol 8: 23-44.

Todd TW, Lyon DW. 1925b. Cranial suture closure: its progress and age relationship. Part III, endocranial closure in adult males of Negro stock. Am J Phys Anthropol 8: 47-71.

Todd TW, Lyon DW. 1925c. Cranial suture closure: its progress and age relationship. Part IV, ectocranial closure in adult males of Negro stock. Am J Phys Anthropol 8: 149-168.

Trinkaus E. 1984. Early modern humans. Ann Rev Anthropol 34: 207-30.

Trinkaus E.1989. Neandertal upper limb morphology and manipulation. In: Giacobini G, editor. Hominidae. Milano: Jaca Book. p 331-338.

Trinkaus E.1993. Femoral neck-shaft angles of the Qafzeh-Skhul early modern humans, and activity levels among immature Near Eastern Middle Paleolithic hominids. J Hum Evol 25: 393-416.

Trinkaus E. 1997. Appendicular robusticity and the paleobiology of modern human emergence. Proc Natl Acad Sci U.S.A. 94:13367-13373.

Trinkaus E, Churchill S, Ruff CB. 1994. Postcranial robusticity in *Homo*, II: Humeral bilateral asymmetry and bone plasticity. Am J Phys Anthropol 93: 1-34.

Tinkaus E, Ruff CB, Churchill SE, Vandermeersch B. 1998. Locomotion and body proportions of the Saint-Césaire 1 Châtelperronian Neandertal. Proc Natl Acad Sci U.S.A. 95: 5836 – 5840.

Trinkaus E, Churchill SE. 1999. Diaphyseal cross-sectional geometry of Near Eastern Middle Paleolithic humans: the humerus. J Archaeol Sci 26: 173-184.

Trinkaus E, Ruff CB. 1999. Diaphyseal cross-sectional geometry of Near Eastern Middle Paleolithic humans: the femur. J Archaeol Sci 26: 409-424.

Tuck SP, Pearce MS, Rawlings DJ, Birrell FN, Parker L, Francis RM. 2005. Differences in bone mineral density and geometry in men and women: the Newcastle thousand families study at 50 years old. Br J Radiol 78: 493-498.

Turner CH, Robling AG. 2003. Designing exercise regimens to increase bone strength. Exerc Sport Sci Rev 31: 45-50.

Ubelaker DH.1979. Skeletal evidence for kneeling in Prehistoric Ecuador. Am J Phys Anthropol 51: 679-85.

Walensky NA. 1965. A study of anterior femoral curvature in man. Anat Rec 151: 559-570.

Weaver TD. 2003. The shape of the Neandertal femur is primarily the consequence of a hyperpolar body form. Proc. Natl Acad Sci U.S.A. 100: 6926 – 6929.

Weiss E. 2003. Understanding muscle markers: aggregation and construct validity. Am J Phys Anthropol 121: 230-240.

Weiss E. 2003b. Effects of rowing on humeral strength. Am J Phys Anthropol 121: 293-302.

Weiss E. 2004. Understanding muscle markers: lower limbs. Am J Phys Anthropol 125: 232-238.

Wescott D. 2001. Structural variation in the humerus and femur in the American Great Plains and adjacent regions: Differences in subsistence strategy and physical terrain. PhD dissertation. University of Tennessee, Knoxville.

Wescott DJ. 2005. Population variation in femur subtrochantric shape. J For Sci 50: 1-8.

Wescott DJ, Cunningham DL. 2005. Temporal changes in Arikara humeral and femoral cross-sectional geometry associated with horticultural intensification. J Archaeol Sci: 1-15.

Wescott DJ. 2006A. Effect of mobility on femur midshaft external shape and robusticity. Am J Phys Anthropol 130: 201-13.

Wescott DJ. 2006. Ontogeny of femur subtrochatric shape in Native Americans and American Blacks and Whites. J For Sci 51: 1-6.

White TD, Folkens PA. 2000. Human osteology 2nd edition. San Diego: Academic Press.

Wilczak CA.1998. Consideration of sexual dimorphism, age, and asymmetry in quantitative measurements of muscle insertion sites. Int J Osteoarchaeol 8: 311-325.

Wilson AW, Davis HMS, Edwards GA, Grills BL. 1999. Can some physical therapy and manual techniques generate potentiality osteogenic levels of strain within mammalian bone? Physical Therapy 79:

Wilson EO. 1998. Consilience: the unity of science. New York: Knof.

Wolff J.1892. Das gesetz der transformation der Konchen. Berlin: A. Hirshwald.

Wohl GR, Boyd SK, Judex S, Zernicke RF. 2000. Functional adaptation of bone to exercise and injury. J Sci Med Sports 3: 313-324.

Woo SL, Kuei SC, Amiel D, Gomez MA, Hayes WC, White FC, Akeson WH. 1981. The effect of prolonged physical training on the properties of long bone: a study of

Wolff's law. J Bone Joint Surg (Am) 63: 780-787.

