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Social Identity Over the Lifecourse at Historic Middenbeemster: A Biocultural Approach

Author

Chilcote, Celise

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Social Identity Over the Lifecourse at Historic Middenbeemster: A Biocultural Approach

By

Celise Chilcote

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Committee in charge:

Professor Sabrina C. Agarwal, Chair
Professor Laurie A. Wilkie
Associate Professor Jeroen Dewulf

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Abstract

Social Identity Over the Lifecourse at Historic Middenbeemster: A Biocultural Approach

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Celise Chilcote

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University of California, Berkeley

Professor Sabrina C. Agarwal, Chair

Clinical and osteological studies have provided evidence that patterns in human skeletal morphological variations can be correlated with general patterns of activity. A whole-body life-course approach, which combines a variety of activity pattern analyses, provides the strongest support for activity related morphological variations and their development during life. By understanding the patterns of types of activities and their associated strain levels, applying biological characteristics of individuals in a life-course perspective, it becomes possible to frame biological and cultural data within a social narrative. This study examines social identity over the life course in the historic dairy farming community of Middenbeemster, NL, through the examination of skeletal markers of bone growth and maintenance and activity-related stress. It was hypothesized that the high demand for Dutch dairy products during the occupation of Middenbeemster would be reflected in the manifestation and intensity of skeletal markers of activity, suggesting sex and age-related patterns of activity and workload. A total of 87 adults (M=46, F=41) were chosen to be analyzed for the following variables: non-pathological osteoarthritis of all appendicular joints, 8 non-genetic non-metric traits, and 27 entheseal insertions (per side) chosen to represent a variety of major muscle groups/movements. Additionally, humeral and femoral diaphyseal cross-sectional geometry was examined in 108 adults (M=57, F= 51) and 22 subadults. Musculoskeletal development analyses provide strong support for a sex-based division of labor with several changes in activity patterns over the life-course for both sexes. Men from Middenbeemster exhibited changes in types of activities that most likely reflect an age-associated change in duties of daily farm life from an apprentice-like position involving milking the herd to more strenuous and variable activities. Women from Middenbeemster also exhibited age-associated changes in types of activities. Overall, the patterns of the results suggest that younger women were involved not only in the caretaking of the home, but were also important contributors in the dairy production process. A review of historical literature provides support for the inferred sex and age-based divisions of labor, however, the conclusions reached in this dissertation suggest a far more active role for women in the economic success of the dairy farms than was historically recorded.

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Neither a purely biological nor purely cultural entity, the human body lies at the intersection between the two, representing the very essence of humanity's complexity. An obsession with the body is as old as humanity itself; from abstract representations and stencils of hands that are thousands of years old to the current knowledge of the mechanical underpinnings of the body at even the genetic level, the body remains a locus of attention across time, space and cultures. Bioarchaeology bridges the biological and social sciences, uniquely poised to addresses issues of social identity via an approach which combines biological identity with cultural and archaeological context (Knüsel 2010:62). Specifically, bioarchaeological analyses can contribute to the formation of inferences about behavioral activity patterns via gross morphological changes to the human skeleton. These patterns can potentially be used to reconstruct aspects of past lifestyles including: food processing techniques, divisions of labor, degrees of task specialization, effects of the environment and even changes in subsistence strategies.

The ability of skeletal morphology to elucidate prehistoric activity patterns is a topic that has been surrounded by debate since its initial suggestion. While methodologically still developing, both clinical and archaeological research has recently provided substantial support for the ability of studies in skeletal morphology to formulate at least general inferences on patterns of activity from variations in cross-sectional geometry, muscle insertion morphology, non-age related osteoarthritis, and the development of non-genetic non-metric traits. These inferences on activity patterns can then be combined with contextual information to provide physical support for reconstructions of past life-ways that many anthropologists have suggested based solely upon the material remnants of previous cultures (for example, gendered divisions of labor). This project aims to examine aspects of social identity in the post-Medieval skeletal sample from the cemetery of Middenbeemster, Netherlands, through the examination of skeletal markers of bone growth and maintenance and activity-related stress.

1.2 OBJECTIVES OF RESEARCH

Founded in 1612, the town of Beemster was, and remains, an extremely important dairy farming community in North Holland, Netherlands. Despite the wide body of research on arable agriculture and its economic importance in the North Sea area during the latter half of the first millennia, there is currently little information on the development of any of the rural societies there (Van Cruyningen 2006:297-298). A repeated theme throughout a publication series devoted to research on the comparative rural history of the North Sea area is the need to focus not just on the overall economic implications of agricultural intensification in this region but to reintroduce the human element: rural social developments, household and occupational duties and identities, biographies of 'ordinary' people and especially the positions of women in pre-twentieth century Dutch farming communities.

This bioarchaeological study of the historic Middenbeemster community will provide information on not only the daily lives of the inhabitants, but also provide an opportunity to study the dynamics of social identity over the lifecourse via how activities and responsibilities changed, but also provide biological information and cultural insights on a society and region that has been neglected in academic literature especially the important, yet historically silent, economic contributions that women made.

1.3 ORGANIZATION OF DISSERTATION

This dissertation is divided into eight chapters. Chapter Two is devoted to a review of the theoretical foundations of the study of the human body and cultural interpretations we may gain from it. The first section of this chapter provides an overview of the treatment of the body in anthropological studies while the second section details embodiment theory, including structures of agency, practice theory and the interplay between the physical body and cultural narratives. The final section of this chapter reviews the concept of 'social bioarchaeology' and its application of biocultural analyses and lifecourse theory.

Chapter Three is devoted to an in-depth review of research on skeletal activity patterns. The first two sections cover the historical background of skeletal activity research and its biological foundations. The last four sections are devoted to each of the four main sub-areas of skeletal activity investigations: biomechanics, entheseal changes, osteoarthritis and non-genetic non-metric traits.

Chapter Four provides a review of the materials used in this research project. The first two sections cover the history of the region and the site of Middenbeemster, including previous bioarchaeological research published on the collection. The final section details the skeletal sample analyzed, including sample descriptions for each of the different methods utilized in this project.

Chapter Five enumerates the methods followed for data collection. The first section includes the measurements taken and different formulas used to control for body size. The second section details the protocols used for taking the computed tomography scans, as well as image analyses. The final three sections outline the variables chosen for analysis and specific scoring methods employed for each of the categories of entheseal changes, osteoarthritis and non-genetic non-metric traits.

Chapter Six presents the results of the statistical analyses and is divided into six sections: subadult cross-sectional geometry, adult cross-sectional geometry, entheseal changes, osteoarthritis and non-genetic non-metric markers. Descriptive statistics are presented for each of these sections, and tables presenting the results of each of the statistical tests performed and levels of significance are also included. Where appropriate, graphs are provided for visualization.

Chapter Seven is a discussion and interpretation of the results chapter. The first five sections discuss the statistical results for each of the five categories of musculoskeletal analyses undertaken. The sixth section incorporates all of the data sets together with a consideration of the historical literature to provide interpretations on age and sex-related patterns of activities.

The final chapter is the conclusion and reviews the research in general. The future potential for further research at the site of Middenbeemster as well as for activity pattern analyses in general are also discussed.

CHAPTER 2: THEORETICAL FOUNDATIONS

2.1 OVERVIEW

The human skeleton is a complex network of both organic and inorganic material. From gestation until death the human body is constantly modifying itself in response to everything from the intake of food and air to the stresses of disease and physical activity. Some of these modifications are temporary but others may permanently affect the skeleton, leaving a multidimensional account of an individual long after death. The human body, however, is not simply a biological entity- it is inherently cultural as well. The ongoing dialogue of an individual's (or group's) social life is analogous to the dialogue going on within the human body itself. As one navigates social and cultural norms and customs, the body may physically respond (for example: disease from poor sanitary conditions or stunted growth due to malnutrition) or even be purposefully changed (for example: cranial deformation, foot binding or dental mutilation). From birth, an individual is both socially and physically affected by the people, culture, society and environment in which they live and take part; it is what allows an individual to form an identity. It is the identities of those in the past that can provide the greatest amount of information to archaeologists and anthropologists trying to 'read' the narratives of history; after all, what better source is there to understand the cultural variation of the past than the very people who created/existed within it? "Identities can be both personal and communal, ascribed and achieved, manipulated and feigned. Gender, age, status, ethnic affiliation and religion all represent forms of social identities with associated behavioral expectations and roles. Identities are about self-perception and self-promotion as well as constraints imposed by others." (Knudson and Stojanowski 2008:398).

Osteoarchaeology and interpretive archaeology have been clearly divided on the concept of the body. Osteologists study variation between skeletons by recognizing certain fixed and universal traits that allow for methodologically rigorous scientific analyses. These analyses permit comparisons between bodies, groups, populations, cultures and time periods. Many osteological analyses, however, traditionally stop at descriptive reports instead of contextualizing the bodies being analyzed and incorporating theoretical approaches to further understand the individual(s) being studied. Even as recently as 2003, a survey of publications focused on modern human osteological remains in the *American Journal of Physical Anthropology* from 1996-2000 found 71% of them to be descriptive and only 29% to be analytical (Armelagos and Van Gerven 2003:59-60); however, Stojanowski and Buikstra (2005) and Hens and Godde (2008) did similar surveys and found the ratio of analytical to descriptive publications balanced. Importantly, many studies may not be able to attempt more detailed biocultural analyses due to poor preservation, sampling bias, or lack of context. In samples that do demonstrate the capacity for both solid physical and historical contextualization, however, the use of social theory and the application of biocultural analyses has become far more prevalent during the 21st century.

In contrast, interpretive archaeologists have been accused of perceiving the body solely as a social construction thereby turning the body into a subjective theoretical space rather than recognizing the corporeal construction of individual identities via bodily experience or 'lived bodies' (Meskell 1998:140). Despite the reliance on osteologists for sex and age of a skeleton, the focus of archaeological interpretations tend to take that data and then imbue the objects surrounding a body with cultural symbolism; thus locating social meaning and identity apart from the body (Sofaer 2006a). This abstraction of the body results in what has been referred to as an archaeological paradox: a social archaeology that lacks any physiological basis for social life (Ingold 1998:27; Sofaer 2006a:9, 125; Geller 2008).

In physical anthropology the study and use of human remains has moved from descriptive typological categorization towards incorporation via socio-cultural contextualization. Conversely, in cultural anthropology consideration of the body can be seen to have moved from an abstracted cultural construction towards an inherently cultural biological entity. The general study of the human body precludes any simple binary divides between biology and culture. Acknowledging the dynamic and complex factors inherent in the human body, bioarchaeologists incorporate lifecourse theory and the biocultural approach to study the ontogeny and life histories of individuals and groups via equal contextualization of biology and cultural in order to better inform on past cultural frameworks. A bridge between biological and social sciences, the field of bioarchaeology is uniquely poised to addresses issues of social identity via an approach which combines biological identity with cultural and archaeological context (Knüsel 2010:62).

2.2 EMBODIMENT THEORY

2.2.1 Emergence of Embodiment

Despite the vast multidisciplinary research that exists on the body in both the 'soft' and 'hard' sciences, in the field of archaeology treatment of the body as more than a material object did not emerge as a major interest until the 1990s. Martin (1992) suggested that the increasing importance of the body in the social sciences during the 1970s and 1980s was representative of changes in (normative Western) social organization that reflected new perceptions towards the body and lived experience. Csordas drew upon Martin's lecture (1992) and his own previous works to suggest that if they were indeed living in such a historically significant period, then it was critical to reformulate theories of culture, self and experience, with a central focus on the body (1994). Csordas criticized previous perspectives on the anthropology of the body as falling into one of three categories: 1) The "analytic body", approaches which specifically focused on either the five senses and proprioception, bodily practice with specific reference to

Mauss' notion of techniques of the body, body parts, bodily processes, or the social treatment of bodily products; 2) The "topical body" approach which focused on attempting to relate the body to specific cultural themes; or 3) The "multiple body" approach in which different theorists suggest an individual has multiple bodies dependent on how many aspects of identity they chose to incorporate (1994). Criticism of these approaches lay in the way that each of them took the concept of *embodiment* for granted, suggesting instead that the "distinction between the body as either empirical thing or analytic theme, and embodiment as the existential ground of culture and self" (Csordas 1994:6) was the key to formulating a new methodology.

Csordas first suggested a paradigmatic shift for archaeological approaches to the body in 1990, when he drew upon phenomenology to suggest that "the body is not an *object* to be studied in relation to culture, but is to be considered as the *subject* of culture, or in other words as the existential ground of culture." (original emphasis, 1990:5). Critical of traditional semiotic approaches in archaeology which focused on the body as a representation upon which social reality was inscribed, Csordas instead proposed the incorporation of Merleau-Ponty's concept of the body as 'being-in-the-world' wherein, "embodiment is the existential condition of possibility for culture and self…defined by perceptual experience and mode of presence and engagement in the world" (1994:12). Thus, Csordas' perspective may be described as a more contextualized view of the body as both a material object and socialized subject, rather than as a fixed entity whose study is grounded in the Cartesian dualism of mind/body, nature/culture, subject/object.

Contemporary interest in embodiment stems from an attempt to rethink the categorical opposition of body and mind (Cartesian dualism) in order to try and understand personhood via a holistic approach integrating phenomenology, practice theory and cognitive science (Strathern and Stewart 2011:388). Csordas outlined an explicit approach to embodiment in *A Companion to the Anthropology of the Body and Embodiment* as a "three-dimensional field [that] includes a system of elementary structures of agency in the body-world relation, the fundamental axis of sexual difference between male and female and the variations along that axis, and a set of components of corporeality" (Csordas 2011:154).

2.2.2 Structures of Agency

A. Phenomenology:

In 1962 the philosopher Merleau-Ponty wrote *The Phenomenology of Perception* to explicitly address the structure of meaning in experience, through perception, and what he termed the 'pre-objective' or "being-in-the-world" (92). "Consciousness projects itself into a physical world and has a body, as it projects itself into a cultural world and has its habits: because it cannot be consciousness without playing upon significances given either in the absolute past of nature or in its own personal past, and because any form of lived experience tends toward a certain generality whether that of our habits or that of our bodily functions." (Merleau-Ponty 1962:137). Essentially, in order to have an experience or perception, you need to have a body in space; all experiences and subjectivity, therefore, are based upon having a body. Merleau-Ponty (1962) considered the pre-objective present as the starting point for explanations focused on understanding the interstitial region between intentionality, the processes of bodily experience, and perception (Kimmel 2008:94-95). A limit of Merleau-Ponty's theory, however, would prove to be his focus on the relationship of an individual existing in a world, with all intentionality of the individual agent being focused externally- towards the world (Macann 1993; Csordas 2011). Anthropologists would advance Merleau-Ponty's phenomenological approach in its application to embodiment by considering the body as a highly variable social and cultural being that remains analogous through time and space.

B. Habitus:

Drawing upon Mauss' *Techniques of the Body* (1935) which focused on attempting to understand the cultural variation in learned bodily habits, Bourdieu's theories on practice (1977, 1990), and especially his concepts of *habitus* and *hexis,* are another highly influential theoretical model that anthropologists have drawn on to explore themes of embodiment. In short, *habitus* may be understood as "an internalized structure or set of structures (derived from pre-existing external structures) that determines how an individual acts in and reacts to the world" (Throop and Murphy 2002:186) while also representing a normalized set of social practices which "are not consciously co-ordinated or governed by any 'rule' " (Thompson 1991:12); this is especially important as it reflects the continuous discourse and negotiation between an individual and the external world whether consciously or not (Bourdieu 1977; Butler 1999). Notably, the concept of *habitus* points out how specific practices may be related to each other, providing information on social structures (Csordas 1990:28). Complementary to, but technically separate from, *habitus* is Bourdieu's concept of *hexis* which is used to "denote the various socially inculcated ways an individual moves, carries, and positions his or her body in the lived world…the collection of ways in which our bodies are conditioned…[are] a central means by which our identities become somatically informed and grounded" (Throop and Murphy 2002:188). Critiques of Bourdieu's two main concepts center around his almost complete disregard for subjective experience; while acknowledging that there is a dialogue between an individual and their external world, he focus' almost unanimously on the force of the external world upon the subconscious essentially leaving the individual agent as a pawn of the social structure (Ortner 1996; Jenkins 1992; Throop and Murphy 2002; Farnell 2000; Butler 1999; Roodenburg 2004).

Csordas (1990, 1994) suggests that the main problem for an approach to embodiment completely adopting either the theoretical approaches of Merleau-Ponty or Bourdieu, is that they both attempt to collapse dualities, subject-object and structure-practice respectively, instead of examining the dialectic between the two opposites. Alternatively, the themes of both perception and practice should be considered as complementary and overlapping realms of the culturally constituted self, in which the exploration of not only the human subject and the socialized body are explored, but also the relation between the two (Csordas 1990:7; Turner 1995:167). An analysis of the human body does not have to imply an abstraction of the material body from social processes, nor does an analysis of social structure have to imply a mind-body duality, instead they should be seen as an integrated and inter-subjective ontological system (Turner 1995; Kimmel 2008).

C. Obviation:

The work of Ingold is possibly the best representation of investigating the overlap between dualistic notions such as the subject and the object, the mind and the body, or the biological and the cultural in order to understand the nuances of embodied identity. Ingold (1990, 1998) defines his 'Obviation Approach' upon the premise that the body is an organism which is incapable of being divided into discrete but complementary parts; therefore, in the study of personhood the focus must reflect on the multitude of continuous processes involved in the development of social identity. For Ingold, "every item of behavior is part of an interaction, and every interaction…is embedded in the evolution of a relationship…Behavior…discloses a moment in a continuous process of development within a relational field whose *outcome* is the mutual complementarity of personhood and environment." (1990:221). Thus, the biological effects of development and senescence are just as important and revealing as the social relations that occur during the embodiment of these ontogenetic processes.

It is through the process of socialization that individuals acquire cultural knowledge ('acceptable' behavior, roles within the community, physical skills with different cultural items/materials). Cultural knowledge can take the form of specific enskillments, which are learned by practice either through formal instruction or imitation (Strathern and Stewart 2011:393). Thus, our motor skills, sensory structures and the ontogeny of our perceptual capacities are all complexly intertwined with the principle of embodiment (Aizawa 2007:25; Strathern and Stewart 2011:401).

2.2.3 The Physical Body and Cultural Narratives

A. Practice and Perception:

Conceptually, the body has now come to be understood as inherently dualistic, simultaneously subject and object, abstract and material, individual and social (Mascia-Lees 2011:1). It has been suggested that the human body is a universal referent and embodiment is at the heart of culture, whereby cultural values become natural to the way we move, and our ways of moving become internalized in a form of 'cultural muscle memory'; because our bodies are necessary for perception our bodies and our culture thus change the way that we experience the world (Strathern and Stewart 2011). One way to conceive of embodied identity is to view it as the interstitial area lying between the two main themes of practice and perception, as influenced by both the physical and social environment of an individual. Corporeality is at the heart of practice and includes both the external and internal body: the five senses, body modifications, and skills, to name a few. "Theories of practice (in the broad sense) suggest that subjectivity is complex and interactive, continually in a process of being shaped and reshaped…partly a project of the self and partly the regulation of the self by other social actors" (Joyce 2004:86). The role of other social actors in theories of practice may most obviously be seen in respect to the role of perception in mediating, repeating or deviating from social norms.

Perception is more complex as it involves subjectivity, intersubjectivity and the materiality of biological bodies. Ortner defines subjectivity as "the ensemble of modes of perception, affect, thought, desire and fear that animate acting subjects" (2006:107); however, this definition fails to incorporate any sense of physical experience. Evelyn Blackwood builds on Ortner's definition in her concept of 'body knowledge': "the bodily aspects of one's subjectivity, which are the physical sensations that are produced by and experienced in social interactions…becoming the evidence for a sense of self that is experienced as a feeling of rightness, correctness, or inappropriateness attached to particular behaviors." (Blackwood 2011:210). Sets of behaviors, and the feelings affected by them, are intersubjectively established social conventions the practice or rejection of which may lead to a particular kind of body (Desjarlais and Throop 2011; Kimmel 2008; Sofaer 2006a:78; Toren 1999).

Further strengthening this argument is Judith Butler's explanation of performativity as the "reiterative power of discourse to produce the phenomena that it regulates and constrains" (1993:2), thereby linking body and mind as a materiality of bodily praxis brought about through the embodiment of behavior in the lived experiences of cultural performance (Moore 1994; Meskell 2000a; Bachand et al. 2003:238). In all societies there exists a metanarrative in which identities have formal categorical associations within which individual identities are contingent upon subjectivity and life experience so that perception and practice become an embodied form of subjectivity (Meskell and Preucel 2004:125).

B. Sex and Gender:

An elementary structure to the study of embodiment is that of sexual difference, wherein the difference between men and women may be considered as important and indeterminate as the dualisms of mind/body, nature/culture, subject/object- yet it is further complicated by the indeterminacy of gender and sexuality (Csordas 2011:143-145). A problem that has commonly plagued the study of gender in different fields is the lack of generally accepted definitions for the terms 'gender' and 'sex'. Biologists, anthropologists and archaeologists have historically used a variety of definitions for these terms and have also debated at length about whether these terms are interchangeable, overlapping or completely separate. At their most fundamental levels, *sex* has been considered to represent a biological difference relating at its core to reproductive ability, while *gender* has been considered a more complex social construction (Walker and Cook 1998). Even at this broad level of description, however, there exists a large body of work arguing both for and against these definitions, as well as the relationship between them.

Approached from either a genotypic or phenotypic perspective, the reality of classifying an individual's biological sex is problematic. The biological determination of *sex* includes differences in general anatomy as well as genetics but as technology has advanced the understanding of the human body, the binary divide once considered clear between 'man' and 'woman' has collapsed in on itself, thus obfuscating divisions of human sex variation (Roughgarden 2004; Sofaer 2006b:157). Individuals with a variety of genetic, chromosomal and/or hormonal disorders exist which, while they may or may not be phenotypically expressed, still establish a non-binary range of human sex variation (Lorber 1993:568-581; Roughgarden 2004; Sofaer 2006b:157; Fausto-Sterling 2000, 2012). Many of these genotypic anomalies are not only incredibly rare, but their skeletal effects are also minimally understood so their role in archaeological populations remains unclear (Mays and Cox 2000).

Osteologists examine gross morphological traits of the human skeleton in attempts to determine sex. Following methods established (for American osteologists) in *Standards* (Buikstra and Ubelaker 1994), a variety of measurements and traits are assessed on the following scale: definite male - possible male - indeterminate - possible female - definite female. Many more individuals tend to fall towards the center of this spectrum than in the outlying poles; this is due not only to the large range of variation seen even in chromosomally 'normal' individuals but also because there are a variety of factors that confound these traits such as: age, pathology and completeness of the skeleton recovered (Geller 2005:598-599).

From a theoretical perspective, the concept of sex can be viewed not only as a complex biological reality but also as a cultural construction. On one hand sex is biologically determined, that is not to say, however, that sex is biologically deterministic when considering gender. In other words, classification of biological sex does not discount the sociality of the individual being analyzed. On the other hand, the act of determining sex may be seen as a process unto itself of producing sex, a concept imposed upon an individual, thereby making sex itself a cultural construct (Foucalt 1978; Sorensen 2000; Sofaer 2006b). Some gender theorists challenge the ability of sex and gender to be separated due to this cultural constructionism, citing the imposition of a static Western binary normative view in the classification of individuals, thereby ignoring any other types of gender in a culture, personal choices/expressions of their gender or the ability to view gender as dynamic during an individual's life (Butler 1990; Nordbladh and Yates 1990; Yates 1993; Moore 1994; Knapp and Meskell 1997; Gilchrist 1999). While it is important to have a reflexive body of theory, especially one that questions fundamental Western assumptions and impositions, by conflating the two terms and thus the ideas, any further line of enquiry is essentially left at a standstill since all osteoarchaeological determinations have thereby been called into question (Sorenson 2004; Sofaer 2006a, 2006b). Despite the range of sexual differences and the extensive debate about whether it is even possible/appropriate to refer to one sex or another anymore, many scholars still agree that there are two basic models that the human body comes in (male and female) which may serve as useful axis' of analysis, and that to either conflate them or alternatively to ignore the body because it is too "messy" a subject, results in a less informed approach to any cultural study (Meskell 1998; Sorenson 2004; Sofaer 2006b). It is not a question of whether or not sex exists, but our ability to classify it and apply it to understanding social practices and categorizations (Sorensen 2000:47-48).

Conceptually, *gender* may be seen as a major component to an archaeology of social identity and relationships since gender concerns not only the relationship between men and women as a fundamental social dynamic, but also considers it to be only one part of continuous and dynamic interactions that take place not only within an individual (who may hold a variety of intertwined social identities) but also between an individual and their society, and through time and space (Moore 1986; Ingold 1990, 1998; Sorenson 2000, 2004). "Identity may be constituted by categories of practice, but we must recognize that individuals associate and live within multiple categories in the course of their life trajectory and further connect to others by various practices of identification." (Meskell and Preucel 2004:122). Thus, the use of gender as a category has been exchanged for the use of gender as a heuristic or exploratory concept in the study of social identity. Biological sex is treated as only one of many dimensions that may play a part in the formation and maintenance of an individual's identity, and neither sex nor gender should be given primacy over other discourses such as age, class, ethnicity, ideology, etc. (for further discussion on intersectionality see: Geller 2009; Back Danielsson 2012; Dill and Kohlman 2012; Fahlander 2012).

C. Senses and Emotions:

Physical senses allow individuals to literally feel the world around them through sight, smell, touch, taste and hearing but it is the interpretation of these senses that are subjectively perceived, thus giving rise to feelings and emotions; "the senses, emotions, and affect are the essence of our embodied materialities and socialities" (Mascia-Lees 2011:2). Different cultures, indeed different communities within a culture, have unique sets of standards. The smell, taste or even sight of a particular cuisine may be a cultural ideal to one group but may be completely appalling to another. Pickled pigs feet, for instance, are a food staple in the southeastern United States, however many people in other areas of the country find even the sight of a pickled pig's foot to be so disgusting that they will never try it. To some people certain perfumes/fragrances are an ideal, while the same smell may be considered revolting to others. The immense variety of musical instruments/traditions and each one's ability to evoke as disparate a reaction as ecstasy or pain speaks to the variety of cultural taste in sound. It is the way in which senses are perceived (in other words, subjectively interpreted) and thus evoke specific guttural reactions, that may inform on the cultural knowledge and standards that become ingrained within the subconscious.

In addition to the standard five senses, Geurts (2003) has suggested a sixth 'inner sense' which "highlight[s] processes happening at the level of proprioception, i.e. the senses of deep tissue, balance, kinesthesia, body displacement and joint position" (Kimmel 2008:92). While this sixth sense may lie more accordingly in the realm of learned habits it, like so many other aspects of embodiment, crosses between the categories of bodily knowledge and a manifestation of subconscious cultural standards that is defined via a display of socially 'approved' bodily comportment. Whether consciously or subconsciously enacted an individual's comportment, including the way in which they occupy space, especially in public, can be considered a dynamic intersubjective signifier of cultural knowledge (Farnell 1999:334).

D. Body Modifications:

Another layer in the construction of an identity, and the most visual component, is the manipulation and representation of the physical body (Fisher and Loren 2003:225). External body modifications can represent meanings that are literally inscribed upon the physical body itself. Intentional modifications have been referred to as a 'social skin', a canvas that may represent the site where culture is literally inscribed, and the place where an individual is defined in/by a cultural landscape (Turner 1980; Schildkrout 2004:338).

Diet, make-up, exercise regimes and cosmetic surgery are all means of 'sculpting bodies' which may carry with them social significance in specific contexts and may reflect dominant social norms so that bodily identity may be seen to be subject to social normalization. The practice of Chinese foot-binding, is an intentional act of body modification in order to materially articulate gender and beauty ideals (Ortner and Putschar 1985; Blake 1994; Sofaer 2006a:105), while corseting and the resulting modification of the female thorax during the Victorian era were also meant to aid women in attaining a normalized ideal of 'beauty'. Cranial deformation, piercing and stretching of piercings and dental modification in the Pre-Columbian Maya have been suggested to hold a variety of possible meanings (ethnicity, status, occupation etc) but what is clear is that they represented a cultural practice through which identity was constituted (Geller 2006).

Tattoos, scarification and branding may be an individual's choice/form of artistic expression in order to publicly promote their sense of individual identity or they may be used as systems of control/surveillance: a symbolic denial of personhood (Schildkrout 2004:323). Although in many modern societies tattoos have become a means of adornment, as in modern Western cultures, the historical usage of tattoos and brandings in this latter sense has been identified in Nazi concentration camps, to mark slaves as property in the pre-Civil War U.S., ancient Greece and Rome, and in the penal systems of Russia and Australia (Gustafson 2000; Schrader 2000; Maxwell-Stewart and Duffield 2000). In Polynesia, however, tattooed skin serves as a means for an individual to negotiate between social groups, society at large and the divine (Gell 1993; Schildkrout 2004:321). In Maori culture, tattooing is used to materially embody philosophical traditions, while in Igbo culture, scarification is used to signify age, gender, and political authority (Levi-Strauss 1963:257; Schildkrout 2004:332). In Kayapo culture, intentional body modification is not only part of everyday life, but is also associated with processes of social production in life-cycle rituals (Turner 1980; Schildkrout 2004). Ritual transformations are most commonly associated with themes of social/public signs of age-related life transitions (Joyce 1993, 2000, 2003) and may include modifications including tattooing or scarification but also practices such as circumcision and ear lobe enlargement.

E. Skills and Habits:

The physical performance of enskillments may permanently affect the internal material body, thus reflecting subjective cultural narratives that may inform on social themes such as sex/gender, class, age or ethnicity. As discussed above, Ingold references the ways in which skills and habits may become embodied through specific modifications to basic features of anatomy that continuously change and develop over the life course (1998:26, 48; 2000: 375); "skill is not simply the 'embodiment' of 'knowledge', but rather physical, neurological, perceptual, and behavioural change of the individual subject so that he or she can accomplish tasks that, prior to enskillment, were impossible" (Downey 2010: 35). These traits may be *incorporated* into the very material of the human skeleton, and are influenced by not only the environment and materials in a given time or place, but also by the social and cultural circumstances surrounding activities and knowledge.

It is through the contextualization of various bioarchaeological analyses that it becomes possible to infer the culturally incorporated differences between individuals, groups and entire populations that in turn may be directly related to culturally specific social categories. For example, chemical studies have been used to provide information about diet, nutrition, health, weaning and migration patterns which can offer information on gender, social class and ethnicity. Analyses of pathological lesions can provide information on health, disease processes, possible forms of treatment and even serve as potential evidence for compassion. Consideration of metric and non-metric variations of the human skeleton can provide information on stature and population affiliation, which can then be used to reconstruct potential migrations and population interactions. Similarly, inferences about behavioral activity patterns of past populations may be derived from gross morphological changes of the human skeleton which in turn can potentially be used to reconstruct aspects of past lifestyles including: food processing techniques, divisions of labor/degrees of task specialization according to gender, age categories or social class, effects of the environment and even changes in subsistence strategies. When combined with contextual information these inferences from the human skeleton can provide physical support for reconstructions of past life-ways, specifically the dynamic interplay between culture and the physical body (Joyce 2004:92).

2.3 A SOCIAL BIOARCHAEOLOGY

2.3.1 The Emergence of Biocultural Analyses

Historically in archaeology, skeletal biology has not been privileged over mortuary data due to a combination of several factors including, but not limited to: ethical issues of dealing with the dead, technological/methodological limitations in analyses and, perhaps most significantly, a schism between the 'hard sciences' of physical and biological anthropology and the more theoretically centered social sciences. Only recently has there been a movement away from a focus on descriptive and typological categorizations of skeletal variation towards an emphasis on the complimentary nature of biological and cultural approaches. This shift has been termed the biocultural approach that began with Sherry Washburn's (1951) "New Physical Anthropology" which proposed incorporating theoretically based research with testable hypotheses and bridged the gap between physical anthropology and other areas/fields of anthropology (Armelagos and Van Gerven 2003; Zuckerman and Armelagos 2011:16-17).

Although it took some time for Washburn's paradigm to be successfully incorporated into skeletal biology, along with the many theoretical developments in the field of anthropology as a whole, the modern concept of a bio-culturally focused bioarchaeology was eventually solidified (Armelagos and Van Gerven 2003; Larsen 2006). Agarwal and Glencross (2011) see this development proceeding in three distinct waves. The first wave centered on population based studies that focused on adaptive responses of the skeleton to large-scale changes in societies. A defining aspect of the second wave is an increase in advanced technologies for analyzing the human skeleton at even the genetic level which has allowed questions to be addressed that previously had no way of being scientifically studied (Goodman and Leatherman 1998:15). The other major feature of the second wave of bioarchaeological thought is an acknowledgement of what has been termed the 'Osteological Paradox' (Wood et al. 1992)- the inherent bias in any skeletal sample due to selective mortality (Ortner 1991; Agarwal and Glencross 2011: 2). The third wave of bioarchaeology implements the biocultural approach to its fullest extent with a focus on the contextualization of human remains (Knudson and Stojanowski 2008; Baker and Agarwal 2017). Building on aspects of the first two waves, recent perspectives attempt to take interpretations further by explicitly engaging with multiple disciplines, as well as informed and reflexive bodies of theory, in order to elucidate social identities by understanding the dynamic relationship between the biological body and the culture context (Agarwal and Glencross 2011:3; Martin, Harrod and Perez 2013:9; Baker and Agarwal 2017).

The importance of recognizing and understanding the organization and relationships of multiple social actors and the factors that differentiate them within a society is vital in attempting any informed archaeological theory about cultural change (Brumfiel 1992, 2000:251; Hendon 1996:45-46). The social construction of identity does not revolve around any one concept, but is intricately informed by gender, social status, class, ethnicity and age (Joyce 2005:141). Biocultural analyses offer a unique perspective in the examination of such a complex and dynamic system by being positioned to not only consider the biological agent(s), but also their interaction(s) with nature, culture and one another (Agarwal and Beauchesne 2011; Zuckerman and Armelagos 2011; Baker and Agarwal 2017). The challenge at this point is that social constructions are unique to every culture and time period and can be difficult to elucidate without historical documentation on the culture and time period in question, hence the emphasis on contextualization in current biocultural thought (Lucy 1994; Rothschild 2002; Baxter 2005; Bluebond-Langner and Korbin 2007; Halcrow and Tayles 2008; Hogberg 2008).

2.3.2 The Body as Material Culture

While many embodiment theorists depend upon material culture in the form of historic texts, images, and iconography of bodies to form inferences about social identities, cultural practices, and dynamics they do not actually draw on information from the archaeological human remains. This results in the separation of corporeal individuals from their social identities and the worlds in which they participated (Ingold 1998:27-28; Meskell 1998:140, Sofaer 2006a:66, 2006b:158; Knudson and Stojanowski 2008:412). However, the study of archaeological structures and objects can inform on not only the production and maintenance of items but also on how changes and adaptations, when contextualized in time and space, reflect the practices, negotiations, expressions and experiences of the agents who produced and maintained the material culture (Sorenson 2004:87). As mentioned previously, while neither sex nor gender should be given primacy over other discourses such as age, class, ethnicity, ideology, etc., nor should biological data be privileged over cultural data. Instead, interpretations which employ multiple lines of evidence account for inherent variability, thus maintaining reflexive, non-normative and multi-scalar thinking (Geller 2005, 2008, 2009; Martin, Harrod and Perez 2013:8). With this in mind it is clear that biocultural analyses, with their focus on contextualization, reinforce the ability of such a dynamic and discursive category as social identity to be analyzed.

The only explicit attempt at outlining a theoretical osteoarchaeology is Joanna Sofaer's *The Body as Material Culture* (2006a). Drawing upon Bourdieu's (1977) concept of 'bodily *hexis*' and Ingold's 'Obviation Approach' (1990, 1998), Sofaer suggests viewing the skeletal body as a material and thus part of material culture- thereby incorporating both biological and social perspectives. From a more general archaeological perspective the body is important not as a purely biological or purely cultural entity, what is significant is how the body represents a contextually dependent materiality. It is within this frame of reference that bioarchaeologists are able to shift their focus from biological categorization to understanding the complex processes effecting the formation of the body (Sofaer 2006a:142).

The human body may be understood via its physical properties like any other biological material. What is especially important in considering the human body as a part of material culture is the malleability of the material. Plasticity refers to bone's ability to adapt to environmental changes (both physiological and behavioural) during life through permanent morphological alterations which cannot be inherited (Roberts 1995; Schell 1995; Knüsel 2000). Many studies have focused on understanding plasticity via the ultimate effects in the adult skeleton. Recently, however, the focus has shifted towards understanding the context, influencing factors and processes of plasticity during ontogeny and over the life course (Oyama et al. 2001; Young and Badyaev 2007; Agarwal and Beauchesne 2011; Kuzawa and Bragg 2012). This notion of developmental plasticity provides the framework for relating cultural and environmental experiences and behaviors to the physical body, thus allowing for the study of the living from the dead since the materiality of the skeleton is "brought into being over the life course, emerging over time as a developmental process [that] is contextually dependent because the expression of plasticity is contextually dependent" (Sofaer 2006a:77).

2.3.3 Lifecourse Theory

Since any one individual's identity/personhood is a hybrid of various identities intertwined to varying degrees at different times, it is important to consider the social as well as biological life-course of the individual. The term lifecourse, therefore, indicates the cultural contextualization of stages of the physical life-cycle which may be marked symbolically and/or materially (Gilchrist 2000:326). It is through the incorporation of the lifecourse perspective in biocultural analyses that the connection between an individual and the different stages of their life and identity can be situated within the context of the larger society in which they exist, thereby illuminating different facets of both (Giele and Elder 1998; Baxter 2008).

Attention to the significance of ontogeny in social bioarchaeology has become increasingly important and the application of lifecourse theory has shed light on the concept of age in several different ways. The first of these is that age should not solely be used as an osteological category, but the process of ageing should be considered instead. Similar to issues with sex and gender, age and the ageing process should be socially and historically contextualized for a more in depth consideration and understanding of the processes that contribute to the formation and modifications of social identities (Gilchrist 2000:326; Meskell 2000b; Prout 2000:12; Harlow and Lawrence 2002; Sofaer 2006a:130-134; Knudson and Stojanowski 2008:410-411; Agarwal 2012, 2016). Physiological changes in the skeleton during development represent not only processes and events that occurred to an individual, but the constant alteration of skeletal structures and even chemical composition over the life-course may also represent a history of relationships between an individual and others (Sofaer 2006a:78; Zvelibil and Pettitt 2013). Furthermore, with the many new technological advancements that are available, bioarchaeologists now have the capacity to reconstruct in depth life-histories of individuals which give insight not only into behavioral patterns, but also allow this behavior to be contextualized in their interactions with the natural environment (Zvelebil and Weber 2013:275; Agarwal 2016).

Methodologically, osteological age categories for children and infants tend to be very narrow (weeks, months, years) while categories become much broader (decades) the older an individual becomes- this is due to the numerous and well documented changes that take place within a body during the formation and solidification of the skeleton after which there are complex etiological aspects of degeneration. What becomes problematic is the way in which biological categorizations form artificial social divisions in age- much like sex categorization has been historically misused as representative of binary gender divisions (Sofaer 2006a:126-128; Halcrow and Tayles 2008, 2011). Drawing upon theoretical approaches to ageing in sociology, some bioarchaeologists suggest biocultural analyses take into consideration Ginn and Arber's (1995) three meanings of age: 1) chronological age, which reflects the actual calendar age of an individual, 2) physiological/biological age, which reflects the ageing process, and 3) social age, which reflects the socio-culturally constructed age of the individual including both self-perception and ascribed age identity (Kamp 2001; Gowland 2006; Sofaer 2006a, 2011; Lewis 2007; Glencross 2011; Halcrow and Tayles 2008, 2011; Prowse 2011).

Although biological and social immaturity are universal to the human condition, the amount of time allocated to and ways in which they are negotiated are highly variable across cultures (Prout 2005:111). As the human body grows and decays, individuals learn skills and habits that continuously change and develop over the lifecourse (Ingold 1998:26, 48). These traits are incorporated into the very material of the human skeleton and are influenced by not only the environment and materials in a given time or place, but also by the social and cultural circumstances surrounding activities and knowledge. "Skeletal changes can be identified as material expressions of actions in as much as they are formed through repeated social practices, habitual actions or postures. Furthermore, people learn by doing and human customs are themselves forms of understanding and knowledge as the world is understood through the body" (Sofaer 2006a:134). Therefore, as we start considering the different types of age it becomes clear that individuals are not only representing the biological age at which they died but their social age as well, thus reiterating the importance of a contextualized lifecourse perspective when possible.

In search of the identities of past individuals archaeologists have traditionally depended upon material culture and representational imagery. New insights drawn from the incorporation of phenomenological, philosophical and sociological theories of the body suggest that the themes of cultural knowledge, experience, practice and perception are all part of an individual's lived reality and are key to an informed investigation of embodied identity. There is no singular identity to be simply 'discovered' for an individual; instead it is the complex interactions of corporeal, social, cultural and environmental influences in each individual's life, and over their life trajectory, that must be examined in order to gain informed insights into the lives and cultures of past peoples.

CHAPTER 3: SKELETAL ACTIVITY PATTERNS

3.1 HISTORICAL BACKGROUND

Interest in the behavioral correlates of skeletal variation originated during the 18th century in the burgeoning field of industrial medicine. The first systematic record of occupationally related pathology was Bernardo Ramazzini's (1700) *Treatise on the Diseases of Tradesmen*, which discussed the metallic poisoning of painters (Kennedy 1989:129-130; Wilczak and Kennedy 1998:460). During the 19th century, Charles Thackrah (1831) published a comprehensive study on patterns of pelvic deformation and frequencies of scoliosis in weavers, which was the first analysis to recognize the influences of nutrition and overall health on the development of skeletal malformations (Kennedy 1989:130). Another notable contribution to the field was made by the anatomist William Lane (1887a, 1887b, 1888), who distinguished skeletal markers developed in response to trauma and age-related degeneration from those developed in response to habitual activities (Kennedy 1989:130). The close of the 19th century saw the synthesis of industrial medicine and physical anthropology when William Turner (1887) emphasized the effects of different habitual activities on different groups (Wilczak and Kennedy 1998:462).

Aleš Hrdlička, working at the Smithsonian in the early 20th century, was the first to give serious attention to skeletal markers of stress and disease while also attempting to determine the range of normal variation within the human skeleton (Kennedy 1989:132; Buikstra 2006:508-509). The shortcoming of many early 20th century bioarchaeological studies was their failure to move beyond general population-level typologies, towards the reconstruction of behaviors and lifestyles, and inferences about plausible sociocultural causes (Robbins 1977:10-11, 20). During the latter half of the 20th century, the work of J. Lawrence Angel and Charles Merbs played significant roles in changing the course of bioarchaeology towards a more interdisciplinary and multi-regional approach that sought to interpret, as well as to explain and understand, variations in skeletal morphology (Kennedy 1989:134; Buikstra and Hoshower 1990:1; Pearson and Buikstra 2006:207). Additionally, technological advancements in engineering and biology made during the late 20th and continuing into the 21st centuries, have contributed substantially to a better understanding of the complex dynamics between musculature and bone plasticity, and genetic influences on phenotypic expression.

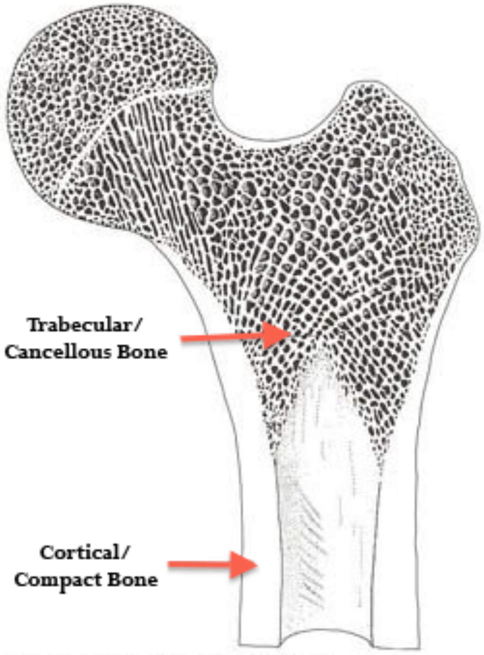
One of the most difficult issues that bioarchaeological analyses still need to overcome is demonstrating, versus inferring, direct relationships between activity-related changes and their respective etiologies. It has been established that osseous irregularities may develop due to periods of prolonged or habitual stress, however, identifying a specific activity responsible is far more complicated than originally thought (Kennedy 1989; Jurmain et al. 2012). Human experimentations of the type required to provide absolute linkages between specific activities and specific morphological changes are not currently possible, so bioarchaeologists are forced to infer behavioral activities from clinical records and ethnographic sources, which are problematic. Clinical studies can contribute to a general understanding of morphological changes and activity marker formation; however, their potential to contribute to an archaeological understanding of marker variation remains a semi-fallow resource. Clinical studies emphasize soft tissue damage and pathology, there are medical interventions and a lack of concordance in terminology between the two fields (Kennedy 1989; Jurmain et al. 2012; Schlecht 2012). Additionally, there is an obvious lack of parallels between pre- and post-industrial tools, workloads and environments (Wilczak and Kennedy 1998:464; Knüsel 2000:395).

3.2 BIOLOGICAL FOUNDATIONS

Chemically, bone is a compound formed from both organic (collagen) and inorganic (hydroxyapatite) properties (Burton 2008). Immature bone, often referred to as 'woven bone', forms very rapidly and microscopically is far less organized than mature bone. Mature bone, known as 'lamellar bone', forms slower and eventually replaces woven bone, is highly organized at a microscopic level and may take one of two forms: cortical or trabecular (Martin and Burr 1989:21-48). Cortical lamellar bone is the dense bone that forms the outer surface of most bones and the shafts of appendicular long bones. Trabecular lamellar bone, also known as cancellous bone, is a light porous bone similar in appearance to a sponge and is commonly located between layers of cortical bone, with the exception of the long bones where it is mainly present at the ends of the bone and not in the tubular shaft itself (Baker et al. 2005).

Modelling is the process during growth in which a bone is not only developing into its ultimate shape, but also involves the replacement of primary woven bone by secondary lamellar bone via the processes of apposition, by bone-forming cells called osteoblasts, and resorption, by bone removing cells called osteoclasts (Scheuer and Black 2000:30, 2004:44-45). Once an individual has achieved skeletal maturity, the process of modeling is significantly reduced and the process of remodelling comes to the forefront. Remodelling involves the removal and replacement of bone to repair microscopic damage (which left untouched could eventually lead to fatigue failure) and also to take out nutrients (Scheuer and Black 2000:30, 2004:45). Therefore, while all elements of the skeleton undergo dramatic change during growth and development they are still capable of changing in adulthood since bone formation takes place throughout an individual's life (White 2000:27).

FIGURE 3.1: Vertical Cross Section of Proximal End of Femur



(Image Adapted from Moran and Rowley 1988:61)

The concept of bone as a dynamic material, continually responding to external stresses through the remodeling of its structure and morphology, was initially advanced by the anatomist Julius Wolff (1892). Around the time of Wolff's publication, W. Roux also published a theory of skeletal functional adaptation, which specified that: "the apposition and resorption of bone is a biological control process and the dependence of this process is on the local state of stress" (Roesler 1981:27). Wolff and Roux's ideas still form the basis of skeletal morphology studies, and while many papers on the subject still refer to Wolff's law, it has become evident that there are other factors which affect shape besides extrinsic loading stresses. Intrinsic and extrinsic factors that have been found to affect bone morphology throughout the life cycle include: trauma, disease, nutrition, health, genetics, activity and environment; therefore, Ruff et al. (2006) suggest that 'Wolff's Law' be substituted with the more inclusive term, 'bone functional adaptation'.

In response to loading and mechanical stress, bone has the ability to respond both elastically and plastically. The elasticity of bone allows for no deformation to the shape or dimensions of a skeletal element to remain after loading strains are removed. Plasticity is a more involved subject, referring to the anatomical ability of bone to adapt to environmental changes (both physiological and behavioural) during life through permanent morphological alteration (Trinkaus et al. 1994:2; Roberts 1995; Schell 1995; Knüsel 2000). There are numerous approaches to the study of patterns of skeletal plasticity, and many are based upon the idea that the extrinsic forces affecting bone morphology correspond directly to forces of both action and reaction (Iscan and Kennedy 1989:2). Frost's theory of the mechanostat, for instance, proposes the existence of a mechanism which monitors bone metabolism in relation to mechanical usage; bones adapt their strength to keep the strain caused by physiological loads close to a set point via the coordination of modeling and remodeling (Frost 1987, 2003). If strain levels increase beyond the bone's yield point then deformation or microdamage will occur, concurrently, if strain levels decrease beyond the minimum level required to simply maintain bone mass (such as in zero gravity environments or immobilization) then mass will be reduced (Pearson and Lieberman 2004; Hart et al. 2017:116-117). An inherent limitation to the mechanostat theory, however, is its failure to address the roles of strain frequency, rate and distribution in bone adaptation (Shaw and Stock 2009a:150; Hart et al. 2017:117).

Plastic changes made during growth and development cannot be inherited and are therefore phenotypically expressed and "defined as an expression of the genotype in a particular environment" (Knüsel 2000:383). While many modern studies of skeletal variation have been focused on understanding plasticity from the aforementioned adaptationist perspective with specific consideration of the ultimate effects in the adult skeleton, recently approaches like Developmental Systems Theory have been incorporated to shift the focus towards understanding the context, influencing factors and processes of plasticity during ontogeny and over the life course (Oyama et al. 2001; Young and Badyaev 2007; Agarwal and Beauchesne 2011). The effects of environmental influences and their interaction with the individual genome have suggested that restrictions on growth and development may be created early in life which can have dramatic effects on the mature phenotype (Mays 1995; Knüsel 2000; Cooper et al. 2002, 2006; Dennison et al. 2005; Viljakainen et al. 2011).

It is now understood that an adult's bone morphology is a representation of that individual's entire life history, a process which begins *in utero* and is profoundly impacted throughout the subadult growth period (Carter et al. 1987; Carter and Orr 1992; Anderson 1996; Knüsel 2000:384; Hart et al. 2017:122). Clinical studies have shown that humans achieve peak bone mass in the third decade of life, with the greatest accrual during the teen years, it is therefore impossible to completely isolate adult activity patterns from those which occur during the formative years, especially those during the period of adolescence (Pearson and Lieberman 2004:89; Meyer et al. 2011:202; Jurmain et al. 2012:536; Hart et al. 2017:114). Bioarchaeologists attempting activity studies need to address the multifactorial etiologies of morphological changes as well as define activity in concordance with clinical definitions: clarifying the type, duration, frequency, intensity, load and age of onset (Jurmain et al. 2012:532).

3.3 INDICATORS OF LIFE HISTORY ON THE SKELETON

Information about individuals, sub-groups and entire populations can be derived through a variety of microscopic and macroscopic bioarchaeological analyses, which has become increasingly important to the field of archaeology, since many aspects of past life-ways leave no material evidence in the archaeological record. The materiality of the skeleton is created over the entire life course and being grounded in the concept of developmental plasticity is contextually dependent upon both physiological cues and behavioral correlates such as culturally defined activities (Toren 1999:86; Sofaer 2006a:77; Kuzawa and Bragg 2012). The four main categories of skeletal activity pattern analysis that employ a 'form reflects function' premise are: biomechanics, entheseal change studies, non-pathological osteoarthritis, and non-genetic non-metric traits.

3.3.1 Biomechanics

A. Overview:

Biomechanical studies of activity patterns are founded upon the ways in which a bone will adapt its overall structure to changes made specifically in its load environment (Cowin 1981:193). The application of biomechanics to the human skeletal system can be traced back to Galileo in the 15th century and is currently used by anthropologists interested in applying mechanical principles to explain variation, the evolution of human bipedalism, primate locomotion and even the effects of diet on cranial morphology (Ruff 2008a:183). Feedback models have demonstrated that increased strain will stimulate new bone deposition and decreased strain will result in bone resorption until the optimum customary strain level or "target strain" for the entire bone is reached (Ruff 2008a:184). Knowledge of the microscopic dynamics of bone growth and alteration is based upon histological studies, which have provided an understanding of not only how bone remodels, but also how remodeling rates change with age and what factors can influence the remodeling process at both cortical and structural levels (Carter et al. 1981; Churches and Howlett 1981:79; Cowin 1981; Woo 1981; Stout 1989:41; Larsen 1997:219; Pfeiffer 2000; Ruff 2008a).

Methods developed for analyzing long-bone diaphyseal structure are founded upon the field of modern engineering and draw heavily upon ‘beam theory’, which assumes that stresses resulting from externally applied loadings can be calculated given the cross-sectional geometric properties of the “beam” (bone) (Ruff 2008a:184). Bone responds to stress and strain loads by modifying aspects of its structure such as size, shape, alignment and distribution (Hart et al. 2017:121).

Studies of diaphyseal structure have used cross-sectional geometric properties and the principles of beam mechanics to calculate the strength and rigidity of a bone. ‘Strength’ is the ability of a bone to resist breaking while ‘rigidity’ is a bone’s ability to resist deformation prior to breaking (Ruff 2008a:185). Both strength and rigidity are influenced by the effects of different types of loadings involved in general routine motions such as axial compression, tension, bending and torsion; however, bones are rarely subjected purely to compression or tension, thus, bending and torsion are more meaningful when studying activity (Ruff 2008a:185). Cross-sections are taken perpendicular to the long axis of a bone and the properties recorded measure the amount and the distribution of skeletal tissue in a section (Larsen 1997:199). These measurements are of different areas of a cross-section and include: cortical area (CA), total subperiosteal area (TA), medullary area (MA), 'second moments of area' (SMAs), Theta (θ) and section moduli (Bridges 1996; Larsen 1997:199; Ruff 2008a). SMAs are proportional to bending and torsional rigidity and commonly include: I_x (bending rigidity in the anterior-posterior plane), I_y (bending rigidity in the medio-lateral plane) and J (torsional and twice average bending rigidity). J provides a reliable index for the overall rigidity of a bone. Theta reflects the “orientation of maximum bending rigidity relative to anatomical axes” (Ruff 2008a:185). Section moduli are proportional to bending and torsional strength and include: Z_x (bending strength in the anterior-posterior plane), Z_y (bending strength in the medio-lateral plane) and Z_p (torsional and twice average bending strength). Section moduli are most commonly calculated by raising the SMA of interest to the power of 0.73 (eg. $J^{0.73}$) (Ruff 2008a). Additionally, cross-sectional shape is an important property, and can be calculated as either I_x/I_y or I_{max}/I_{min}, the latter being less sensitive to errors made in scan orientation (Stock and Pfeiffer 2001). Cross-sectional *size* is thought to reflect the generalized stress level of a bone, while cross-sectional *shape* is thought to reflect the type of biomechanical load (Boyd 1996:220; Shaw and Stock 2009a:157).

B. Methodological Issues:

There are four main methods employed in the study of cross-sectional bone geometry: direct sectioning, the elliptical model method (EMM), the latex cast method (LCM) and computed tomography scanning (CT). Directly sectioning a bone is destructive and rarely an option for research with archaeological skeletal material. EMM is based on biplanar radiography and is the least accurate of the methods, although refinement of applied regression equations could improve its accuracy (O'Neill and Ruff 2004; Jurmain et al. 2012). The LCM uses biplanar radiography as well as a mold of the external contours of the diaphysis to estimate cross-sectional geometry and has been found to estimate cross-sectional parameters with less than 5% of error compared to CT scanning (O'Neill and Ruff 2004; Stock and Shaw 2007; Macintosh et al. 2013); however, when comparing growth trends across the life cycle the lack of an accurate endosteal area is far more problematic (Sparacello and Pearson 2010). CT scanning is the most accurate method for obtaining cross-sectional properties, however, procedural guidelines need to be precisely adhered to, it can be very expensive, and is not always available (O'Neill and Ruff 2004; Jurmain et al. 2012).

The bones most frequently analyzed in cross-sectional geometry studies include the humerus, femur and tibia although several studies have examined properties of the mandible, clavicle, radius, ulna, ribs and metacarpals. It has been established that the geometric properties of upper limb bones are superior sources of information for making inferences about possible activities in humans, since they are free of locomotor responsibilities (Wanner et al. 2007:255; Stewart et al. 2015). Additionally, differences in loading regimes have a more significant effect on proximal elements, therefore the humerus is preferential to the radius or ulna (Shaw and Stock 2009b:160). The lower limbs, in turn, primarily reflect body size and the physical demands imposed by locomotion, thus they are a good indicator of mobility levels when body size has been controlled for (Ruff 1999, 2003, 2006; Doyle et al. 2011). Since articular areas are under tighter genetic control than diaphyses, cross-sections taken along diaphyses will better reflect the loading history and activity patterns of an individual, especially since diaphyses are susceptible to activity related growth for a longer period of time (Ruff et al. 1991:411; Knüsel 2000:384; Garofalo 2012:22; Ruff et al. 2013). A number of studies have compared differences in cross sections taken along the entire diaphysis of different long bones and it is now generally accepted that the most circular area of the diaphysis is preferable (Ruff and Larsen 1990, 2001; Ruff 2008a).

Studies focused on understanding activity patterns via biomechanical stress patterns have produced contradictory results (Weiss 2005; Wanner et al. 2007; Kujanová et al. 2008; Wescott 2014). Potential sources of error lie mostly in the uncertain relationship between which biomechanical factor (stress magnitude, stress rate, stress interval etc.) is primarily responsible for stimulating remodeling reactions, whether the responsible factor is additionally affected by any of the other factors, and even how the biomechanical stress is transferred from a microscopic to a macroscopic expression (Wanner et al. 2007:264). Researchers have also realized that the manner in which bone remodels is more complex than previously thought and morphology is influenced by age, body size and health which, therefore, have to be controlled for in analyses (Mays 1999; Pearson and Buikstra 2006; Ruff 2008a).

The need to control for age is particularly important when examining diaphyseal cross sectional geometry, as it is the result of two simultaneous processes (bone deposition and resorption) which are systemically controlled throughout the life cycle. Cortical expansion is the direct result of subperiosteal bone deposition, which occurs throughout growth and continues into adulthood, while endosteal resorption and deposition are slightly more complicated. During infancy and childhood the medullary cavity is enlarged primarily through endosteal resorption, a process that changes to deposition during adolescence and early adulthood but returns to a state of resorption in late adulthood (Pfeiffer 1980; Ruff and Hayes 1983; Knüsel 2000). Essentially, external dimensions and subperiosteal area increase with age while cortical area decreases in later age, especially for post-menopausal women (Ruff and Hayes 1988).

Cortical bone is extremely sensitive to environmental variables during childhood. Studies on modern populations living under similar ideal conditions show relatively little variation in growth and body size from 0-5 years of age, suggesting that children who deviate from the norm are likely suffering from disease or malnutrition (Graitcer and Gentry 1981; WHO 1999; Garofalo 2012:11; Ruff et al. 2013:30). Malnutrition, for example, may lead to a decrease in percent cortical area commonly caused by an increase in endosteal relative to periosteal dimensions (Garn et al. 1969; Hummert 1983; Mays et al. 2009). Alternatively, mechanical loading prior to adolescence can actually cause periosteal apposition and slow the rate of endosteal resorption (Frisancho et al. 1970; Schoutens et al. 1989; Ruff et al. 1994; Anderson 1996; Bass et al. 2002; Ruff 2005a; Ruff et al. 2013). It has therefore been established that an adult's cortical bone morphology is in part a reflection of loading patterns during adolescence (Pearson and Lieberman 2004:89).

Stature, body mass and body shape have also been found to influence the distribution of bone in a cross section. Body mass has the most significant effect on cross sectional properties, which in turn will effect interpretation of SMAs, and therefore needs to be accounted for in analyses (Robling and Stout 2003:187-188; Doyle et al. 2011; Shaw and Stock 2011). Controlling for body size is especially important in studies that wish to compare differences between the sexes or different populations.

Additionally, the failure of biomechanical approaches to address the erroneous assumption that the axis of bending passes through the centroid of a cross-section needs to be more fully addressed since this could significantly affect previous calculations and potentially be the cause of many contradictory results (Lieberman et al. 2004; Pearson and Buikstra 2006:214). To help alleviate issues with the application of beam theory to such a dynamic system suggestions include: limiting cross sectional analyses to slices taken at the most circular areas of long bone shafts, realizing that cross sectional values are beneficial in analyzing patterns but absolute values will likely be incorrect and, finally, using SMAs (ie. J) are preferable to section moduli, since the latter will compound errors of bending rigidity (Ruff 2003, 2005b; Pearson and Lieberman 2004:167-169).

C. Behavioral Interpretations:

Biomechanical studies have focused on the geometric properties of long-bone diaphyseal structure to interpret patterns of locomotion in the primate order (Ruff and Hayes 1983; Ruff 2002) and hominin evolution (Trinkaus 1976; Ruff et al. 1993, 1994; Trinkaus and Ruff 1999a, b, 2012; Marchi 2008; Ruff 2008b, 2009), and clinical studies of modern athletes (Shaw and Stock 2009a, b; Haapasalo et al. 2000; Bass et al. 2002). Bioarchaeological studies are commonly focused on inter- and intra-population differences in activity/mobility (Trinkaus and Churchill 1999; Holt 2003; Weiss 2003a, 2005, 2009; Stock and Pfeiffer 2001, 2004; Rhodes and Knüsel 2005; Ruff 2006; Sladek et al. 2006, 2016; Stock 2006; Wescott 2006; Maggiano et al. 2008; Marchi 2008; Sparacello et al. 2011; Shaw and Stock 2013), changes in activity patterns that have been correlated with changes in subsistence strategies/economies (Ruff and Hayes 1983; Ruff et al. 1984; Bridges 1989; Ogilvie and Hilton 2011) and sex-based divisions of labor (Ruff and Hayes 1983; Mays 1999; Weiss 2003a; Stock and Pfeiffer 2004; Maggiano et al. 2008; Ogilvie and Hilton 2011; Sparacello et al. 2011). Evolutionary trends suggest a major decline in human femoral bone strength (which we are still experiencing at an exponential loss), which is most likely the result of a decrease in physical activity due to technological innovations (Ruff et al. 1993; Ruff 2005b, 2008a; Shaw and Stock 2013; Ruff et al. 2015). Studies of changes in activity patterns that have been correlated with changes in subsistence strategies/economies have suggested several trends. The first is that femoral midshaft strength declines and cross sectional shape becomes more circular with the adoption of agricultural, which is assumed to reflect a decrease in mechanical load and a decrease in mobility, respectively (Ruff and Hayes 1983; Ruff et al. 1984; Ruff 1987; Bridges 1989; Ruff et al. 1993; Larsen 1997; Stock and Pfeiffer 2001; Ruff 2006:689; Stock 2006; Wescott 2006; Maggiano et al. 2008; Ruff et al. 2015). The previous trend is correlated with a decrease in sexual dimorphism in measures of midhshaft femoral rigidity from hunter-gatherers to agriculturalists to industrialists (Ruff 1987, 1999, 2005b, 2006, 2008; Ruff and Larsen 2001). Sexual dimorphism in measures of humeral cross-sectional properties remain highly variable throughout time period and region (Sladek et al. 2016; Macintosh et al. 2017).

Studies of locomotory patterns in ontogeny (Ruff 2003; Cowgill et al. 2010; Garofalo 2012) as well as the effects of stress on ontogeny (Hummert 1983; Schug and Goldman 2014; Eleazer and Jankauskas 2016) have recently become more prevalent in archaeological literature. The ratio of bending rigidity at the midshaft femur has been shown to be similar for adults and toddlers, however, the orientation of maximum bending rigidity differs as the skill of walking is perfected during ontogeny. Knowledge of this highly regulated system is especially valuable because it allows for the analysis of stress and health on a population via the distribution of bone in subadults. Additionally, maintenance of properties of bone strength are prioritized over bone mass during extended periods of stress regardless of sex or age (Ruff 1999; Doyle et al. 2011; Schug and Goldman 2014; Eleazer and Jankauskas 2016). Many studies have found that endosteal resorption can recommence during periods of stress in order to maintain subperiosteal dimensions as they are biomechanically more important; thus, percentage of cortical area has been used to assess endosteal resorption/cortical thinning, as an indicator of prolonged periods of nutritional stress during the lifecourse (Mays et al. 2009; Garofalo 2012:17-18).

3.3.2 Entheseal Changes

A. Overview:

Early literature which focused on the relationship between muscle attachment areas and gross morphological changes of bone surfaces commonly referred to these areas as musculoskeletal stress markers (MSM) or 'markers of occupational stress', since the prime objective was to relate specific variations to specific occupations. Recently, the term 'entheseal change' has become preferable, since it has been widely accepted that the etiology behind entheseal variation is too complex to accurately reflect more than general activity patterns, which are not necessarily related to a person's occupation (Capasso et al. 1999:5; Wilczak and Kennedy 1998:466-469; Jurmain 1999:145-146; Pearson and Buikstra 2006:225; Jurmain et al. 2012: 532; Schlecht 2012:1239; Cardoso and Henderson 2013; Perréard Lopreno et al. 2013). Despite demonstrating relatively generalized activity patterns, analyses of entheseal changes have been successfully used to identify sexually based divisions of labor, group level differences in activities, the effects of agriculture, and degrees of task specialization (Hawkey and Merbs 1995; Munson-Chapman 1997; Robb 1998; Steen and Lane 1998; Lovell and Dublenko 1999; Weiss 2007; Villotte et al. 2010a; Milella et al. 2015; Palmer et al. 2016).

Entheseal changes are hypertrophic manifestations at sites where a tendon or ligament inserts into the periosteum of a bone. The union of muscle and bone is accomplished by the gradual incorporation of a tendon or ligament into unmineralized fibrocartilage, which is then integrated into mineralized fibrocartilage via deeply penetrating collagen fibers known as 'Sharpey's fibers', and finally into bone (Jurmain 1999:142-143). Sharpey's fibers are believed to respond to an increase in activity by strengthening and augmenting themselves as well as, “raising multiaxial musculoskeletal exchange beneficially…[and] may be the histological basis for the theoretical “mechanostat” of Frost” (Aaron 2012:8).

The physiological joining of soft and hard tissues is a fundamental engineering challenge achieved via a complex structure called the enthesis (Thomopoulos et al. 2010:35). The enthesis not only secures the two disparate tissues together it is also pivotal in the transmission of force and is macroscopically visible since a certain degree of contact deformation can be expected when joining a hard and soft tissue together (Suresh 2001; Waite et al. 2004; Benjamin et al. 2006:479-480; Schlecht 2012:1242). The stiffer a tendon, the greater ability of the muscle to generate force; therefore, “a stiff tendon can accept high loads (stress) and experience very low deformation (strain).” (Brumitt and Cuddeford 2015:755). Clinical studies have found that tendon stiffness and skeletal muscle hypertrophy can be increased via resistance training, which rarely leads to a tendon injury, however, they are also at risk of simultaneous overuse, traumatic and degenerative injury, especially if the tendon is overloaded or already injured (Brumitt and Cuddeford 2015:754-755). Enthesopathies known from clinical studies in the field of sports medicine are most commonly indicative of tendinosis, a chronic non-inflammatory degenerative condition of the tendon caused by microtrauma or age (Benjamin et al. 2006:484; Brumitt and Cuddeford 2015:755).

The mechanobiology of the enthesis is still poorly understood, even in clinical literature, however, there are several features that are clear: entheses often intermingle, there is a difference in the foundational structure between fibrous and fibrocartilagionous entheses, they are vulnerable to acute and overuse injuries, and the unique transitional tissue which exists between tendon and bone at the insertion site is not recreated after injury (Benjamin et al. 2006:471; Thomopoulos et al. 2010:41; Schlecht 2012:1242; Apostolakos et al. 2014). Entheses often intermingle providing greater tendon security by overlapping the attachment sites; this is the concept of myofascial continuity which stresses the lack of isolation of any muscle (Benjamin et al. 2006:479). Entheses can be classified into two separate types, fibrocartilaginous and fibrous, based upon differences in their interface structure, although some scholars regard this division as overly simplistic since most fibrocartilaginous entheses are actually largely fibrous (Hems and Tillmann 2000; Benjamin et al. 2002; Benjamin et al. 2006). Fibrous entheses commonly attach a tendon/ligament directly to a diaphysis, marked by a large rugous area on the shaft, or they indirectly attach to the bone via the periosteum, usually marked by a large smooth area (Hems and Tillman 2000; Benjamin et al. 2006:472; Schlecht 2012:1244; Apostolakos et al. 2014). Three main stages of changes at fibrous entheses have been recorded: "the surface being globally regular; an irregular surface and gaps in the cortex of the bone; and large gaps or several hills of gaps in the cortical bone" (Weiss 2015:282), however major skeletal changes are common in individuals 60 years and older (Alves Cardoso and Henderson 2010). Fibrous periosteal entheseal attachments become bonier with age as the periosteum disintegrates and continued mechanical strain may result in surface depressions (from compressive force) or osteophytes/depressions (from tensile force) (Benjamin et al. 2002; Schlecht 2012:1243). Fibrous entheses are still poorly understood, however, recent research into the role of myokines (muscle-derived pepetides) at these sites is beginning to clarify how the growth and maintenance of bone at these sites is directly influenced by the surrounding muscle at the molecular level (Jurmain et al. 2012:541; Hart et al. 2017:123-124; Giudice and Taylor 2017).

Fibrocartilaginous entheses, on the other hand, attach tendons to small, localized regions of bone where stress dissipation results in a well circumscribed area with deformation of the cortical surface (Schlecht 2012:1243-1244; Benjamin et al. 2002, 2006). Fibrocartilaginous insertions have commonly been separated into 4 zones: tendon, unmineralized fibrocartilage, mineralized fibrocartilage and bone, with a distinct area known as the 'tidemark' separating the uncalcified and calcified fibrocartilage (Apostolakos et al. 2014). Recent clinical evidence suggests that there is more of a gradient between these 'zones' than previously thought and the exact nature of the tidemark is not clearly understood (Benjamin et al. 2006:475; Thomopoulos et al. 2010:36-37). It is important to note that Sharpey's fibres mostly exist in fibrous entheses, not fibrocartilaginous ones; in the latter "collagen fibre continuity across the hard/soft tissue boundary occurs predominantly at the level of the tidemark…it is perhaps these fibres which should be regarded as the functional equivalent of Sharpey's fibres in a fibrous enthesis." (Benjamin et al. 2006:479). Since fibrocartilage is an adaptation to compression/shearing forces, it is the deeper part of the attachment site that is compressed and thus the more frequent location of clinically recognizable pathology (Benjamin et al. 2006:480; Benjamin and

Ralphs 2004; Maganaris et al. 2004). Fibrocartilaginous entheses are more vulnerable to overuse injuries and not influenced by body mass, therefore, they have been suggested to be the best for osteological activity studies (Benjamin et al. 2002; Villotte et al. 2010b:230; Villotte and Knüsel 2013). The increased vulnerability of fibrocartilaginous entheses is due in part to the avascular nature of this interface, which is necessary due to the largely compressive forces it endures, but which also contributes to a poor healing response (Benjamin et al. 2006:475).

Both fibrous and fibrocartilaginous entheses seem to be similarly affected by the same physical activities/patterns of activity, however, it is important to differentiate between the two types since fibrous entheses are influenced by a variety of other factors such as hormones, body mass, and genetics (Chen et al. 2007; Jurmain and Roberts 2008; Villotte et al. 2010b:230; Lieverse et al. 2013:430; Villotte and Knüsel 2013; Weiss 2015:287). Debates on entheseal subdivsions aside, bioarchaeological studies have embraced the two broad types and current methodologies are largely reflective of this (Alves Cardoso and Henderson 2010; Villotte et al. 2010b).

B. Methodological Issues:

Hawkey and Merbs (1995) suggest several sample requirements to examine entheseal changes such as the need for large and well-preserved skeletal series, which preferably dates to a relatively narrow time span, where cultural and genetic isolation exist, and a limited number of specialized activities are known. Additionally, they suggest the exclusion of individuals exhibiting severe pathology or age-related degenerative joint disease (which could obscure markers or increase stress rates on non-pathological areas of the body), and the exclusion of children because their bones are still in the process of formation (Hawkey and Merbs 1995:326). Adults that an age cannot be ascertained for should be eliminated from statistical analyses because rates of bone remodeling change over a lifetime, are dually influenced by health and nutrition (Shaibani et al 1993; Jurmain 1999), and because the older an individual is the more opportunity they have had to experience stress (Weiss 2004:237; Alves Cardoso and Henderson 2010; Villotte et al. 2010b; Niinimäki 2011; Millela et al. 2012; Cardoso and Henderson 2013; Niinimäki and Sotos 2013). It is also important to control for age because of standard physiological changes in growth and development over the life course, for instance subadults are more likely to have 'fossae' at metaphyseal attachments which could be incorrectly indentified as 'stress lesions' if age is not correctly determined (Villotte and Knüsel 2013:142). Adults with morphologically sexually ambiguous features (unless sex is known from historical records) should also be eliminated from a study sample because sex is correlated to body size, and thus to skeletal robusticity, which must be accounted for in order for inter- and intra-population comparisons to be made (Stirland 1991; Wilczak and Kennedy 1998:464; Knüsel 2000:390; Weiss et al. 2012; Niinimäki and Sotos 2013; Brumitt and Cuddeford 2015:749). The need to control for all of these factors is essential to the credibility of any analysis of entheseal changes (Merbs 1983; Stirland 1991; Peterson 1998; Robb 1998; Wilczak 1998; Weiss 2003b, 2004, 2007).

Formulating a standardized and objective methodology for scoring entheseal changes has been especially problematic and entheseal research on activity remains the most methodologically questionable (Jurmain et al. 2012:537; Djukic et al. 2014).

Quantitatively based approaches include Davidson's (1992) method of photographing insertion sites followed by the AUTOCAD mapping program to calculate area, Wilczak's (1998) method of videotaping chalk-outlined sites and calculating the area through the NIH Image program, Stirland's (1998) method of comparing subjective insertion scores with measurements taken from X-rays on high-grade mammography film, Zumwalt's (2005, 2006) experimental method of three dimensional scanning with fractal analysis on sheep (the applicability of which is limited due to key differences between humans and other mammals in length of skeletal maturation, life span and limb structure (Schlecht 2012:1247) and, most recently, Nolte and Wilczak's (2013) three dimensional laser scanning of entheseal surface area on biceps brachii. It is probable that 3D laser scanning is the future for EC studies but current limitations still include issues with replicability in defining area, even on the most clearly defined entheses, time, data processing and sheer computing power (Jurmain et al. 2012:542; Nolte and Wilczak 2013). Future research on entheseal development/morphology is also moving in the direction of histomorphometric studies to validate the application of macroscopically quanitifiable data in activity pattern studies (Schlecht 2012:1248). Overall, current quantitative methods fail to address aspects of morphology other than absolute area, and are less time and cost efficient than qualitative grading methods.

Qualitative assessments, however, have been criticized for being overly subjective which leads to scoring inaccuracy and problems with replicability (Mariotti et al. 2007; Villotte 2009; Davis et al. 2013; Henderson et al. 2013). While a categorical grading system remains subjective, several suggestions have been proposed which help to reduce this problem. Until recently, the most widely used foundation for qualitative analyses followed the protocols outlined in Hawkey and Merbs' seminal work "Activity-induced Musculoskeletal Stress Markers and Subsistence Strategy Changes among Ancient Hudson Bay Eskimos" (1995); the last three decades, however, have seen a great deal of criticism of this methodology as being categorically too general with high rates of both inter- and intra-observer error (Mariotti et al. 2007; Villotte 2009; Davis et al. 2013; Henderson et al. 2013). Hawkey and Merbs (1995) defined three broad categories of gross morphological expression: robusticity, stress lesions and ossification exostoses. They suggested that robusticity is expressed by the degree of rigidity of the attachment area, and reflects continued muscle use in habitual and repetitive activities, stress lesions include pitting and furrowing of an attachment area and appear to be associated with continuous microtrauma, while the final category, ossification exostoses, are bony projections formed when an abrupt macrotrauma (i.e. muscle rupture) causes new bone formation to be incorporated into tendon or ligament tissue (Hawkey and Merbs 1995:328-329). It's recommended that photographs of each insertion site and category studied, and representing each grade of morphological expression (0=absent, 1=faint, 2=moderate, and 3=strong), should be compiled from the sample being analyzed and used as references for scoring. Critiques of this method are numerous. Many researchers feel that the categories and scoring system are far too general, especially since it is the same for all muscles being considered and fails to distinguish between fibrous and fibrocartilaginous entheses (Alves Cardoso and Henderson 2010; Villotte et al. 2010b; Schlecht 2012; Jurmain et al. 2012; Davis et al. 2013; Villotte and Knüsel 2013). Furthermore, many studies using this methodology consider the categories of rugosity and stress lesions to be two components on a single ordinal scale and therefore collapse them into one scoring scheme, despite a lack of evidence to support this assumption, thereby overemphasizing the significance of stress lesions (Jurmain et al. 2012; Niinimäki 2012:4; Schlecht 2012; Henderson et al. 2013). While some studies using this methodology have reported low rates of inter- and intra-observer error (Peterson 1998; Steen and Lane 1998; Weiss 2003b) many more have reached the opposite conclusion (Mariotti et al. 2007:297; Davis et al. 2013) and a number of other methodologies have been suggested.

Alves Cardoso and Henderson (2010) have suggested a modified Hawkey and Merbs methodology which analyzes fibrous and fibrocartilaginous entheses separately using a binary presence/absence scale for morphological changes solely in the category of robusticity, but found it to produce overly generalized results. Mariotti et al. (2004, 2007) also suggested a new methodology, which is in general similar to Hawkey and Merbs', but provides significantly more detailed and stringent guidelines to categorize morphological changes as attributable to robusticity or enthesopathy, with the latter divided into either osteolytic or osteophytic forms. Mariotti et al. (2004, 2007) provided a standardized scoring scheme with detailed photographs and descriptions of each degree of development in the category of robusticity for 23 postcranial entheses, although they have been criticized for failing to consider entheseal anatomy/aetiology in changes and some researchers have reported high intra- and inter-observer error rates (Villotte 2009; Jurmain et al. 2012; Henderson et al. 2013). Villotte (2006) also suggested a new protocol which analyzes the calcified histological zone of a fibrocartilaginous enthesis and classifies it as either healthy ["a smooth, well-defined imprint on the bone, without vascular foramina, and with a regular margin" (Villotte et al 2010b:226)] or pathological. This latter condition defines an enthesopathy as present whenever there is an "Irregularity or enthesophyte(s) located at the outer part, and/or irregularity, foramina (at least three), cystic changes, calcification deposit, bony production, or osseus defect area found at the inner part." (Villotte et al 2010b:226). It should be noted that current clinical research has found the purpose/presence of enthesophytes to be unclear despite the generally accepted assumption that they are a skeletal response to stress, such as in a compromised synovial joint (Benjamin et al. 2006:485-486). Issues with Villotte's (2006) methodology include the use of binary categories (healthy/pathological) which provide only highly generalized information, the indiscriminant use of both origin and insertion sites and a lack of consideration of groups of muscles and therefore movements.

Due to the lack of a commonly accepted and standardized qualitative methodology for analyzing entheseal changes in 2009 many of the authors of the above methodologies formed a working group devoted to combining their expertise and developing 'The New Coimbra Method' (2016). The New Coimbra Method analyzes fibrocartilaginous insertions by dividing them into two zones and scoring them on a 0-2 scale for two different features in Zone 1 and six different features in Zone 2. Although this method is now recommended for widespread use it still has not tested the effects of age, recommends in-person training by the authors and is still in the process of developing an illustrative guide to distinguishing the two zones at each fibrocartilaginous enthesis (Henderson et al. 2016).

In addition to the standardization of skeletal sample criteria and scoring methods, a number of other important considerations have been recognized. The need to analyze entire groups of muscles, and not just individual insertion sites was first recognized by Stirland (1998), who pointed out that no muscle works independently and therefore it makes no sense to analyze them as such. This point was supported by Peterson and

Hawkey (1998:303), and the benefit of analyzing groups of muscles was demonstrated by Weiss (2003b). Analysis of muscular insertion sites from the entire skeleton also merits consideration because more than one activity may be reflected in an individual, and ad hoc assumptions about what markers may be present will limit the scope and credibility of an analysis (Wilczak and Kennedy 1998:465). It is also important to consider multiple skeletal areas because individuals in a society may perform similar tasks in different ways and variations in things like handedness, pain threshold and experience may affect musculoskeletal marker expression as well (Wilczak and Kennedy 1998:466).

Recognizing the need to account for so many skeletal elements, Elizabeth Weiss (2003b) suggested the application of the principle of aggregation for entheseal change research. Aggregating over several measures not only allows for groups of muscles to be studied simultaneously, but also allows for error in measurement and idiosyncratic variance to be averaged out. In her study, Weiss (2003b) demonstrated that the more entheseal changes that are scored and aggregated, the greater their correlation with sex, body size, age and cross-sectional morphology. This paper also firmly established a correlation between entheseal changes and skeletal robusticity, thus validating the use of entheseal changes as indicators of activity levels from which behavioral patterns may be discerned (Weiss 2003b:238). Aggregate measures are not appropriate for studies that are only concerned with a specific phenomenon or a specific bone, and disaggregated measures can still be informative as long as body size is controlled for (Weiss 2007:939); however, using aggregate measures can greatly increase the chance of finding significant correlations and should be applied whenever appropriate.

Entheseal change morphological expression on upper versus lower limb bones is restricted by the obscuring effects of locomotor influences, similar to biomechanical studies. Weiss (2004) did, however, show that there is a strong correlation between lower limb bone entheses and body size, which speaks again to the importance of controlling for body size in any study using fibrous entheses. Robb (1998:370) suggested that when analyzing a skeletal sample for a sex-based social division in activities, upper-limb markers are more appropriate than lower, since lower-limb markers in males will already be more robust than in females due to supporting their (generally) greater body weight.

Consideration of bilateral asymmetry in entheseal expression is also important because it can provide evidence for handedness and regional variation in cultural practices (Larsen 1997:188; Peterson 1998; Wilczak 1998:322). Handedness, however, can be complicated by the lack of exclusively unilateral activities; the non-dominant hand could frequently be used to assist the dominant hand, thus obscuring asymmetrical expression (Steen and Lane 1998; Wilczak 1998). Another important matter is the need to consider the relative importance of a task or activity- specifically, the ratio of strain level to the frequency of activity repetition (Bridges 1990; Churchill and Morris 1998:407; Steen and Lane 1998). Despite an increased level of strain imposed by a certain activity, if it is not habitual then it will be less likely to permanently affect the musculoskeletal morphology than a less strenuous but habitual activity. For example, early studies of entheseal changes attempted to identify activities related to using specific weapons for hunting, like atlatl elbow (Angel 1966). The frequency with which hunting activities took place, and thus the opportunity to use an atlatl, however, would not necessarily have been enough to permanently affect the skeletal system when compared to a strenuous and repetitive activity such as hide-scraping. Additionally, the age of an individual when an activity became habitual and how long that activity was continued may play a significant role in musculoskeletal development and should also be considered.

C. Behavioral Interpretations:

The study of entheseal changes is arguably one of the most challenged methodologies in the field of bioarchaeology; however, significant methodological developments during the last two decades have established it as a useful tool for reconstructing general patterns of activity, which carry the potential for forming sociocultural inferences. The development and degree of expression of these bony manifestations have been linked to forceful and repetitive activities involving specific groups of muscles (Kennedy 1989; Hawkey and Merbs 1995; Wilczak and Kennedy 1998; Knüsel 2000; Weiss 2003b, 2004). In general, it has been accepted that specific activities are less likely to be recognized than the organization of general patterns of activity and the levels of stress associated with them (Robb 1998:364). Task specialization may be determined, however, as long as the activity pattern associated with it falls far outside any normal range of motion or locomotion, and all other variables that may contribute to marker formation have been incorporated into the analysis (i.e. age, sex, health, body size) (Wilczak and Kennedy 1998:466).

Analyses of entheseal changes have also provided key insights into the less tangible aspects of prehistoric societies which have been suggested based upon subjective material culture assumptions. Both individual and population level differences can be identified through the analysis of entheseal variability, which may illuminate facets of social organization such as sex-based divisions of labor (Hawkey and Merbs 1995; Steen and Lane 1998; Lieverse et al. 2013; Palmer et al. 2016) or the presence of distinct sub-groups (Stirland 1998). Evidence for care and compassion within a prehistoric society may be identified as in Hawkey's (1998) study of an adult male from New Mexico who suffered from atrophied muscles due to an extremely debilitating case of juvenile rheumatoid arthritis that would have caused him to be completely dependent on others for some time prior to his death. Intra-population changes over time can also be examined and may suggest temporal changes in activity patterns (Munson-Chapman 1997; Lieverse et al. 2013), while inter-population comparisons can be used to help clarify the role of environment on activities as reflected in morphological variability (Churchill and Morris 1998; Steen and Lane 1998; Wilczak 1998; Lieverse et al. 2013). There has even been an investigation of Neandertal entheses, specifically looking for any skeletal locomotor differences with modern *Homo sapiens* (Mariotti and Belcastro 2011). Identification of activity involving the use of a specific technology is a slightly more complex topic, and the weight given a priori to ethnohistorical sources or archaeological cultural contexts must be carefully considered; there is a significant difference between knowing what tools or weapons were used, and inferring how they were used (Churchill and Morris 1998:391; Robb 1998:363; Jurmain 1999:151; Rhodes and Churchill 2009; Meyer et al. 2011). Lovell and Dublenko's (1999) osteobiographical study of four adults associated with a historic Canadian fur-trading outpost, used entheseal changes at the tibio-fibular articulation to provide potential support for an association with driving a dog sled, which was a historically recorded activity in the region. Since the field of entheseal change research is still developing, it is important to remain cognizant of ethnohistorical sources as support for activity identification, but they must be used cautiously.

3.3.3 Osteoarthritis

A. Overview:

Osteoarthritis is one of the most common pathological conditions to affect the skeletal system, and is used to describe the abnormal state of a synovial joint (Dieppe 1990:262). Amphiarthrodial synovial joints are slightly mobile joints which are found between vertebral bodies and in the anterior of the hips; their primary purpose is to provide stability (Larsen 1997:162; Jurmain 1999:12). Diarthrodial joints are the other form of synovial joint and include all of the major articulations of the appendages; these joints provide stability as well as mobility (Jurmain 1999:12). This distinction is especially important to a research plan focused on identifying potential variations in activity patterns because, while still poorly understood, the relative weight of certain factors involved in the etiology of osteoarthritis is different for these joint types (Larsen 1997:162).

The multifactorial etiology of osteoarthritis includes such factors as sex, age, ancestry, genetic disposition, climate, weight, metabolism, nutrition, bone density, infection/disease, trauma and mechanical stress (Bridges 1992; Rogers and Waldron 1995:33, 105; Larsen 1997:163; Knüsel 2000:393-401;Weiss and Jurmain 2007; Jurmain et al. 2012). Genetic research has found that more than half of the phenotypic variability recorded in osteoarthritis can be accounted for by differences in genotypes, and that while genetics has little role in the presence or absence of osteoarthritis, it can affect the severity of its development (Weiss and Jurmain 2007:439-440). Sex differences related to osteoarthritis are also complicated since anatomical variance in body size and limb proportions are as equally confounding as hormonal effects. The increased presence of osteoarthritis in women, for example, is directly related to their propensity towards type I osteoporosis (Weiss and Jurmain 2007:440; Agarwal 2008:390-391). Age, however, remains the most crucial paleoepidemiologically confounding factor in the study of osteoarthritis (Jurmain et al. 2012:540).

Not only do individuals vary in their level of risk for developing osteoarthritis but different joints do as well (Pearson and Buikstra 2006:216-217; Jurmain 1999:105). Most osteologists now reserve the term osteoarthritis for diarthrodial joint changes, because amphiarthrodial joints seem to have a stronger etiological correlation to age and are therefore less reliable as sources of activity information (Wilczak and Kennedy 1998:474; Jurmain 1999:12). Despite the wide body of research considering spinal degenerative changes (Bridges 1989, 1994; Sofaer Derevenski 2000; Ciranni and Fornaciari 2003), it is now widely accepted that the vertebral column should not be used in studies focusing on activity indicators (Bridges 1994; Knüsel et al. 1997; Weiss and Jurmain 2007; Jurmain et al. 2012:539). Additionally, research into osteoarthritis has found that changes due to biomechanical stress are more like to appear on the surface of a joint, while marginal changes are commonly due to advancing age; marginal osteophytes in particular tend to develop around 35 years of age and proliferate after 50 (Cooper et al. 1994; Wilczak and Kennedy 1998:476). Rogers and Waldron have suggested that if only lipping of the joint margin or porosity is present, then activity-related osteoarthritis should not be diagnosed; however, it may be diagnosed if both of these traits even slightly co-occur (1995:44).

B. Methodological Issues:

Methods for scoring osteoarthritis have been variable, but the application of an ordinal scoring system has been recommended and widely adopted (Bridges 1993; Wilczak and Kennedy 1998; Weiss and Jurmain 2007). Bridges (1993:290) recommends scoring all major appendicular joints available for the three categories of subchondral porosity, lipping and eburnation, and on the same zero to three scale for degree of expression as that suggested for entheseal change studies. The category of porosity is self-explanatory, and lipping is represented by osteophytic growth around the margins of an articular surface. Eburnation results from the complete dissolution of articular cartilage, which causes direct bone-on-bone contact and results in a shiny grooved surface, with the grooves running in the direction of movement of the joint (Rogers and Waldron 1995:36).

Joints on both sides of the body should be recorded since bilateral asymmetry in degenerative changes provides strong support for an activity induced etiology (Wilczak and Kennedy 1998:476). Differences in the severity between joints and specific location of osteoarthritic modifications also have the potential to elucidate an individual's general activity pattern (Weiss and Jurmain 2007:445). Recent research has also stressed the need to score a joint's marginal changes separately from its surface changes (due to the differences in age-correlated presence discussed above), and Kennedy and Wilczak (1998:476) have gone so far as to recommend the division of an articular surface into quadrants in order to provide more detailed information.

C. Behavioral Interpretations:

A good deal of caution must be exercised in any study using osteoarthritis to infer activity patterns. Overall, osteoarthritis is not a very reliable indicator and is best used in combination with other markers for patterns in populations, including the identification of discrete groups (Rogers and Waldron 1995:107; Jurmain 1999:139; Weiss and Jurmain 2007:444; Jurmain et al. 2012; Palmer et al. 2016). Waldron's 1987 study of osteoarthritis from Christ Church, Spitalfields considered patterns of arthritis in the spine (which alone would not have been adequate enough for a correlation to occupation as stated previously), shoulders and hands of individuals to provide potential support for a community of weavers (Stirland 1991). Other studies have focused on osteoarthritis as evidence for the use of certain technologies, like Angel's 'atlatl elbow' (1966) already mentioned in the section on entheseal changes. Results that have produced non-significant or contradictory results are often due to a priori assumptions placed upon the data. Angel's atlatl study is a prime example of this; women had higher rates of osteoarthritis than men in the shoulder and elbow joints, which was unexpected since it was hypothesized that men would have higher rates from using an atlatl (Bridges 1990). These results could have been from a more stressful or more habitual activity, like seed grinding, or because women are biologically prone to higher rates of osteoarthritis. When interpreting data, a researcher must be careful not to confuse biological sex differences with differences in cultural activity patterns (Weiss and Jurmain 2007:440; Rhodes and Churchill 2009; Meyer et al. 2011).

Another confounding factor in interpreting patterns of osteoarthritis is the failure of clinical studies to clarify the relationship between osteoarthritic patterns and specific activities. Early studies focused on limitations to activity that osteoarthritis would have caused, rather than the reasons for its presence or degree (Buikstra 2006:512). No correlation has yet been discovered between the severity of osteoarthritis and the amount of pain an individual is suffering from (Rogers and Waldron 1995:102). There has also been no correlation found between the visual scoring system osteologists use and radiographic evidence of osteoarthritis (Bridges 1993:293), although many early stages of osteoarthritis cannot be detected in x-rays. Inquiries into the relationship between specific patterns of osteoarthritis and specific sports or occupationally related activities have produced mixed results, even for the same activity and the same joint. In fact, there appears to be an inverse relationship between osteoarthritis and biomechanical robusticity if a habitual strenuous level of activity is begun before physiological maturity (Puranen et al. 1975; Lane et al. 1986; Panush and Brown 1987; Bridges 1989, 1991; Knüsel 2000). Furthermore, the differences between modern work environments/technologies and prehistoric ones are so extreme, that few modern studies should be considered applicable towards studies of specific prehistoric activities.

Case studies that have been considered to have found positive correlations between a habitual activity that may be found in a pre-industrial society and a pattern of osteoarthritis include Pearce et al's (1996) research on the link between osteoarthritis in knee joints and sailors, and Hadler et al's (1978) investigation of osteoarthritis in the hands of textile workers. Future research into the relationship between known occupationally-related patterns of osteoarthritis and time-period appropriate occupations could no doubt provide support for activity-induced osteoarthritis. The complexity of both the etiology of osteoarthritis and the ways in which it is expressed will not be a challenge simply overcome.

3.3.4 Non-Metric Traits

A. Overview:

Non-metric traits are skeletal variants that have both a genetic disposition as well as a non-genetic one (Saunders 1989:95; Saunders and Rainey 2008:533). Genetic non-metric traits can usually be recorded by simple presence/absence, and have been used successfully in studies of biological distance and post-marital residence patterns (Spence 1974). Non-genetic non-metric traits are slightly more complex because while some of these traits may be directly correlated to activity, they may also have a genetic disposition that can be phenotypically influenced by habitual activities through the development of the surrounding soft-tissue structures (Saunders 1989:95; Mays 1998:102; Saunders and Rainey 2008:533, 547).

B. Methodological Issues:

In order to facilitate the recording and comparison of these heterogeneous anomalies, Gruneberg's model of quasicontinuous variation has been successfully applied. While there is no standardized recording system for non-metric traits, because there is no simple genetic explanation for them, Gruneberg's model "holds that some discontinuous traits have continuous genotypic distributions with underlying (absent) and visible (present) scales separated by a physiological threshold" (Scott 2008:270). Essentially, some non-metric traits have a genetic component to them but they only physically manifest after a certain amount (the threshold) of a specific activity has occurred. This threshold, or minimum degree of expression recorded, is established arbitrarily by the individual observer and should be accounted for in detail so that comparisons with other data sets can be made, even if different thresholds are used. Obviously, the infracranial skeleton is more susceptible to changes caused by activity (vs. cranium), but it is important to consider whether an activity is the reason behind the formation of a trait or if the activity provided an environment in which the potential for expressing the trait pushed it over the developmental threshold, thus accounting for its initial presence (Saunders and Rainey 2008:549).

Age can also contribute to the formation of a non-metric trait and is therefore an important factor to consider when deciding upon an appropriate skeletal sample. Traits characterized by a lack of fusion should not be considered present unless an individual is old enough to have definitively passed the developmental stage of fusion for the specific area under consideration (Mays 1998:102; Saunders and Rainey 2008:548). Lack of control for this factor is a possible reason that Stirland's (1991) study of os acromiale (lack of fusion of the acromion process of the scapula) in potential archers should not be unanimously accepted. Another confounding factor due to age in the study of non-metric traits are the correlations between hypostotic traits (localized deficiency in bone formation) with young individuals, and hyperostotic traits (localized excess formation of bone) with older individuals (Mays 1998:104-105; Saunders and Rainey 2008:548).