Yamanaka A, Gunji H, Ishida H. 2005. Curvature, length, and cross-sectional geometry of the femur and humerus in anthropoid primates. Am J Phys Anthropol 127: 46-57.

Zopac TS. 1983. Postcraniometric variation among the Arikara. PhD Dissertation. The University of Tennessee, Knoxville.

Zeffer A, Johanson LC, Marmebro A 2003. Functional correlation between habitat use and leg morphology in birds (Aves). Biological Journal of the Linnean Society, 79: 461- 484.

Zumwalt A. 2005. A new method for quantifying the complexity of muscle attachment sites. Anat Rec 286B: 21-28.

Zumwalt A. 2006. The effect of endurance exercise on the morphology of muscle attachment sites. J Exp Biol 209: 444-454.

APPENDIX

DATA COLLECTION PROTOCOL **SEX ________**
AGE ________

Site Name _________________ **Catalog # _______________**
Recorder _________________ **Tomb/Individual # _______**

SKELETAL SEXING

Features: Masculine (M)- Indeterminant (I) – Feminine (F)

- Greater sciatic notch	____	Sacrum shape	____
- Height of auricular surface	____	Femur head diameter	____
- Preauricular sulcus	____	Humerus head diameter	____
- Pubis shape	____	Bone robusticity	____
- Subpubic angle	____	Sup. Orbital shape	____
- Ventral arc	____	Mastoid process	____
- Dorsal pitting	____	Mandible/chin shape	____

Nuchal crest	_____
Zygoma extension	_____
Auditory meatus	_____
Iliac flare	_____
Brow ridge	_____
Ascend ramus angle	_____
Infant features	_____

Femur Head Diameter (mm) Humeral Head Diameter (mm)

F < | F? | I | M? | > M F< | F? | I | M? | > M

42.5< 42.6 – 47.4 > 47.5 43 < 44-46 >47

Determined Sex

| F | F? | Ind. | M? | M

SKELETAL AGING

Epiphyseal Closure: (Open - % Fused – Fused)

- Basilar suture	_____	Sacrum 1-5	_____
- Medial clavicle	_____	Anterior iliac crest	_____
- Cervical rim	_____	Ischial tuberosity	_____
- Thoracic rim	_____	Prox. Humerus	_____
- Lumbar rim	_____	Dist. Humerus	_____

- Prox. Radius _____
- Dist. Radius _____
- Prox. Ulna _____
- Dist. Ulna _____
- Femur head _____
- Greater trochanter _____
- Dist. Femur _____
- Prox. Tibia _____
- Dist. Tibia _____

Age Range ______________

Dental Age:_________________| Third Molar Eruption _______________

Pubic Symphsis (Todd Stage): Left ______ Right _____ Age Range ____
Auricular surface stage: Left ______ Right _____ Age Range ____
Sternal Rib (4^{th}, 5^{th}, or 6^{th}): Left ______ Right _____ Age Range ____

Cranial Suture Closure (Open-Closed):

Superior Vault		***Lateral Vault***	
- Midlambdoidal	_______	Midcoronal	______
- Lambda	_______	Pterion	______
- Obelion	_______	Sphenoforntal	______
- Anterior Sagittal	_______	Infer. Sphenotem.	______
- Bregma	_______	Sup. Sphenotemp.	______
Summary and S-Value	_______	**Summary and S-Value**	______
Age Range	_______	**Age Range**	______

Interior Vault

- Lambdoid ______
- Sagittal ______
- Coronal ______

Summary and S-Value ______
Age Range ______

Determined Age

Overall Age Range ______________ **Probable Age** _______________

Postcranial Measurements

Site ______________ Sex ___________ Recorder ___________

Tomb # ______________ Age ___________ Date ___________

Humerus	**L eft | Right**	**Femur**	**Left | Right**
Maximum Length	____ | ____	Max. length	____ | ____
Min. diameter at midshaft	____ | ____	Max. diam. head	____ | ____
Max. diam. midshaft	____ | ____	M-L diam. midshaft	____ | ____
Circum. midshaft	____ | ____	A-P diam. midshaft	____ | ____
Least circum. on shaft	____ | ____	Circum. midshaft	____ | ____
M-L diam. midshaft	____ | ____	M-L diam. subtroch.	____ | ____
A-P diam. midshaft	____ | ____	A-P diam. subtroch.	____ | ____
A maximum Length	____ | ____	Low distal point	____ | ____
Length of the cord	____ | ____	Low proximal point	____ | ____
Subtense 1 (Prox.)	____ | ____	Max. anter. curv.	____ | ____
Location of P1 from the distal end	____ | ____	Length of diaphysis	____ | ____
Subtense 2			
Location of P2 from the distal end	____ | ____	Upper length of diaphysis	____ | ____
Subtense 3			
Location of P3 from the distal end	____ | ____		