C. Behavioral Interpretations:

Types of non-metric traits that have been correlated with activity patterns include pressure facets, articular border extensions, grooves, auditory hyperostosis (i.e. exostoses) and activity-induced dental modifications. Pressure facets and articular border extensions may be caused by habitual pressure/rubbing between opposing surfaces (Wilczak and Kennedy 1998:478). Studies of squatting (Dlamini and Morris 2005) and kneeling (Ubelaker 1979, 1989) facets fall into this category and are thought to be caused by habitual extreme extension and flexion, although Miles' (2000) study on subacromial humeral-impingement facets showed no correlation to activity patterns. Hyperostosis of the auditory tori has been definitively linked to cold-water exposure of the ear canal, which can be occupationally linked to diving for cold water resources (Kennedy 1986; Standen et al. 1997; Mays 1998:119; Jurmain 1999:181-182). The presence of auditory exostoses is also frequently correlated with supernumerary condyle formation and arthritis at the base of the skull, which provide further support for habitual diving activities (Munizaga 1991). Activity-induced dental modifications include localized anomalies such as grooving or chipping of teeth which have been correlated with activities including holding/biting thread, stripping animal sinew or holding a pipe in one's mouth (Turner and Caiden 1969; Cybulski 1974; Schulz 1977; Brown and Molnar 1990; Ubelaker et al. 1996; Mayes and Barber 2008:580; Molnar 2008).

CHAPTER 4: MATERIALS

4.1 REGIONAL BACKGROUND

The history of the Netherlands is a complex web of endogenous and exogenous factors that have shaped, and reshaped, not only the country's political and economic face but also its physical landscape. The extremely variable geography and soils throughout the Netherlands, combined with the effects of the Little Ice Age (AD 1300-1850), presented numerous difficulties for an intensification of agriculture (de Vries 1997:16; Fagan 2000). In the province of Holland, the challenge was to occupy the extensive peat bogs, which were both a blessing because they provided a cheap source of fuel, and an impediment to arable farming or animal husbandry because they were so soggy (de Vries 1997:16-17, 37). During the 14th and 15th centuries there was a 'low technology agricultural revolution' which involved the implementation of lay farming to reduce fallow land, and the introduction of windmills for draining/pumping water away from fields (Schama 1987:38-40; Fagan 2000:106). Between 1610 and 1640 intense lake drainage and land reclamation was accomplished through the introduction of polders ('ring canals') that used turnable windmills to drain an area. By c.1650 Holland's farmland had increased by a third and a large new class of farmers had emerged (de Vries 1997:18, 29; Fagan 2000:107).

Despite the success of these innovations and alterations, much of the soil of North Holland was unsuitable for arable farming and, instead, the occupants focused on cattle and dairy farming- cultivating nitrogen-rich clover to feed the animals as well as enrich the soil (Kossmann 1978:31; van Zanden 1994:6, 73; Fagan 2000:106; Ibelings 2001:256). These changes allowed for a commercial orientation to agriculture to develop in the Netherlands which fed the demands of the growing city of Amsterdam, as well as to supply the numerous trading ships of the Dutch East India Company, which had been established in Amsterdam in 1602 (de Vries 1985:663, 667, 671, 1997:33; Hagen 1988:45; Van Oostrom 2008:38). Agriculture became the largest sector in the Dutch economy but was heavily impacted, both positively and negatively, during the Thirty Years War (1618-1648), the War of Spanish Succession (1701-1714), the Fourth Anglo-Dutch War (1780-1784), the French Revolution (1789-1799) and the Napoleonic Wars (1803-1815) (de Vries 1976:44, 69, 1985:667; 1997:24-25, 195, 210, 223-224; Hooker 1999:100). Despite the significant hardships that the shifting political climate had on the arable farming areas of the

FIGURE 4.1: Map of the Provinces of the Netherlands

Image from: http://d-maps.com/m/europa/netherlands/paysbas/paysbas17.gif

Netherlands, the specialized dairy farming areas remained mostly unaffected due to the irreplaceable demand for their exports (van Bavel 1999, 2010; van Zanden and van Riel 2004:53-57). Towards the end of the 18th century, England became Europe's largest food importer and was supplied heavily from the nearby Netherlands; by the beginning of the 19th century, twenty percent of Dutch dairy products alone were being exported (de Vries 1997:226-227; van Zanden and van Riel 2004:55).

4.2 SITE BACKGROUND

4.2.1 Historical Context

The small town of Middenbeemster is located in the center of the modern municipality of Beemster, in the province of North Holland, 10 km from the western coast of Lake Markermeer and 20 km to the east of the North Sea (Figure 4.2). The Beemster

FIGURE 4.2: Map of the Municipalities of North Holland

Image adapted from:
http://d-maps.com/m/europa/netherlands/noordholland/noordholland21.gif

polder was completed in 1612, during the intense land reclamation previously mentioned (de Jong et al. 1998:85; Van Oostrom 2008; Falger et al. 2012). Despite the unstable political and economic climate of the 17th and 18th centuries for much of the North Sea area, rural Beemster (Figure 4.3) became one of the largest dairy farming villages in Holland (de Vries 1997:510; de Jong et al. 1998:85; Falger et al. 2012). Beemster's dairy farming economy initially prospered but experienced hardship during the mid-18th century caused by two rinder pests ("cattle plagues") as well as the effects of major crop failures in the mid-19th century throughout Europe (Bergman 1967; Mokyr 1974; Vanhaute et al. 2007; Falger et al. 2012).

FIGURE 4.3: Map of Beemster in 1869

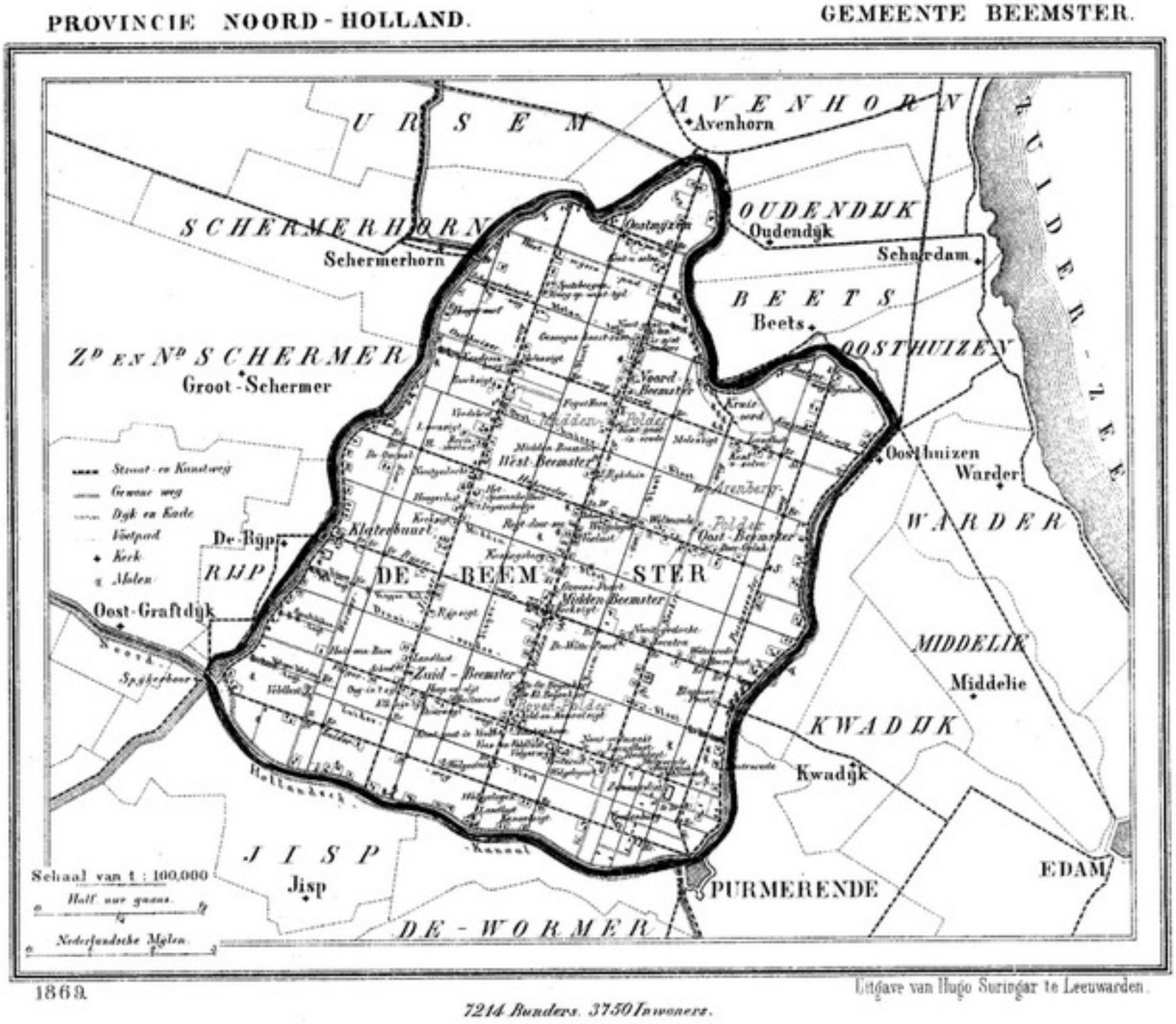


Image from: http://www.humanosteoarchaeology.com/uploads/9/7/1/1/9711942/2205567.jpg?628

During the summer of 2011, the majority of the Keyserkerk cemetery used by the colonizing farming community of the Beemster polder from 1623-1866, was excavated as part of a joint rescue project by Hollandia Archeologen and the Laboratory for Human Osteoarchaeology of Leiden University. Approximately 450 individuals were recovered representing all ages and many in excellent preservation. The majority of the graves are from the 19th century and were carefully laid out and numbered with historical records of the individuals interred there from 1829-1866 with information including name, sex, age and sometimes occupation, family relations or nationality if they had immigrated (Waters-Rist 2011: personal communication; Lemmers et al. 2013). The collection is currently being housed at the Laboratory for Human Osteoarchaeology at Leiden University.

The Middenbeemster skeletal sample provides a unique opportunity to examine age and gender-related divisions of activity and labor during this dynamic and challenging historical period. Census data suggests that the division of labor in preindustrial rural Holland included men working while women were seemingly confined to housework and childcare (van Cruyningen 2005; Falger et al. 2012; Schmidt and van Nederveen Meerkerk 2012; Saers et al. 2017). Known occupations from Middenbeemster include those of farmer (mostly dairy), baker, doctor, turf-skipper, carpenter, cooper, shopkeeper, day laborers, teachers, painter, postman and priest (Falger et al. 2012). While family enterprises during this time period were commonly run in the male head of households name, feminist economists have recently challenged the role of women as housewives suggesting that in reality both spouses would have contributed significantly (Schmidt and van Nederveen Meerkerk 2012:75). Expectations of being a housewife became the social norm for all classes over the course of the 19th century throughout the Netherlands, even among wives of farmers who did not yet have children (van Poppel et al. 2009:99-100). For the lower classes, women not working was not an affordable option so many women must have worked either 'undercover' so that they appeared to be adhering to the social norm or else worked in a 'cottage industry' (for example, dairy production (van Poppel et al. 2009:118, 124; van Nederveen Meerkerk 2015).

Traditionally, women's agricultural contributions included the production of dairy products (milking cows, churning butter, making cheese) and it has been estimated that in the early 19th century, this type of 'agricultural labor' constituted the most important activities of married women in these rural dairy farming areas (van Poppel et al. 2009; Schmidt and van Nederveen Meerkerk 2012; van Nederveen Meerkerk and Paping 2014; van Nederveen Meerkerk 2015). Women's role in dairy production was so important that even the Labor Act of 1889 made an exception to Sunday work for women in the butter and cheese industry (van Nederveen Meerkerk 2015). In addition to dairy production, women would also work in the fields during times of need, such as the month-long harvest (van Nederveen Meerkerk 2015).

In the cottage industries, which were closely linked to agricultural activities, the entire family worked together with specific parts of the production process designated by sex/age (van Poppel et al. 2009:116). Thus, the sexual division of labor in rural areas of the Netherlands began as early as five years of age; boys typically helped on the farm/with the cattle while girls assisted with chores in the home and caring for younger siblings, often under the supervision of their grandmothers (Schenkeveld 2008; Schmidt and van Nederveen Meerkerk 2012:85-86; Veselka et al. 2015).

4.2.2 Previous Bioarchaeological Research

Several dozen MSc's focused on the Middenbeemster collection have come out of the Laboratory for Human Osteoarchaeology at the University of Leiden; many of these investigate issues of physiological stress and health in the population, explore cultural causes and impacts of the above, as well as test the accuracy/validity of different osteoarchaeological methods. Two previously published studies focused on activity patterns and the division of labor in the Middenbeemster population have been developed from two of these MSc's, those by Saers et al. (2017) and Palmer et al. (2016). Saers et al. (2017) examined the cross sectional bone geometry of adult femurs and tibiae, and found the latter to be more elliptically shaped in males, which was interpreted as representing high levels of terrestrial mobility. Palmer et al. (2016) analyzed osteoarthritis and entheseal changes in the upper limbs of the adult Middenbeemster population suggesting a gendered division of labor in activity. This dissertation goes beyond these studies by combining cross-sectional data with osteoarthritis, non-genetic non-metric traits and entheseal data from across the entire body while employing a lifecourse perspective.

Several paleopathological case studies on the historic Middenbeemster population have also been published including the differential diagnoses of disproportionate dwarfism in a mother and at least two of her seven children (Waters-Rist and Hoogland 2013; Colombo et al. 2018), an intranasal inverted Schneiderian papilloma (Carroll et al. 2016), osteochondritis dissecans of the foot in a comparatively large proportion of the population (Vikatou et al. 2017), as well as the presence of rickets and residual rickets in the population. Veselka et al. explored sociocultural causes for the high presence of rickets in subadults four years of age and younger at Middenbeemster and proposed that "poor weaning foods, prolonged swaddling, occlusive clothing, and a lack of time spent outdoors" (2015:673) could all have been contributing factors. This study was elaborated with Veselka et al.'s (in press) analyses of residual rickets in the adults of the Middenbeemster population which further supports the historical record of a sexually based division of labor in which males would have had greater exposure to sunlight and thus a greater chance of overcoming early vitamin D deficiencies.

4.3 SKELETAL SAMPLE UTILIZED

Activity related pattern studies require large and well-preserved skeletal series, which preferably date to a relatively narrow time span, where cultural and genetic isolation exist, and a limited number of specialized activities are known (Hawkey and Merbs 1995:325). Additional criteria for skeletal series include the exclusion of individuals exhibiting severe pathology or age-related degenerative joint disease (which could obscure markers or increase stress rates on non-pathological areas of the body) (Hawkey and Merbs 1995:326).

In this study, historic records provide supporting information on sex and age of individuals interred in the Middenbeemster cemetery. Commonly, adult skeletons for whom sex cannot be determined are excluded from an analysis, since sex is correlated to body size, and thus to skeletal robusticity, it must be accounted for in order for inter- and intra-population comparisons to be made (Stirland 1991; Wilczak and Kennedy 1998:464; Knüsel 2000:390). Similiarly, activity studies typically exclude adults of an undetermined age, as rates of bone remodeling change over a lifetime (Shaibani et al. 1993; Jurmain 1999). Subadults are also commonly excluded from activity related studies because their skeletons are still in the processes of forming, however, since one of the main goals of this research project is to explore changes over the lifecourse of the occupants of Middenbeemster, subadults were included in the cross-sectional bone analyses.

Adult age at death was estimated from the morphology of the pubic symphysis, auricular surface and sternal rib ends as well as estimates of cranial suture closure. Sex estimates were assessed according to methods outlined in *Standards* (Buikstra and Ubelaker 1994) as well as those of the Workshop of European Anthropologists (WEA 1980). Sex for subadults was taken from the historic records when available. Age for subadults was estimated from dental development and eruption, epiphyseal fusion, and osteometrics according to methods outlined in *Standards* (Buikstra and Ubelaker 1994). In general, historic records corroborated osteological age and sex estimates. Adults with sexually ambiguous features who did not have a historic record were ultimately eliminated from the sample.

In total, 138 individuals (adults and subadults) were chosen for analysis and historic records corroborated the information for 87 of them; 110 adults were analyzed for entheseal changes, appendicular osteoarthritis and non-genetic non-metric traits, and 138 individuals representing age categories across the life course were chosen for CT scans. Tables 4.1 through 4.3 detail the age and sex cohorts for the different analyses performed. Adult age categories for all analyses were divided as follows: Early Young Adult (17-25 years of age), Late Young Adult (26-35 years of age), Mature Adult (36-49 years of age) and Old Adult (50+ years of age). Subadult age categories for CSBG analyses were divided as follows: Perinate (around birth), Infant (3 months-0.99 years of age), Young Child (1-4.99 years of age), Middle Child (5-9.99 years of age), Older Child (10-13.99) and Adolescent (14-16.99 years of age). Such narrow age categories were possible due in part to information from the historical records.

TABLE 4.1: Sample Descriptions of Adult Skeletons Analyzed for Entheseal Changes, Osteoarthritis and Non-genetic Non-metric Markers

Early Young Adult Females:	7
Late Young Adult Females:	14
Mature Adult Females:	16
Old Adult Females:	14
Total Number of Females:	**51**

Early Young Adult Males:	11
Late Young Adult Males:	15
Mature Adult Males:	16
Old Adult Males:	17
Total Number of Males:	**59**

Total Number of Early Young Adults:	**18**
Total Number of Late Young Adults:	**29**
Total Number of Mature Adults:	**32**
Total Number of Old Adults:	**31**

Total Number of Adult Individuals:	**110**

TABLE 4.2: Sample Descriptions of Adult Skeletons Analyzed for Cross Sectional Bone Geometry

Early Young Adult Females:	7
Late Young Adult Females:	14
Mature Adult Females:	13
Old Adult Females:	14
Total Number of Females:	**48**

Early Young Adult Males:	11
Late Young Adult Males:	14
Mature Adult Males:	15
Old Adult Males:	17
Total Number of Males:	**57**

Total Number of Early Young Adults:	**18**
Total Number of Late Young Adults:	**28**
Total Number of Mature Adults:	**28**
Total Number of Old Adults:	**31**

Total Number of Adult Individuals:	**105**

TABLE 4.3: Sample Descriptions of Subadult Skeletons Analyzed for Cross Sectional Bone Geometry

Female Perinates:	3
Female Infants:	0
Female Young Children:	2
Female Middle Children:	4
Female Older Children:	2
Female Adolescents:	0
Total Number of Females:	**11**

Male Perinates:	0
Male Infants:	0
Male Young Children:	3
Male Middle Children:	1
Male Older Children:	1
Male Adolescents:	1
Total Number of Males:	**6**

Unknown Sex Perinates:	3
Unknown Sex Infants:	0
Unknown Sex Young Children:	3
Unknown Sex Middle Children:	0
Unknown Sex Older Children:	1
Unknown Sex Adolescents:	4
Total Number of Unknown Sex:	**11**

Total Number of Perinates:	**6**
Total Number of Infants:	**0**
Total Number of Young Children:	**8**
Total Number of Middle Children:	**5**
Total Number of Older Children:	**4**
Total Number of Adolescents:	**5**

Total Number of Subadults:	**28**

CHAPTER 5: METHODS OF DATA COLLECTION

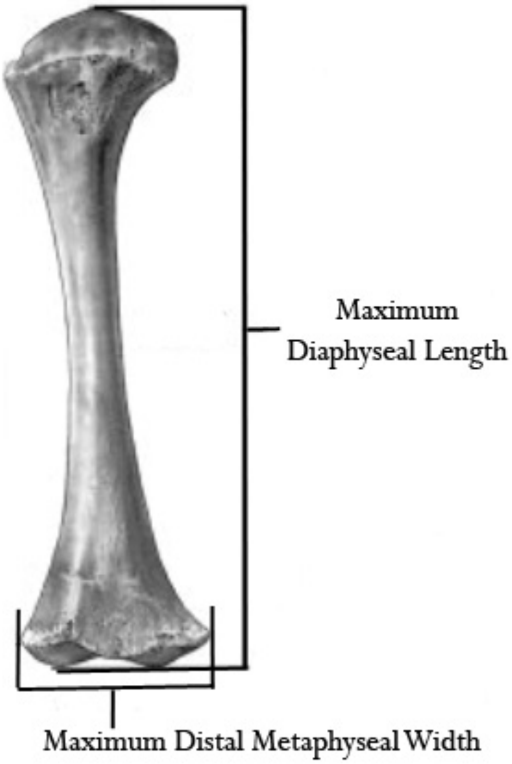
5.1 SIZE STANDARDIZATION

Body size has a significant effect on cross-sectional geometry, entheseal development and osteoarthritis and any study which wishes to compare sex or population differences for these measures needs to control for this factor. It is now accepted that bone length/stature estimates alone are not adequate means of controlling for differences in body size. The preferable method uses either bi-iliac breadth (which was not available due to preservation issues) or femoral head diameter to predict body mass (Ruff et al. 1991; Ruff 2000). Body mass for adults was estimated by using an average of three equations, following Pomeroy and Stock (2012) using femoral head diameter (FHD):

1. McHenry (1992): 2,2393 x FHD - 39.9
2. Grine et al. (1995): 2,2683 x FHD – 36.5
3. Ruff et al. (1991)*: for Males: 2,7413 x FHD – 54.9 ; for females: 2,426 x FHD – 35.1
   *these estimates were then reduced by 10% to account for the increased adiposity of modern North American adults, as recommended by the authors)

To control for body size in subadults less than seven years of age, body mass estimates were created using age specific predicting equations (see Ruff 2007) based on the maximum width of the most medial and lateral points of the distal metaphysis (Figure 5.1), which are not quite perpendicular to the shaft. For subadults seven years and older, body mass estimates were created using age specific predicting equations (see Ruff 2007) based on the superior-inferior breadth of the femoral head taken perpendicular to the neck-head axis to the nearest 0.1mm. It should be noted that for adolescents 15 to 17 years of age the most accurate way to estimate body mass is a sex-specific predicting equation which combines measures of bi-iliac breadth with long bone lengths, however, preservation is a common issue with obtaining bi-iliac breadths in which case the femoral head measure equation is an acceptable alternative for individuals up to 14.5 years of age and 16.5 years of age and older; there are currently no predicting equations for individuals 15-16 years old (Ruff 2007).

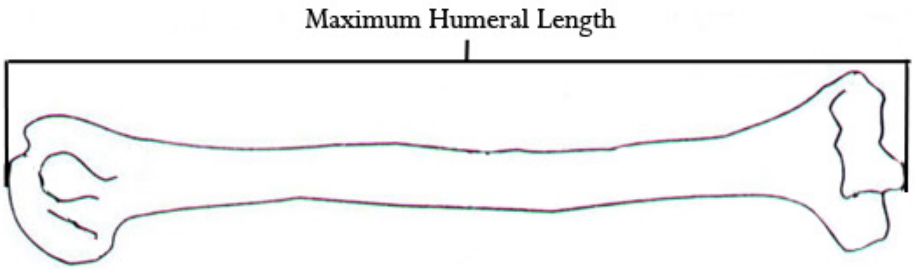
FIGURE 5.1: Subadult (< 7 yrs.) Femoral Measurements



(Modified from Scheuer and Black 2000)

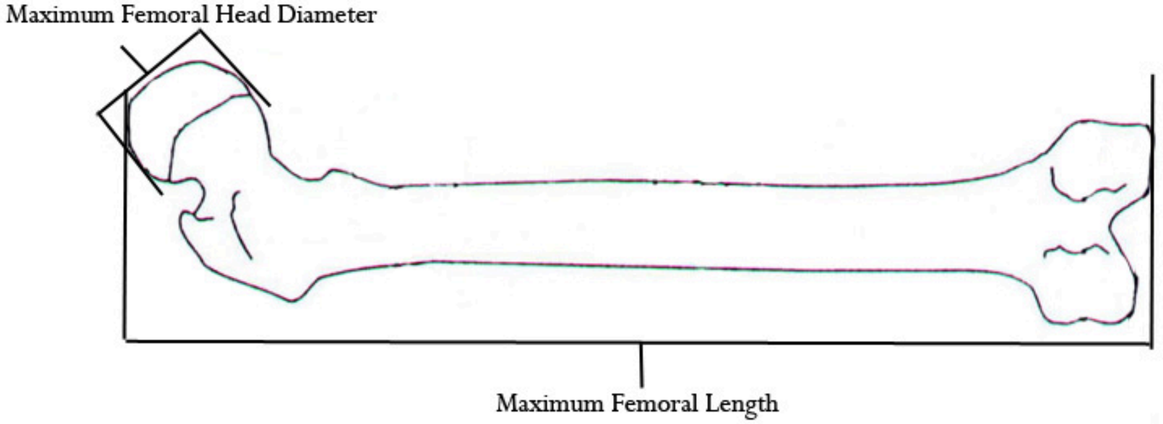
Standardization of several cross-sectional properties further require the length of the bone being analyzed; to that end, maximum humeral (Fig 5.2) and femoral (Fig 5.3) length measurements were taken according to the guidelines in Buikstra and Ubelaker (1994). For individuals aged 13-17 years old with unfused epiphyses which cannot be temporarily attached, maximum diaphyseal lengths (Figs 5.1 and 5.6) can be converted into total lengths following Ruff (2007): femur diaphyseal length *1.097 and humeral diaphyseal length*1.079. For subadults, cross sectional areas were corrected by dividing the property by body mass, second moments of area were corrected by dividing the property by the product of body mass and bone length^2.

FIGURE 5.2: Humeral Measurements



(Modified from Buikstra and Ubelaker 1994)

FIGURE 5.3: Femoral Measurements



(Modified from Buikstra and Ubelaker 1994)

5.2 CROSS-SECTIONAL GEOMETRY

Computed tomography (CT) scans were taken at the Leiden University Medical Center on a Toshiba Vision One Aquillon Machine with the assistance of medical professionals. Machine settings are listed below in Table 5.1 and image reconstruction was initially completed using Bone Standard FC30, which gives a better detail of trabecular architecture with full rotation for reconstruction. Images were saved as dicom files, then exported to ImageJ (http://rsweb.nih.gov/ij/index.html) and analyzed using the MomentMacro plugin (http://www.hopkinsmedicine.org/fae/mmacro.htm).

TABLE 5.1: Computed Tomography Machine Settings

Display Field of View	60.5mm
Kv	100
mA	200
Eff. mAs	200
Rotation Time	1 second
Focus Size	Small
Slice Thickness	1mm

Pre-scan preparation included inspection of each bone for any postmortem cracks in the area to be scanned, as this would distort the cross sectional geometry. Each bone was then placed on a custom L-shaped wooden board and orientated according to established protocols (Ruff and Hayes 1983; Ruff and Leo 1986; Ruff 2002; Cowgill et al. 2010; Garofalo 2012). For adult humerii, the coronal plane is the antero-posterior midpoint of the diaphysis at the surgical neck to the antero-posterior midpoint of the diaphysis at the proximal edge of the olecranon fossa (Ruff 2002:337). The sagittal plane is the medio-lateral midpoint of the shaft at the surgical neck through the lateral lip of the trochlea (Ruff

2002:339; Garofalo 2012:80). The distal end of the trochlea was placed against the wooden backboard, then lifted with a small amount of modeling clay until the posterior side was level with the (proximal) neck at the junction of the humeral head as shown in Figure 5.4. For subadult humerii, the coronal plane is the same as an adult's, however, the sagittal plane's distal most point is 1/3 of metaphyseal breadth from the lateral edge (Garofalo 2012:80).

FIGURE 5.4: Humeral Orientation for CT Scanning

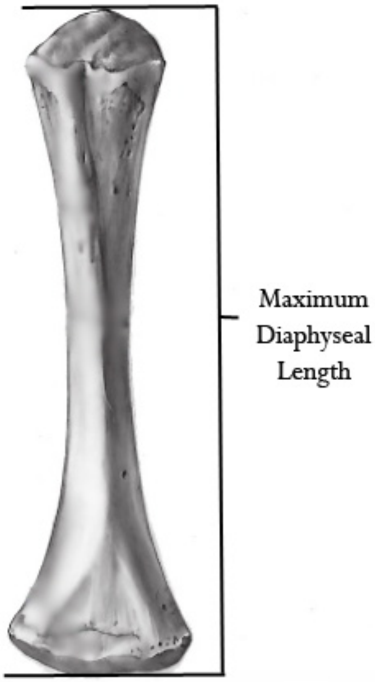
For adult femurs, the coronal plane extends from the midpoint of the diaphysis just distal to the lesser trochanter, to the midpoints of the antero-posterior width on the medial and lateral sides just proximal to the condyles (Garofalo 2012:79). The femoral sagittal plane extends from the mid-point of the medio-lateral diameter of the diaphysis just distal to the lesser trochanter to the deepest point of the intercondylar notch (Garofalo 2012:79). The femur was placed posterior side down with the distal end of the medial epicondyle against the wooden backboard, the proximal end was then lifted with a small amount of modeling clay until the coronal plane was parallel to the surface of the board, essentially a line bisecting the greater trochanter and the center of the epicondyle when viewed laterally (Figure 5.5) (Ruff and Hayes 1983: 363; Ruff 2002:337).   For subadult femurs, the coronal plane ends just before the distal flare of the diaphysis (Garofalo 2012:79). The subadult femoral sagittal plane is similar to adults; the linea aspera can be used as a guideline and the deepest point of the anterior hollow can be used to approximate the location of where the intercondylar notch will be (Cowgill et al 2010:54; Garofalo 2012:79).

FIGURE 5.5: Femoral Orientation for CT Scanning

Determination of the CT scan point depends on the type of bone being examined as well as the skeletal maturity of the individual. For the humerus, biomechanical length (BL) in adults extends from the most proximal point on the head to the distal most projection of the lateral trochlea (Ruff 2002:339). In subadults humeral BL extends from the most proximal point on the head to the distal most projection of the capitulum (prior to trochlear fusion). Intermetaphyseal lengths (IL) of humerii were used for infants and subadults with unfused/missing both epiphyses (Figure 5.6); these are defined as maximum diaphyseal length (Buikstra and Ubelaker 1994:46).

For the femur, adult's BL is determined as the average distal projection of the condyles to the intersection of the long axis with the superior surface of the femoral neck (Trinkaus et al. 2002:442; Ruff and Hayes 1983:363; Ruff 2002:337). This was taken by using spreading calipers to first measure from the most superior point on the neck to the most distal projection of the medial condyle, then from the most superior point on the neck to the most distal projection of the lateral condyle, final BL is the average of these two measurements. For subadults with femoral epiphyses, I attached the distal epiphyses with a tiny amount of modeling clay and then measured BL according to the adult protocol, using either sliding calipers (to the nearest 0.01mm) or an osteometric board (to the nearest 0.5mm). Intermetaphyseal lengths (IL) of femora were used for infants and subadults with unfused/missing epiphyses; these are defined as the maximum diaphyseal length (Figure 5.1) which can be measured according to Measurement #17(a) for immature remains in *Standards* (Buikstra and Ubelaker 1994:46).

FIGURE 5.6: Subadult Humeral Intermetaphyseal Length



(Modified from Cunningham et al. 2016)

The scan point for adult humerii was taken at 35% of BL from the distal end (BL x 0.035= scan point), which is now standard procedure in order to avoid inconsistencies that may be caused by the *deltoideus* insertion (Niinimäki 2012; Ruff 2008a:187; Stock and Shaw 2007). The scan point for subadult humerii was taken at 36% of IL from the distal end. It should be noted that Garofalo (2012) uses 41% of IL from the distal end, however, she also uses 40% of BL in adults instead of the now standard 35%, thus, I chose to maintain the more widely accepted scan point of 35% with a 1% increase to adjust for the unfused epiphyses (Garofalo 2012:80).

The scan point for adult femora was 50% of BL from the proximal end (since the distal point is on an imaginary line) (Ruff et al. 1983; Ruff 2000, 2002). For subadults with epiphyses, the adult protocol was followed as well, so long as BL was able to be taken. For subadults/infants without epiphyses, the scan point was determined as 54.5% of IL, taken from the proximal end (Ruff 2003; Cowgill et al 2010:54; Garofalo 2012:69).

5.3 ENTHESEAL CHANGES

A large number of musculoskeletal insertion sites were chosen from across the human body in order to represent a variety of major muscle groups as well as a wide range of movement. Insertion sites were chosen instead of origin sites since muscle contraction produces the greatest osteological effects at the insertion (Hawkey and Merbs 1995:329). Table 5.2 lists the twenty-seven insertion sites chosen for data collection as well as the associated bony element, respective movements and type of entheseal structure; location of these sites are illustrated in Figures 5.7 through 5.19. It should be noted that during data collection I found the *sartorius*, *gracilis* and *semtendinous* muscle insertions to be too close together to clearly delineate individual scores so they were treated as a single insertion site. The *supraspinatus, infraspinatus* and *teres minor* were also combined into a single insertion site score as they are not only too close together to delineate individual scores but also move in unison to perform certain movements (Dugas et al. 2002; Curtis et al. 2006; Alves Cardoso and Henderson 2010). Combination of entheseal insertion sites that are too close together to confidently score individually was also required for the *latissimus dorsi* and *teres major* entheses of the humerus, as well as for the *piriformis, obturator internus and gemelli* entheses of the femur.

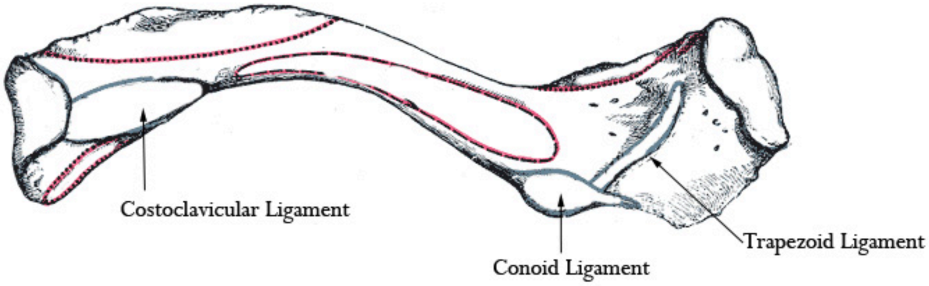
TABLE 5.2: Entheseal Insertion Sites Chosen for Analysis

ELEMENT	**ENTHESIS**	**MOVEMENT**	**STRUCTURE**
Clavicle			
	Costoclavicular Ligament	Primary restraint for the sterno-clavicular joint (Gray 1977:247)	Fibrocartilaginous
	Conoid Ligament	Limits rotation of the scapula posteriorly (Gray 1977:249)	Fibrocartilaginous
	Trapezoid Ligament	Limits rotation of the scapula anteriorly (Gray 1977:249)	Fibrocartilaginous
Humerus			
	Supraspinatus; Infraspinatus/Teres Minor	Weak Abductor; Horizontal Extensors with Lateral Rotation	Fibrocartilaginous
	Subscapularis	Extensor, Medial Rotator and Adductor	Fibrocartilaginous
	Pectoralis Major	Flexor, Extensor, Adductor and Medial Rotator	Fibrous
	Latissimus Dorsi / Teres Major	Horizontal Extensors, Medial Rotators and Adductors	Fibrous
	Deltoideus	Major Abductor	Fibrous
Ulna			
	Brachialis	Flexor	Fibrocartilaginous
	Triceps Brachii	Extensor	Fibrocartilaginous
Radius			
	Biceps Brachii	Flexor and Supinator (of forearm)	Fibrocartilaginous
	Supinator	Supinator	Fibrous
	Pronator Teres	Flexor and Pronator	Fibrous
Fifth Metacarpal			
	Extensor Carpi Ulnaris	Extensor	Fibrocartilaginous
	Flexor Carpi Ulnaris	Flexor	Fibrocartilaginous

TABLE 5.2: Entheseal Insertion Sites Chosen for Analysis (continued)

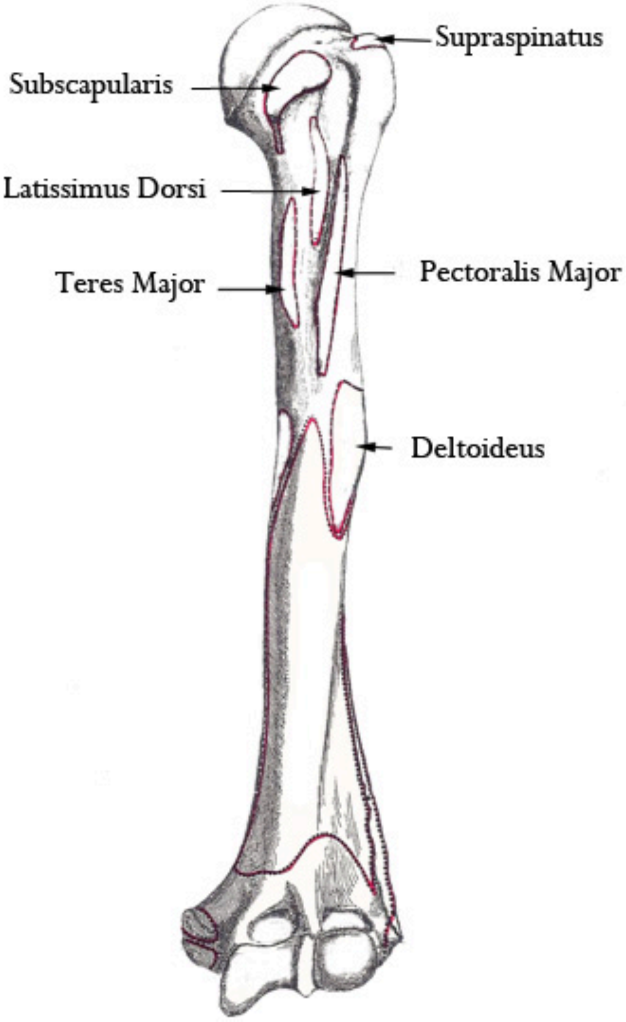
Femur			
	Piriformis/Obturator Internus/Gemelli	Abductor (when sitting) and Lateral Rotators (when standing) (Gray 1977:431)	Fibrocartilaginous
	Adductor Magnus	Adductor and Lateral Rotator	Fibrous
	Iliopsoas	Flexor and Lateral Rotator	Fibrocartilaginous
	Quadratus Femoris	Lateral Rotator	Fibrocartilaginous
	Gluteus Maximus	Extensor and Lateral Rotator	Fibrous
	Glueteus Medius	Abductor with Lateral Rotation	Fibrocartilaginous
	Gluteus Minimus	Abductor and Medial Rotator	Fibrocartilaginous
Patella			
	Quadriceps (rectus femoris, vastus lateralis, vastus intermedius and vastus medialis)	Extensor	Fibrocartilaginous
Tibia			
	Popliteus	Flexor and Medial Rotator	Fibrocartilaginous
	Semimembranosus	Extensor, Flexor (at knee) and Medial Rotator	Fibrocartilaginous
	Sartorius/Gracilis/ Semitendinous	Flexor and Lateral Rotator/ Adductor, Flexor (at knee) and Medial Rotator/Extensor, Flexor (at knee) and Medial Rotator	Fibrous (Benjamin et al. 2004)
Calcaneus			
	Gastrocnemius/Soleus (Achilles Tendon)	Plantar-flexor	Fibrocartilaginous

FIGURE 5.7: *Ligament Attachment Sites of the Inferior Clavicle*



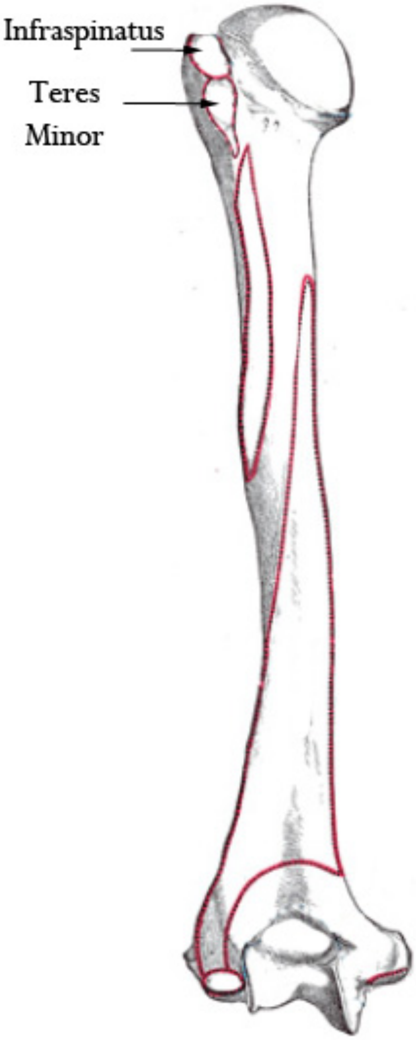
(Modified from Gray 1977)

FIGURE 5.8: Muscle Insertion Sites of the Anterior Humerus



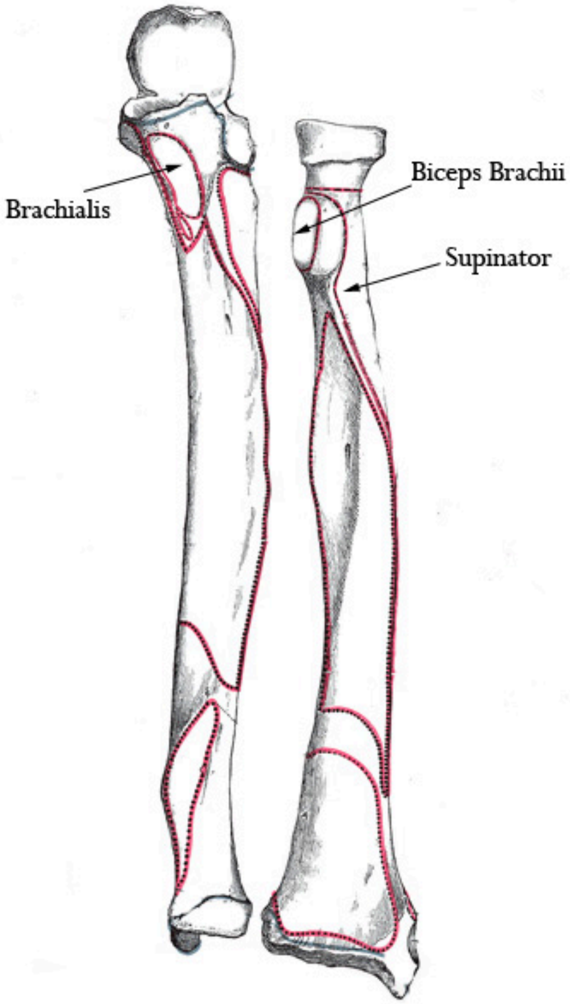
(Modified from Gray 1977)

FIGURE 5.9: Muscle Insertion Sites of the Posterior Humerus



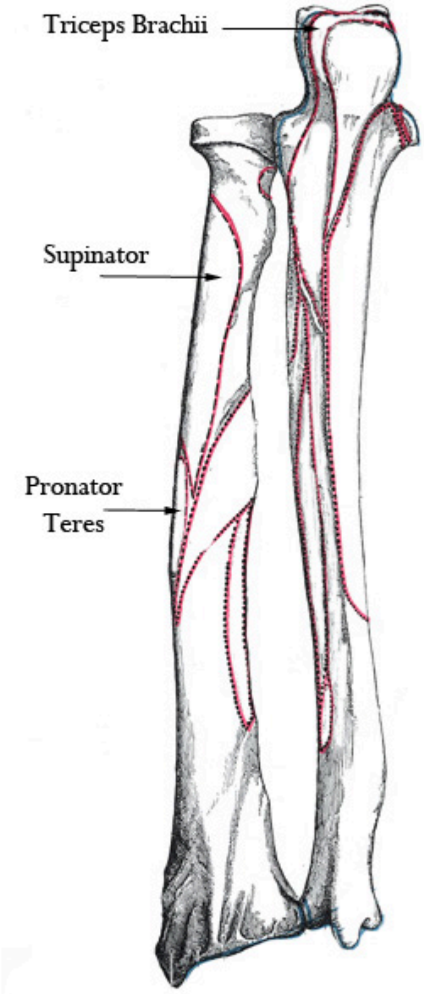
(Modified from Gray 1977)

FIGURE 5.10: Muscle Insertion Sites of the Anterior Radius and Ulna



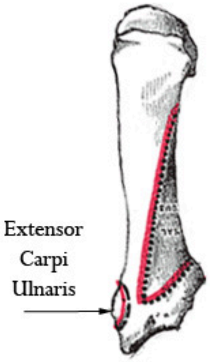
(Modified from Gray 1977)

FIGURE 5.11: Muscle Insertion Sites of the Posterior Radius and Ulna



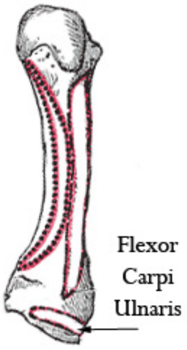
(Modified from Gray 1977)

FIGURE 5.12: Insertion Site of the Dorsal 5th Metacarpal



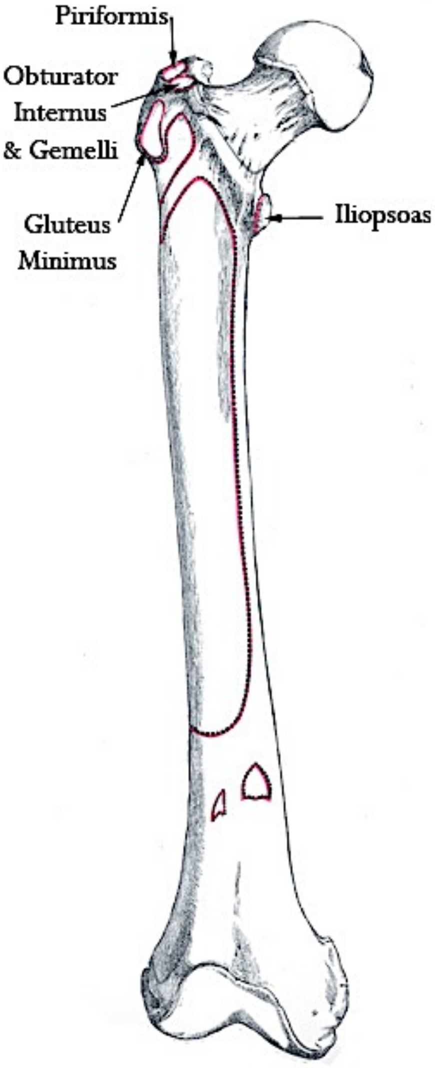
(Modified from Gray 1977)

FIGURE 5.13: Insertion Site of the Palmar 5th Metacarpal



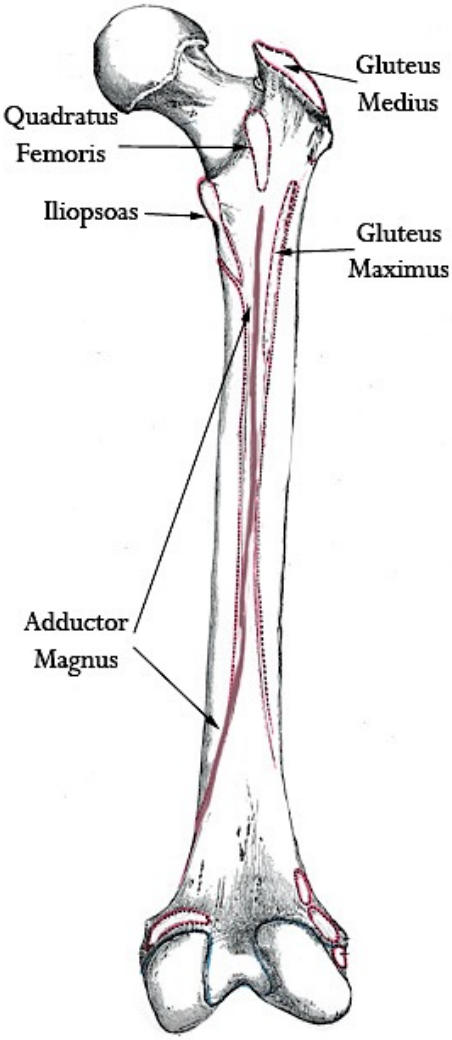
(Modified from Gray 1977)

FIGURE 5.14: Muscle Insertion Sites of Anterior Femur



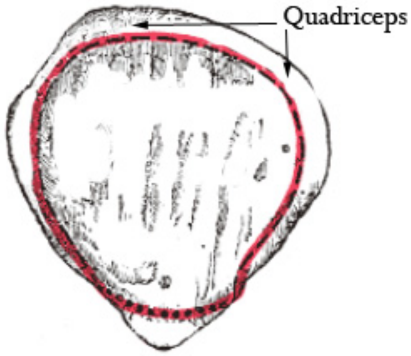
(Modified from Gray 1977)

FIGURE 5.15: Muscle Insertion Sites of the the Posterior Femur



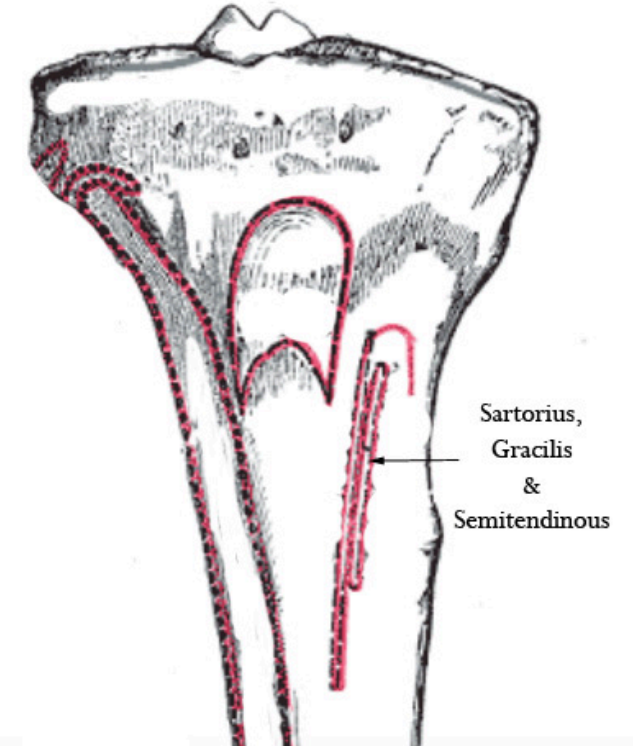
(Modified from Gray 1977)

FIGURE 5.16: Muscle Insertion Site of the Anterior Patella



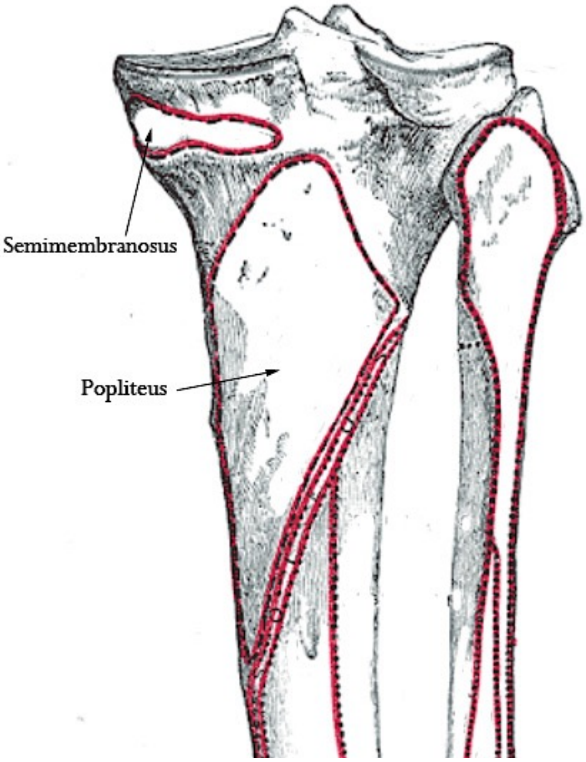
(Modified from Gray 1977)

FIGURE 5.17: Muscle Insertion Sites of the Anterior Tibia



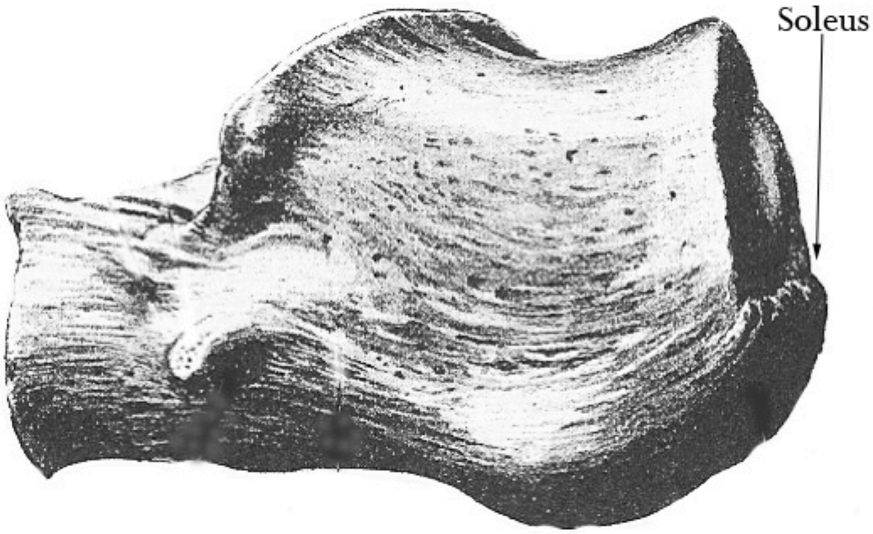
(Modified from Gray, 1977)

FIGURE 5.18: Muscle Insertion Sites of the Posterior Tibia



(Modified from Gray, 1977)

FIGURE 5.19: Muscle Insertion Site of the Calcaneus



(Modified from Gray, 1977)

Entheseal changes were scored in three broad categories of gross morphological expression: **robusticity**, **osteophytic formations** (ossification exostoses) and **osteolytic formations** (stress lesions). Each of these three categories was scored on a zero to three scale with zero representing absence and three representing severe, following protocols (when possible) established by Mariotti et al. (2004, 2007). It should be noted that while the 'New Coimbra Method' is currently recommended for research involving entheseal changes (as discussed in Chapter 3), at the time of data collection it had not yet been published. The methods established by Mariotti et al. were chosen because they provide standardized scoring schemes with detailed photographs and descriptions of each degree of development specific to each of 23 postcranial entheses and originally reported low rates of inter- and intraobserver error. Despite being criticized for failing to consider entheseal anatomy, the specificity of these descriptions often include a description of the 'tidemark' for fibrocartilaginous entheses (e.g. *biceps brachii* and *iliopsoas*) although this terminology is not specifically used.

A total of 14 entheseal insertions were analyzed for robusticty according to the Mariotti et al. (2007) protocol, the remaining 13 variables (which are not represented in the above protocol) were analyzed according to photographs and descriptions developed by Chilcote (2011) based on a repeated observations from a number of different skeletal collections (See Appendix). Additionally, although the categories of robusticity and osteolytic formations have often been collapsed into a single ordinal scale, where the former reflects continued muscle use in habitual activities and the latter reflects continuous microtrauma (a more rigorous and thus destructive muscle use), it is currently believed that this overemphasizes stress lesions and was therefore not done in this study (Niinimäki 2012:4). Tables 5.3 and 5.4 detail the protocols used for scoring enthesopathies at all 27 insertion sites analyzed.

TABLE 5.3: Scoring Scheme for Osteolytic Formations

Score		
0	=	Absence
1	=	Slight Stress Lesion: Presence of fine porosity (holes <1mm in diameter) *or* a pit less than 1mm deep
2	=	Moderate Stress Lesion: Diffuse porosity (holes ~1mm in diameter) *or* an area of erosion ~4mm in length and 1.1mm to 2.9mm deep
3	=	Severe Stress Lesion: several areas of erosion (~4mm in length) *or* a lesion longer than 4mm and >3mm deep

(Modified from Hawkey 1988, Hawkey and Merbs 1995, and Mariotti et al. 2004)

TABLE 5.4: Scoring Scheme for Osteophytic Formations

Score		
0	=	Absent
1	=	Slight Ossification Exostosis: less than 1mm long
2	=	Moderate Ossification Exostosis: 1.1mm to 4.0mm long
3	=	Severe Ossification Exostosis: 4.1 mm or longer

(After Mariotti et al. 2004)

5.4 OSTEOARTHRITIS

Appendicular joints chosen for the analysis of osteoarthritis are listed below in Table 5.5. Osteoarthritis was also scored on a zero to three scale where zero represents absence, one represents porosity, two represents lipping and three represents eburnation. Figure 5.20 depicts each of the three categories of osteoarthritis and was used as the standard reference for all joint surfaces recorded. To avoid over interpretation of results, as cautioned by Jurmain et al. (2012), presence of osteoarthritis for statistical analyses was limited to individuals who either exhibited eburnation or the co-occurrence of porosity and lipping.

FIGURE 5.20: Scoring Characteristics of Osteoarthritis

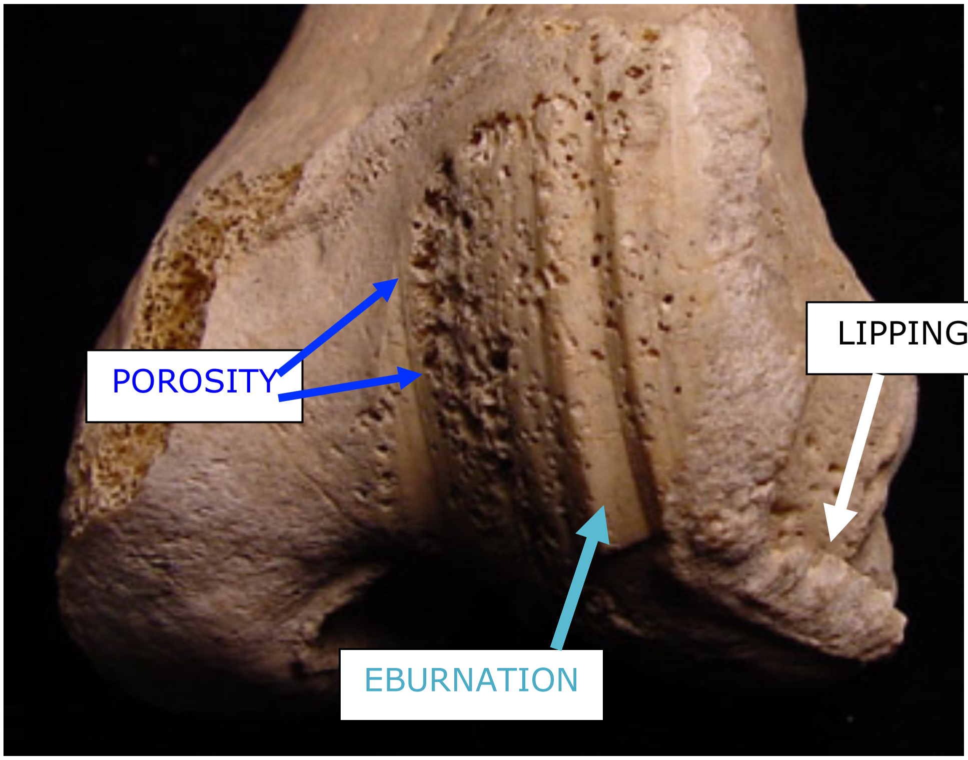


TABLE 5.5: Joints Analyzed for Osteoarthritis

JOINT	**BONES INVOLVED**	**SURFACE(S) INVOLVED**
Shoulder		
	Scapula	Glenoid Fossa
	Humerus	Humeral Head
Elbow		
	Humerus	Trochlea
		Capitulum
		Olecranon Fossa
	Ulna	Trochlear Notch
	Radius	Radial Head
Wrist		
	Ulna	Distal Ulnar Articular Surface
	Radius	Distal Radial Articular Surface
Hip		
	Innominate	Lunate Surface (w/in Acetabulum)
	Femur	Femoral Head
Knee		
	Femur	Medial Condyle
		Lateral Condyle
		Patellar Surface
	Tibia	Medial Condyle
		Lateral Condyle
Ankle		
	Tibia	Distal Articular Surface
	Talus	Trochlea
		Inferior Articular Surface
	Calcaneus	

5.5 NON-GENETIC NON-METRIC TRAITS

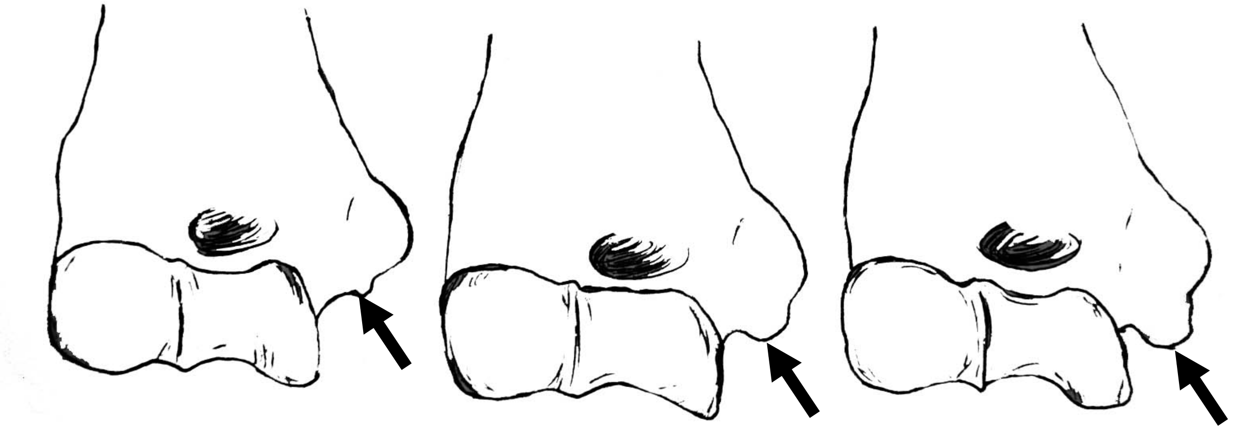
A total of eight non-genetic non-metric traits were also chosen with the goal of representing a variety of areas and thus movements of the body. The non-genetic non-metric traits analyzed are illustrated below in Table 5.6 and were chosen based upon the strength of previous research supporting their correlation to a habitual movement. Following Gruneberg's quasicontinuous model, as described previously, non-metric traits were scored on a zero to three scale following parameters I set before beginning data collection. These are illustrated below in Figures 5.21 through 5.31.

TABLE 5.6: Non-Genetic Non-Metric Traits Chosen for Analysis

ELEMENT	NON-METRIC TRAIT
Humerus	
	Epicondylar Exostosis
Femur	
	Exostoses of the Trochanteric Fossa
	Articular Border Convexity
	Poirier's Facet
	Tibial Imprint
	Martin's Facet
Tibia	
	Osgood-Schlatter
	Ankle Flexion Facet

Epicondylar exostoses (Figure 5.21) of the humerus are hypertrophic manifestations that occur on the medial epicondyle. Formation of these osteophytes has been correlated to hyperactivity of the *flexor carpi radialis, palmaris longus, flexor digitorum superficialis, flexor carpi ulnaris* and *pronator teres*, the usage of which has been linked to the throwing and swinging of objects (Dutour 1986; Capasso *et al* 1999:64).

FIGURE 5.21: Categories of Epicondylar Exostosis



Left to Right: Grade 1 = ≤ 2.9mm. Grade 2 = 3mm to 6.9mm. Grade 3 = 7mm or greater.

Exostoses of the trochanteric fossae (Figure 5.22) are hypertrophic manifestations "located on the superior medial surface of the trochanteric fossa at the insertion site of the *obturator externus*" (Capasso *et al* 1999:120). Hawkey and Street (1992) linked the formation of these exostoses to sitting with the legs extended for prolonged periods of time.

FIGURE 5.22: Categories of Exostoses of the Trochanteric Fossae

Left to Right: Grade 1 = one or two bone spicules ≤ 1.0 mm in length. Grade 2 = 1.1mm to 4.0 mm in length. Grade 3 = 4.1mm or greater, and merging of exostoses results in a cauliflower-like appearance.

Articular border convexity (Figure 5.23) is apparent when the articular anterior-superior border of the femoral neck is prominently curved to a well-marked convexity, and there is a well-defined groove for the *obturator externus* (Capasso *et al* 1999:103). The formation of this particular non-metric trait has been linked to both squatting and sartorial posture (Charles 1893-1894).

FIGURE 5.23: Categories of Articular Border Convexity

Left to Right: Grade 1 = Slight blending of articular surface and neck. Grade 2 = Defined blending. Grade 3 = Blending and formation of a lip.

Poirier's facet (Figures 5.24 and 5.25) is the bulging of the femoral head at its most anterior and medial extension, and it is often accompanied by an anterior cervical eminence on the femoral neck (Capasso *et al* 1999:104). The formation of this facet has been linked to normal locomotion, but more commonly results from extreme extension (Capasso *et al* 1999:104).

FIGURE 5.24: Poirier's Facet

FIGURE 5.25: Categories of Poirier's Facet

Left to Right: Grade 1 = Slight blending. Grade 2 = Marked eminence. Grade 3 = Severe eminence including a ridge at border of femoral head.

The **tibial imprint** (Figure 5.26 and 5.27) is an indentation located on the posterior of the distal femur, most commonly above the medial condyle although it may appear bilaterally (i.e. above the lateral condyle) as well (Capasso *et al* 1999:108). The presence of a tibial imprint has also been related to habitual squatting (Kostick 1963).

FIGURE 5.26: Tibial Imprint

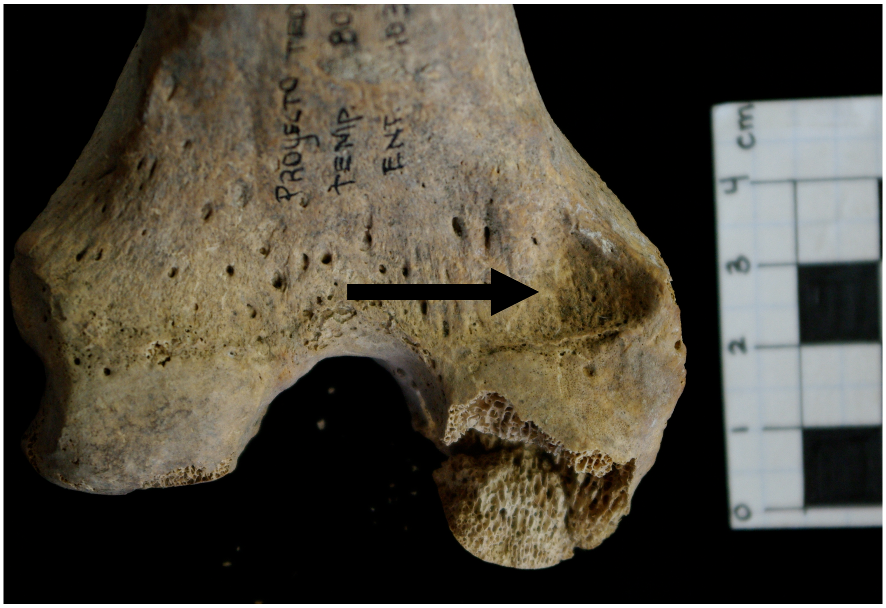


FIGURE 5.27: Categories of Tibial Imprint

Left to Right: Grade 1 = Slight impression medially. Grade 2 = Distinct impression medially. Grade 3 = Severe impression(s) or bilateral occurrence.

Martin's facet (Figure 5.28 and 5.29) is represented by the "rounding of the lateral trochlear margin as the articular surface is extended to the outer surface of the femoral condyle…when viewed laterally, the facet is crescent-shaped" (Capasso *et al* 1999:109). The presence of Martin's facet has also been associated with habitual squatting (Kostick 1963).

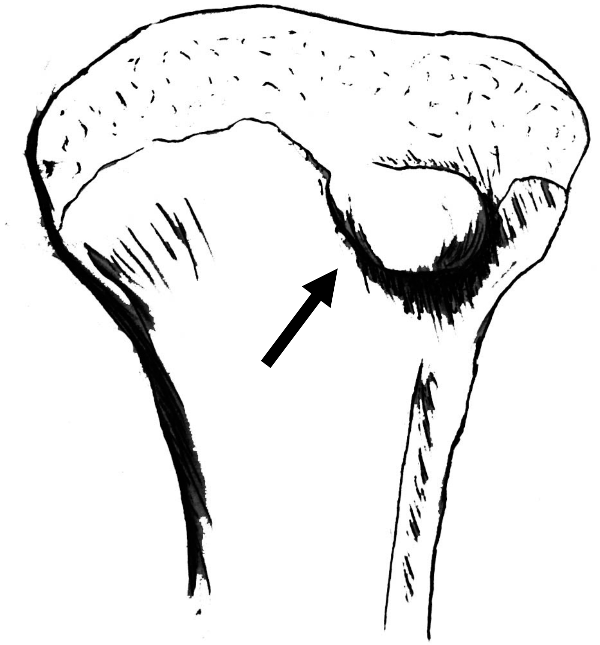
FIGURE 5.28: Martin's Facet

FIGURE 5.29: Categories of Martin's Facet

Left to Right: Grade 1 = Slight rounding at the top of the lateral trochlear margin. Grade 2 = Rounding from the top down the side of the lateral trochlear margin. Grade 3 = Full blending of the upper area of the lateral trochlear margin.

Osgood Schlatter's disease (Figure 5.30) is, despite the name, not a pathological trait. It is a "lesion of the tibial tubercule resulting from partial avulsion of the patellar tendon insertion due to the pull of the quadriceps" on an unfused epiphyseal plate (Capasso *et al* 1999:123).

FIGURE 5.30: Categories of Osgood-Schlatter's Disease



Scored as present (depicted above) or absent.

Ankle flexion facets (Figure 5.31), also known as squatting facets, can occur on both the distal anterior edge of the tibia and the anterior edge of the trochlea of the talus.

These facets are the result of pressure from the opposing surfaces during dorsiflexion and have been linked to squatting (Capasso *et al* 1999:127) as well as to the kneeling position engaged by Anasazi women when using a metate (Merbs and Euler 1985).

FIGURE 5.31: Categories of Tibial Ankle Flexion Facet

Left to Right: Grade 1 = Very slight indentation. Grade 2 = Superior edge of indentation almost defined. Grade 3 = Superior edge of indentation clearly defined across entire length.

CHAPTER 6: RESULTS

6.1 SUB-ADULT CROSS-SECTIONAL GEOMETRY

Prior to cross-sectional analyses, subadult body masses were calculated for size standardization following the protocols discussed in the previous chapter. Unfortunately, for three out of the four adolescent individuals in this research project it was not possible to measure bi-iliac breadth. Further, ages are not accurate to within the required one year, and sex is unknown from historical documents for all of them. Due to these complications these individuals were excluded from further analyses. Since only one individual aged 14 remained in the adolescent category, I chose to expand the 'Older Child Category' from 10-13.99 years of age to 10-14 years of age. Table 6.1 presents the final sample sizes, minimum and maximum measurements, means and standard deviations for the variables used to correct for body size.

Since no body mass predicting equation exists for the perinate category their cross sectional data is not comparable to the other standardized subadult categories, however ratios are the same whether the data is standardized or not so they are included in shape analyses. Tests for normal distribution on the subadult femur sample revealed one extreme outlier in the Young Child category whose Ix/Iy value was 9 standard deviations (SD) above the mean and their Imax/Imin value was 6 SDs above the mean. These extreme values are likely reflective of an underlying pathological condition, therefore this individual was removed from further analyses. The final sample sizes, means and standard deviations for each of the femoral cross sectional variables analyzed are listed in Table 6.2 and illustrated by boxplots in Figures 6.1-6.11.

TABLE 6.1: Sample Descriptions for Subadult Body Mass Estimates

Age Category		**Femoral Length* (mm)**	**Body Mass (kg)**
Perinate	Mean:	77.4	N/A
N=6	Min:	72.7	N/A
	Max:	80.1	N/A
	SD:	2.6	N/A
Infant	Mean:	N/A	N/A
N=0	Min:	N/A	N/A
	Max:	N/A	N/A
	SD:	N/A	N/A
Young Child	Mean:	185.7	12.8
N=7	Min:	108.3	8.1
	Max:	229	15.7
	SD:	40.9	3.2
Middle Child	Mean:	288.7	24.8
N=4	Min:	251.4	16.0
	Max:	322	32.8
	SD:	28.9	7.1
Older Child	Mean:	341.6	33.6
N=5	Min:	303	25.0
	Max:	419	51.8
	SD:	52.0	10.8

*Femoral lengths are intermetaphyseal for the Perinate and Young Child catgeories and biomechanical for the Middle and Older Child categories

TABLE 6.2: Descriptive Statistics for Subadult Femoral Cross Sectional Variables

Age Category	**N**	**Total Area**		**Cortical Area**		**Medullary Area**		**% Cortical Area**	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Young Child	6	9.85	2.07	6.13	1.57	3.71	0.77	61.69	6.16
Middle Child	4	9.73	2.11	5.74	0.41	3.99	1.75	60.56	9.57
Older Child	5	8.63	0.25	5.8	0.37	2.83	0.6	67.35	5.94

Age Category	**N**	**Ix**		**Iy**		**Ix/Iy**	
		Mean	SD	Mean	SD	Mean	SD
Perinate	6	N/A	N/A	N/A	N/A	0.86	0.07
Young Child	6	0.002	0.001	0.003	0.001	0.88	0.06
Middle Child	4	0.002	0.001	0.002	0.001	0.92	0.18
Older Child	5	0.001	0	0.001	0	1.12	0.12

Age Category	**N**	**Imax**		**Imin**		**Imax/Imin**	
		Mean	SD	Mean	SD	Mean	SD
Perinate	6	N/A	N/A	N/A	N/A	1.25	0.11
Young Child	6	0.003	0.001	0.002	0.001	1.28	0.06
Middle Child	4	0.002	0.001	0.002	0.001	1.27	0.12
Older Child	5	0.002	0	0.001	0	1.2	0.08

Age Category	**N**	**J**	
		Mean	SD
Young Child	6	0.005	0.001
Middle Child	4	0.004	0.001
Older Child	5	0.003	0

FIGURE 6.1: Distribution of Subadult Mean Scores for Total Area by Age Group

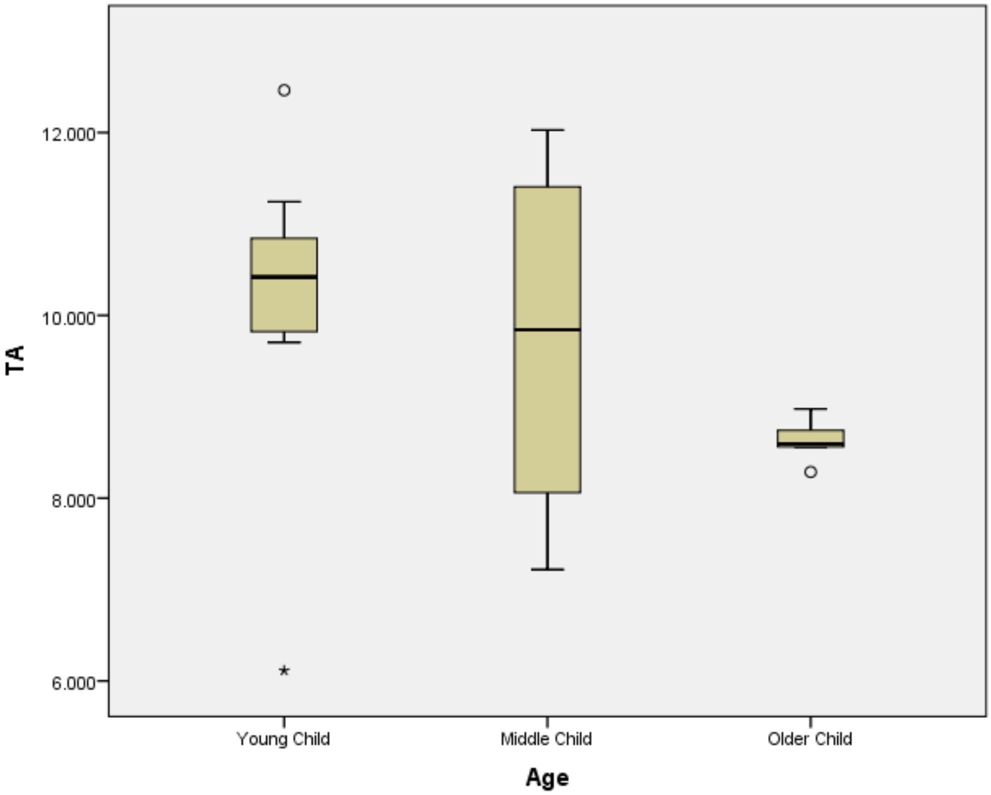


FIGURE 6.2: Distribution of Subadult Mean Scores for Cortical Area by Age Group

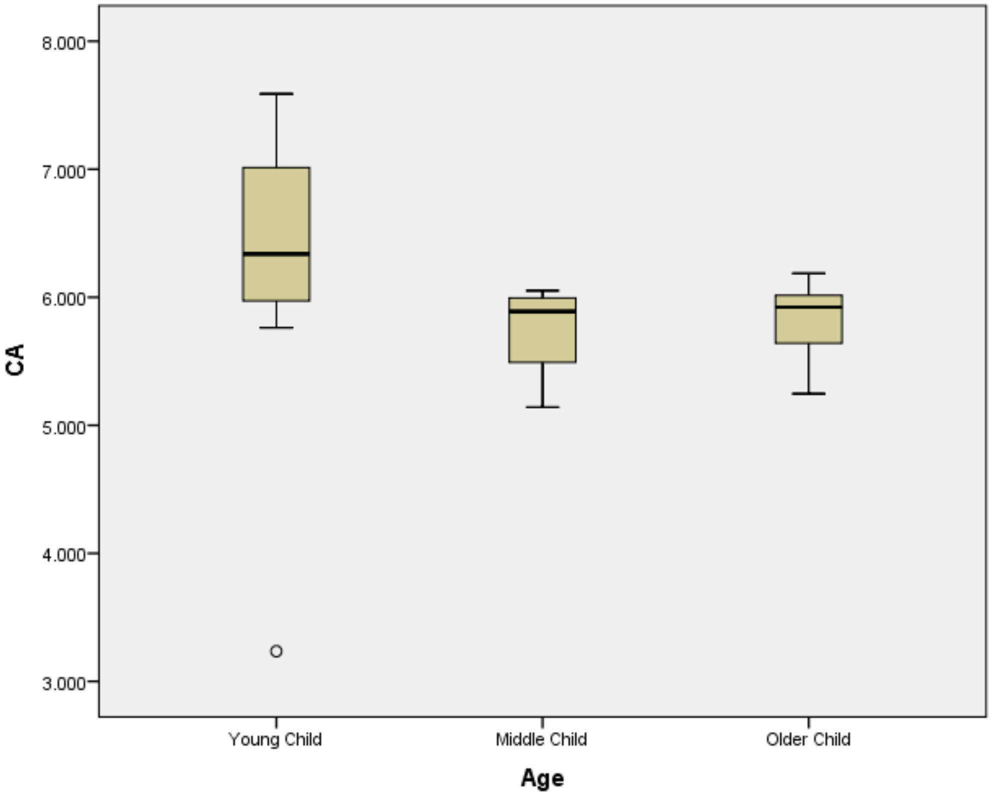


FIGURE 6.3: Distribution of Subadult Mean Scores for Medullary Area by Age Group

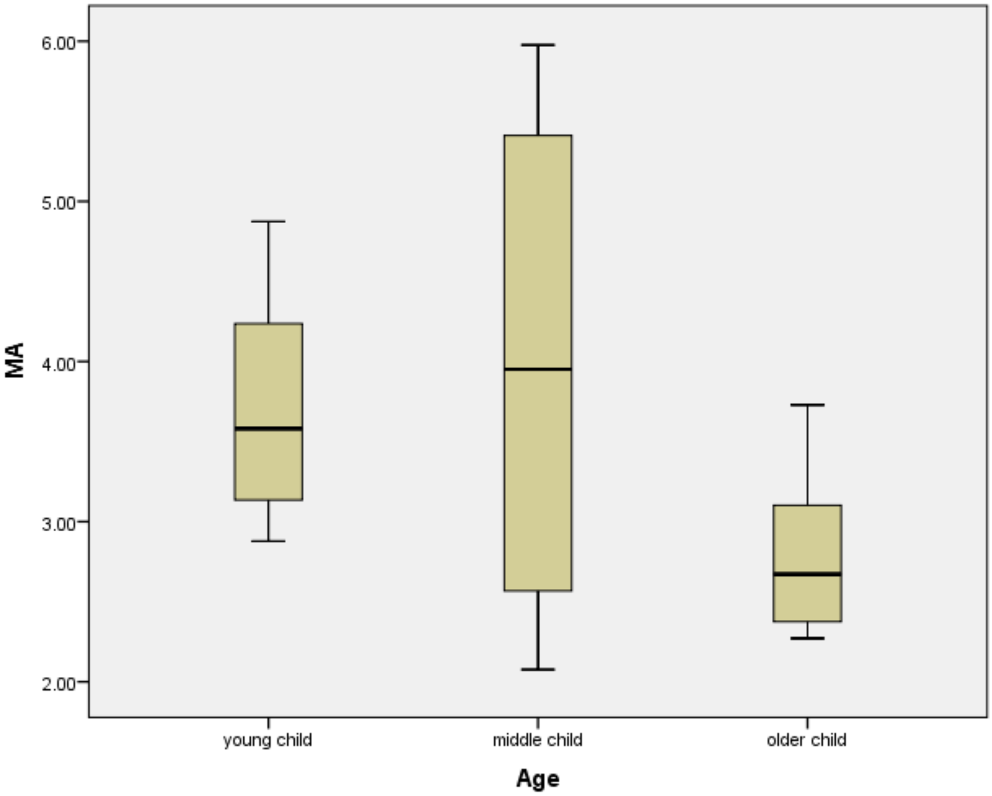


FIGURE 6.4: Distribution of Subadult Mean Scores for Percent Cortical Area by Age Group