Entheses Scoring Form

Site ____________________ Sex __________ Recorder ___________
Tomb# ____________________ Age __________ Date ___________

Coding (Hawkey 1988; Hawkey and Merbs 1995; and Rhode 2003)

Habitual Use	**Abrupt Trauma**
Robusticity Markers (RM) (ridges, crests)	Ossification Exostoses (OS) (bone growth)
Stress Lesions (SL) (furrows, grooves)	
0 = absence of expression (normal/smooth)	**0** = absence of expression
1 = robusticity grade 1 (RM1) (faint/smooth)	**1** = ossif. exo.grade (OS1) (faint/trace)
2 = robusticity grade 2 (RM2) (moderate)	**2** = ossif.exo.grade (OS2) (moderate)
3 = robusticity grade 3 (RM3) (strong)	**3 =** ossif. exo. Grade (OS3) (strong)
4 = stress lesion grade 1 (SL1) (faint/trace)	
5 = stress lesion grade 2 (SL2) (moderate)	**999** = score if location is missing or obscured
6 = stress lesion grade 3 (SL3) (strong)	

Humerus	**Left | Right**	**Femur**	**Left| Right**
Supraspinatus (ant.grtr.tub.)	____ | ____	Gluteus medius (gtr.troch)	____ | ____
Infraspinatus (med.grtr.tub.)	____ | ____	Obturator externus (troch.fossa)	____ | ____
Teres minor (post.grtr.tub.)	____ | ____	Gluteus maximus (sup.lin.aspera)	____ | ____
Subscapularis (ant.lesr.tub.)	____ | ____	Psoas major, Iliacus (lsr. troch.)	____ | ____
Teres major (med.itg.)	____ | ____	Gastrocenmius MH (dist. Post.)	____ | ____
Latissimus dorsi (med.itg)	____ | ____	**Tibia**	
Pectoralis major (lat.itg.)	____ | ____	tibial tuberosity (ant. sup. tub.)	____ | ____
Deltoids (lat.midshaft tub.)	____ | ____	Soleus (soleal in. prox. Post.)	____ | ____
Coracobrachialis (post.midshaft)	____ | ____	Squatting facet (ant.distal cond.)	____ | ____
C. Extensors (co lat.condyle.)	____ | ____		
C. Flexors (co med. condyl.)	____ | ____		

Radius

Supinator (sup.prox. rad.)	____ | ____
Biceps brachii (med.rad.tub.)	____ | ____
Pronator teres (lat.mishaft)	____ | ____
Pronator quadratus (sup.dist.)	____ | ____

Ulna

Triceps brachii (post.semlun.)	____ | ____

Aconeus (post.semlun.) ____ | ____
Brachialis (ant.sub.semlun.) ____ | ____
Supinator (sup.crest lat.) ____ | ____

Pathology Data Form (Cranial)

Site ____________________ Sex _______________ Recorder _________________
Tomb # _________________ Age _______________ Date _____________________

Cranial	**1st Pathology**						**2nd Pathology**					
	Gen.	Spec.	Sev.	Loc.	Stat.	L/W	Gen.	Spec.	Sev.	Loc.	Stat.	L/W
Frontal												
L	C. Orbitalia											
R	C. Orbitalia											
Parietal												
	Poro. Hyper.											
	Poro. Hyper.											

Pathology Data Form (Postcranial)

Postcranial	**1st Pathology**						**2nd Pathology**					
	Gen.	Spec.	Sev.	Loc.	Stat.	L/W	Gen.	Spec.	Sev.	Loc.	Stat.	L/W
Tibia L												
R												

Vertebral Pathology Form

Site ____________ Sex ___________ Recorder _________________

Tomb # _________ Age __________ Date _________________

Vertebrae	1st Pathology						2nd Pathology					
	Gen.	Spec.	Sev.	Loc.	Stat.	L/W	Gen.	Spec.	Sev.	Loc.	Stat.	L/W
C1												
C2												
C3												
C4												
C5												
C6												
C7												
T1												
T2												
T3												
T4												
T5												
T6												
T7												
T8												
T9												

T10												
T11												
T12												

Vertebral Pathology Form (cont.)

Vertebrae	**1st Pathology**						**2nd Pathology**					
L1	Gen.	Spec.	Sev.	Loc.	Stat.	L/W	Gen.	Spec.	Sev.	Loc.	Stat.	**L/W**
L2												
L3												
L4												
L5												
S1												

NOTE:

Curriculum Vitae

Ahmad Yosuf Abu Dalou was born in Jordan in April, $13^{th,}$ 1971. I graduated from Jordan University of Science & Technology with a bachelor degree in Nursing in 1993. I got my Master degree in Physical Anthropology from Institute of Archaeology & Anthropology-Yarmouk University in 1998.