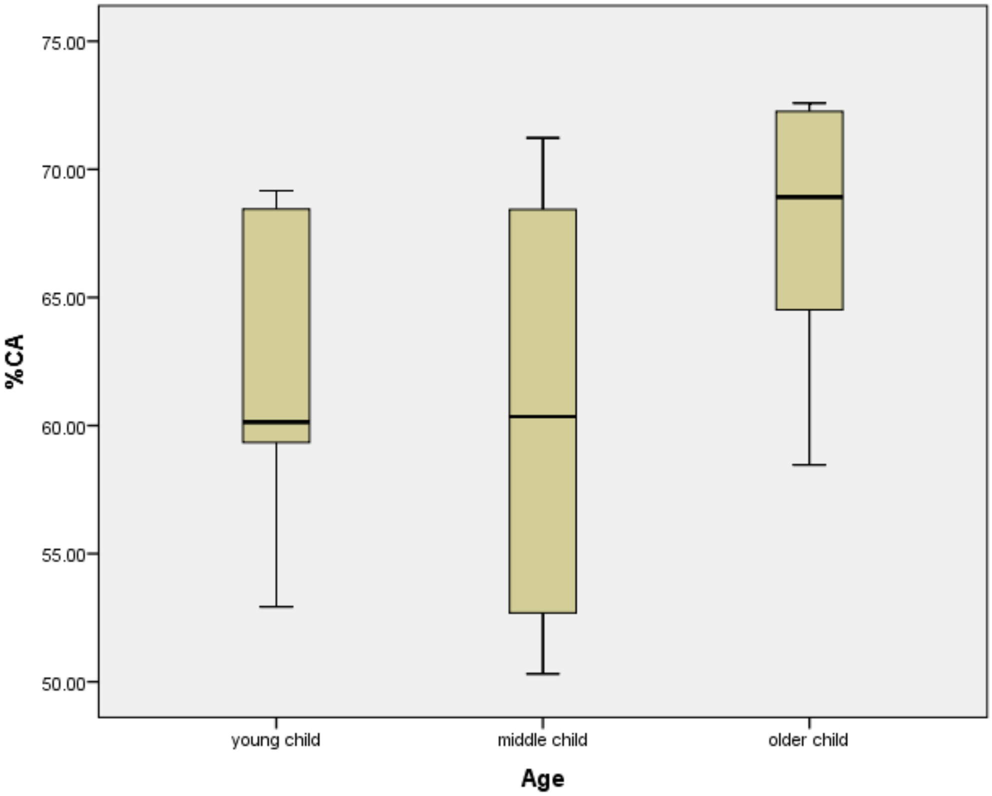


FIGURE 6.5: Distribution of Subadult Mean Scores for Ix by Age Group

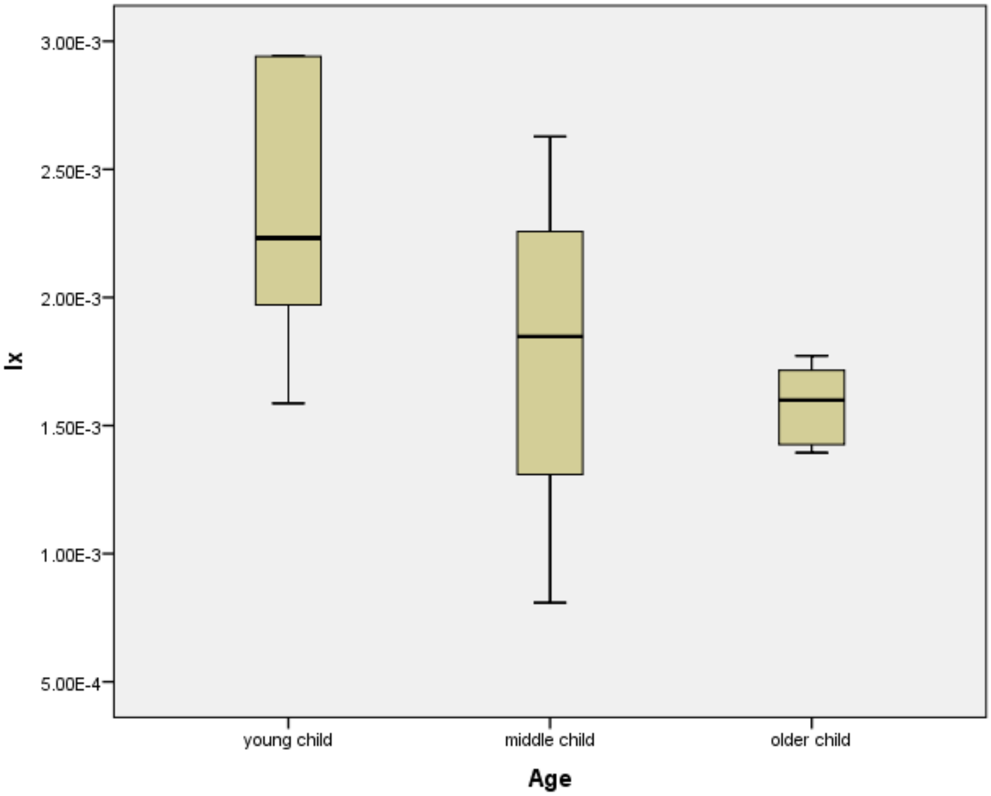


FIGURE 6.6: Distribution of Subadult Mean Scores for Iy by Age Group

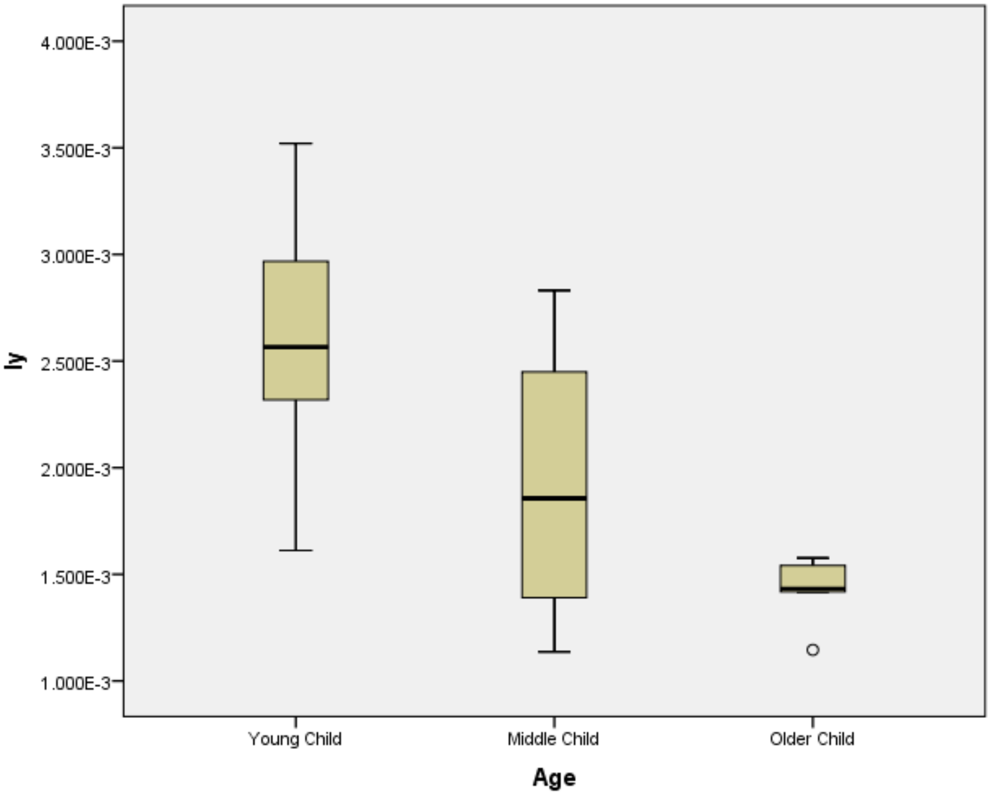


FIGURE 6.7: Distribution of Subadult Mean Scores for Ix/Iy by Age Group

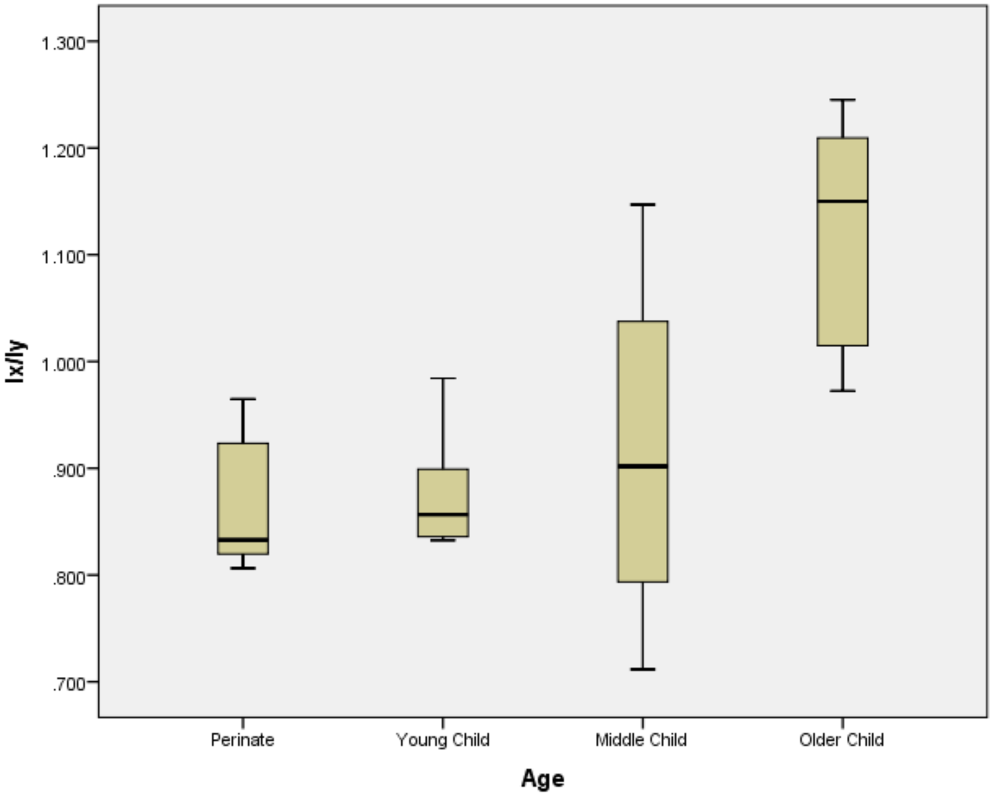


FIGURE 6.8: Distribution of Subadult Mean Scores for Imax by Age Group

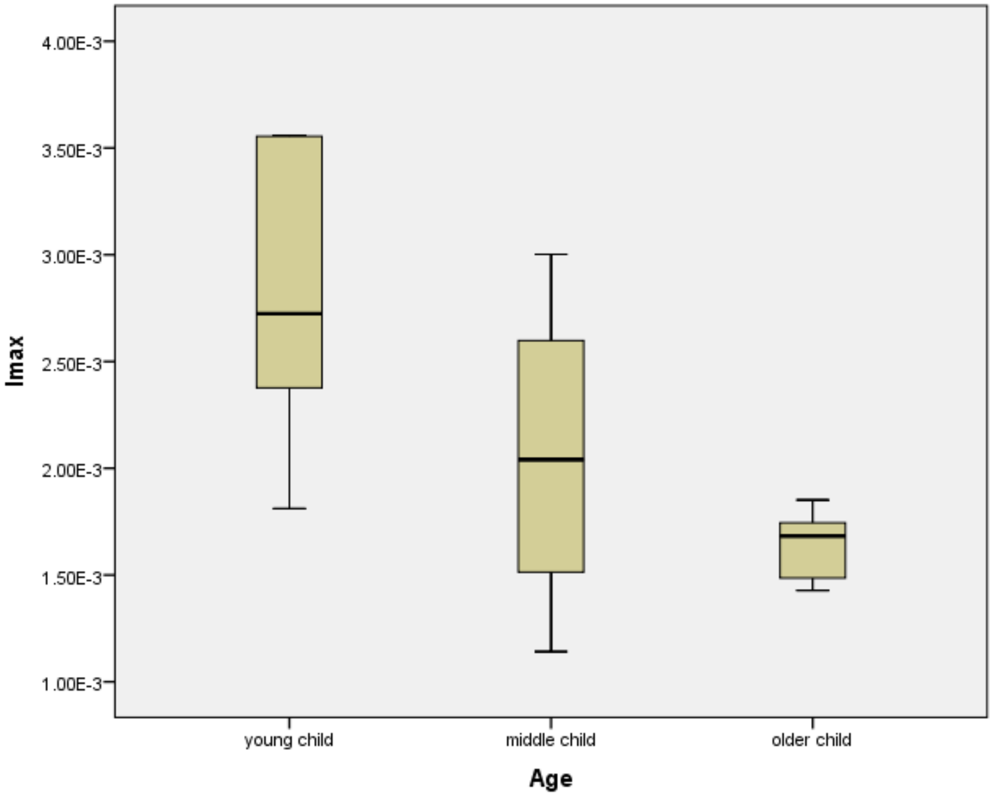


FIGURE 6.9: Distribution of Subadult Mean Scores for Imin by Age Group

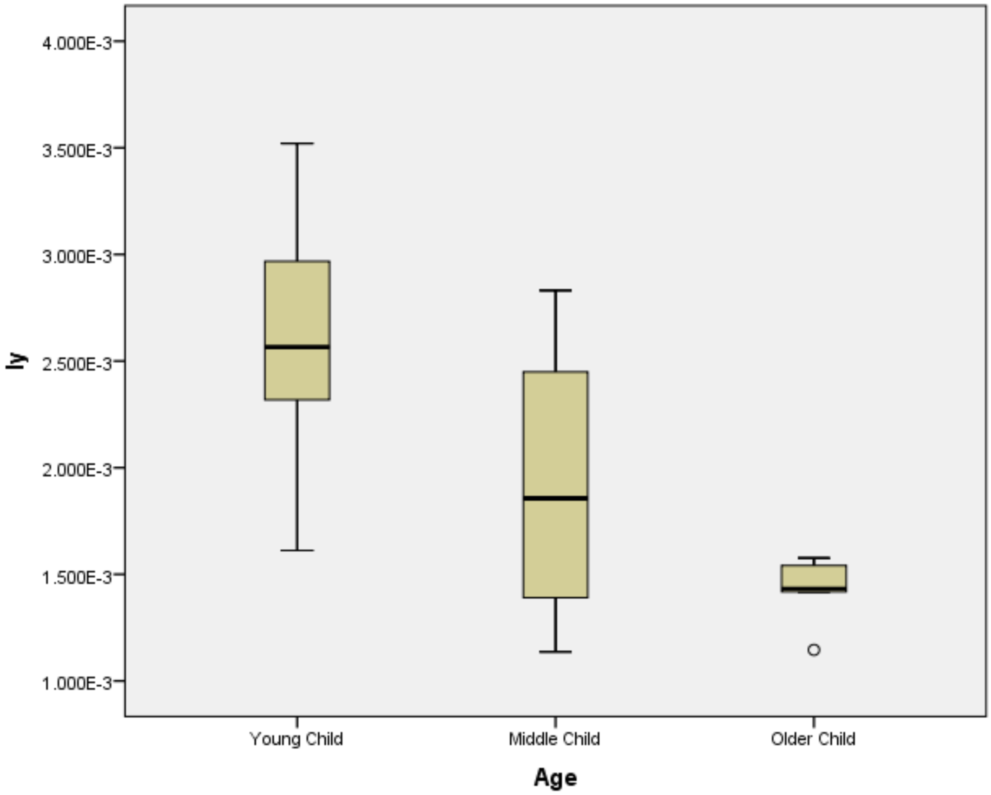


FIGURE 6.10: Distribution of Subadult Mean Scores for Imax/Imin by Age Group

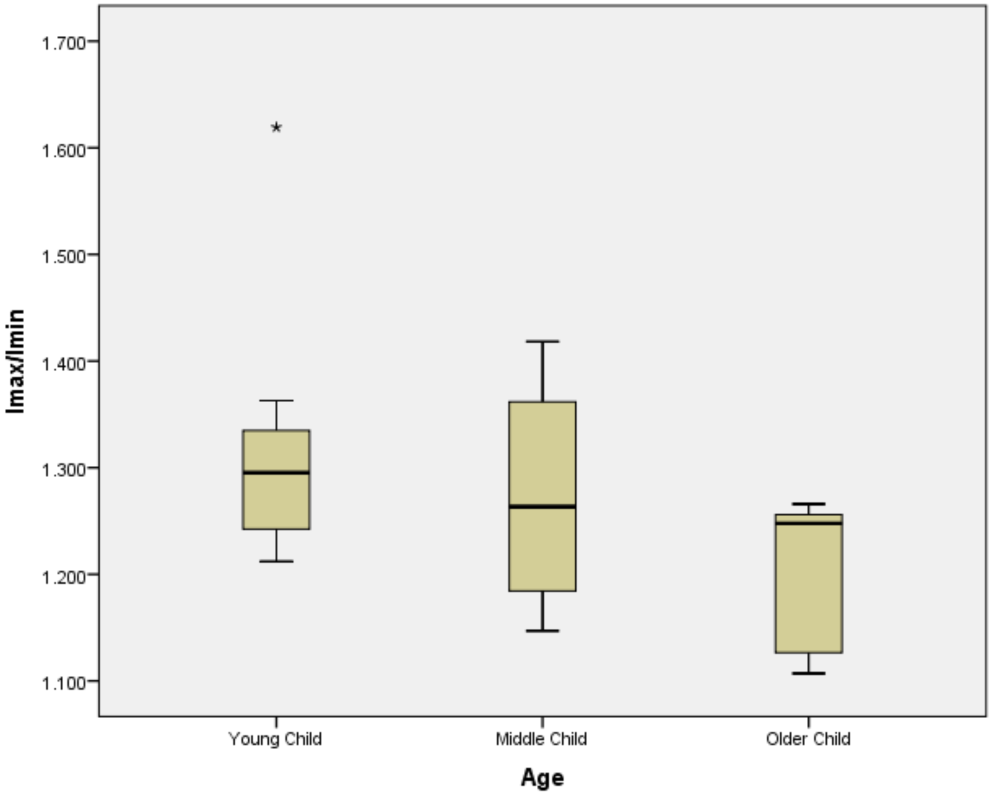
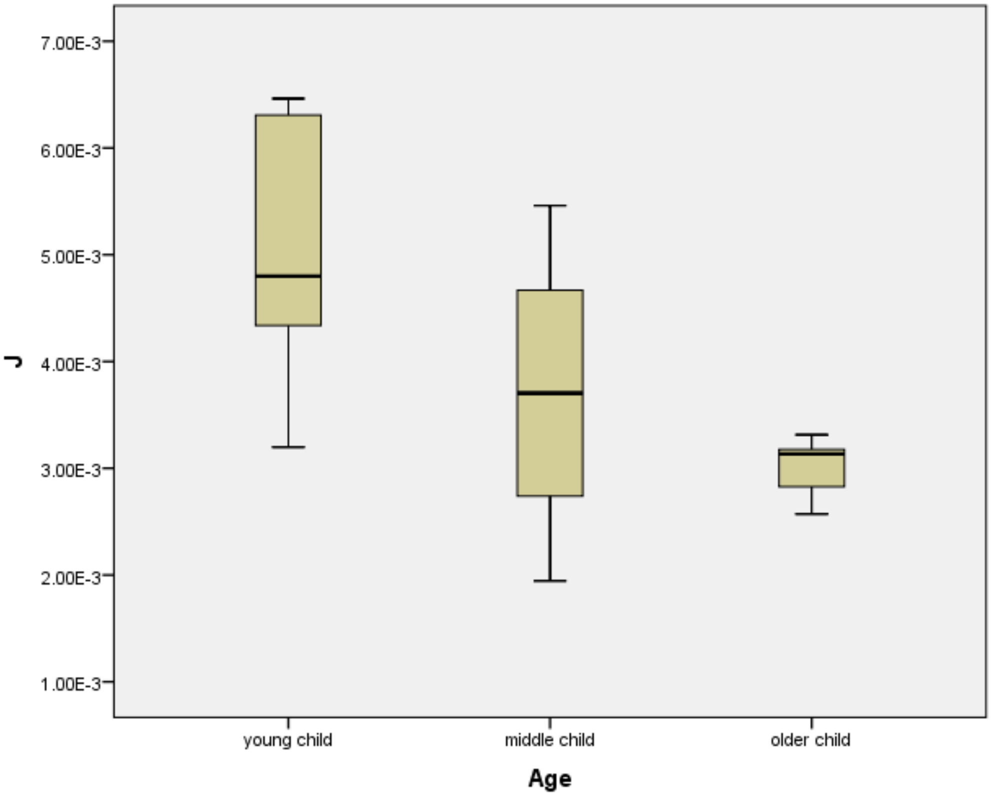


FIGURE 6.11: Distribution of Subadult Mean Scores for J by Age Group



Due to the extremely small sample sizes for each age category non-parametric tests were used to analyze the data. Spearman correlations were run on all variables to see if age correlated with measures of cross sectional geometry. The Spearman rho correlation coefficients and significance values are listed in Table 6.3; with the exception of cortical area and the Imax/Imin ratio, all variables showed a moderate to strong correlation with age. Percent cortical area and the Ix/Iy ratio increase as age increases, while all other cross-sectional properties decrease as age increases. Age correlates significantly with Ix ($P = 0.011$), Iy ($P = 0.002$), Imax ($P = 0.003$), Imin ($P = 0.011$) and J ($P = 0.003$).

TABLE 6.3: Two-tailed Spearman Correlation Coefficients for Age and Cross Sectional Properties of Subadults

Variable	**Correlation Coefficient**	**Significance**
TA	-0.429	0.11
CA	-0.294	0.287
MA	-0.448	0.094
% CA	0.319	0.246
Ix	-0.632*	0.011
Iy	-0.741**	0.002
Ix/Iy	0.644**	.002
Imax	-0.705**	0.003
Imin	-0.632*	0.011
Imax/Imin	-0.214	.351
J	-0.705**	0.003

*$P \leq 0.05$
**$P \leq 0.01$

Kruskal-Wallis tests were used to compare cross sectional variables across the age groups analyzed and returned significant results for Iy, Ix/Iy, Imax and J, as detailed in Table 6.4. Mann-Whitney U tests with a Bonferroni adjustment were then applied to explore which age groups were statistically significantly different from one another. For the second moments of area this adjustment sets the significance level at $P \leq 0.017$, however, in order to keep the alpha level manageable for the Ix/Iy ratio, which included the Perinate age category, it was necessary to limit the number of comparisons being made, thus the young child and middle child groups were not compared and significance was set at $P \leq 0.01$. Table 6.5 details the Mann-Whitney U test comparisons; significant differences were found between the Young Child and Older Child categories for Iy ($P = 0.006$), Imax ($P = 0.011$), and J ($P = 0.011$). For the Ix/Iy ratio, significant differences were found between both the Perinate and Older Child categories ($P = 0.006$) as well as the Young Child and Older Child Categories ($P = 0.01$).

TABLE 6.4: Kruskal-Wallis Test Between Age and Cross Sectional Variables of Subadults

Variable	Age	Mean Rank	Significance
Total Area	Young Child	9.67	0.224
	Middle Child	9	
	Older Child	5.2	
Cortical Area	Young Child	9.83	0.426
	Middle Child	6.5	
	Older Child	7	
Medullary Area	Young Child	9.83	0.214
	Middle Child	8.75	
	Older Child	5.2	
% Cortical Area	Young Child	7	0.335
	Middle Child	6.5	
	Older Child	10.4	
Ix	Young Child	11	0.061
	Middle Child	7.75	
	Older Child	4.6	
Iy	Young Child	11.5	0.021*
	Middle Child	7.75	
	Older Child	4	
Ix/Iy	Perinate	7.17	0.018*
	Young Child	9	
	Middle Child	10.5	
	Older Child	18.4	
Imax	Young Child	11.33	0.031*
	Middle Child	7.75	
	Older Child	4.2	
Imin	Young Child	11	0.061
	Middle Child	7.75	
	Older Child	4.6	
Imax/Imin	Perinate	11.5	0.557
	Young Child	12.67	
	Middle Child	12	
	Older Child	7.6	
J	Young Child	11.33	0.03*
	Middle Child	7.75	
	Older Child	4.2	

$^*P \leq 0.05$

TABLE 6.5: Mann-Whitney U Test Between Age Groups for Significant Cross Sectional Variables of Subadults

Variable	Age	Mann-Whitney U	Significance
Iy	Young Child	6	0.201
	Middle Child		
	Middle Child	5	0.221
	Older Child		
	Young Child	0	0.006**
	Older Child		
Imax	Young Child	6	0.201
	Middle Child		
	Middle Child	5	0.221
	Older Child		
	Young Child	1	0.011*
	Older Child		
J	Young Child	6	0.201
	Middle Child		
	Middle Child	5	0.221
	Older Child		
	Young Child	1	0.011*
	Older Child		
Ix/Iy	Perinate	13	0.423
	Young Child		
	Perinate	9	0.522
	Middle Child		
	Perinate	0	0.006**
	Older Child		
	Young Child	1	0.01**
	Older Child		
	Middle Child	2	0.05
	Older Child		

*$P \leq 0.017$
**$P \leq 0.01$

6.2 ADULT CROSS-SECTIONAL GEOMETRY

Prior to any statistical analyses, adult body masses were calculated for size standardization following the protocols discussed previously. Two male adults (one Early Young Adult and one Older Adult) did not have complete femoral heads and therefore had to be eliminated from the sample. Out of the remaining 108 adult individuals, five were missing left femoral head measurements and 11 were missing right; therefore, left femoral head measurements were used for body mass equations except in the five cases where only a right measure was available. Table 6.6 presents the final sample sizes, means, standard deviations, minimum and maximum measures for final adult body mass estimates (kg).

TABLE 6.6: Sample Descriptions for Adult Body Mass Estimates

FEMALES:		
Early Young Adult		
	N:	7
	Mean:	57.36
	SD:	6.10
	Minimum:	50.99
	Maximum:	68.83

Late Young Adult		
	N:	15
	Mean:	59.46
	SD:	8.65
	Minimum:	39.83
	Maximum:	68.83

Mature Adult		
	N:	16
	Mean:	61.41
	SD:	6.02
	Minimum:	50.99
	Maximum:	73.29

Older Adult		
	N:	13
	Mean:	60.01
	SD:	3.72
	Minimum:	50.99
	Maximum:	64.37

MALES:		
Early Young Adult		
	N:	10
	Mean:	73.43
	SD:	3.97
	Minimum:	69.66
	Maximum:	81.28

Late Young Adult		
	N:	14
	Mean:	74.55
	SD:	3.37
	Minimum:	70.66
	Maximum:	81.28

Mature Adult		
	N:	17
	Mean:	75.13
	SD:	6.36
	Minimum:	67.33
	Maximum:	85.93

Older Adult		
	N:	16
	Mean:	72.59
	SD:	6.65
	Minimum:	62.68
	Maximum:	89.12

Both directional asymmetry and percent asymmetry in the sample were assessed by testing the cross sectional variables of total area (TA), percent cortical area (%CA) and J on 30 pairs of female and 42 pairs of male humeri. Directional asymmetry (DA) informs on both the direction (side dominance) and general degree of asymmetry and is assessed using the formula: %DA = [(Right-Left)/(mean of left and right)]*100; negative values indicate left side dominance and positive values right side dominance. Percent asymmetry

(%A) was also evaluated since it removes the influence of handedness in order to evaluate the predominance of uni- versus bimanual activities. %A is assessed using the formula: %A = [(Max-Min)/Min]*100, where results greater than or equal to 13% suggest asymmetry, thereby indicating uni-manual activities (Ogilvie et al. 2011:14). Table 6.7 details the means and standard deviations of the asymmetry tests for each sex. Based on the lack of significant asymmetric results for either sex, only a single humerus per individual was included in further analyses. Since there were slightly more left humeri (n=44) than right (n=42), left humeri were used except in cases where only a right was available.

TABLE 6.7: *Adult Humeral Asymmetry Test Results*

FEMALES:		
Total Area		
Directional Asymmetry		
	Mean:	2.9%
	SD:	4.6
% Asymmetry		
	Mean:	4.4%
	SD:	3.6

MALES:		
Total Area		
Directional Asymmetry		
	Mean:	0.8%
	SD:	4.7
% Asymmetry		
	Mean:	3.8%
	SD:	3.0

Percent Cortical Area		
Directional Asymmetry		
	Mean:	0.8%
	SD:	6.7
% Asymmetry		
	Mean:	5%
	SD:	5.2

Percent Cortical Area		
Directional Asymmetry		
	Mean:	0.03%
	SD:	5.9
% Asymmetry		
	Mean:	4.4%
	SD:	4.3

J		
Directional Asymmetry		
	Mean:	6.1%
	SD:	9.7
% Asymmetry		
	Mean:	10.1%
	SD:	7.1

J		
Directional Asymmetry		
	Mean:	1.8%
	SD:	10.1
% Asymmetry		
	Mean:	8.1%
	SD:	7.3

6.2.1 Femoral Results

The femoral adult sample was divided by sex and age, and cross sectional properties were inspected for normality by evaluating the results of the Kolmogorov-Smirnov test, boxplots and normal Q-Q scatterplot distributions as well as comparing the overall mean with the 5% trimmed mean. One individual, an older adult female, was an extreme outlier for several variables: her femoral medullary area value was 50% or 6 SDs above the mean and her percent cortical area was 50% or 6 SDs below the mean. These extreme values are likely reflective of an underlying pathological condition, therefore she was removed from further analyses. The dataset was considered to have a normal distribution and was thus acceptable for parametric statistical evaluations. Table 6. 8 details the number, mean and standard deviation of each age category included in cross-sectional analyses and the boxplots in Figures 6.12-6.22 illustrate the distribution of scores for each cross-sectional property by sex and age category.

TABLE 6.8: Descriptive Statistics for Cross Sectional Properties of Adult Femurs by Subsample

	Age		Sex	
			Male	Female
MA	Early Young Adult	N	9	7
		Mean	200.53	203.42
		SD	28.55	61.03
	Late Young Adult	N	10	14
		Mean	200.52	207.41
		SD	33.15	31.25
	Mature Adult	N	14	11
		Mean	217.69	226.78
		SD	41.63	39.21
	Older Adult	N	14	12
		Mean	240.65	269.55
		SD	49.18	43.41
TA	Early Young Adult	N	9	7
		Mean	765.95	760.79
		SD	64.77	48.16
	Late Young Adult	N	10	14
		Mean	743.67	790.49
		SD	56.03	91.50
	Mature Adult	N	14	11
		Mean	792.95	779.63
		SD	75.45	79.03
	Older Adult	N	14	12
		Mean	798.22	783.39
		SD	53.39	80.06

TABLE 6.8: Descriptive Statistics for Cross Sectional Properties of Adult Femurs by Subsample (continued)

CA	Early Young Adult	N	9	7
		Mean	565.42	557.37
		SD	64.00	59.91
	Late Young Adult	N	10	14
		Mean	543.15	583.07
		SD	60.41	92.50
	Mature Adult	N	14	11
		Mean	575.26	552.85
		SD	52.42	53.31
	Older Adult	N	14	12
		Mean	557.57	513.84
		SD	52.95	64.31

%CA	Early Young Adult	N	9	7
		Mean	73.72	73.37
		SD	3.75	7.65
	Late Young Adult	N	10	14
		Mean	72.94	73.49
		SD	4.63	4.47
	Mature Adult	N	14	11
		Mean	72.64	71.00
		SD	3.83	3.08
	Older Adult	N	14	12
		Mean	69.91	65.59
		SD	5.62	4.56

Ix	Early Young Adult	N	9	7
		Mean	142.80	136.75
		SD	14.91	21.94
	Late Young Adult	N	10	14
		Mean	141.05	138.64
		SD	18.83	31.71
	Mature Adult	N	14	11
		Mean	154.47	135.05
		SD	29.38	31.51
	Older Adult	N	14	12
		Mean	159.42	132.50
		SD	22.39	27.32

TABLE 6.8: Descriptive Statistics for Cross Sectional Properties of Adult Femurs by Subsample (continued)

Iy	Early Young Adult	N	9	7
		Mean	155.58	156.46
		SD	43.85	33.44
	Late Young Adult	N	10	14
		Mean	161.02	162.57
		SD	34.18	40.47
	Mature Adult	N	14	11
		Mean	186.92	162.61
		SD	45.34	33.86
	Older Adult	N	14	12
		Mean	175.11	156.73
		SD	45.13	26.89

Ix/Iy	Early Young Adult	N	9	7
		Mean	0.97	0.89
		SD	0.23	0.15
	Late Young Adult	N	10	14
		Mean	0.91	0.86
		SD	0.21	0.09
	Mature Adult	N	14	11
		Mean	0.87	0.84
		SD	0.25	0.15
	Older Adult	N	14	12
		Mean	0.94	0.85
		SD	0.17	0.15

Imax	Early Young Adult	N	9	7
		Mean	168.92	164.30
		SD	36.75	29.12
	Late Young Adult	N	10	14
		Mean	172.36	166.31
		SD	27.12	40.69
	Mature Adult	N	14	11
		Mean	200.26	169.08
		SD	45.37	33.37
	Older Adult	N	14	12
		Mean	190.06	161.35
		SD	44.98	29.05

TABLE 6.8: Descriptive Statistics for Cross Sectional Properties of Adult Femurs by Subsample (continued)

Imin	Early Young Adult	N	9	7
		Mean	129.46	128.91
		SD	16.53	24.89
	Late Young Adult	N	10	14
		Mean	129.70	134.90
		SD	18.15	31.42
	Mature Adult	N	14	11
		Mean	141.13	128.58
		SD	19.11	28.25
	Older Adult	N	14	12
		Mean	144.47	127.88
		SD	15.63	22.40

Imax/Imin	Early Young Adult	N	9	7
		Mean	1.30	1.28
		SD	0.18	0.13
	Late Young Adult	N	10	14
		Mean	1.33	1.24
		SD	0.09	0.15
	Mature Adult	N	14	11
		Mean	1.43	1.33
		SD	0.35	0.15
	Older Adult	N	14	12
		Mean	1.31	1.27
		SD	0.21	0.17

J	Early Young Adult	N	9	7
		Mean	298.38	293.21
		SD	50.38	52.01
	Late Young Adult	N	10	14
		Mean	302.07	301.21
		SD	44.00	70.19
	Mature Adult	N	14	11
		Mean	341.39	297.66
		SD	55.46	59.16
	Older Adult	N	14	12
		Mean	334.53	289.23
		SD	57.12	47.76

FIGURE 6.12: Distribution of Mean Scores for Adult Femoral Total Area by Sex and Age

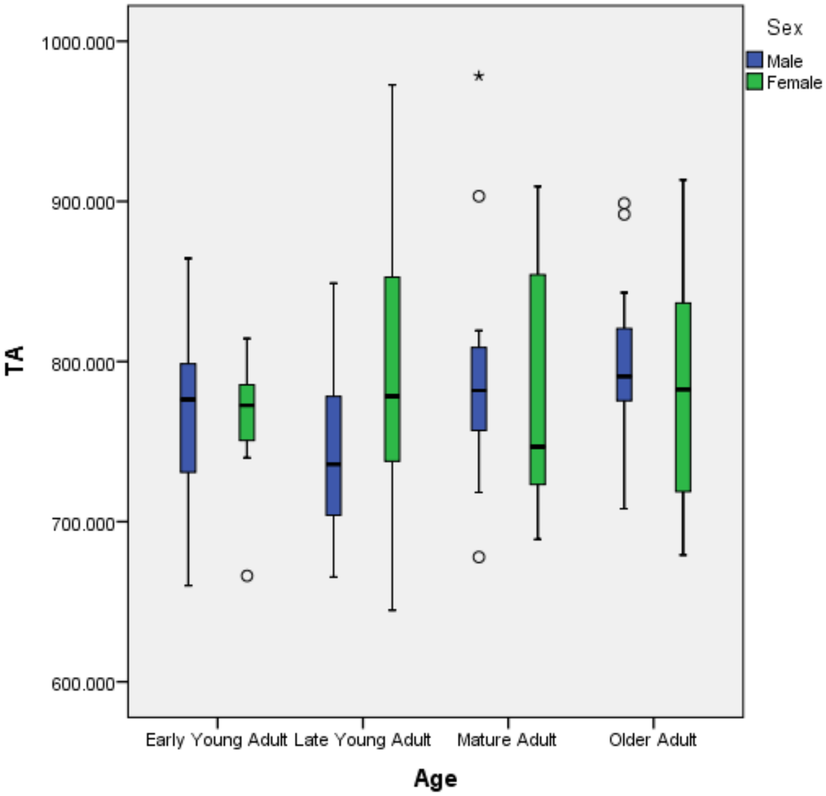


FIGURE 6.13: Distribution of Mean Scores for Adult Femoral Cortical Area by Sex and Age

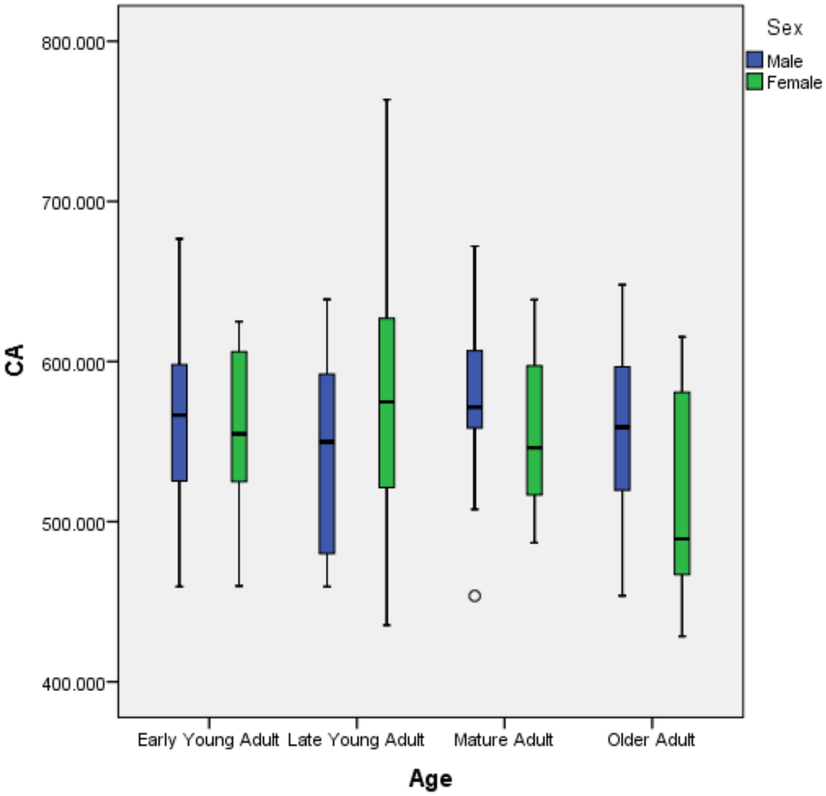


FIGURE 6.14: Distribution of Mean Scores for Adult Femoral Medullary Area by Sex and Age

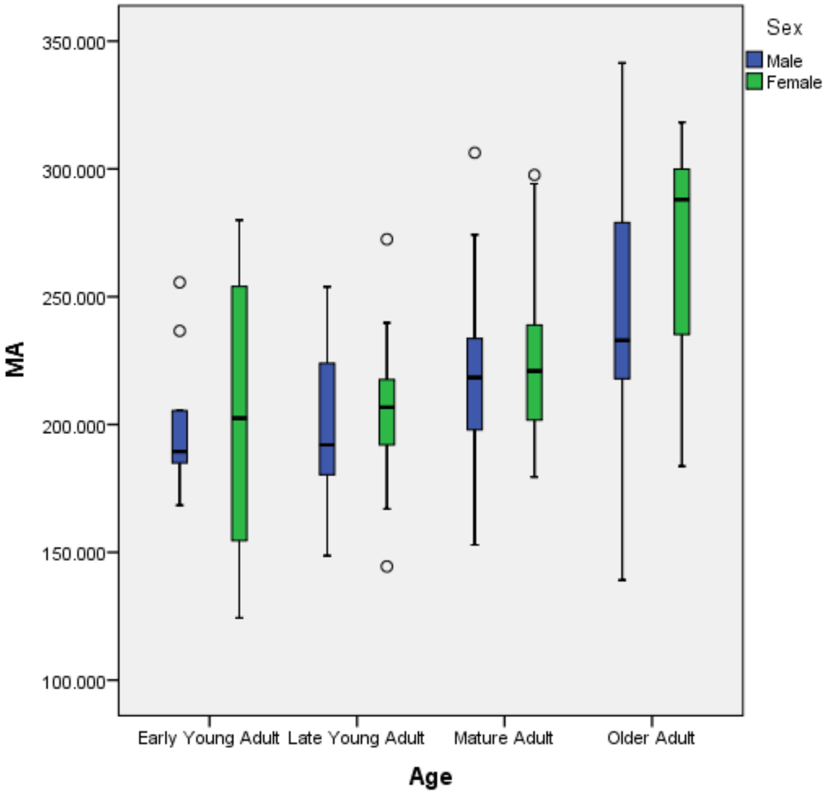


FIGURE 6.15: Distribution of Mean Scores for Adult Femoral Percent Cortical Area by Sex and Age

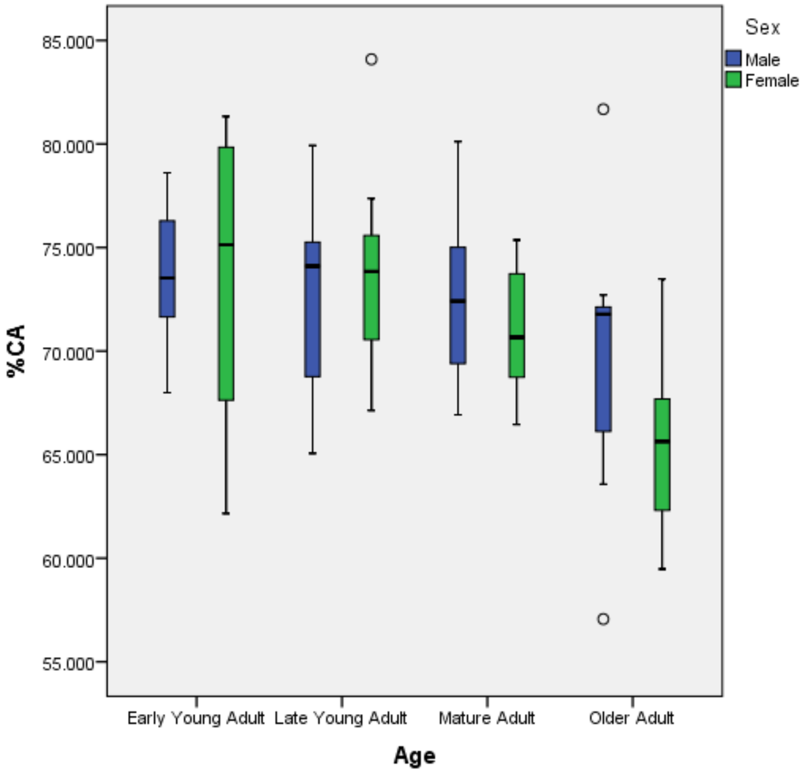


FIGURE 6.16: Distribution of Mean Scores for Adult Femoral Ix by Sex and Age

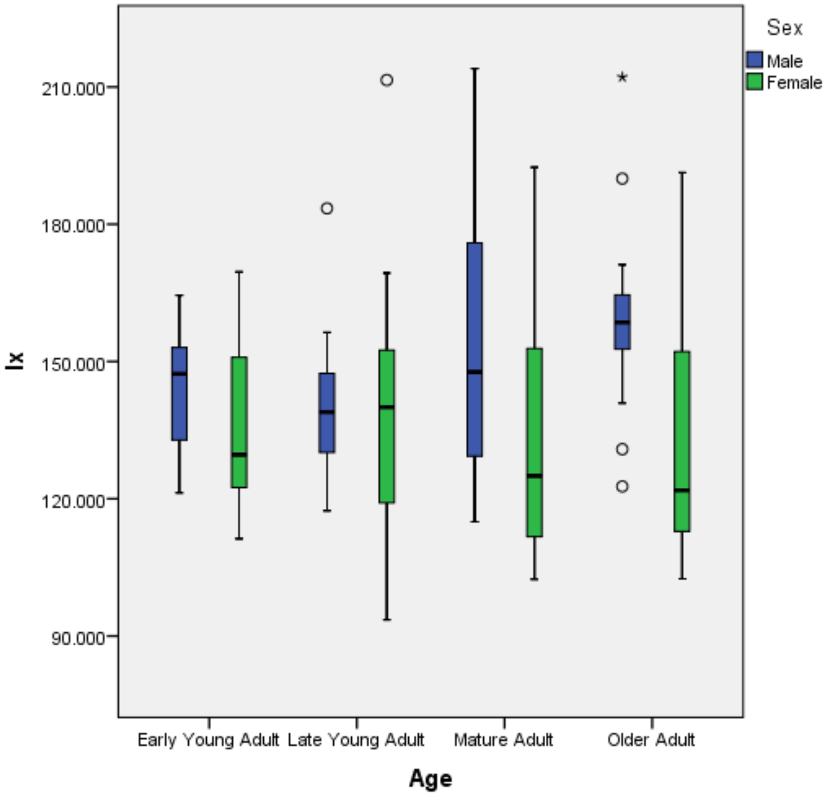


FIGURE 6.17: Distribution of Mean Scores for Adult Femoral Iy by Sex and Age

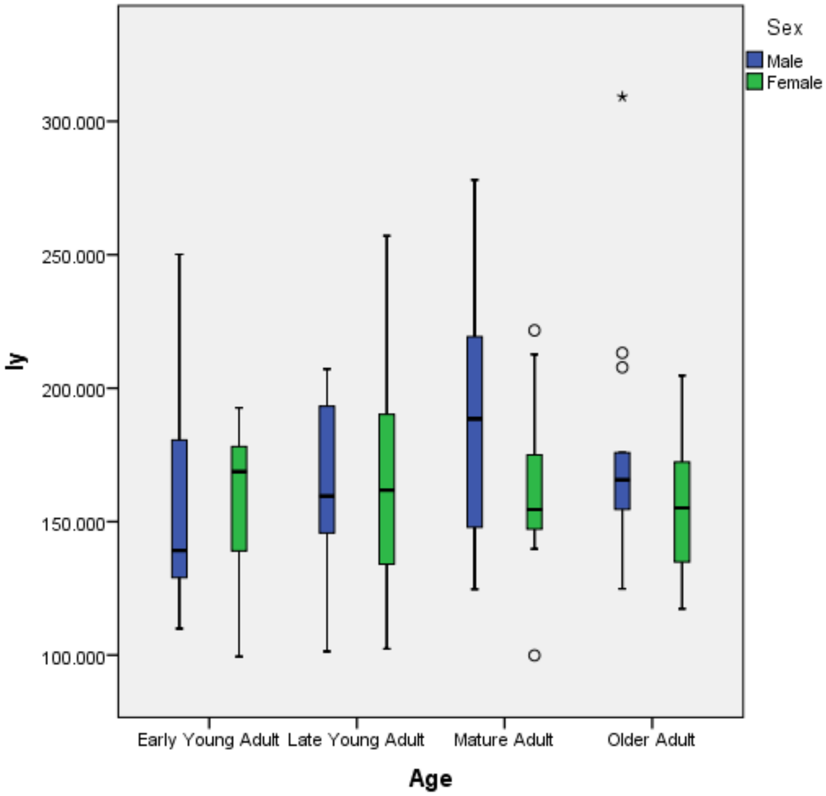


FIGURE 6.18: Distribution of Mean Scores for Adult Femoral Ix/Iy by Sex and Age

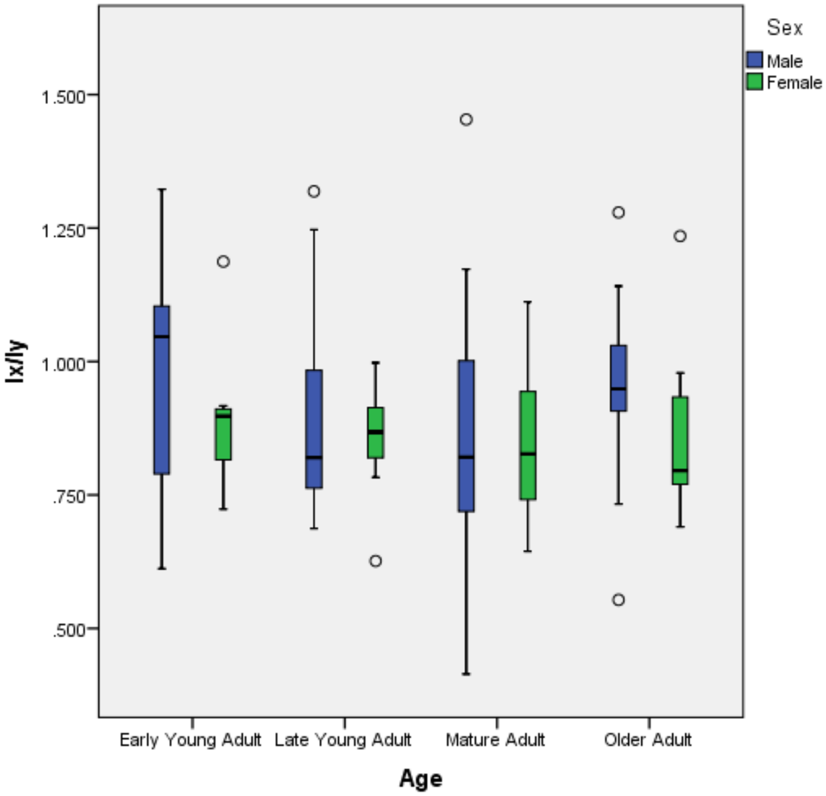


FIGURE 6.19: Distribution of Mean Scores for Adult Femoral Imax by Sex and Age

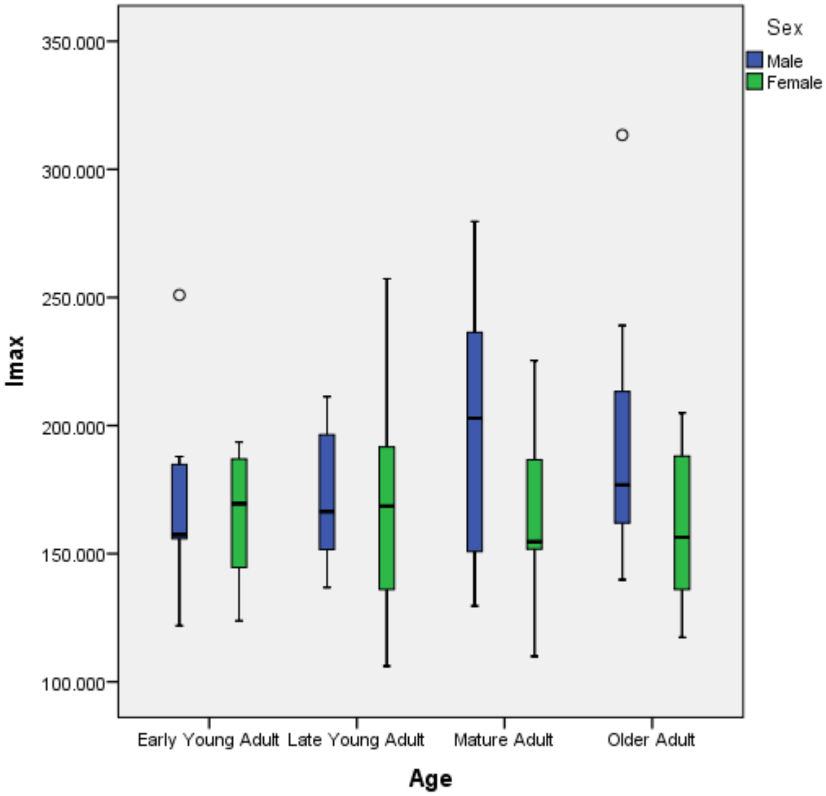


FIGURE 6.20: Distribution of Mean Scores for Adult Femoral Imin by Sex and Age

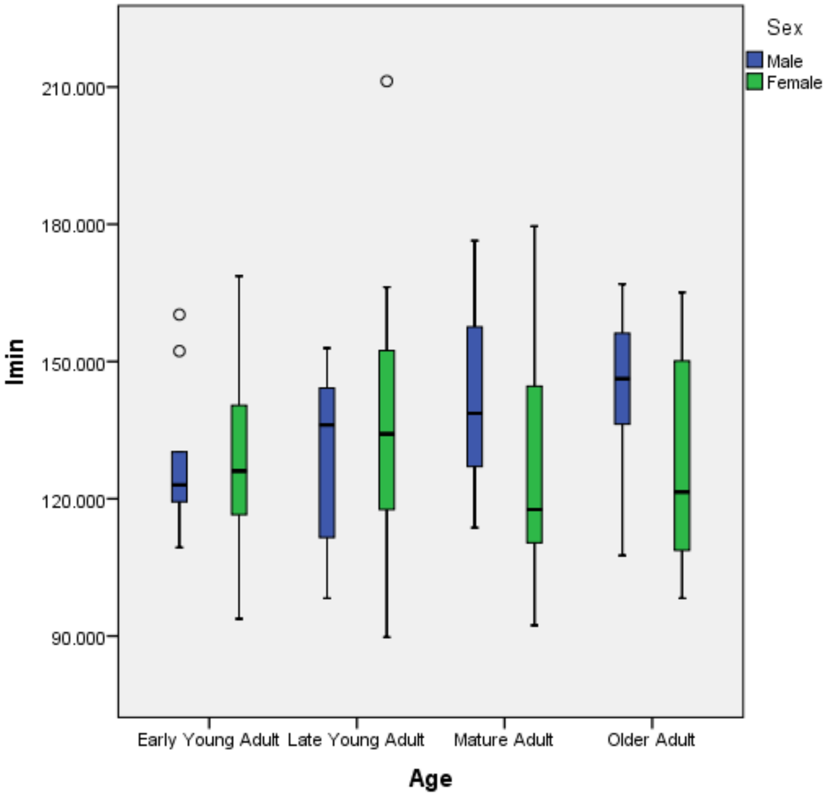


FIGURE 6.21: Distribution of Mean Scores for Adult Femoral Imax/Imin by Sex and Age

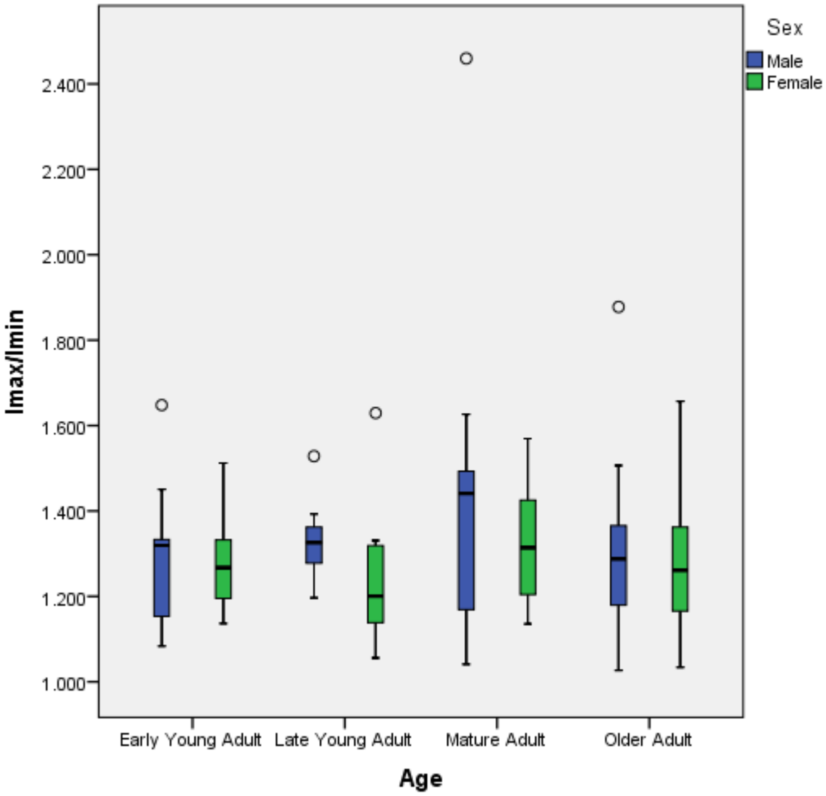
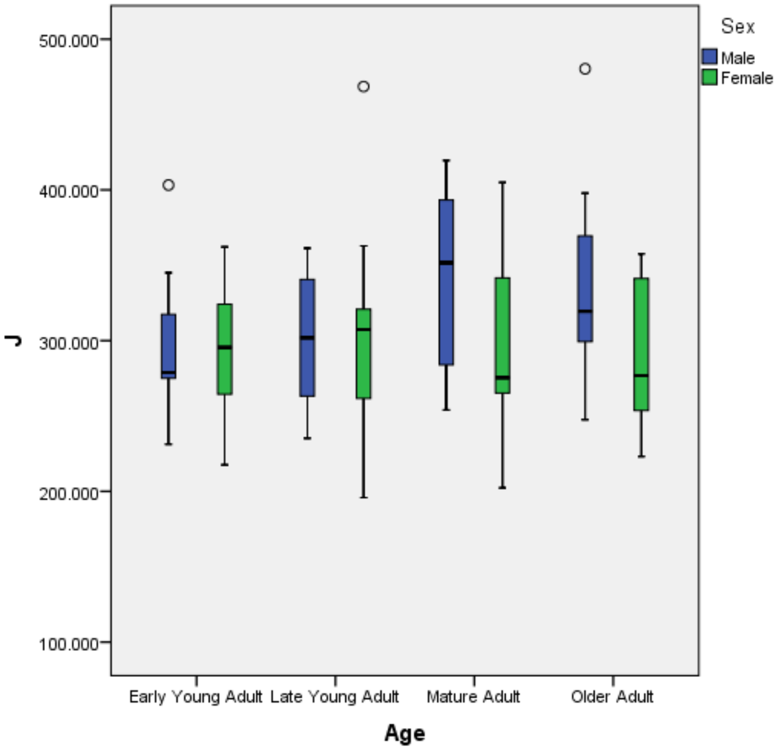


FIGURE 6.22: Distribution of Mean Scores for Adult Femoral J by Sex and Age



The Pearson correlation coefficients and significance values for cross sectional properties of the femur are listed in Table 6.9; medullary area and percent cortical area showed a moderate correlation while all other variables had an extremely small correlation with age. For the femur, percent cortical area decreases as age increases, while medullary area increases with advancing age.

TABLE 6.9: Two-tailed Pearson Correlation Coefficients for Age and Cross Sectional Properties of the Adult Femur

Variable	Correlation Coefficient	Significance
TA	0.15	0.156
CA	-0.141	0.182
MA	0.435**	0
%CA	-.403**	0
Ix	0.112	0.289
Iy	0.116	0.272
Ix/Iy	-0.058	0.587
Imax	0.127	0.232
Imin	0.117	0.268
Imax/Imin	0.051	0.63
J	0.132	0.212

*$P \leq 0.05$

**$P \leq 0.01$

Independent samples t-tests were performed in order to check for significant differences between the sexes in the mean scores of each cross sectional variable (Table 6.10). When age categories are collapsed, there are statistically significant differences between the sexes for Ix (P = 0.007), Imax (P = 0.013) and J (P = 0.024). When sex differences are evaluated for each age group, significant differences are only found in the Older Adult group for %CA (P = 0.044), Ix (P = 0.011), Imin (P = 0.036) and J (P = 0.040).

TABLE 6.10: Adult Femoral Independent Samples T-Test Between the Sexes

	Ages Combined		**Early Young Adult**		**Late Young Adult**		**Mature Adult**		**Older Adult**	
	t	**Sig**	**t**	**Sig**	**t**	**Sig**	**t**	**Sig**	**t**	**Sig**
TA	-0.15	0.881	0.18	0.863	-1.43	0.166	0.43	0.672	0.56	0.579
CA	0.63	0.531	0.26	0.801	-1.19	0.246	1.05	0.303	1.90	0.069
MA	-1.15	0.255	-0.12	0.91	-0.52	0.609	-0.56	0.584	-1.58	0.128
%CA	1.28	0.203	0.11	0.914	-0.29	0.771	1.15	0.261	2.13	0.044*
Ix	2.77	0.007**	0.66	0.522	0.21	0.832	1.59	0.126	2.76	0.011*
Iy	1.46	0.148	-0.04	0.966	-0.1	0.922	1.48	0.152	1.23	0.229
Ix/Iy	1.59	0.116	0.73	0.477	0.65	0.529	0.32	0.751	1.39	0.177
Imax	2.53	0.013*	0.27	0.79	0.41	0.687	1.91	0.069	1.9	0.07
Imin	1.46	0.149	0.05	0.958	-0.47	0.644	1.32	0.199	2.22	0.036*
Imax/ Imin	1.7	0.093	0.22	0.828	1.8	0.092	0.91	0.374	0.5	0.622
J	2.3	0.024*	0.20	0.844	0.03	0.973	1.90	0.07	2.17	0.04*

*$P \leq 0.05$

**$P \leq 0.01$

To test for statistical differences in the mean scores of each cross sectional variable for each age category, one-way analysis of variance (ANOVA) and Tukey's HSD post-hoc tests were run; results are presented in Tables 6.11 and 6.12, respectively. The ANOVA test returned significant differences for MA (P = 0.000) and %CA (P = 0.000). Post-hoc comparisons using Tukey's HSD indicate that for MA, the mean score for the Older Adult category is significantly higher than each of the Early Young Adult (P = 0.001), Late Young Adult (P = 0.000), and Mature Adult (P = 0.032) age categories. For %CA, Tukey's HSD indicates the mean score for the Older Adult category is significantly lower than each of the Early Young Adult (P = 0.002), Late Young Adult (P = 0.001), and Mature Adult (P = 0.019) age categories.

TABLE 6.11: Results of One-way ANOVA on Age Differences and Femoral Cross-sectional Properties for All Adults

Variable	**Significance**
TA	0.55
CA	0.345
MA	0**
%CA	0**
Ix	0.716
Iy	0.39
Ix/Iy	0.569
Imax	0.315
Imin	0.736
Imax/Imin	0.23
J	0.447

*$P \leq 0.05$

**$P \leq 0.01$

TABLE 6.12: Mean Differences, Standard Error and Significance Results for Tukey's HSD Post-hoc Test of Age on Adult Femoral Cross-sectional Properties

		Early Young Adult			Late Young Adult			Mature Adult			Older Adult		
		Late Young Adult	Mature Adult	Older Adult	Early Young Adult	Mature Adult	Older Adult	Early Young Adult	Late Young Adult	Older Adult	Early Young Adult	Late Young Adult	Mature Adult
TA	Mean Diff.	-7.3	-23.4	-27.7	7.3	-16.1	-20.4	23.4	16.1	-4.3	27.7	20.4	4.3
	Std. Error	23.1	22.9	22.7	23.1	20.4	20.2	22.9	20.4	20.0	22.7	20.2	20.0
	Sig.	1.0	0.7	0.6	1.0	0.9	0.7	0.7	0.9	1.0	0.6	0.7	1.0
CA	Mean Diff.	-4.5	-3.5	24.5	4.5	1.0	29.1	3.5	-1.0	28.0	-24.5	-29.1	-28.0
	Std. Error	21.0	20.9	20.7	21.0	18.6	18.4	20.9	18.6	18.3	20.7	18.4	18.3
	Sig.	1.0	1.0	0.6	1.0	1.0	0.4	1.0	1.0	0.4	0.6	0.4	0.4
MA	Mean Diff.	-2.7	-19.9	-52.20*	2.7	-17.1	-49.45*	19.9	17.1	-32.30*	52.20*	49.45*	32.30*
	Std. Error	13.3	13.2	13.1	13.3	11.8	11.7	13.2	11.8	11.5	13.1	11.7	11.5
	Sig.	1.0	0.4	0.0	1.0	0.5	0.0	0.4	0.5	0.0	0.0	0.0	0.0
%CA	Mean Diff.	0.3	1.6	5.65*	-0.3	1.3	5.35*	-1.6	-1.3	4.00*	-5.65*	-5.35*	-4.00*
	Std. Error	1.5	1.5	1.5	1.5	1.4	1.4	1.5	1.4	1.3	1.5	1.4	1.3
	Sig.	1.0	0.7	0.0	1.0	0.8	0.0	0.7	0.8	0.0	0.0	0.0	0.0
Ix	Mean Diff.	0.5	-5.8	-6.8	-0.5	-6.3	-7.3	5.8	6.3	-1.1	6.8	7.3	1.1
	Std. Error	8.8	8.7	8.6	8.8	7.8	7.7	8.7	7.8	7.6	8.6	7.7	7.6
	Sig.	1.0	0.9	0.9	1.0	0.9	0.8	0.9	0.9	1.0	0.9	0.8	1.0
Iy	Mean Diff.	-6.0	-20.3	-10.7	6.0	-14.3	-4.7	20.3	14.3	9.6	10.7	4.7	-9.6
	Std. Error	12.6	12.5	12.4	12.6	11.1	11.0	12.5	11.1	10.9	12.4	11.0	10.9
	Sig.	1.0	0.4	0.8	1.0	0.6	1.0	0.4	0.6	0.8	0.8	1.0	0.8

TABLE 6.12: Mean Differences, Standard Error and Significance Results for Tukey's HSD Post-hoc Test of Age on Adult Femoral Cross-sectional Properties (continued)

Ix/Iy	Mean Diff.	0.1	0.1	0.0	-0.1	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0
	Std. Error	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Sig.	0.8	0.5	0.9	0.8	1.0	1.0	0.5	1.0	0.8	0.9	1.0	0.8
Imax	Mean Diff.	-1.9	-19.6	-9.9	1.9	-17.7	-8.0	19.6	17.7	9.7	9.9	8.0	-9.7
	Std. Error	12.4	12.3	12.2	12.4	11.0	10.9	12.3	11.0	10.8	12.2	10.9	10.8
	Sig.	1.0	0.4	0.9	1.0	0.4	0.9	0.4	0.4	0.8	0.9	0.9	0.8
Imin	Mean Diff.	-3.5	-6.4	-7.6	3.5	-2.9	-4.1	6.4	2.9	-1.2	7.6	4.1	1.2
	Std. Error	7.4	7.4	7.3	7.4	6.6	6.5	7.4	6.6	6.4	7.3	6.5	6.4
	Sig.	1.0	0.8	0.7	1.0	1.0	0.9	0.8	1.0	1.0	0.7	0.9	1.0
Imax/ Imin	Mean Diff.	0.0	-0.1	0.0	0.0	-0.1	0.0	0.1	0.1	0.1	0.0	0.0	-0.1
	Std. Error	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Sig.	1.0	0.5	1.0	1.0	0.2	1.0	0.5	0.2	0.4	1.0	1.0	0.4
J	Mean Diff.	-5.4	-26.0	-17.5	5.4	-20.6	-12.1	26.0	20.6	8.5	17.5	12.1	-8.5
	Std. Error	18.5	18.3	18.2	18.5	16.4	16.2	18.3	16.4	16.0	18.2	16.2	16.0
	Sig.	1.0	0.5	0.8	1.0	0.6	0.9	0.5	0.6	1.0	0.8	0.9	1.0

*$P \leq 0.05$
**$P \leq 0.01$

A two-way between groups ANOVA was then conducted to explore the impact of age and sex on each cross-sectional property and if these two variables interact with each other. No statistically significant interaction effects between age and sex were found for any femoral cross-sectional property. Both %CA and MA showed a statistically significant main effect for age (as detailed above in the results of the one-way ANOVA). Both Ix and Imax showed a statistically significant main effect for sex (*P* = 0.017 and *P* = 0.032). These findings are in accordance with the results of the independent samples t-tests, with males exhibiting an increase in both variables with advancing age while women's values stay relatively the same across the lifecourse. These results are illustrated below in Figures 6.23 and 6.24, which graph estimated marginal means to illustrate the general trends of the sample by removing outliers to smooth distribution curves.

FIGURE 6.23: Estimated Marginal Means of Adult Femoral Ix Between the Sexes

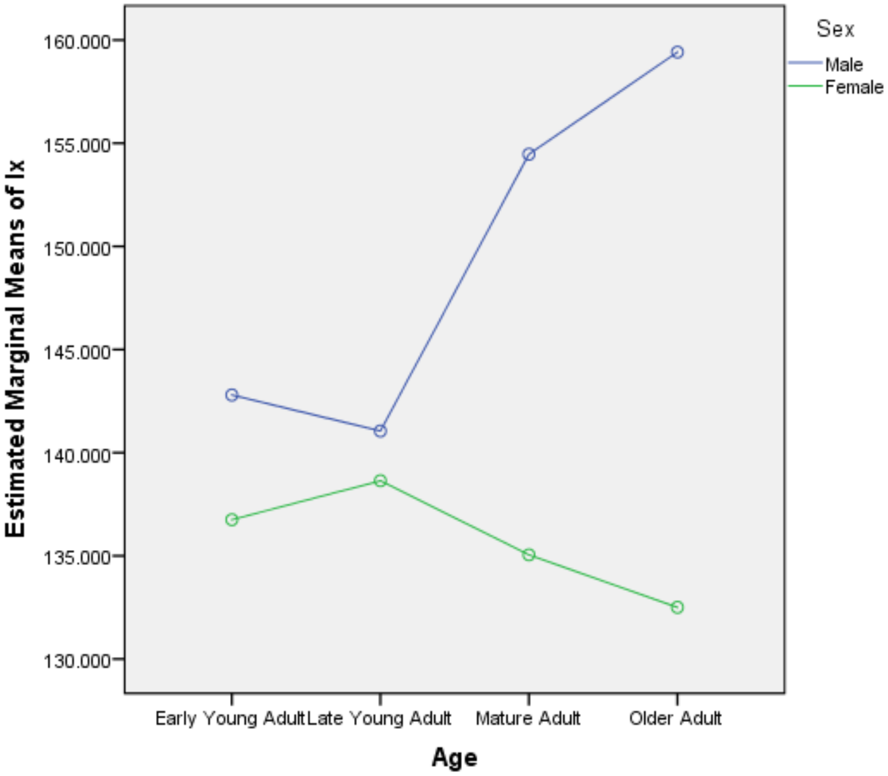
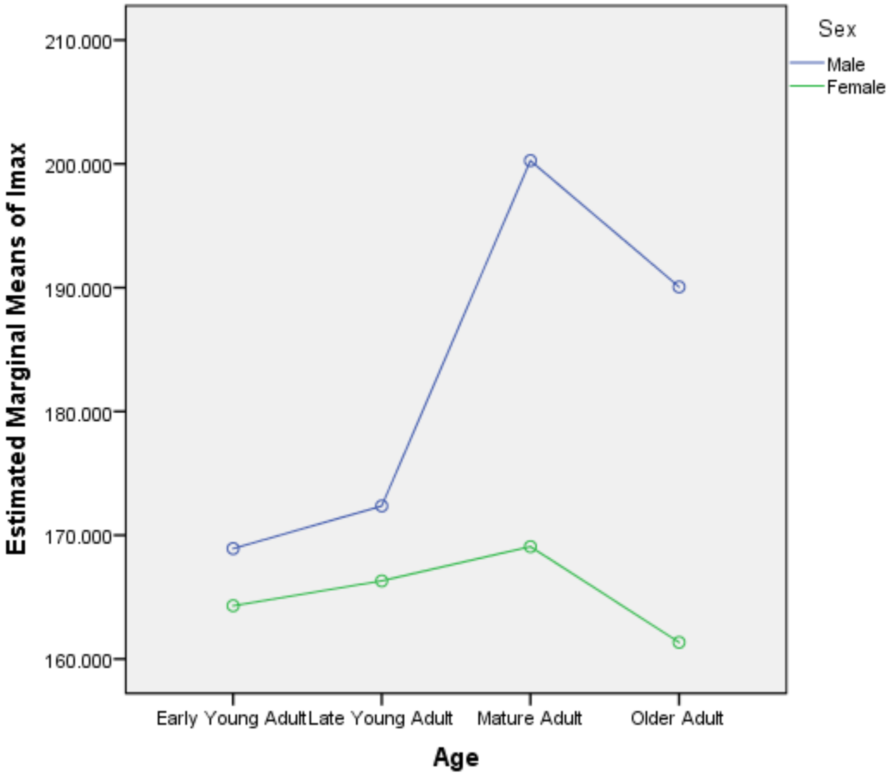


FIGURE 6.24: Estimated Marginal Means of Adult Femoral Imax Between the Sexes



To gain a clearer picture, a one-way ANOVA with Tukey's HSD post-hoc tests were run for each individual sex. Results of this final ANOVA found that significant age differences remained for MA ($P = 0.002$) and %CA ($P = 0.003$), but only for women (Tables 6.13 and 6.14). MA in Older Adult women is significantly higher than for either Early Young Adult ($P = 0.011$) or Late Young Adult ($P = 0.003$) women (Figure 6.25). %CA in Older Adult women is significantly lower than each of the Early Young Adult ($P = 0.008$), Late Young Adult ($P = 0.001$), and Mature Adult ($P = 0.05$) female age categories (Figure 6.26).

TABLE 6.13: Results of One-way ANOVA on Age Differences and Adult Femoral Cross-sectional Properties Per Sex

Males:

Variable	Significance
MA	0.061
TA	0.158
CA	0.579
%CA	0.201
Ix	0.173
Iy	0.304
Ix/Iy	0.71
Imax	0.22
Imin	0.096
Imax/Imin	0.504
J	0.134

Females:

Variable	Significance
MA	0.002*
TA	0.882
CA	0.128
%CA	0.003*[a]
Ix	0.959
Iy	0.955
Ix/Iy	0.868
Imax	0.957
Imin	0.908
Imax/Imin	0.543
J	0.962

*$P \leq 0.05$

[a] *Failed homogeneity of variance, P value listed is for Welch equality of means test*

FIGURE 6.25: Estimated Marginal Means of Adult Femoral Medullary Area Between the Sexes

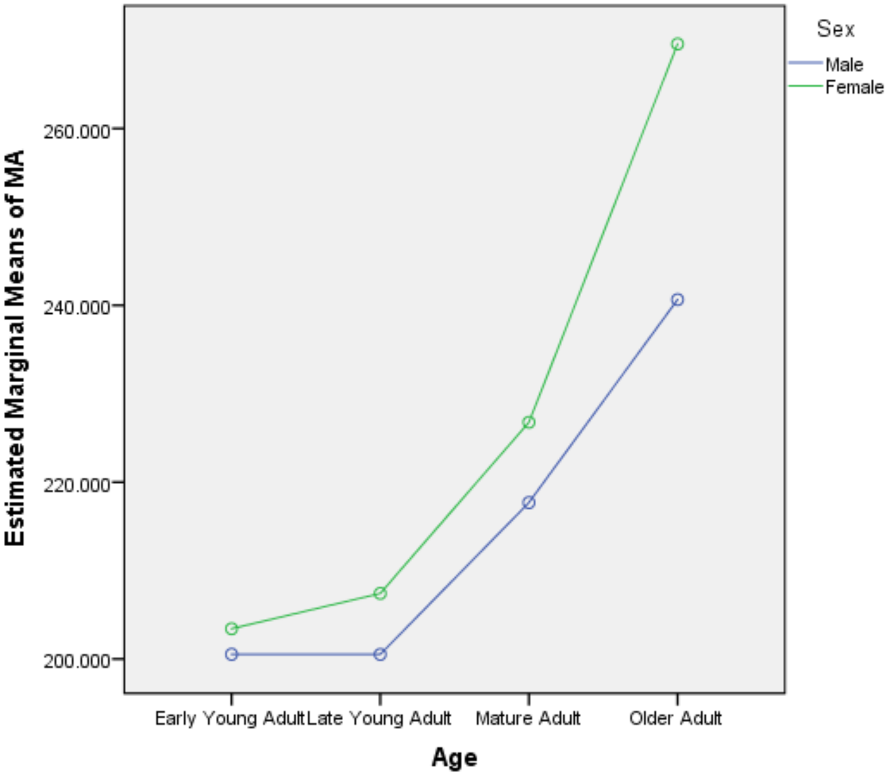


FIGURE 6.26: Estimated Marginal Means of Adult Femoral Percent Cortical Area Between the Sexes

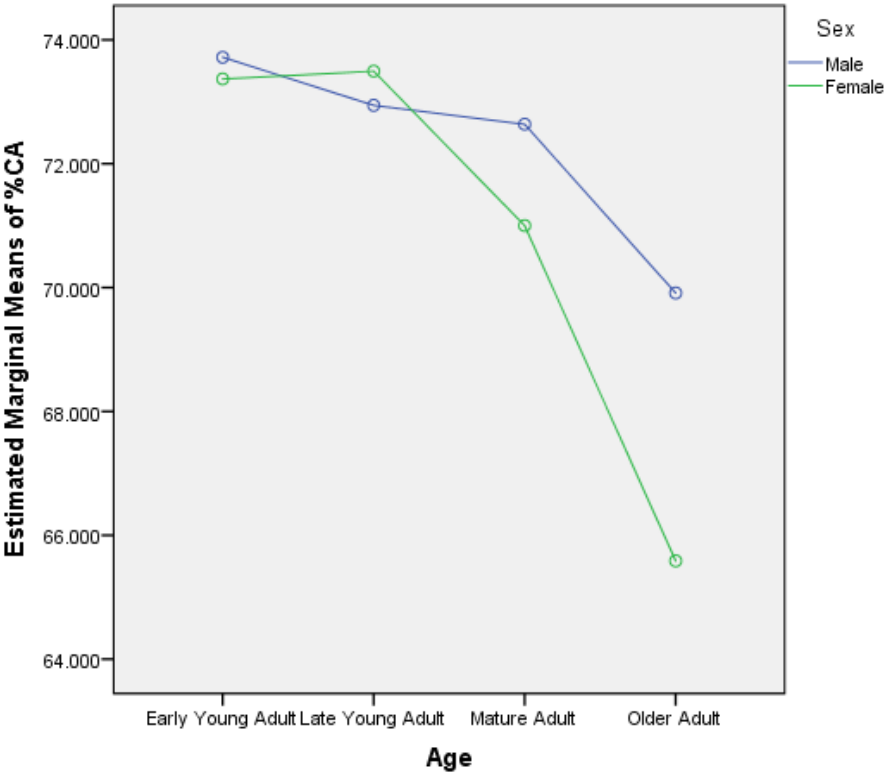


TABLE 6.14: Mean Differences, Standard Error and Significance Results for Tukey's HSD Post-hoc Test of Age on Adult Femoral Cross-sectional Properties for Females

		Early Young Adult			Late Young Adult			Mature Adult			Older Adult		
		Late Young Adult	Mature Adult	Older Adult	Early Young Adult	Mature Adult	Older Adult	Early Young Adult	Late Young Adult	Older Adult	Early Young Adult	Late Young Adult	Mature Adult
TA	Mean Diff.	29.69	18.84	22.60	-29.69	-10.86	-7.10	-18.84	10.86	3.76	-22.60	7.10	-3.76
	Std. Error	37.01	38.66	38.03	37.01	32.22	31.46	38.66	32.22	33.38	38.03	31.46	33.38
	Sig.	0.85	0.96	0.93	0.85	0.99	1.00	0.96	0.99	1.00	0.93	1.00	1.00
CA	Mean Diff.	25.70	-4.52	-43.54	-25.70	-30.22	-69.24	4.52	30.22	-39.01	43.54	69.24	39.01
	Std. Error	33.27	34.75	34.19	33.27	28.96	28.28	34.75	28.96	30.00	34.19	28.28	30.00
	Sig.	0.87	1.00	0.59	0.87	0.73	0.08	1.00	0.73	0.57	0.59	0.08	0.57
MA	Mean Diff.	3.99	23.36	66.13**	-3.99	19.37	62.14**	-23.36	-19.37	42.77	-66.13**	-62.14**	-42.77
	Std. Error	19.52	20.39	20.06	19.52	16.99	16.59	20.39	16.99	17.60	20.06	16.59	17.60
	Sig.	1.00	0.66	0.01	1.00	0.67	0.00	0.66	0.67	0.09	0.01	0.00	0.09
%CA	Mean Diff.	0.13	-2.37	-7.78**	-0.13	-2.49	-7.91**	2.37	2.49	-5.41*	7.78**	7.91**	5.41*
	Std. Error	2.24	2.34	2.30	2.24	1.95	1.90	2.34	1.95	2.02	2.30	1.90	2.02
	Sig.	1.00	0.74	0.01	1.00	0.58	0.00	0.74	0.58	0.05	0.01	0.00	0.05
Ix	Mean Diff.	1.89	-1.70	-4.25	-1.89	-3.59	-6.14	1.70	3.59	-2.55	4.25	6.14	2.55
	Std. Error	13.52	14.12	13.89	13.52	11.76	11.49	14.12	11.76	12.19	13.89	11.49	12.19
	Sig.	1.00	1.00	0.99	1.00	0.99	0.95	1.00	0.99	1.00	0.99	0.95	1.00
Iy	Mean Diff.	6.11	6.15	0.26	-6.11	0.05	-5.84	-6.15	-0.05	-5.89	-0.26	5.84	5.89
	Std. Error	15.94	16.65	16.38	15.94	13.87	13.55	16.65	13.87	14.37	16.38	13.55	14.37
	Sig.	0.98	0.98	1.00	0.98	1.00	0.97	0.98	1.00	0.98	1.00	0.97	0.98

TABLE 6.14: Mean Differences, Standard Error and Significance Results for Tukey's HSD Post-hoc Test of Age on Adult Femoral Cross-sectional Properties for Females (continued)

Ix/Iy	Mean Diff.	-0.03	-0.05	-0.04	0.03	-0.02	-0.01	0.05	0.02	0.01	0.04	0.01	-0.01
	Std. Error	0.06	0.07	0.06	0.06	0.05	0.05	0.07	0.05	0.06	0.06	0.05	0.06
	Sig.	0.95	0.84	0.91	0.95	0.98	1.00	0.84	0.98	1.00	0.91	1.00	1.00
Imax	Mean Diff.	2.01	4.78	-2.95	-2.01	2.77	-4.96	-4.78	-2.77	-7.73	2.95	4.96	7.73
	Std. Error	15.87	16.58	16.31	15.87	13.82	13.49	16.58	13.82	14.31	16.31	13.49	14.31
	Sig.	1.00	0.99	1.00	1.00	1.00	0.98	0.99	1.00	0.95	1.00	0.98	0.95
Imin	Mean Diff.	5.99	-0.33	-1.03	-5.99	-6.32	-7.02	0.33	6.32	-0.70	1.03	7.02	0.70
	Std. Error	12.69	13.25	13.04	12.69	11.04	10.78	13.25	11.04	11.44	13.04	10.78	11.44
	Sig.	0.97	1.00	1.00	0.97	0.94	0.92	1.00	0.94	1.00	1.00	0.92	1.00
Imax/ Imin	Mean Diff.	-0.05	0.04	-0.01	0.05	0.09	0.03	-0.04	-0.09	-0.06	0.01	-0.03	0.06
	Std. Error	0.07	0.07	0.07	0.07	0.06	0.06	0.07	0.06	0.06	0.07	0.06	0.06
	Sig.	0.92	0.93	1.00	0.92	0.47	0.94	0.93	0.47	0.82	1.00	0.94	0.82
J	Mean Diff.	7.99	4.45	-3.99	-7.99	-3.55	-11.98	-4.45	3.55	-8.43	3.99	11.98	8.43
	Std. Error	27.42	28.64	28.17	27.42	23.87	23.30	28.64	23.87	24.73	28.17	23.30	24.73
	Sig.	0.99	1.00	1.00	0.99	1.00	0.96	1.00	1.00	0.99	1.00	0.96	0.99

*$P \leq 0.05$
**$P \leq 0.01$

6.2.2 Humeral Results

The humeral adult sample was divided by sex and age, and distribution of cross sectional properties were inspected for normality by evaluating the results of the Kolmogorov-Smirnov test, boxplots and normal Q-Q scatterplot distributions as well as comparing the overall mean with the 5% trimmed mean. Overall, the dataset was considered to have a reasonably normal distribution and was thus acceptable for parametric statistical evaluations. Table 6.15 details the number, mean and standard deviation of each age category included in cross-sectional analyses and the boxplots in Figures 6.27-6.37 illustrate the distribution of scores for each cross sectional property by sex and age category.

TABLE 6.15: Descriptive Statistics for Cross Sectional Properties of Adult Humeri by Subsample

	Age		**Sex**	
			Male	Female
TA	Early Young Adult	N	10	5
		Mean	401.29	381.15
		SD	19.76	70.61
	Late Young Adult	N	12	14
		Mean	421.35	385.82
		SD	31.91	49.92
	Mature Adult	N	15	12
		Mean	420.23	384.57
		SD	30.14	59.19
	Older Adult	N	16	11
		Mean	433.63	383.56
		SD	48.81	54.64

TABLE 6.15: Descriptive Statistics for Cross Sectional Properties of Adult Humeri by Subsample (continued)

CA	Early Young Adult	N	10	5
		Mean	294.18	273.09
		SD	20.96	67.37
	Late Young Adult	N	12	14
		Mean	301.13	267.96
		SD	25.12	54.61
	Mature Adult	N	15	12
		Mean	294.53	234.57
		SD	36.67	52.28
	Older Adult	N	16	11
		Mean	259.25	210.86
		SD	41.95	29.31

MA	Early Young Adult	N	10	5
		Mean	107.11	108.06
		SD	20.47	25.16
	Late Young Adult	N	12	14
		Mean	120.22	117.87
		SD	27.41	28.14
	Mature Adult	N	15	12
		Mean	125.69	150
		SD	33.55	71.87
	Older Adult	N	16	11
		Mean	174.38	172.7
		SD	56.1	58.13

%CA	Early Young Adult	N	10	5
		Mean	73.35	71.21
		SD	4.61	7.73
	Late Young Adult	N	12	14
		Mean	71.62	69.02
		SD	5.24	8.54
	Mature Adult	N	15	12
		Mean	70.12	61.74
		SD	7.86	14.44
	Older Adult	N	16	11
		Mean	60.23	55.76
		SD	10.36	10.02

TABLE 6.15: Descriptive Statistics for Cross Sectional Properties of Adult Humeri by Subsample (continued)

Ix	Early Young Adult	N	10	5
		Mean	85.08	84.81
		SD	9.48	33.84
	Late Young Adult	N	12	14
		Mean	100.16	78.63
		SD	15.67	22.37
	Mature Adult	N	15	12
		Mean	97.81	72.38
		SD	17.08	16.13
	Older Adult	N	16	11
		Mean	90.80	67.86
		SD	15.08	11.95

Iy	Early Young Adult	N	10	5
		Mean	64.48	61.50
		SD	10.00	24.63
	Late Young Adult	N	12	14
		Mean	74.80	56.61
		SD	11.64	13.32
	Mature Adult	N	15	12
		Mean	77.19	55.54
		SD	12.92	13.26
	Older Adult	N	16	11
		Mean	73.89	50.34
		SD	16.74	11.51

Ix/Iy	Early Young Adult	N	10	5
		Mean	1.33	1.39
		SD	0.13	0.14
	Late Young Adult	N	12	14
		Mean	1.35	1.39
		SD	0.15	0.19
	Mature Adult	N	15	12
		Mean	1.27	1.31
		SD	0.13	0.13
	Older Adult	N	16	11
		Mean	1.25	1.36
		SD	0.13	0.12

TABLE 6.15: Descriptive Statistics for Cross Sectional Properties of Adult Humeri by Subsample (continued)

Imax	Early Young Adult	N	10	5
		Mean	86.57	86.75
		SD	9.64	34.18
	Late Young Adult	N	12	14
		Mean	101.88	80.30
		SD	15.04	22.78
	Mature Adult	N	15	12
		Mean	100.43	73.74
		SD	17.91	15.74
	Older Adult	N	16	11
		Mean	92.75	70.01
		SD	16.52	13.65

Imin	Early Young Adult	N	10	5
		Mean	62.98	59.56
		SD	9.99	24.68
	Late Young Adult	N	12	14
		Mean	73.08	54.94
		SD	12.47	12.99
	Mature Adult	N	15	12
		Mean	74.57	54.19
		SD	11.52	13.82
	Older Adult	N	16	11
		Mean	71.93	48.19
		SD	14.71	9.78

Imax/Imin	Early Young Adult	N	10	5
		Mean	1.39	1.49
		SD	0.13	0.27
	Late Young Adult	N	12	14
		Mean	1.41	1.47
		SD	0.18	0.20
	Mature Adult	N	15	12
		Mean	1.35	1.38
		SD	0.12	0.16
	Older Adult	N	16	11
		Mean	1.30	1.46
		SD	0.11	0.09

TABLE 6.15: Descriptive Statistics for Cross Sectional Properties of Adult Humeri by Subsample (continued)

J	Early Young Adult	N	10	5
		Mean	149.55	146.31
		SD	18.42	58.20
	Late Young Adult	N	12	14
		Mean	174.96	135.24
		SD	25.40	34.36
	Mature Adult	N	15	12
		Mean	175.00	127.93
		SD	28.53	28.65
	Older Adult	N	16	11
		Mean	164.69	118.20
		SD	30.35	23.16

FIGURE 6.27: Distribution of Mean Scores for Adult Humeral Total Area by Sex and Age

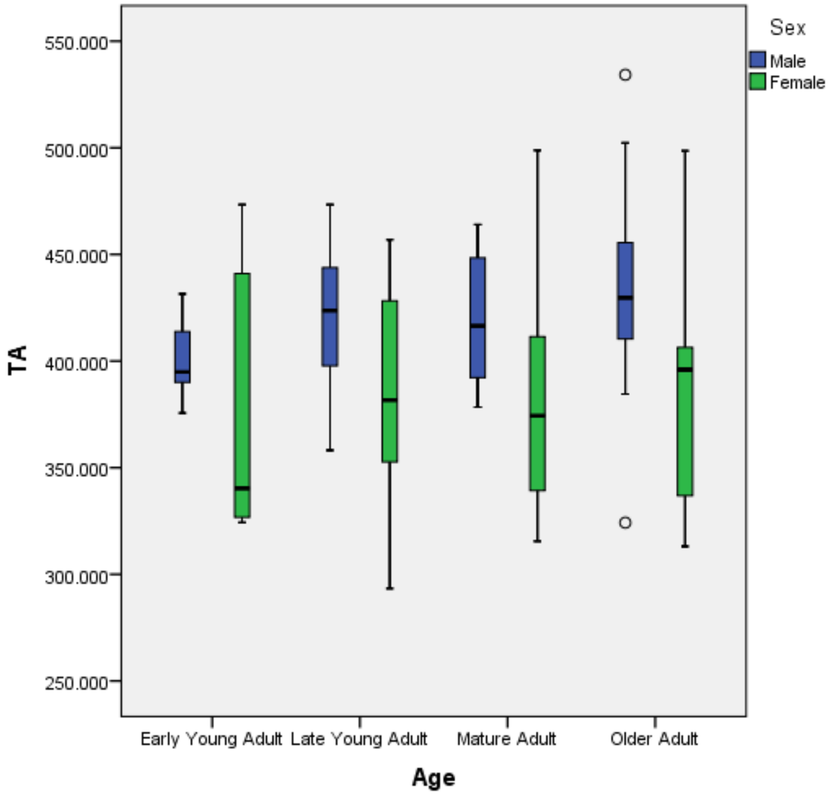


FIGURE 6.28: Distribution of Mean Scores for Adult Humeral Cortical Area by Sex and Age

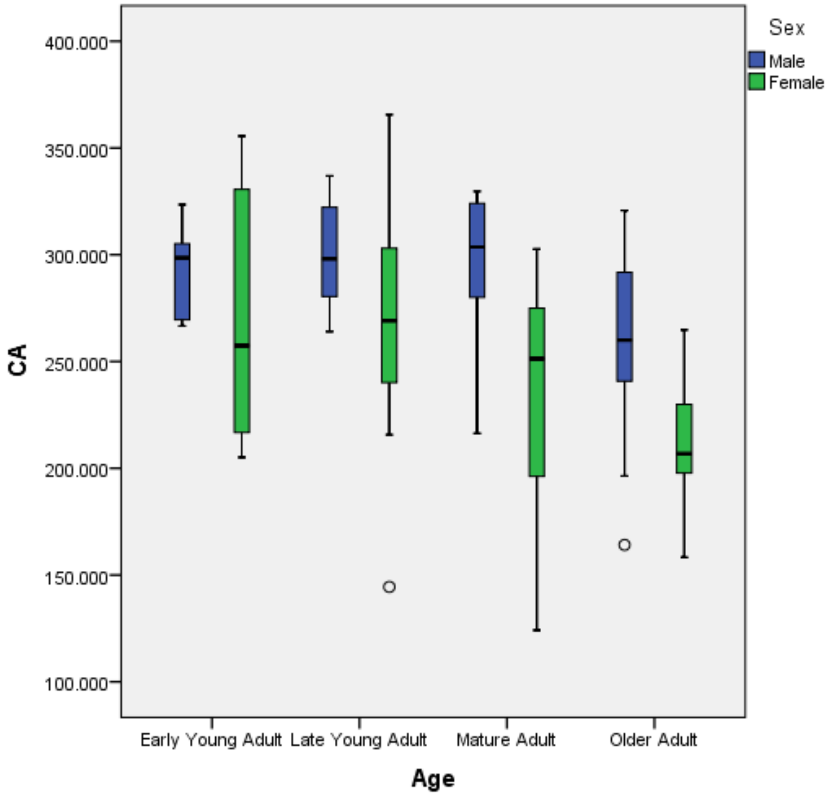


FIGURE 6.29: Distribution of Mean Scores for Adult Humeral Medullary Area by Sex and Age

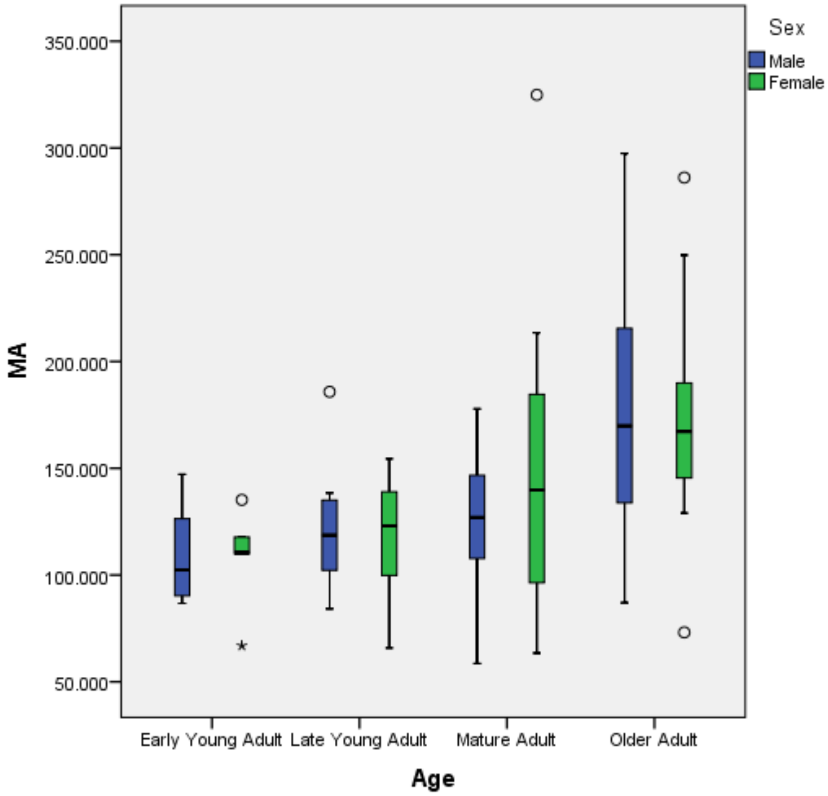


FIGURE 6.30: Distribution of Mean Scores for Adult Humeral Percent Cortical Area by Sex and Age

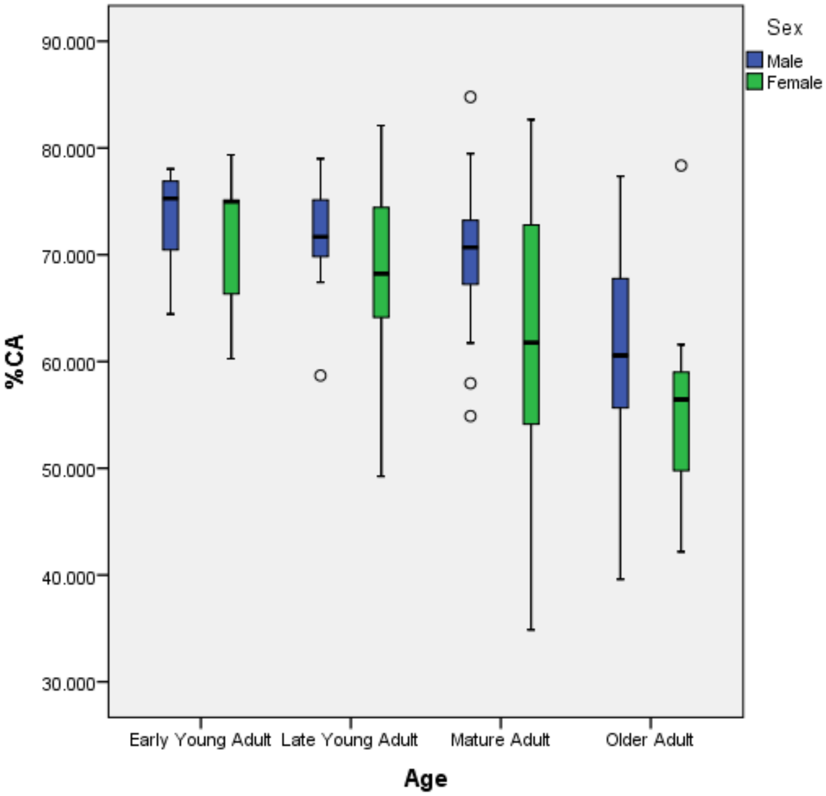


FIGURE 6.31: Distribution of Mean Scores for Adult Humeral Ix by Sex and Age

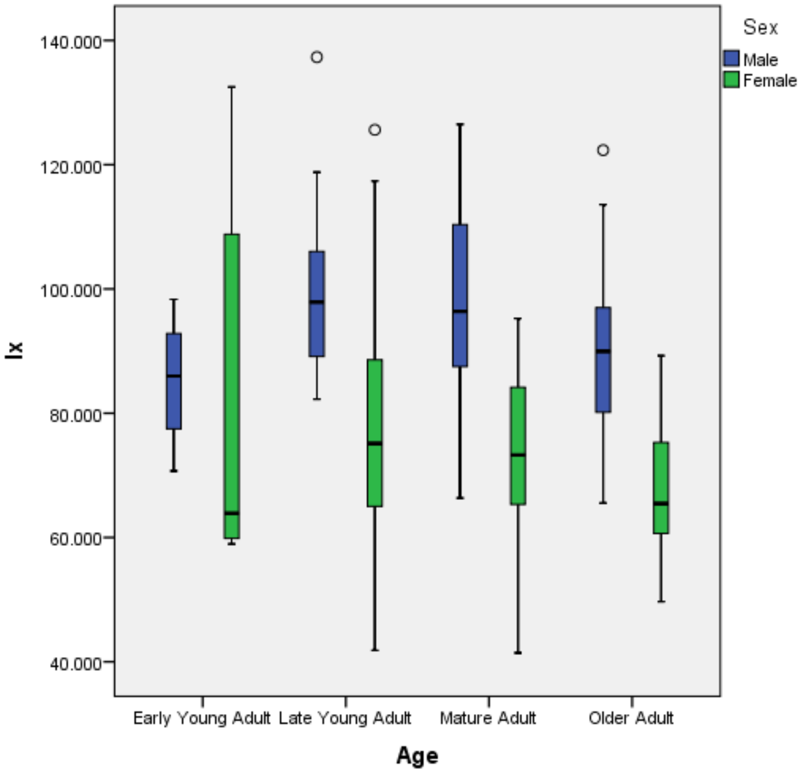


FIGURE 6.32: Distribution of Mean Scores for Adult Humeral Iy by Sex and Age

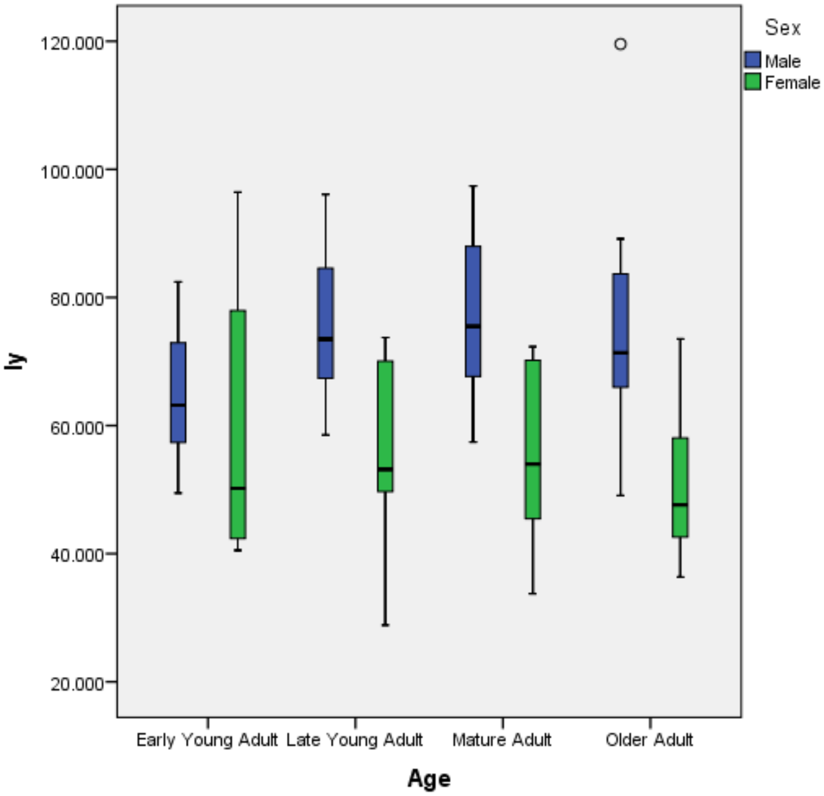


FIGURE 6.33: Distribution of Mean Scores for Adult Humeral Ix/Iy by Sex and Age

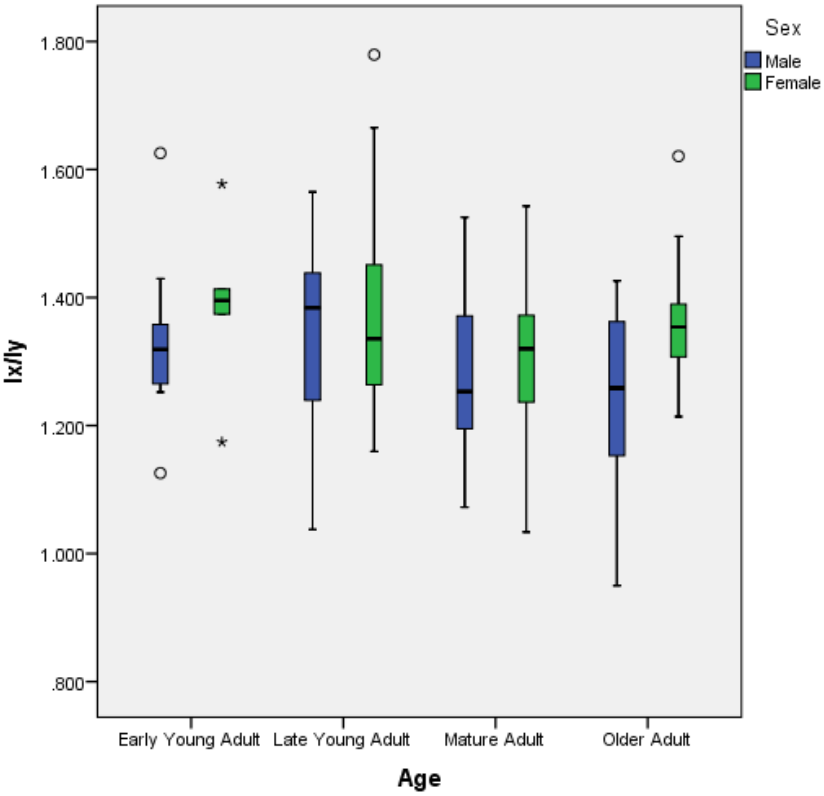


FIGURE 6.34: Distribution of Mean Scores for Adult Humeral Imax by Sex and Age

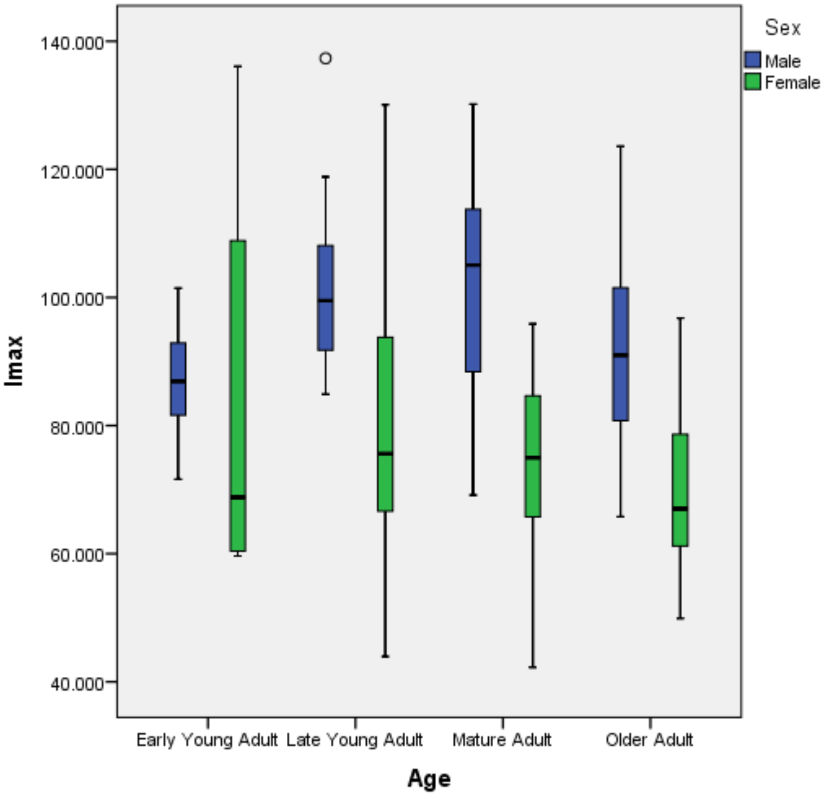


FIGURE 6.35: Distribution of Mean Scores for Adult Humeral Imin by Sex and Age

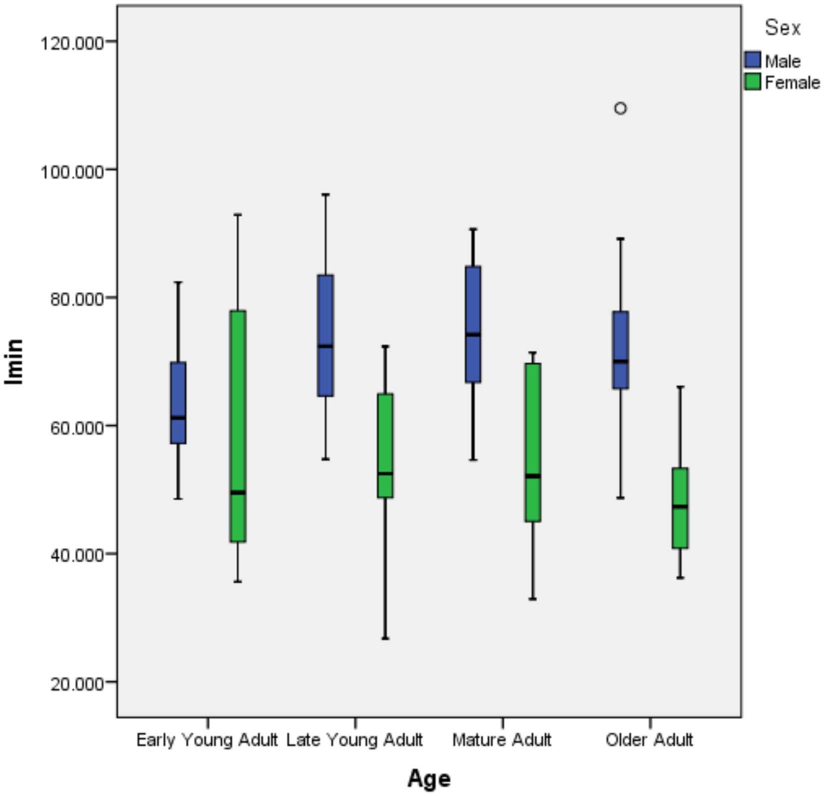


FIGURE 6.36: Distribution of Mean Scores for Adult Humeral Imax/Imin by Sex and Age

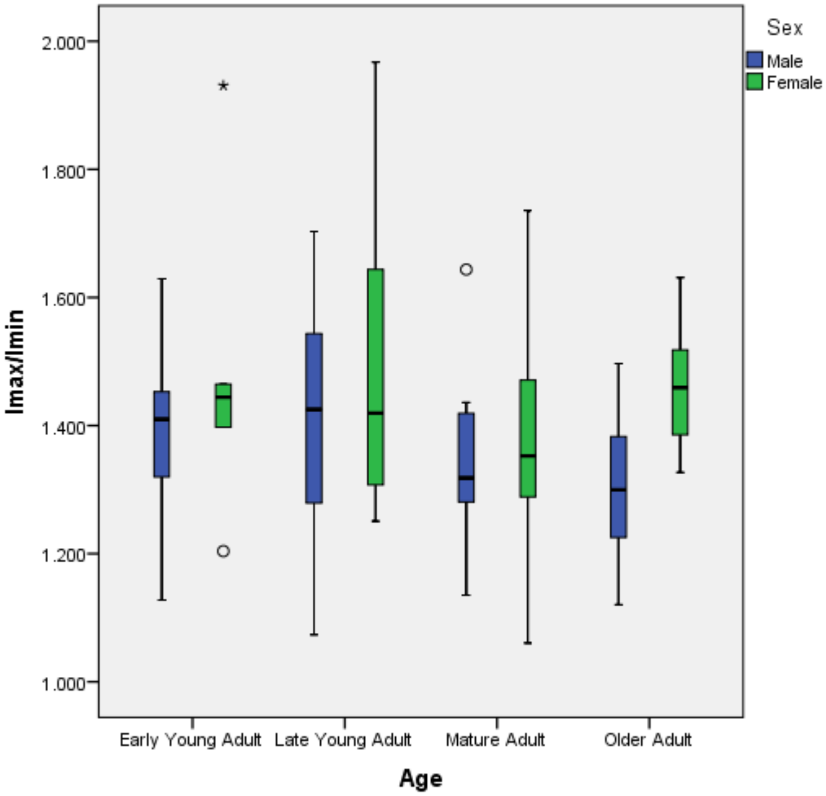
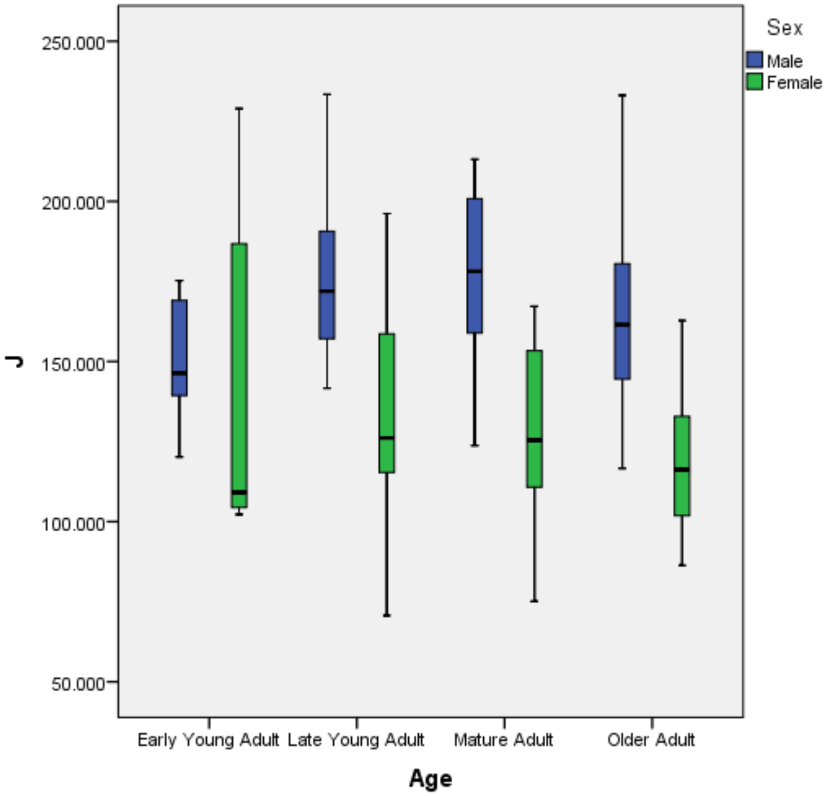


FIGURE 6.37: Distribution of Mean Scores for Adult Humeral J by Sex and Age



Two-tailed Pearson correlations were run on all variables to see if age correlated with any measures of cross sectional geometry. The Pearson correlation coefficients and significance values for cross sectional properties of the humerus are listed in Table 6.16. For the humerus, only medullary area, cortical area and percent cortical area showed a moderate correlation with age, all other variables displayed an extremely small correlation; cortical area and percent cortical area decrease as age increases, while medullary area increases with increasing age.

TABLE 6.16: Two-tailed Pearson Correlation Coefficients for Age and Cross Sectional Properties of the Adult Humerus

Variable	Correlation Coefficient	Significance
TA	0.125	0.228
CA	-.359**	0
MA	.473**	0
%CA	-.480**	0
Ix	-0.089	0.391
Iy	0.021	0.839
Ix/Iy	-0.193	0.061
Imax	-0.079	0.447
Imin	0.012	0.911
Imax/Imin	-0.181	0.08
J	-0.04	0.698

*$P \leq 0.05$

**$P \leq 0.01$

Independent samples t-tests were performed in order to check for significant differences between the sexes in the mean scores of each cross sectional variable; results are detailed below in Table 6.17. When age categories are collapsed, there are significant differences between the sexes for all cross sectional variables except MA. When sex differences are evaluated for each age group, a number of statistically significant differences are found in the Late Young, Mature and Older Adult age categories but none were found in the Early Young Adult group.

TABLE 6.17: Adult Humeral Independent Samples T-Test Between the Sexes

	Ages Combined		**Early Young Adult**		**Late Young Adult**		**Mature Adult**		**Older Adult**	
	t	**Sig.**	**t**	**Sig.**	**t**	**Sig.**	**t**	**Sig.**	**t**	**Sig.**
TA	3.75**	0	0.63	0.563	2.12*	0.045	2.03	0.053	2.5*	0.02
CA	4.2**	0	0.68	0.529	1.93	0.065	3.50**	0.002	3.30**	0.003
MA	-0.44	0.662	-0.08	0.938	0.22	0.832	-1.08	0.297	0.08	0.941
%CA	1.99*	0.048	0.68	0.509	0.92	0.368	1.92	0.066	1.12	0.275
Ix	5.2**	0	0.02	0.987	2.8**	0.01	3.94**	0.001	4.21**	0
Iy	6.19**	0	0.26	0.806	3.68**	0.001	4.28**	0	4.04**	0
Ix/Iy	-2.28*	0.025	-0.75	0.469	-0.63	0.537	-0.8	0.435	-2.33*	0.028
Imax	5.13**	0	-0.01	0.991	2.8**	0.01	4.06**	0	3.76**	0.001
Imin	6.39**	0	0.3	0.778	3.62**	0.001	4.18**	0	4.68**	0
Imax /Imin	-2.73**	0.008	-0.99	0.34	-0.74	0.469	-0.65	0.521	-3.86**	0.001
J	5.87**	0	0.12	0.908	3.30**	0.003	4.25**	0	4.29**	0

*$P \leq 0.05$

**$P \leq 0.01$

To test for statistical differences in the mean scores of each cross sectional variable for pooled sexes, one-way analysis of variance (ANOVA) and Tukey's HSD post-hoc tests were run; results are presented in Tables 6.18 and 6.19, respectively. The ANOVA test returned significant differences for MA ($P = 0.000$), CA ($P = 0.003$) and %CA ($P = 0.000$). Post-hoc comparisons using Tukey's HSD indicate that for MA the mean score for the Older Adult category is significantly higher than each of the Early Young Adult ($P = 0.000$), Late Young Adult ($P = 0.000$), and Mature Adult ($P = 0.015$) age categories. For CA, Tukey's HSD indicates the mean score for the Older Adult category is significantly lower than the Early Young Adult ($P = 0.011$) and Late Young Adult ($P = 0.005$) age categories. For %CA, Tukey's HSD indicates the mean score for the Older Adult category is significantly lower than each of the Early Young Adult ($P = 0.000$), Late Young Adult ($P = 0.000$), and Mature Adult ($P = 0.013$) age categories.

TABLE 6.18: Results of One-way ANOVA on Age Differences and Humeral Cross-sectional Properties for All Adults

Variable	**Significance**
TA	0.677
CA	0.003**
MA	0**[a]
%CA	0**[a]
Ix	0.626
Iy	0.857
Ix/Iy	0.13
Imax	0.669
Imin	0.866
Imax/Imin	0.196
J	0.807

*$P \leq 0.05$

**$P \leq 0.01$

[a] *Failed homogeneity of variance, P value listed is for Welch equality of means test*

TABLE 6.19: Mean Differences, Standard Error and Significance Results for Tukey's HSD Post-hoc Test of Age on Adult Humeral Cross-sectional Properties

		Early Young Adult			**Late Young Adult**			**Mature Adult**			**Older Adult**		
		Late Young Adult	Mature Adult	Older Adult	Early Young Adult	Mature Adult	Older Adult	Early Young Adult	Late Young Adult	Older Adult	Early Young Adult	Late Young Adult	Mature Adult
MA	Mean Diff.	11.53	29.07	66.27**	-11.53	17.55	54.74**	-29.07	-17.55	37.20*	-66.27**	-54.74**	-37.2*
	Std. Error	14.52	14.42	14.42	14.52	12.30	12.30	14.42	12.30	12.19	14.42	12.30	12.19
	Sig.	0.86	0.19	0.00	0.86	0.49	0.00	0.19	0.49	0.02	0.00	0.00	0.02
TA	Mean Diff.	7.64	9.80	18.65	-7.64	2.16	11.01	-9.80	-2.16	8.85	-18.65	-11.01	-8.85
	Std. Error	15.88	15.77	15.77	15.88	13.46	13.46	15.77	13.46	13.33	15.77	13.46	13.33
	Sig.	0.96	0.93	0.64	0.96	1.00	0.85	0.93	1.00	0.91	0.64	0.85	0.91
CA	Mean Diff.	-3.88	-19.27	-47.61**	3.88	-15.39	-43.73**	19.27	15.39	-28.34	47.61**	43.73**	28.34
	Std. Error	15.18	15.08	15.08	15.18	12.87	12.87	15.08	12.87	12.74	15.08	12.87	12.74
	Sig.	0.99	0.58	0.01	0.99	0.63	0.01	0.58	0.63	0.12	0.01	0.01	0.12
%CA	Mean Diff.	-2.42	-6.24	-14.23**	2.42	-3.82	-11.81**	6.24	3.82	-7.99**	14.23**	11.81**	7.99**
	Std. Error	3.06	3.04	3.04	3.06	2.59	2.59	3.04	2.59	2.57	3.04	2.59	2.57
	Sig.	0.86	0.18	0.00	0.86	0.46	0.00	0.18	0.46	0.01	0.00	0.00	0.01
Ix	Mean Diff.	3.58	1.52	-3.54	-3.58	-2.06	-7.11	-1.52	2.06	-5.06	3.54	7.11	5.06
	Std. Error	6.55	6.50	6.50	6.55	5.55	5.55	6.50	5.55	5.50	6.50	5.55	5.50
	Sig.	0.95	1.00	0.95	0.95	0.98	0.58	1.00	0.98	0.79	0.95	0.58	0.79

TABLE 6.19: Mean Differences, Standard Error and Significance Results for Tukey's HSD Post-hoc Test of Age on Adult Humeral Cross-sectional Properties (continued)

Iy	Mean Diff.	1.52	4.09	0.81	-1.52	2.56	-0.71	-4.09	-2.56	-3.27	-0.81	0.71	3.27
	Std. Error	5.46	5.43	5.43	5.46	4.63	4.63	5.43	4.63	4.59	5.43	4.63	4.59
	Sig.	0.99	0.88	1.00	0.99	0.95	1.00	0.88	0.95	0.89	1.00	1.00	0.89
Ix/Iy	Mean Diff.	0.02	-0.06	-0.05	-0.02	-0.08	-0.08	0.06	0.08	0.01	0.05	0.08	-0.01
	Std. Error	0.05	0.05	0.05	0.05	0.04	0.04	0.05	0.04	0.04	0.05	0.04	0.04
	Sig.	0.97	0.56	0.64	0.97	0.18	0.24	0.56	0.18	1.00	0.64	0.24	1.00
Imax	Mean Diff.	3.63	1.94	-3.14	-3.63	-1.69	-6.78	-1.94	1.69	-5.08	3.14	6.78	5.08
	Std. Error	6.72	6.67	6.67	6.72	5.69	5.69	6.67	5.69	5.64	6.67	5.69	5.64
	Sig.	0.95	0.99	0.97	0.95	0.99	0.63	0.99	0.99	0.80	0.97	0.63	0.80
Imin	Mean Diff.	1.47	3.67	0.42	-1.47	2.20	-1.05	-3.67	-2.20	-3.25	-0.42	1.05	3.25
	Std. Error	5.27	5.23	5.23	5.27	4.46	4.46	5.23	4.46	4.42	5.23	4.46	4.42
	Sig.	0.99	0.90	1.00	0.99	0.96	1.00	0.90	0.96	0.88	1.00	1.00	0.88
Imax/ Imin	Mean Diff.	0.02	-0.06	-0.06	-0.02	-0.08	-0.08	0.06	0.08	0.00	0.06	0.08	0.00
	Std. Error	0.05	0.05	0.05	0.05	0.04	0.04	0.05	0.04	0.04	0.05	0.04	0.04
	Sig.	0.98	0.65	0.68	0.98	0.27	0.30	0.65	0.27	1.00	0.68	0.30	1.00
J	Mean Diff.	5.10	5.61	-2.72	-5.10	0.51	-7.83	-5.61	-0.51	-8.33	2.72	7.83	8.33
	Std. Error	11.66	11.58	11.58	11.66	9.88	9.88	11.58	9.88	9.79	11.58	9.88	9.79
	Sig.	0.97	0.96	1.00	0.97	1.00	0.86	0.96	1.00	0.83	1.00	0.86	0.83

*$P \leq 0.05$
**$P \leq 0.01$

A two-way between groups analysis of variance was then conducted to explore the impact of age and sex on each cross-sectional property and if these two variables interact with each other. A number of cross-sectional properties failed Levene's test for homogeneity of variances, therefore a stricter significance level ($P \leq 0.01$) was set for the following variables: MA, TA, CA Ix, Imax, J and Zp. No statistically significant interaction effects between age and sex were found for any humeral cross-sectional property. MA, CA and %CA showed statistically significant main effects for age (as detailed above in the results of the one-way ANOVA), however, CA ($P = 0.000$) and %CA ($P = 0.032$) also showed significant main effects for sex.

To gain a clearer picture, a one-way ANOVA with Tukey's HSD post-hoc tests were run for each individual sex. Results of this final ANOVA found that significant age differences remained for both sexes for all three variables (Tables 6.20 - 6.22). MA in Older Adult men is significantly higher than for either Early Young Adult ($P = 0.001$), Late Young Adult ($P = 0.004$) or Mature Adult ($P = 0.006$) age groups (Figure 6.38). CA in the Older Adult male category is significantly lower than for the Late Young Adult ($P = 0.011$) or Mature Adult ($P = 0.028$) categories (Figure 6.39). %CA in Older Adult men is also significantly lower than the Early Young Adult ($P = 0.001$), Late Young Adult ($P = 0.002$) or Mature Adult ($P = 0.005$) age categories (Figure 6.40). In women, the ANOVA test returned a significant difference in MA ($P = 0.040$) between the age categories, however, Tukeys post hoc test did not return any significant differences between them. This is especially strange as the women have very similar values in MA to the male age cagetories (which did reach significance across all age groups) and may be explained by the higher standards of error associated with the female sample. CA in Older Adult women is significantly lower than in the Late Young Adult ($P = 0.036$) category. %CA in Older Adult women is also significantly lower than in the Late Young Adult ($P = 0.022$) age category. It should be noted that for women, both CA and %CA actually show a larger difference in their mean values between the Early Young Adult and the Older Adult age categories than the Late Young Adult and Older Adult categories do, however, the difference does not reach statistical significance as it does in the latter comparison- again, this is possibly explained by the higher standards of error associated with the female sample in the post-hoc tests. Overall, MA, CA and %CA all show the same trend (Figures 6.38- 6.40): they begin around the same value for both sexes in early adulthood, however, while male values stay consistent until older age, females show a significant change between the Late Young and Mature Adult age categories, this pattern continues throughout the lifecycle.

TABLE 6.20: Results of One-way ANOVA on Age Differences and Adult Humeral Cross-sectional Properties Per Sex

Males:

Variable	Significance
MA	0.002**[a]
TA	0.186
CA	0.006**
%CA	0**
Ix	0.077
Iy	0.142
Ix/Iy	0.198
Imax	0.077
Imin	0.142
Imax/Imin	0.151
J	0.095
Zp	0.121

Females:

Variable	Significance
MA	0.04*
TA	0.999
CA	0.028*
%CA	0.014*
Ix	0.426[a]
Iy	0.575[a]
Ix/Iy	0.587
Imax	0.502[a]
Imin	0.439[a]
Imax/Imin	0.556
J	0.471[a]
Zp	0.159[a]

*$P \leq 0.05$

**$P \leq 0.01$

[a] *Failed homogeneity of variance, P value listed is for Welch equality of means test*

TABLE 6.21: Mean Differences, Standard Error and Significance Results for Tukey's HSD Post-hoc Test of Age on Adult Humeral Cross-sectional Properties for Males

		Early Young Adult			**Late Young Adult**			**Mature Adult**			**Older Adult**		
		Late Young Adult	Mature Adult	Older Adult	Early Young Adult	Mature Adult	Older Adult	Early Young Adult	Late Young Adult	Older Adult	Early Young Adult	Late Young Adult	Mature Adult
MA	Mean Diff.	-13.1	-18.6	-67.27**	13.1	-5.5	-54.16**	18.6	5.5	-48.68**	67.27*	54.16**	48.68**
	Std. Error	16.8	16.0	15.8	16.8	15.2	14.9	16.0	15.2	14.1	15.8	14.9	14.1
	Sig.	0.9	0.7	0.0	0.9	1.0	0.0	0.7	1.0	0.0	0.0	0.0	0.0
TA	Mean Diff.	-20.1	-18.9	-32.3	20.1	1.1	-12.3	18.9	-1.1	-13.4	32.3	12.3	13.4
	Std. Error	15.4	14.7	14.5	15.4	13.9	13.7	14.7	13.9	12.9	14.5	13.7	12.9
	Sig.	0.6	0.6	0.1	0.6	1.0	0.8	0.6	1.0	0.7	0.1	0.8	0.7
CA	Mean Diff.	-7.0	-0.3	34.9	7.0	6.6	41.88**	0.3	-6.6	35.28**	-34.9	-41.88**	-35.28**
	Std. Error	14.5	13.8	13.6	14.5	13.1	12.9	13.8	13.1	12.2	13.6	12.9	12.2
	Sig.	1.0	1.0	0.1	1.0	1.0	0.0	1.0	1.0	0.0	0.1	0.0	0.0
%CA	Mean Diff.	1.7	3.2	13.12**	-1.7	1.5	11.39**	-3.2	-1.5	9.89**	-13.12**	-11.39**	-9.89**
	Std. Error	3.3	3.2	3.1	3.3	3.0	3.0	3.2	3.0	2.8	3.1	3.0	2.8
	Sig.	1.0	0.7	0.0	1.0	1.0	0.0	0.7	1.0	0.0	0.0	0.0	0.0
Ix	Mean Diff.	-15.1	-12.7	-5.7	15.1	2.3	9.4	12.7	-2.3	7.0	5.7	-9.4	-7.0
	Std. Error	6.4	6.1	6.0	6.4	5.8	5.7	6.1	5.8	5.4	6.0	5.7	5.4
	Sig.	0.1	0.2	0.8	0.1	1.0	0.4	0.2	1.0	0.6	0.8	0.4	0.6

TABLE 6.21: Mean Differences, Standard Error and Significance Results for Tukey's HSD Post-hoc Test of Age on Adult Humeral Cross-sectional Properties for Males (continued)

Iy	Mean Diff.	-10.3	-12.7	-9.4	10.3	-2.4	0.9	12.7	2.4	3.3	9.4	-0.9	-3.3
	Std. Error	5.8	5.5	5.4	5.8	5.2	5.2	5.5	5.2	4.9	5.4	5.2	4.9
	Sig.	0.3	0.1	0.3	0.3	1.0	1.0	0.1	1.0	0.9	0.3	1.0	0.9
Ix/Iy	Mean Diff.	0.0	0.1	0.1	0.0	0.1	0.1	-0.1	-0.1	0.0	-0.1	-0.1	0.0
	Std. Error	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.0
	Sig.	1.0	0.7	0.4	1.0	0.5	0.2	0.7	0.5	1.0	0.4	0.2	1.0
Imax	Mean Diff.	-15.3	-13.9	-6.2	15.3	1.5	9.1	13.9	-1.5	7.7	6.2	-9.1	-7.7
	Std. Error	6.7	6.4	6.3	6.7	6.0	6.0	6.4	6.0	5.6	6.3	6.0	5.6
	Sig.	0.1	0.1	0.8	0.1	1.0	0.4	0.1	1.0	0.5	0.8	0.4	0.5
Imin	Mean Diff.	-10.1	-11.6	-9.0	10.1	-1.5	1.1	11.6	1.5	2.6	9.0	-1.1	-2.6
	Std. Error	5.4	5.1	5.1	5.4	4.9	4.8	5.1	4.9	4.5	5.1	4.8	4.5
	Sig.	0.3	0.1	0.3	0.3	1.0	1.0	0.1	1.0	0.9	0.3	1.0	0.9
Imax/ Imin	Mean Diff.	0.0	0.0	0.1	0.0	0.1	0.1	0.0	-0.1	0.0	-0.1	-0.1	0.0
	Std. Error	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.0
	Sig.	1.0	0.9	0.4	1.0	0.6	0.1	0.9	0.6	0.8	0.4	0.1	0.8
J	Mean Diff.	-25.4	-25.5	-15.1	25.4	0.0	10.3	25.5	0.0	10.3	15.1	-10.3	-10.3
	Std. Error	11.5	11.0	10.8	11.5	10.4	10.3	11.0	10.4	9.7	10.8	10.3	9.7
	Sig.	0.1	0.1	0.5	0.1	1.0	0.7	0.1	1.0	0.7	0.5	0.7	0.7

*$P \leq 0.05$
**$P \leq 0.01$

TABLE 6.22: Mean Differences, Standard Error and Significance Results for Tukey's HSD Post-hoc Test of Age on Adult Humeral Cross-sectional Properties for Females

		Early Young Adult			**Late Young Adult**			**Mature Adult**			**Older Adult**		
		Late Young Adult	Mature Adult	Older Adult	Early Young Adult	Mature Adult	Older Adult	Early Young Adult	Late Young Adult	Older Adult	Early Young Adult	Late Young Adult	Mature Adult
MA	Mean Diff.	-9.8	-41.9	-64.6	9.8	-32.1	-54.8	41.9	32.1	-22.7	64.6	54.8	22.7
	Std. Error	27.2	27.8	28.1	27.2	20.5	21.0	27.8	20.5	21.8	28.1	21.0	21.8
	Sig.	1.0	0.4	0.1	1.0	0.4	0.1	0.4	0.4	0.7	0.1	0.1	0.7
TA	Mean Diff.	-4.7	-3.4	-2.4	4.7	1.3	2.3	3.4	-1.3	1.0	2.4	-2.3	-1.0
	Std. Error	29.4	30.0	30.4	29.4	22.2	22.7	30.0	22.2	23.5	30.4	22.7	23.5
	Sig.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
CA	Mean Diff.	5.1	38.5	62.2	-5.1	33.4	57.09**	-38.5	-33.4	23.7	-62.2	-57.09**	-23.7
	Std. Error	26.1	26.7	27.0	26.1	19.7	20.2	26.7	19.7	20.9	27.0	20.2	20.9
	Sig.	1.0	0.5	0.1	1.0	0.3	0.0	0.5	0.3	0.7	0.1	0.0	0.7
%CA	Mean Diff.	2.2	9.5	15.5	-2.2	7.3	13.26**	-9.5	-7.3	6.0	-15.5	-13.26**	-6.0
	Std. Error	5.7	5.8	5.9	5.7	4.3	4.4	5.8	4.3	4.5	5.9	4.4	4.5
	Sig.	1.0	0.4	0.1	1.0	0.3	0.0	0.4	0.3	0.6	0.1	0.0	0.6
Ix	Mean Diff.	6.2	12.4	17.0	-6.2	6.2	10.8	-12.4	-6.2	4.5	-17.0	-10.8	-4.5
	Std. Error	10.5	10.7	10.8	10.5	7.9	8.1	10.7	7.9	8.4	10.8	8.1	8.4
	Sig.	0.9	0.7	0.4	0.9	0.9	0.6	0.7	0.9	0.9	0.4	0.6	0.9

TABLE 6.22: Mean Differences, Standard Error and Significance Results for Tukey's HSD Post-hoc Test of Age on Adult Humeral Cross-sectional Properties for Females (continued)

Iy	Mean Diff.	4.9	6.0	11.2	-4.9	1.1	6.3	-6.0	-1.1	5.2	-11.2	-6.3	-5.2
	Std. Error	7.6	7.7	7.8	7.6	5.7	5.8	7.7	5.7	6.1	7.8	5.8	6.1
	Sig.	0.9	0.9	0.5	0.9	1.0	0.7	0.9	1.0	0.8	0.5	0.7	0.8
Ix/Iy	Mean Diff.	0.0	0.1	0.0	0.0	0.1	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.1
	Std. Error	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Sig.	1.0	0.8	1.0	1.0	0.6	1.0	0.8	0.6	0.8	1.0	1.0	0.8
Imax	Mean Diff.	6.4	13.0	16.7	-6.4	6.6	10.3	-13.0	-6.6	3.7	-16.7	-10.3	-3.7
	Std. Error	10.7	10.9	11.1	10.7	8.1	8.3	10.9	8.1	8.6	11.1	8.3	8.6
	Sig.	0.9	0.6	0.4	0.9	0.8	0.6	0.6	0.8	1.0	0.4	0.6	1.0
Imin	Mean Diff.	4.6	5.4	11.4	-4.6	0.8	6.7	-5.4	-0.8	6.0	-11.4	-6.7	-6.0
	Std. Error	7.4	7.6	7.7	7.4	5.6	5.7	7.6	5.6	5.9	7.7	5.7	5.9
	Sig.	0.9	0.9	0.5	0.9	1.0	0.6	0.9	1.0	0.7	0.5	0.6	0.7
Imax/ Imin	Mean Diff.	0.0	0.1	0.0	0.0	0.1	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.1
	Std. Error	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Sig.	1.0	0.7	1.0	1.0	0.6	1.0	0.7	0.6	0.7	1.0	1.0	0.7
J	Mean Diff.	11.1	18.4	28.1	-11.1	7.3	17.0	-18.4	-7.3	9.7	-28.1	-17.0	-9.7
	Std. Error	17.6	18.0	18.2	17.6	13.3	13.6	18.0	13.3	14.1	18.2	13.6	14.1
	Sig.	0.9	0.7	0.4	0.9	0.9	0.6	0.7	0.9	0.9	0.4	0.6	0.9

*$P \leq 0.05$

**$P \leq 0.01$

FIGURE 6.38: Estimated Marginal Means of Adult Humeral MA Between the Sexes

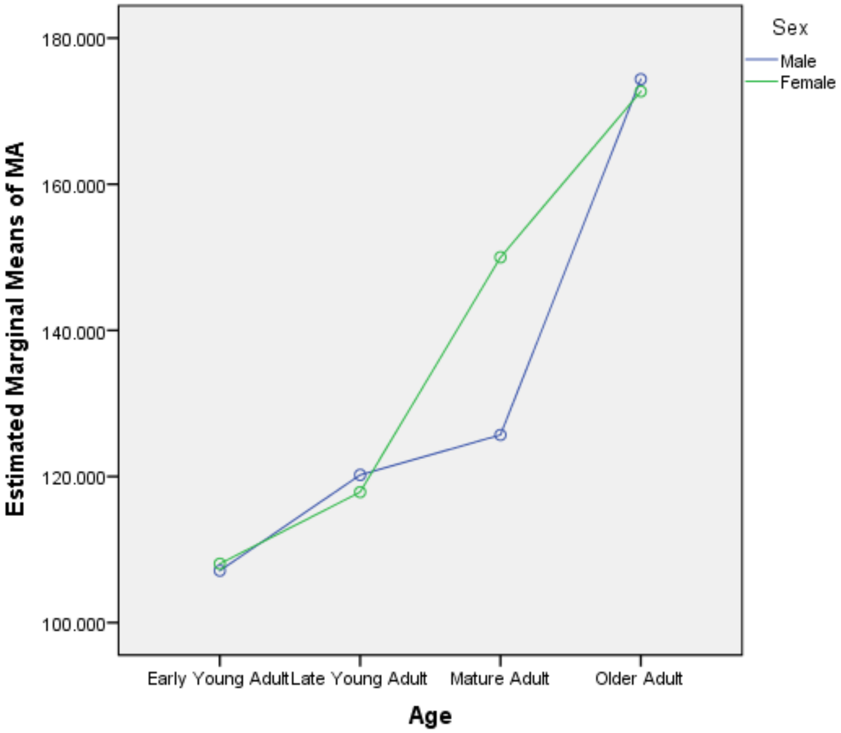


FIGURE 6.39: Estimated Marginal Means of Adult Humeral CA Between the Sexes

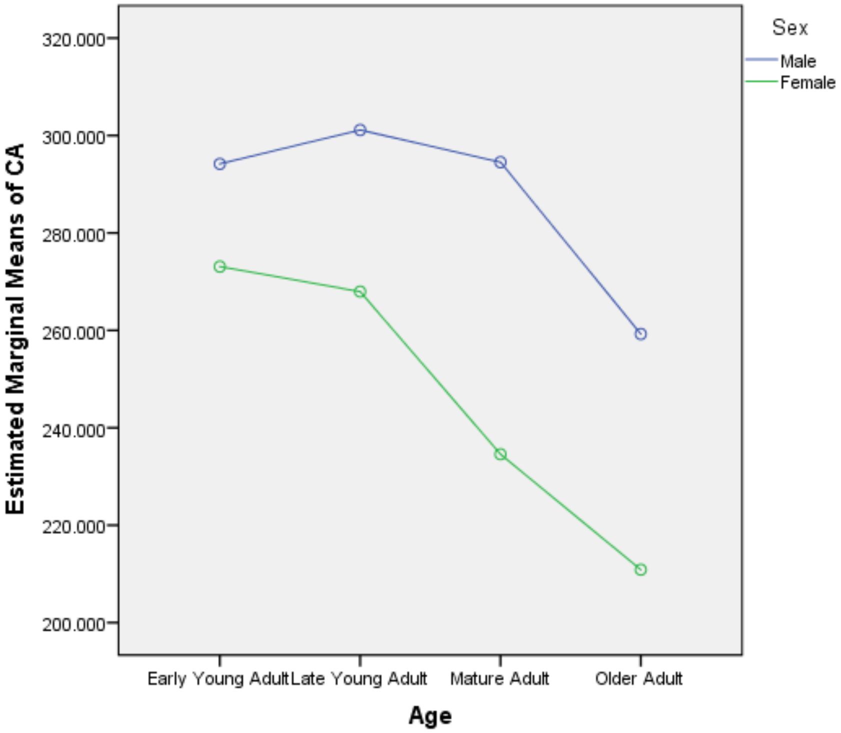
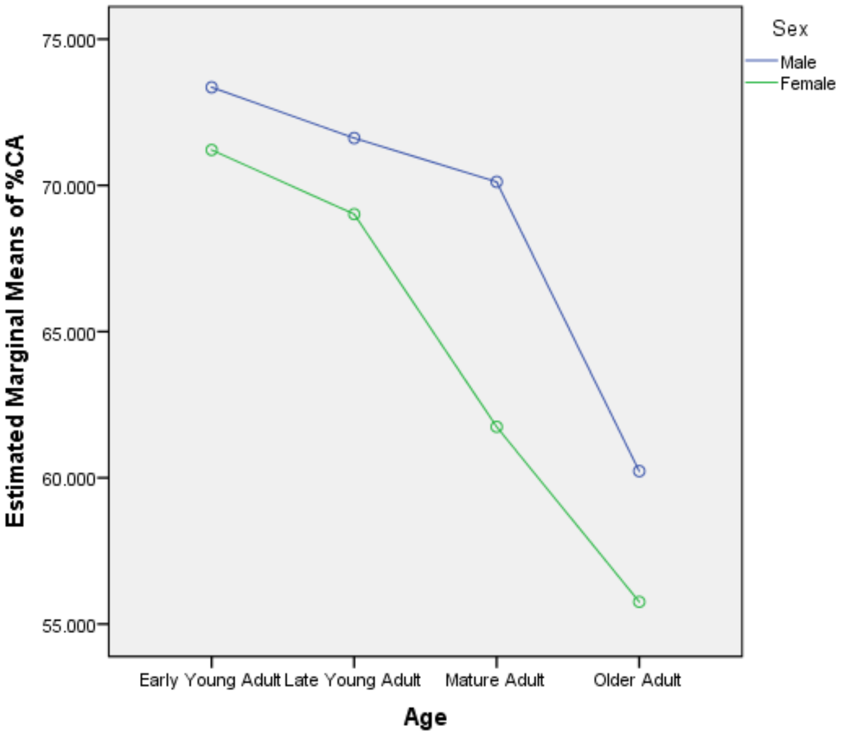


FIGURE 6.40: Estimated Marginal Means of Adult Humeral %CA Between the Sexes



Total area as well as all SMAs and shape ratios showed statistically significant main effects for sex: TA (*P* = 0.001), Ix (*P* = 0.000), Iy (*P* = 0.000), Ix/Iy (*P* = 0.044), Imax (*P* = 0.000), Imin (*P* = 0.000), Imax/Imin (*P* = 0.011) and J (*P* = 0.000). These results were in accordance with the independent samples t-test, and are illustrated below in Figures 6.41 through 6.48. The estimated marginal means for Ix, Iy, Imax, Imin and J all show the same trend for the sexes: male values increase between the Early Young and Late Young Adulthood age categories and stay relatively the same throughout life while values for women show a steady decrease throughout life. Finally, for the shape ratios Ix/Iy and Imax/Imin, females have significantly higher scores than males throughout life suggesting a more antero-posteriorly strengthened humeral shaft.

FIGURE 6.41: Estimated Marginal Means of Adult Humeral TA Between the Sexes

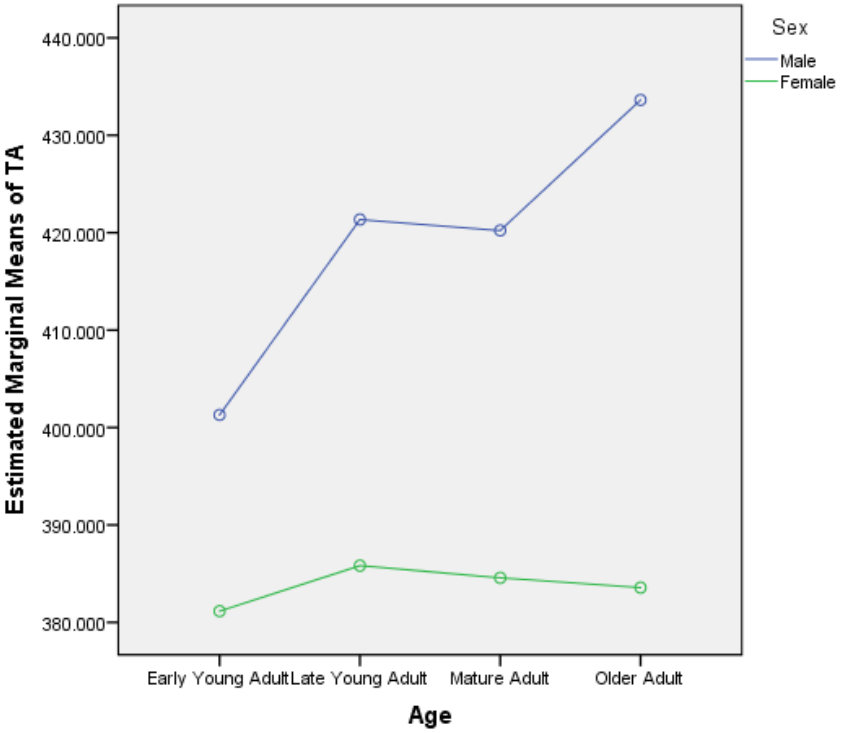


FIGURE 6.42: Estimated Marginal Means of Adult Humeral Ix Between the Sexes

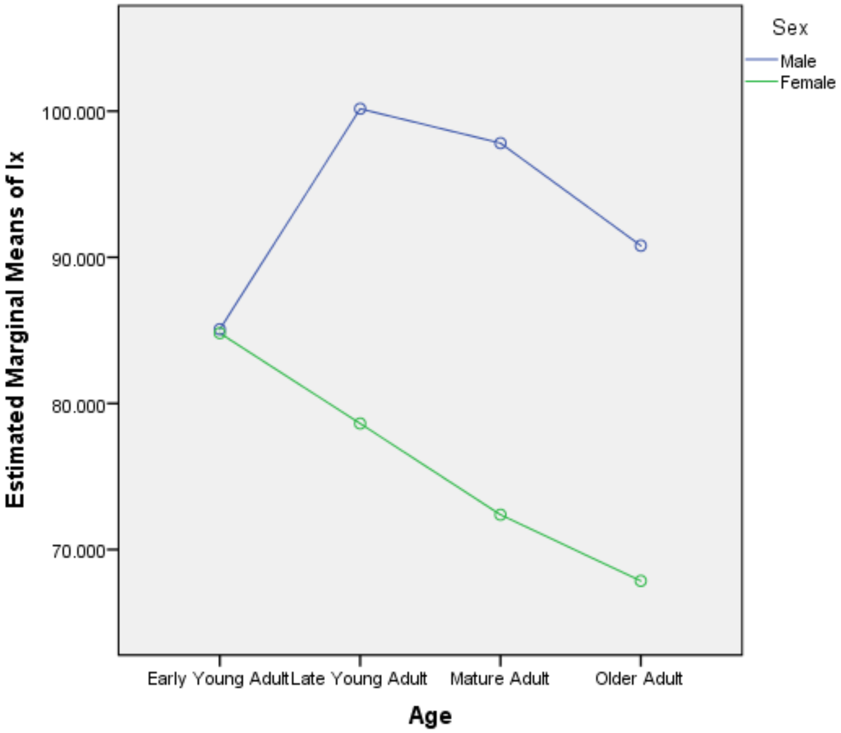


FIGURE 6.43: Estimated Marginal Means of Adult Humeral Iy Between the Sexes

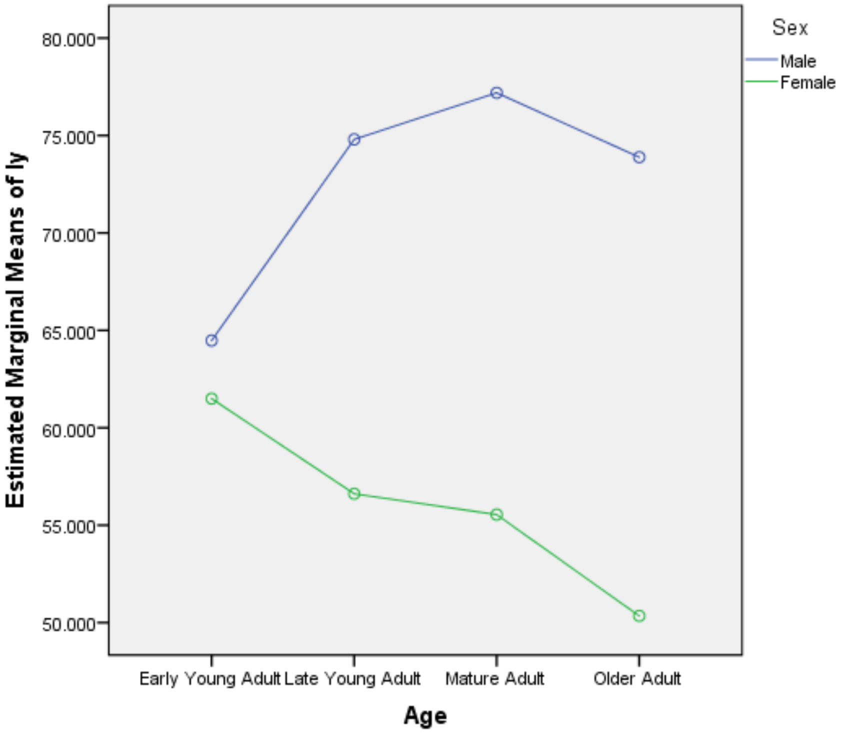


FIGURE 6.44: Estimated Marginal Means of Adult Humeral Ix/Iy Between the Sexes

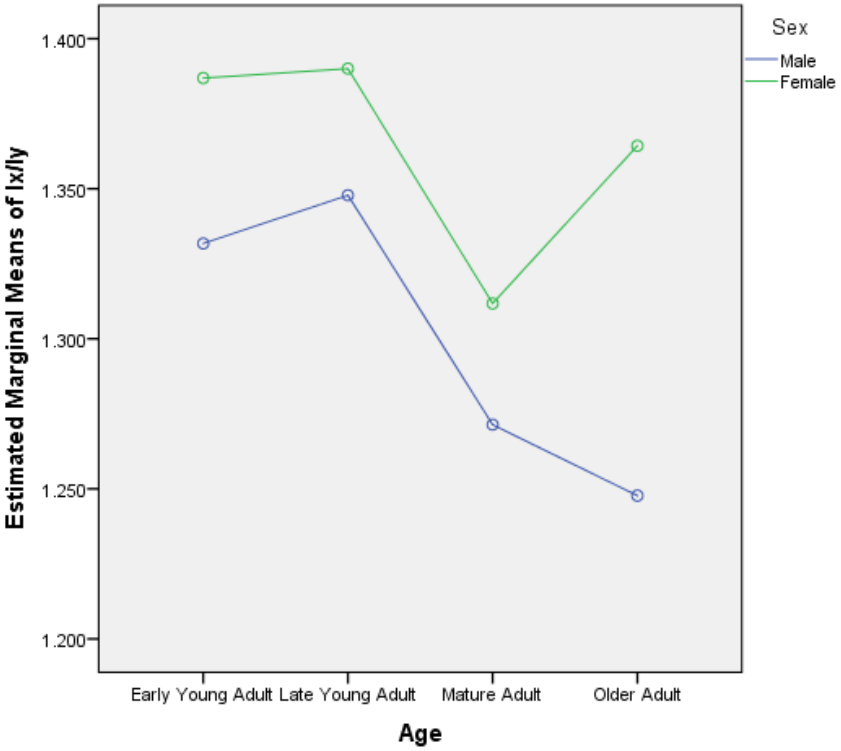


FIGURE 6.45: Estimated Marginal Means of Adult Humeral Imax Between the Sexes

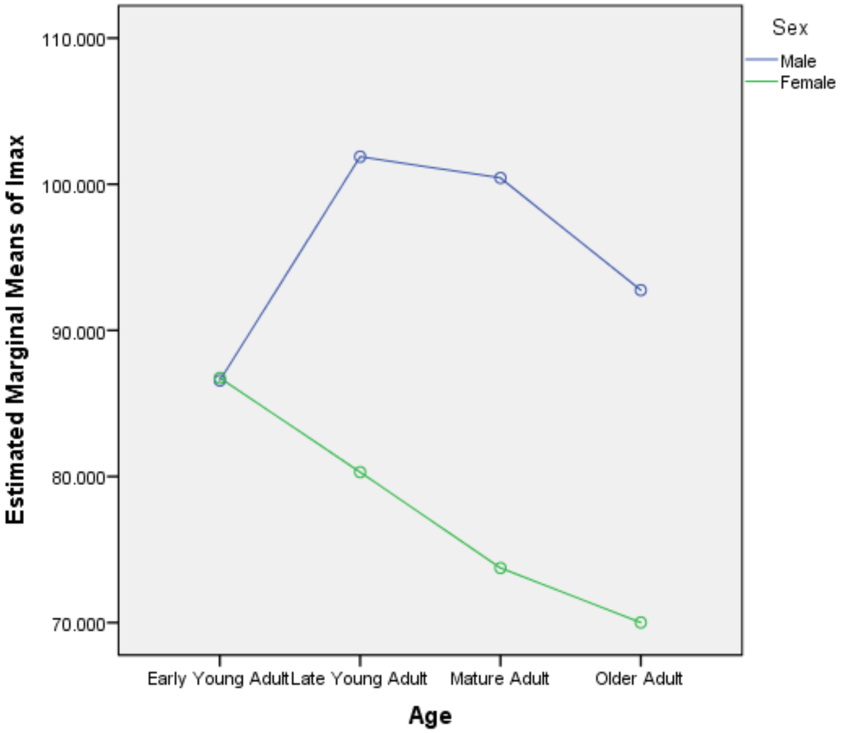


FIGURE 6.46: Estimated Marginal Means of Adult Humeral Imin Between the Sexes

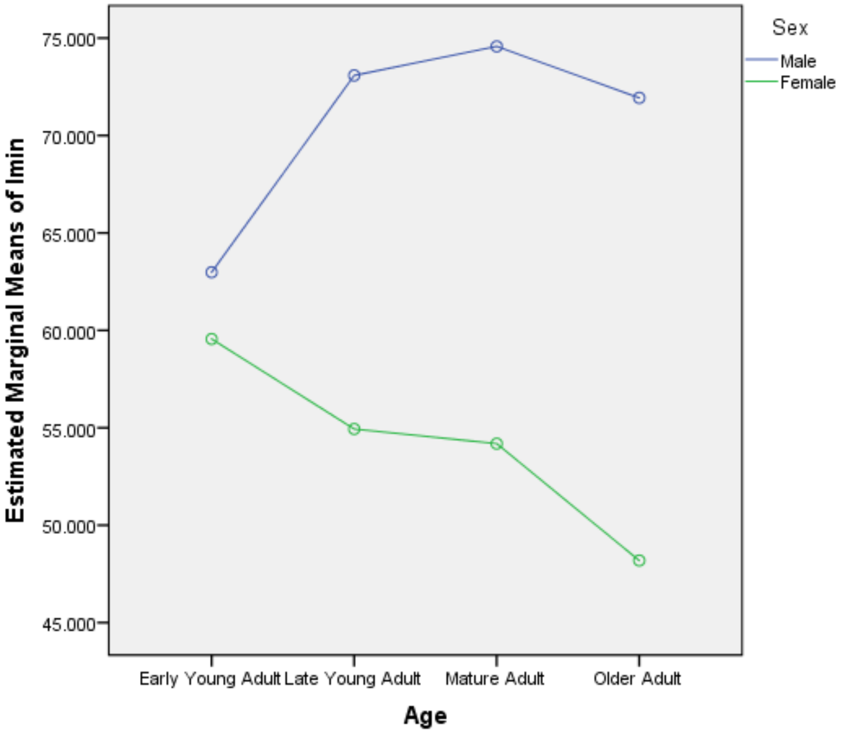


FIGURE 6.47: Estimated Marginal Means of Adult Humeral Imax/Imin Between the Sexes

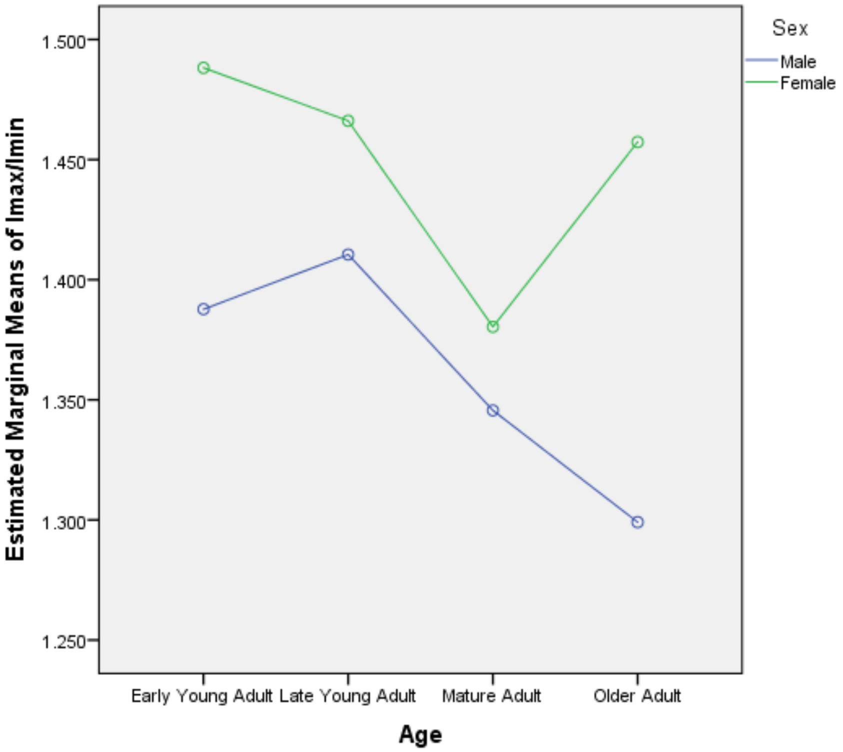
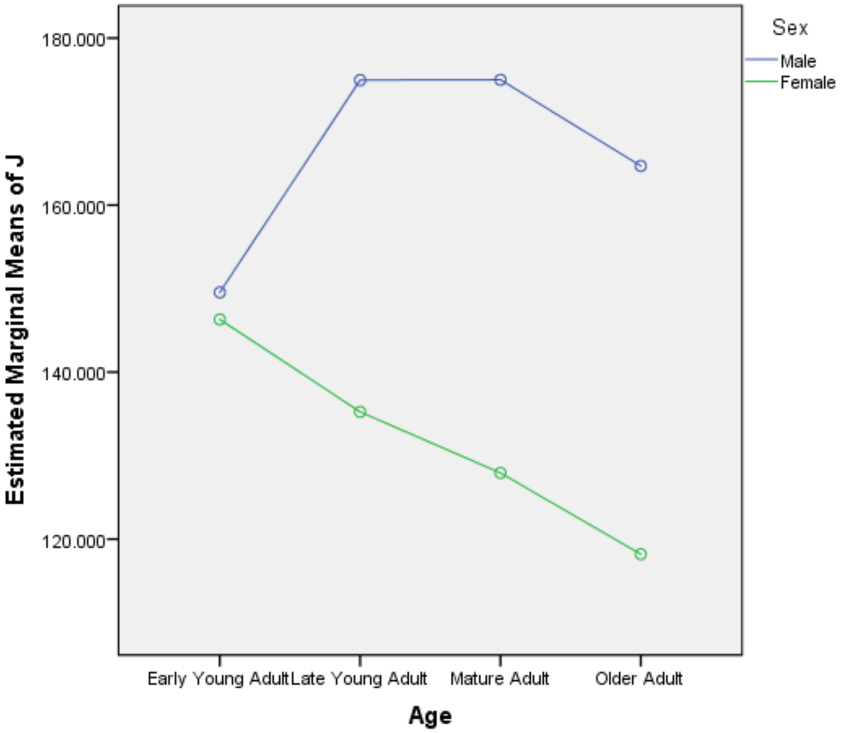


FIGURE 6.48: Estimated Marginal Means of Adult Humeral J Between the Sexes



6.3 ENTHESEAL CHANGES

Due to the nature of ordinal data, the asymmetry tests for entheseal changes, non-genetic non-metric traits and osteoarthritis could not be calculated as it was for the numerical cross-sectional property data; instead, the skeletal sample was divided by sex and Spearman's rank order correlation coefficients were calculated for each variable to check for asymmetry between left and right sides. Spearman correlation coefficients (rho's) for entheseal changes were very strong in almost all categories of robusticity and osteolytic lesions (Table 6.23), demonstrating a strong positive correlation between scores for the right and left sides. Osteophytic formations had low rho coefficients and were therefore most commonly asymmetric. Based on these results the sides were combined for the categories of robusticity and osteolytic formations; since there were more scores for the left side than the right, right side scores were substituted only in cases where the left side data were unavailable. Analyses of osteophytic formations remained separated by side. No treatment for missing data was used, as such, sample sizes are listed per statistical analysis.

TABLE 6.23: Spearman's Rank Order Correlations for Asymmetry of Entheseal Changes

FEMALES:

Upper Limb:

		Robusticity	Osteolytic Formations	Osteophytic Formations
***Costoclavicular* Ligament**	rho	.602**	.429*	.801**
	Sig.	0.001	0.02	0
	N	29	29	29
***Conoid* Ligament**	rho	.907**	.900**	.539**
	Sig.	0	0	0.007
	N	24	24	24
***Trapezoid* Ligament**	rho	.813**	.895**	.798**
	Sig.	0	0	0
	N	24	24	24
Subscapularis	rho	0.271	.515**	.426*
	Sig.	0.147	0.004	0.019
	N	30	30	30
Supraspinatus; Infraspinatus/Teres Minor	rho	.655**	.666**	.999**
	Sig.	0	0	0
	N	28	28	28
Pectoralis Major	rho	.794**	.695**	.
	Sig.	0	0	.
	N	31	31	30
Latissimus Dorsi / Teres Major	rho	.831**	.385*	.
	Sig.	0	0.048	.
	N	27	27	27

MALES:

Upper Limb:

		Robusticity	Osteolytic Formations	Osteophytic Formations
***Costoclavicular* Ligament**	rho	.648**	.407*	.457**
	Sig.	0.454	0.014	0.005
	N	36	36	36
***Conoid* Ligament**	rho	.789**	.876**	-0.046
	Sig.	0	0	0.801
	N	32	32	32
***Trapezoid* Ligament**	rho	.535**	.646**	.805**
	Sig.	0.001	0	0
	N	37	37	37
Subscapularis	rho	.584**	.630**	.631**
	Sig.	0	0	0
	N	40	41	40
Supraspinatus; Infraspinatus/Teres Minor	rho	.783**	.776**	-0.048
	Sig.	0	0	0.774
	N	38	38	38
Pectoralis Major	rho	.747**	.711**	.698**
	Sig.	0	0	0
	N	39	39	39
Latissimus Dorsi / Teres Major	rho	.853**	0.301	-0.065
	Sig.	0	0.059	0.689
	N	40	40	40

TABLE 6.23: Spearman's Rank Order Correlations for Asymmetry of Entheseal Changes (continued)

Deltoideus	rho	.751**	.682**	.
	Sig.	0	0	.
	N	31	31	31
Triceps Brachii	rho	.928**	.	.839**
	Sig.	0	.	0
	N	26	26	26
Brachialis	rho	.680**	.536**	.558**
	Sig.	0	0.002	0.001
	N	32	32	32
Biceps Brachii	rho	.753**	.366*	0.172
	Sig.	0	0.028	0.317
	N	36	36	36
Supinator	rho	.886**	.	.
	Sig.	0	.	.
	N	34	34	34
Pronator Teres	rho	.827**	.477**	.
	Sig.	0	0.004	.
	N	34	34	34
Extensor Carpi Ulnaris	rho	.655*	.	1.000**
	Sig.	0.011	.	.
	N	14	14	14
Flexor Carpi Ulnaris	rho	.635*	.	1.000**
	Sig.	0.015	.	.
	N	14	14	14

Deltoideus	rho	.893**	.639**	-0.026
	Sig.	0	0	0.874
	N	39	39	39
Triceps Brachii	rho	.872**	.	.
	Sig.	0	.	.
	N	31	31	31
Brachialis	rho	.751**	.461**	.710**
	Sig.	0	0.002	0
	N	42	42	42
Biceps Brachii	rho	.833**	.471**	.596**
	Sig.	0	0.003	0
	N	38	38	38
Supinator	rho	.805**	.	.
	Sig.	0	.	.
	N	44	44	44
Pronator Teres	rho	.906**	.805**	.
	Sig.	0	0	.
	N	38	38	38
Extensor Carpi Ulnaris	rho	0.172	1.000**	.
	Sig.	0.443	.	.
	N	22	22	22
Flexor Carpi Ulnaris	rho	0.371	.	.
	Sig.	0.098	.	.
	N	21	21	21

TABLE 6.23: Spearman's Rank Order Correlations for Asymmetry of Entheseal Changes (continued)

Lower Limb:				
Piriformis/Obturator Internus/Gemelli	rho	.863**	-0.063	0.304
	Sig.	0	0.77	0.148
	N	24	24	24
Gluteus Minimus	rho	.608**	0.339	.426*
	Sig.	0	0.072	0.021
	N	29	29	29
Gluteus Medius	rho	.701**	1.000**	.
	Sig.	0	.	.
	N	27	27	27
Quadratus Femoris	rho	.547*	.	.
	Sig.	0.01	.	.
	N	21	21	21
Gluteus Maximus	rho	.898**	.723**	.829**
	Sig.	0	0	0
	N	33	33	33
Iliopsoas	rho	.832**	.718**	.808**
	Sig.	0	0	0
	N	26	26	26
Adductor Magnus	rho	.820**	.698**	.698**
	Sig.	0	0	0
	N	39	39	39
Quadriceps	rho	.513*	.	0.344
	Sig.	0.017	.	0.127
	N	21	21	21
Popliteus	rho	.890**	.470**	.633**
	Sig.	0	0.004	0
	N	35	35	35

Lower Limb:				
Piriformis/Obturator Internus/Gemelli	rho	.729**	.595**	.490**
	Sig.	0	0	0.003
	N	34	34	34
Gluteus Minimus	rho	.709**	.649**	.391*
	Sig.	0	0	0.018
	N	36	36	36
Gluteus Medius	rho	.713**	1.000**	.833**
	Sig.	0	.	0
	N	34	34	34
Quadratus Femoris	rho	.757**	1.000**	.
	Sig.	0	.	.
	N	28	28	28
Gluteus Maximus	rho	.920**	.603**	.806**
	Sig.	0	0	0
	N	42	41	41
Iliopsoas	rho	.811**	.698**	.344*
	Sig.	0	0	0.03
	N	41	40	40
Adductor Magnus	rho	.941**	.	.447**
	Sig.	0	.	0.003
	N	44	44	43
Quadriceps	rho	.881**	.	.997**
	Sig.	0	.	0
	N	21	21	21
Popliteus	rho	.881**	.699**	.392**
	Sig.	0	0	0.008
	N	45	45	45

TABLE 6.23: *Spearman's Rank Order Correlations for Asymmetry of Entheseal Changes (continued*

Semimembranosus	rho	.541**	.360*	.
	Sig.	0.001	0.043	.
	N	32	32	32
Sartorius/Gracilis/ Semitendinous	rho	.830**	.	.697**
	Sig.	0	.	0
	N	36	36	36
Soleus (Achilles Tendon)	rho	.891**	.	.908**
	Sig.	0	.	0
	N	23	23	21

Semimembranosus	rho	.626**	.	.
	Sig.	0	.	.
	N	28	29	29
Sartorius/Gracilis/ Semitendinous	rho	.726**	.	.520**
	Sig.	0	.	0.001
	N	39	40	40
Soleus (Achilles Tendon)	rho	.831**	.719**	.692**
	Sig.	0	0	0
	N	31	31	30

*$P \leq 0.05$
**$P \leq 0.01$

6.3.1 Robusticity and Osteolytic Formations

Mann-Whitney U tests were run on the entire sample to explore possible differences between the sexes for the categories of robusticity and osteolytic formations. Table 6.24 presents the results of the Mann-Whitney U test which was performed on all of the entheseal robusticity and osteolytic scores using sex as the grouping variable. Males had statistically significant higher scores than females for robusticity of the *latissimus dorsi /teres major* ($P = 0.021$) and *iliopsoas* ($P = 0.032$) entheses as well as for osteolytic formations at the *costoclavicular* ($P = 0.000$), *subscapularis* ($P = 0.042$) and *biceps brachii* ($P = 0.003$) entheses. Females had statistically higher scores than males for robusticity of the *triceps brachii* ($P = 0.001$) and *flexor carpi ulnaris* ($P = 0.05$).

TABLE 6.24: Mann-Whitney U Test Between the Sexes for Changes in Mean Rank of Robusticity and Osteolytic Formations, Ages Combined

			Male		Female		Total
Entheseal Variable	Mann-Whitney U	Significance	Mean Rank	N	Mean Rank	N	N
Costoclavicular RB	711	0.445	41.57	42	38.22	37	79
Costoclavicular OL	284.5	0.000**	51.73	42	26.69	37	79
Conoid RB	572.5	0.765	35.64	35	34.34	34	69
Conoid OL	595	1	35	35	35	34	69
Trapezoid RB	624	0.741	36.36	42	37.87	31	73
Trapezoid OL	530	0.111	39.88	42	33.1	31	73
Subscapularis RB	780	0.44	43.54	46	40.08	37	83
Subscapularis OL	702	0.042*	45.24	46	37.97	37	83
Supraspinatus etc. RB	716.5	0.715	40.22	44	38.57	34	78
Supraspinatus etc. OL	606.5	0.072	42.72	44	35.34	34	78
Pectoralis RB	741	0.581	39.34	44	41.92	36	80
Pectoralis OL	725	0.213	42.02	44	38.64	36	80
Latissimus etc. RB	548	0.021*	44.82	45	33.62	34	79
Latissimus etc. OL	629.5	0.094	43.01	45	36.01	34	79
Deltoideus RB	626.5	0.224	36.57	43	42.07	34	77
Deltoideus OL	723	0.848	39.19	43	38.76	34	77
Triceps Brachii RB	340	0.001**	28.45	38	42.17	30	68

$^{*}P \leq 0.05$

$^{**}P \leq 0.01$

TABLE 6.24: Mann-Whitney U Test Between the Sexes for Changes in Mean Rank of Robusticity and Osteolytic Formations, Ages Combined (continued)

Triceps Brachii OL	555	0.374	34.89	38	34	30	68
Brachialis RB	652	0.141	37.32	44	44.39	36	80
Brachialis OL	697	0.138	42.66	44	37.86	36	80
Biceps Brachii RB	726.5	0.128	45.71	46	38.62	38	84
Biceps Brachii OL	647	0.003**	47.43	46	36.53	38	84
Supinator RB	641	0.095	37.43	46	45.69	35	81
Supinator OL	805	1	41	46	41	35	81
Pronator Teres RB	742.5	0.632	41.5	45	39.21	35	80
Pronator Teres OL	740	0.272	41.56	45	39.14	35	80
Extensor Carpi Ulnaris RB	410	0.296	29.56	34	33.86	28	62
Extensor Carpi Ulnaris OL	462	0.364	31.91	34	31	28	62
Flexor Carpi Ulnaris RB	359	0.05*	28.06	34	35.68	28	62
Flexor Carpi Ulnaris OL	459	0.27	31	34	32.11	28	62
Piriformis etc. RB	530.5	0.198	33.94	41	39.89	31	72
Piriformis etc. OL	611	0.483	37.1	41	35.71	31	72
Gluteus Minimus RB	714	0.785	39.59	41	38.33	36	77
Gluteus Minimus OL	668.5	0.224	40.7	41	37.07	36	77
Gluteus Medius RB	674	0.46	40.56	41	37.22	36	77
Gluteus Medius OL	708	0.51	39.73	41	38.17	36	77
Quadratus Femoris RB	588	0.594	34.83	36	37.2	35	71
Quadratus Femoris OL	595	0.16	36.97	36	35	35	71
Gluteus Maximus RB	899	0.993	42.98	45	43.03	40	85
Gluteus Maximus OL	827.5	0.453	43.69	44	41.19	40	84
Iliopsoas RB	590.5	0.032*	45.27	43	34.96	37	80
Iliopsoas OL	783.5	0.783	40.78	43	40.18	37	80
Adductor Magnus RB	841	0.549	44.39	44	41.51	41	85
Adductor Magnus OL	900.5	0.96	42.97	44	43.04	41	85
Quadriceps RB	477	0.802	32.47	34	31.45	29	63
Quadriceps OL	493	1	32	34	32	29	63
Popliteus RB	756	0.564	42.2	45	39.5	36	81
Popliteus OL	783	0.433	40.4	45	41.75	36	81
Semimembranosus RB	682	0.995	37.49	39	37.51	35	74
Semimembranosus OL	650.5	0.464	38.32	39	36.59	35	74
Sartorius etc. RB	707	0.714	39.83	40	38.11	37	77
Sartorius etc. OL	721.5	0.336	39.46	40	38.5	37	77
Soleus RB	374.5	0.064	28.51	34	36.09	29	63
Soleus OL	478.5	0.356	32.43	34	31.5	29	63

$^{*}P \leq 0.05$

$^{**}P \leq 0.01$

Kruskal-Wallis tests were then run on the entire sample with both sexes to explore potential differences between age groups. Table 6.25 presents the results of the Kruskal-Wallis test, which was performed on all of the entheseal robusticity and osteolytic scores using age as the grouping variable. Statistically significant differences in scores of robusticity between age categories were found for *supraspinatus* (*P* = 0.017), *latissimus* (*P* = 0.049), *brachialis* (*P* = 0.038), *biceps brachii* (*P* = 0.010), *supinator* (*P* = 0.000), *pronator teres* (*P* = 0.000), *piriformis* (*P* = 0.000), *gluteus minimus* (*P* = 0.017), *quadratus femoris* (*P* = 0.008), *gluteus maximus* (*P* = 0.000), *iliopsoas* (*P* = 0.003), *adductor magnus* (*P* = 0.000), and the *sartorius* (*P* = 0.000) entheses. Statistically significant differences in scores of osteolytic formations between age categories were returned for the *conoid* ligament (*P* = 0.036), *pectoralis* (*P* = 0.003), *pronator teres* (*P* = 0.000), *gluteus maximus* (*P* = 0.029) and *popliteus* (*P* = 0.000) entheses.

TABLE 6.25: Kruskal-Wallis Test Between Age Groups for Mean Ranks of Robusticity and Osteolytic Formations, Sexes Combined

		Early Young Adult		Late Young Adult		Mature Adult		Older Adult		Total
Entheseal Variable	Sig.	Mean Rank	N	Mean Rank	N	Mean Rank	N	Mean Rank	N	N
Costoclavicular RB	0.227	31.53	17	41.3	20	41.96	28	44.5	14	79
Costoclavicular OL	0.632	42.59	17	40.23	20	41.61	28	33.32	14	79
Conoid RB	0.811	35.6	15	31.8	20	36.2	25	37.78	9	69
Conoid OL	0.017*	28	15	35.15	20	34.8	25	46.89	9	69
Trapezoid RB	0.611	31.66	16	36.79	17	39.67	30	37.9	10	73
Trapezoid OL	0.513	33.91	16	37.53	17	35.88	30	44.4	10	73
Subscapularis RB	0.044*	31.85	17	42.25	24	49.14	29	38.88	13	83
Subscapularis OL	0.156	42.06	17	41.06	24	38.74	29	50.92	13	83

TABLE 6.25: Kruskal-Wallis Test Between Age Groups for Mean Ranks of Robusticity and Osteolytic Formations, Sexes Combined (continued)

Supraspinatus etc. RB	0.008**	24.87	15	41.26	23	46.27	28	38.63	12	78
Supraspinatus etc. OL	0.613	34.9	15	38.3	23	41.89	28	41.96	12	78
Pectoralis RB	0.055	27.63	15	41.18	22	43.91	29	46.14	14	80
Pectoralis OL	0.009**	49.87	15	38.25	22	39.29	29	36.5	14	80
Latissimus etc. RB	0.027*	26.4	15	39.38	21	46.83	29	41.36	14	79
Latissimus etc. OL	0.538	46	15	37.52	21	39.69	29	37.93	14	79
Deltoideus RB	0.029*	25.9	15	42.98	22	39.81	27	45.69	13	77
Deltoideus OL	0.097	44.2	15	36.5	22	37.93	27	39.46	13	77
Triceps Brachii RB	0.091	26.38	16	32.61	19	38.79	21	40.83	12	68
Triceps Brachii OL	0.355	36.13	16	34	19	34	21	34	12	68
Brachialis RB	0.025*	25.61	14	42.56	24	42.12	29	49.12	13	80
Brachialis OL	0.462	45.89	14	39.31	24	38.72	29	40.85	13	80
Biceps Brachii RB	0.006**	27.97	16	43.1	25	51.03	29	40.36	14	84
Biceps Brachii OL	0.807	39.91	16	41.28	25	44.45	29	43.61	14	84
Supinator RB	0**	25.17	15	31.28	23	50.31	29	54.64	14	81
Supinator OL	1	41	15	41	23	41	29	41	14	81
Pronator Teres RB	0**	20.6	15	36.13	23	52.93	28	44.14	14	80
Pronator Teres OL	0.003**	48.67	15	38	23	38	28	40.86	14	80
Extensor Carpi Ulnaris RB	0.076	22.73	13	33.33	18	31.5	22	40.5	9	62
Extensor Carpi Ulnaris OL	0.287	33.38	13	31	18	31	22	31	9	62
Flexor Carpi Ulnaris RB	0.058	20.75	12	34.13	19	34.59	22	32.72	9	62
Flexor Carpi Ulnaris OL	0.117	31	12	31	19	31	22	34.44	9	62
Piriformis etc. RB	0**	19	15	30.63	20	44.98	28	52.33	9	72
Piriformis etc. OL	0.678	34.5	15	36.25	20	37.14	28	38.39	9	72

TABLE 6.25: Kruskal-Wallis Test Between Age Groups for Mean Ranks of Robusticity and Osteolytic Formations, Sexes Combined (continued)

Gluteus Minimus RB	0.009**	28.35	17	33.76	21	46.79	28	45.64	11	77
Gluteus Minimus OL	0.343	34	17	41.1	21	39.75	28	40.82	11	77
Gluteus Medius RB	0.087	29	17	38.38	21	43.35	26	44.38	13	77
Gluteus Medius OL	0.443	36	17	41.55	21	38.87	26	39.08	13	77
Quadratus Femoris RB	0.004**	23.17	15	36.28	20	45.44	24	32.71	12	71
Quadratus Femoris OL	0.422	35	15	36.75	20	35	24	38	12	71
Gluteus Maximus RB	0**	20.74	17	38.07	23	55.05	31	51.46	14	85
Gluteus Maximus OL	0.057	50.65	17	41.41	23	41.75	30	36	14	84
Iliopsoas RB	0.001**	23.85	17	39.08	20	49.6	30	43.46	13	80
Iliopsoas OL	0.201	38	17	39.95	20	43.37	30	38	13	80
Adductor Magnus RB	0**	17.21	17	43.9	24	54.97	30	47.14	14	85
Adductor Magnus OL	0.294	42	17	42	24	44.83	30	42	14	85
Quadriceps RB	0.996	32.5	12	32.47	17	31.8	23	31.14	11	63
Quadriceps OL	1	32	12	32	17	32	23	32	11	63
Popliteus RB	0.038*	27.5	16	43.35	23	44.6	30	45.5	12	81
Popliteus OL	0.168	44.56	16	41.26	23	39.5	30	39.5	12	81
Semimembranosus RB	0.115	26.8	15	39.58	20	40.83	27	39.92	12	74
Semimembranosus OL	0.547	36.93	15	38.15	20	35.85	27	40.83	12	74
Sartorius etc. RB	0**	19	16	37.75	20	50.19	29	40.71	12	77
Sartorius etc. OL	0.647	38.5	16	38.5	20	39.83	29	38.5	12	77
Soleus RB	0.076	19.83	9	33.25	18	32.78	25	38.14	11	63
Soleus OL	0.193	31.5	9	31.5	18	31.5	25	34.36	11	63

*$P \leq 0.05$

**$P \leq 0.01$

To gain a clearer idea of the nature of these potential differences, the data set was separated by sex and Kruskal-Wallis tests were conducted to look for significant differences across age categories for each sex (Table 6.26). Males had significant differences across age categories for robusticity of the *pectoralis* (P = 0.023), *deltoideus* (P = 0.003), *triceps brachii* (P = 0.034), *supinator* (P = 0.008), *pronator teres* (P = 0.000), *brachialis* (P = 0.040), *iliopsoas* (P = 0.010), *adductor magnus* (P = 0.001), *gluteus maximus* (P = 0.002) *popliteus* (P = 0.038) and *sartorius* (P = 0.001) entheses, as well as for osteolytic formations of the *pronator teres* (P = 0.040). Females had significant differences across age categories for robusticity of the *supinator* (P = 0.020), *pronator teres* (P = 0.025), *piriformis* (P = 0.000), *quadratus femoris* (P = 0.004), *iliopsoas* (P = 0.039), *adductor magnus* (P = 0.001), *gluteus maximus* (P = 0.002) *popliteus* and *sartorius* (P = 0.033) entheses, as well as for osteolytic formations of the *pectoralis* (P = 0.005).

TABLE 6.26: Kruskal-Wallis Tests Between Age Categories By Sex for Mean Ranks of Robusticity and Osteolytic Formations

MALES:				
Entheseal Variable	Sig.	Age	N	Mean Rank
Costoclavicular RB	0.647	EYA	10	18.4
		LYA	10	21.7
		MA	15	23.87
		OA	7	20.57
		Total	42	
Costoclavicular OL	0.137	EYA	10	25.65
		LYA	10	21
		MA	15	22.8
		OA	7	13.5
		Total	42	

FEMALES:				
Entheseal Variable	Sig.	Age	N	Mean Rank
Costoclavicular RB	0.127	EYA	7	13
		LYA	10	20.2
		MA	13	18.54
		OA	7	24.14
		Total	37	
Costoclavicular OL	0.502	EYA	7	14.36
		LYA	10	21.1
		MA	13	19.85
		OA	7	19.07
		Total	37	

TABLE 6.26: Kruskal-Wallis Tests Between Age Categories By Sex for Mean Ranks of Robusticity and Osteolytic Formations (continued)

Conoid RB	0.634	EYA	10	18.75
		LYA	9	14.67
		MA	13	19.15
		OA	3	20.5
		Total	35	
Conoid OL	0.104	EYA	10	14.5
		LYA	9	18.67
		MA	13	18.42
		OA	3	25.83
		Total	35	
Trapezoid RB	0.649	EYA	10	20.7
		LYA	9	18.94
		MA	17	21.68
		OA	6	26.17
		Total	42	
Trapezoid OL	0.236	EYA	10	17.8
		LYA	9	20.83
		MA	17	21.38
		OA	6	29
		Total	42	
Subscapularis RB	0.12	EYA	10	16.6
		LYA	12	23.42
		MA	17	27.65
		OA	7	23.43
		Total	46	
Subscapularis OL	0.228	EYA	10	22.3
		LYA	12	23
		MA	17	21.53
		OA	7	30.86
		Total	46	
Supraspinatus etc. RB	0.057	EYA	10	14.65
		LYA	12	22.79
		MA	15	27.2
		OA	7	23.14
		Total	44	

Conoid RB	0.989	EYA	5	16.6
		LYA	11	17.36
		MA	12	17.5
		OA	6	18.5
		Total	34	
Conoid OL	0.213	EYA	5	14
		LYA	11	17.09
		MA	12	16.83
		OA	6	22.5
		Total	34	
Trapezoid RB	0.264	EYA	6	11.25
		LYA	8	17.69
		MA	13	18.31
		OA	4	12.25
		Total	31	
Trapezoid OL	0.904	EYA	6	16.67
		LYA	8	17.31
		MA	13	15.08
		OA	4	15.38
		Total	31	
Subscapularis RB	0.393	EYA	7	15.86
		LYA	12	19.42
		MA	12	22
		OA	6	15.83
		Total	37	
Subscapularis OL	0.557	EYA	7	20.14
		LYA	12	18.96
		MA	12	17.5
		OA	6	20.75
		Total	37	
Supraspinatus etc. RB	0.177	EYA	5	10.3
		LYA	11	19
		MA	13	19.69
		OA	5	15.7
		Total	34	

TABLE 6.26: Kruskal-Wallis Tests Between Age Categories By Sex for Mean Ranks of Robusticity and Osteolytic Formations (continued)

Supraspinatus etc. OL	0.175	EYA	10	17.8
		LYA	12	19.92
		MA	15	25.3
		OA	7	27.64
		Total	44	
Pectoralis RB	0.023*	EYA	10	13
		LYA	11	27.41
		MA	16	25.22
		OA	7	22.14
		Total	44	
Pectoralis OL	0.292	EYA	10	26.25
		LYA	11	21.36
		MA	16	22.25
		OA	7	19.5
		Total	44	
Latissimus etc. RB	0.068	EYA	10	14.25
		LYA	11	26.68
		MA	17	26.06
		OA	7	22.29
		Total	45	
Latissimus etc. OL	0.063	EYA	10	29.85
		LYA	11	18.64
		MA	17	24.09
		OA	7	17.43
		Total	45	
Deltoideus RB	0.003**	EYA	10	11.5
		LYA	11	25.18
		MA	15	22.97
		OA	7	29.93
		Total	43	
Deltoideus OL	0.275	EYA	10	24.8
		LYA	11	20.5
		MA	15	21.93
		OA	7	20.5
		Total	43	

Supraspinatus etc. OL	0.658	EYA	5	17.6
		LYA	11	19
		MA	13	17.35
		OA	5	14.5
		Total	34	
Pectoralis RB	0.216	EYA	5	17.3
		LYA	11	14.82
		MA	13	19.08
		OA	7	24.07
		Total	36	
Pectoralis OL	0.005**	EYA	5	24.7
		LYA	11	17.5
		MA	13	17.5
		OA	7	17.5
		Total	36	
Latissimus etc. RB	0.074	EYA	5	11.1
		LYA	10	14.2
		MA	12	21.71
		OA	7	19.57
		Total	34	
Latissimus etc. OL	0.228	EYA	5	14
		LYA	10	19.2
		MA	12	15.58
		OA	7	20.86
		Total	34	
Deltoideus RB	0.987	EYA	5	16.8
		LYA	11	18.27
		MA	12	17.38
		OA	6	16.92
		Total	34	
Deltoideus OL	0.225	EYA	5	19.9
		LYA	11	16.5
		MA	12	16.5
		OA	6	19.33
		Total	34	

TABLE 6.26: Kruskal-Wallis Tests Between Age Categories By Sex for Mean Ranks of Robusticity and Osteolytic Formations (continued)

Triceps Brachii RB	0.034*	EYA	10	13.5
		LYA	9	17.72
		MA	13	23.73
		OA	6	23
		Total	38	
Triceps Brachii OL	0.423	EYA	10	20.9
		LYA	9	19
		MA	13	19
		OA	6	19
		Total	38	
Brachialis RB	0.04*	EYA	10	15
		LYA	12	22.33
		MA	16	23.5
		OA	6	32.67
		Total	44	
Brachialis OL	0.843	EYA	10	24.7
		LYA	12	21.5
		MA	16	22.25
		OA	6	21.5
		Total	44	
Biceps Brachii RB	0.103	EYA	10	15.55
		LYA	12	25.46
		MA	17	27.09
		OA	7	22.79
		Total	46	
Biceps Brachii OL	0.778	EYA	10	21.25
		LYA	12	22.5
		MA	17	24.38
		OA	7	26.29
		Total	46	
Supinator RB	0.008**	EYA	10	16.7
		LYA	12	17
		MA	17	29.03
		OA	7	30.93
		Total	46	

Triceps Brachii RB	0.727	EYA	6	13.83
		LYA	10	14
		MA	8	17.06
		OA	6	17.58
		Total	30	
Triceps Brachii OL	1	EYA	6	15.5
		LYA	10	15.5
		MA	8	15.5
		OA	6	15.5
		Total	30	
Brachialis RB	0.538	EYA	4	12.5
		LYA	12	20.13
		MA	13	19.35
		OA	7	17.57
		Total	36	
Brachialis OL	0.415	EYA	4	21.38
		LYA	12	18.46
		MA	13	17
		OA	7	19.71
		Total	36	
Biceps Brachii RB	0.062	EYA	6	12.25
		LYA	13	19.23
		MA	12	24.29
		OA	7	18
		Total	38	
Biceps Brachii OL	0.783	EYA	6	18.5
		LYA	13	19.96
		MA	12	20.08
		OA	7	18.5
		Total	38	
Supinator RB	0.02*	EYA	5	9.5
		LYA	11	14.27
		MA	12	21.63
		OA	7	23.71
		Total	35	

TABLE 6.26: Kruskal-Wallis Tests Between Age Categories By Sex for Mean Ranks of Robusticity and Osteolytic Formations (continued)

Supinator OL	1	EYA	10	23.5
		LYA	12	23.5
		MA	17	23.5
		OA	7	23.5
		Total	46	
Pronator Teres RB	0**	EYA	10	10.45
		LYA	12	19.88
		MA	16	29.19
		OA	7	32.14
		Total	45	
Pronator Teres OL	0.0*4	EYA	10	27.75
		LYA	12	21
		MA	16	21
		OA	7	24.21
		Total	45	
Extensor Carpi Ulnaris RB	0.448	EYA	9	14.33
		LYA	8	17.56
		MA	13	18.04
		OA	4	22.75
		Total	34	
Extensor Carpi Ulnaris OL	0.427	EYA	9	18.89
		LYA	8	17
		MA	13	17
		OA	4	17
		Total	34	
Flexor Carpi Ulnaris RB	0.175	EYA	9	12.33
		LYA	8	18.88
		MA	13	19.27
		OA	4	20.63
		Total	34	

Supinator OL	1	EYA	5	18
		LYA	11	18
		MA	12	18
		OA	7	18
		Total	35	
Pronator Teres RB	0.025*	EYA	5	11
		LYA	11	16.64
		MA	12	24.25
		OA	7	14.43
		Total	35	
Pronator Teres OL	0.112	EYA	5	21
		LYA	11	17.5
		MA	12	17.5
		OA	7	17.5
		Total	35	
Extensor Carpi Ulnaris RB	0.258	EYA	4	8.38
		LYA	10	15.5
		MA	9	14.17
		OA	5	18
		Total	28	
Extensor Carpi Ulnaris OL	1	EYA	4	14.5
		LYA	10	14.5
		MA	9	14.5
		OA	5	14.5
		Total	28	
Flexor Carpi Ulnaris RB	0.509	EYA	3	10
		LYA	11	14.91
		MA	9	16.5
		OA	5	12.7
		Total	28	

TABLE 6.26: Kruskal-Wallis Tests Between Age Categories By Sex for Mean Ranks of Robusticity and Osteolytic Formations (continued)

Flexor Carpi Ulnaris OL	1	EYA	9	17.5
		LYA	8	17.5
		MA	13	17.5
		OA	4	17.5
		Total	34	
Piriformis etc. RB	0.058	EYA	10	13.5
		LYA	11	21.36
		MA	15	23.5
		OA	5	27.7
		Total	41	
Piriformis etc. OL	0.598	EYA	10	19.5
		LYA	11	21.32
		MA	15	20.93
		OA	5	23.5
		Total	41	
Gluteus Minimus RB	0.174	EYA	10	15.9
		LYA	10	19
		MA	16	25.09
		OA	5	22.1
		Total	41	
Gluteus Minimus OL	0.389	EYA	10	17.5
		LYA	10	23.4
		MA	16	21.5
		OA	5	21.6
		Total	41	
Gluteus Medius RB	0.161	EYA	10	15.55
		LYA	11	23.64
		MA	14	20.57
		OA	6	26.25
		Total	41	

Flexor Carpi Ulnaris OL	0.204	EYA	3	14
		LYA	11	14
		MA	9	14
		OA	5	16.8
		Total	28	
Piriformis etc. RB	0**	EYA	5	5.8
		LYA	9	10
		MA	13	21.31
		OA	4	25
		Total	31	
Piriformis etc. OL	0.709	EYA	5	15.5
		LYA	9	15.5
		MA	13	16.69
		OA	4	15.5
		Total	31	
Gluteus Minimus RB	0.066	EYA	7	12.71
		LYA	11	15.5
		MA	12	22.13
		OA	6	23.5
		Total	36	
Gluteus Minimus OL	0.778	EYA	7	17
		LYA	11	18.59
		MA	12	18.58
		OA	6	19.92
		Total	36	
Gluteus Medius RB	0.131	EYA	7	13.57
		LYA	10	15.65
		MA	12	23.13
		OA	7	19.57
		Total	36	

TABLE 6.26: Kruskal-Wallis Tests Between Age Categories By Sex for Mean Ranks of Robusticity and Osteolytic Formations (continued)

Gluteus Medius OL	0.125	EYA	10	19
		LYA	11	24.68
		MA	14	20.39
		OA	6	19
		Total	41	
Quadratus Femoris RB	0.412	EYA	8	15.25
		LYA	10	17.45
		MA	13	21.96
		OA	5	16.8
		Total	36	
Quadratus Femoris OL	0.307	EYA	8	17.5
		LYA	10	19.25
		MA	13	17.5
		OA	5	21.2
		Total	36	
Gluteus Maximus RB	0.002**	EYA	10	9.85
		LYA	11	24.91
		MA	17	28.15
		OA	7	26.29
		Total	45	
Gluteus Maximus OL	0.202	EYA	10	27.1
		LYA	11	22.41
		MA	16	21.44
		OA	7	18.5
		Total	44	
Iliopsoas RB	0.01**	EYA	10	11.5
		LYA	10	24.3
		MA	17	25.18
		OA	6	26.67
		Total	43	

Gluteus Medius OL	0.533	EYA	7	17.5
		LYA	10	17.5
		MA	12	18.96
		OA	7	20.14
		Total	36	
Quadratus Femoris RB	0.004**	EYA	7	8.14
		LYA	10	19.2
		MA	11	24.27
		OA	7	16.29
		Total	35	
Quadratus Femoris OL	1	EYA	7	18
		LYA	10	18
		MA	11	18
		OA	7	18
		Total	35	
Gluteus Maximus RB	0.002**	EYA	7	12.07
		LYA	12	14.17
		MA	14	27.57
		OA	7	25.64
		Total	40	
Gluteus Maximus OL	0.421	EYA	7	23.71
		LYA	12	19.67
		MA	14	20.86
		OA	7	18
		Total	40	
Iliopsoas RB	0.039*	EYA	7	12.71
		LYA	10	15.9
		MA	13	24.96
		OA	7	18.64
		Total	37	

TABLE 6.26: Kruskal-Wallis Tests Between Age Categories By Sex for Mean Ranks of Robusticity and Osteolytic Formations (continued)

Iliopsoas OL	0.186	EYA	10	20.5
		LYA	10	20.5
		MA	17	24.29
		OA	6	20.5
		Total	43	
Adductor Magnus RB	0.001**	EYA	10	9.4
		LYA	11	24.05
		MA	16	27.88
		OA	7	26.5
		Total	44	
Adductor Magnus OL	0.626	EYA	10	22
		LYA	11	22
		MA	16	23.38
		OA	7	22
		Total	44	
Quadriceps RB	0.67	EYA	9	16.61
		LYA	6	21.5
		MA	14	16.93
		OA	5	15.9
		Total	34	
Quadriceps OL	1	EYA	9	17.5
		LYA	6	17.5
		MA	14	17.5
		OA	5	17.5
		Total	34	
Popliteus RB	0.038*	EYA	10	14.05
		LYA	11	27.91
		MA	17	25.35
		OA	7	22.36
		Total	45	
Popliteus OL	0.321	EYA	10	24.75
		LYA	11	22.5
		MA	17	22.5
		OA	7	22.5
		Total	45	

Iliopsoas OL	0.732	EYA	7	18
		LYA	10	19.8
		MA	13	19.46
		OA	7	18
		Total	37	
Adductor Magnus RB	0.001*	EYA	7	8
		LYA	13	20.81
		MA	14	27.57
		OA	7	21.21
		Total	41	
Adductor Magnus OL	0.587	EYA	7	20.5
		LYA	13	20.5
		MA	14	21.96
		OA	7	20.5
		Total	41	
Quadriceps RB	0.828	EYA	3	17.83
		LYA	11	13.59
		MA	9	15.44
		OA	6	15.5
		Total	29	
Quadriceps OL	1	EYA	3	15
		LYA	11	15
		MA	9	15
		OA	6	15
		Total	29	
Popliteus RB	0.332	EYA	6	14.08
		LYA	12	17.25
		MA	13	19.73
		OA	5	23.6
		Total	36	
Popliteus OL	0.462	EYA	6	20.5
		LYA	12	19
		MA	13	17.5
		OA	5	17.5
		Total	36	

TABLE 6.26: Kruskal-Wallis Tests Between Age Categories By Sex for Mean Ranks of Robusticity and Osteolytic Formations (continued)

Semimembranosus RB	0.11	EYA	9	12.94
		LYA	9	21.72
		MA	16	23.06
		OA	5	19.8
		Total	39	
Semimembranosus OL	0.808	EYA	9	20.11
		LYA	9	20.11
		MA	16	19.19
		OA	5	22.2
		Total	39	
Sartorius etc. RB	0.001**	EYA	10	9.5
		LYA	8	22.56
		MA	16	27.38
		OA	6	17.75
		Total	40	
Sartorius etc. OL	0.682	EYA	10	20
		LYA	8	20
		MA	16	21.25
		OA	6	20
		Total	40	
Soleus RB	0.337	EYA	5	12.8
		LYA	9	20.67
		MA	15	17.7
		OA	5	15.9
		Total	34	
Soleus OL	0.122	EYA	5	17
		LYA	9	17
		MA	15	17
		OA	5	20.4
		Total	34	

Semimembranosus RB	0.781	EYA	6	15
		LYA	11	18.5
		MA	11	17.77
		OA	7	20.14
		Total	35	
Semimembranosus OL	0.541	EYA	6	17
		LYA	11	18.59
		MA	11	17
		OA	7	19.5
		Total	35	
Sartorius etc. RB	0.033*	EYA	6	10
		LYA	12	17
		MA	13	23.15
		OA	6	23
		Total	37	
Sartorius etc. OL	1	EYA	6	19
		LYA	12	19
		MA	13	19
		OA	6	19
		Total	37	
Soleus RB	0.071	EYA	4	7.63
		LYA	9	13.61
		MA	10	16
		OA	6	20.33
		Total	29	
Soleus OL	1	EYA	4	15
		LYA	9	15
		MA	10	15
		OA	6	15
		Total	29	

*$P \leq 0.05$

**$P \leq 0.01$

Since a number of entheseal variables are statistically significantly different between the sexes as well as across age groups, Two-tailed Spearman correlations were calculated to see if the variables of age, sex or body size may be influencing the results. Table 6.27 presents the Two-tailed Spearman correlation coefficients of the entheseal variables with age, sex and body size. Sex significantly correlated with robusticity of the *latissimus* (*P* = 0.02), *triceps brachii* (*P* = 0.001), *flexor carpi ulnaris* (*P* = 0.049), *iliopsoas* (*P* = 0.031) and osteolytic scores of the *costoclavicular* ligament (*P* = 0.000), *subscapularis* (*P* = 0.041) and *biceps brachii* (*P* = 0.002) entheses. Age significantly correlated with robusticity of the *supraspinatus* (*P* = 0.022), *pectoralis* (*P* = 0.016), *latissimus* (*P* = 0.021), *deltoideus* (*P* = 0.028), *triceps brachii (P* = 0.011), *brachialis* (*P* = 0.012), *biceps brachii* (*P* = 0.027), *supinator* (*P* = 0.000), *pronator teres* (*P* = 0.000), *extensor carpi ulnaris* (*P* = 0.032), *piriformis* (*P* = 0.000), *gluteus minimus* (*P* = 0.001), *gluteus medius* (*P* = 0.016), *quadratus femoris* (*P* = 0.028), *gluteus maximus* (*P* = 0.000), *iliopsoas* (*P* = 0.001), *adductor magnus* (*P* = 0.000), *popliteus* (*P* = 0.021), *sartorius* (*P* = 0.000), *soleus* (*P* = 0.039) as well as osteolytic scores of the *conoid* ligament (*P* = 0.006), *pectoralis* (*P* = 0.001), *pronator teres* (*P* = 0.044), *gluteus maximus* (*P* = 0.016) and *popliteus* (*P* = 0.041) entheses. Body size correlated significantly with robusticity of the *triceps brachii* (*P* = 0.003), *supinator* (*P* = 0.029), *flexor carpi ulnaris* (*P* = 0.021), *iliopsoas* (*P* = 0.032), *soleus* (*P* = 0.025) and osteolytic scores of the *costoclavicular* ligament (*P* = 0.000) and *biceps brachii* (*P* = 0.001) entheses. These results suggest that all variables play significant roles in the morphology of entheses and thus were likely influencing the results of the Mann-Whitney U and Kruskal-Wallis tests.

TABLE 6.27: Two-tailed Spearman Correlation Coefficients for Robusticity and Osteolytic Formations with Age, Sex and Body Size

		Sex	Age	Body Size
Costoclavicular RB	rho	-0.087	0.204	0.123
	Sig.	0.448	0.072	0.28
	N	79	79	79
Costoclavicular OL	rho	-0.579**	-0.106	0.491**
	Sig.	0	0.354	0
	N	79	79	79
Conoid RB	rho	-0.036	0.064	0.129
	Sig.	0.767	0.604	0.29
	N	69	69	69
Conoid OL	rho	0	0.326**	0.002
	Sig.	1	0.006	0.984
	N	69	69	69
Trapezoid RB	rho	0.039	0.131	0.127
	Sig.	0.743	0.269	0.284
	N	73	73	73
Trapezoid OL	rho	-0.188	0.124	0.163
	Sig.	0.112	0.295	0.167
	N	73	73	73
Subscapularis RB	rho	-0.085	0.184	0.127
	Sig.	0.444	0.096	0.251
	N	83	83	83
Subscapularis OL	rho	-0.225*	0.097	0.096
	Sig.	0.041	0.381	0.389
	N	83	83	83
Supraspinatus etc. RB	rho	-0.042	0.259*	-0.036
	Sig.	0.718	0.022	0.753
	N	78	78	78
Supraspinatus etc. OL	rho	-0.205	0.145	0.153
	Sig.	0.072	0.204	0.181
	N	78	78	78
Pectoralis RB	rho	0.062	0.268*	-0.046
	Sig.	0.584	0.016	0.686
	N	80	80	80
Pectoralis OL	rho	-0.14	-0.288**	0.117
	Sig.	0.215	0.01	0.303
	N	80	80	80

TABLE 6.27: Two-tailed Spearman Correlation Coefficients for Robusticity and Osteolytic Formations with Age, Sex and Body Size (continued)

Latissimus etc. RB	rho	-0.262*	0.26*	0.171
	Sig.	0.02	0.021	0.133
	N	79	79	79
Latissimus etc. OL	rho	-0.19	-0.101	0.065
	Sig.	0.094	0.374	0.569
	N	79	79	79
Deltoideus RB	rho	0.139	0.25*	-0.106
	Sig.	0.226	0.028	0.357
	N	77	77	77
Deltoideus OL	rho	-0.022	-0.121	0.088
	Sig.	0.849	0.294	0.448
	N	77	77	77
Triceps Brachii RB	rho	0.391**	0.305*	-0.357**
	Sig.	0.001	0.011	0.003
	N	68	68	68
Triceps Brachii OL	rho	-0.109	-0.168	0.115
	Sig.	0.378	0.171	0.35
	N	68	68	68
Brachialis RB	rho	0.166	0.281*	-0.154
	Sig.	0.142	0.012	0.173
	N	80	80	80
Brachialis OL	rho	-0.167	-0.102	0.075
	Sig.	0.139	0.367	0.507
	N	80	80	80
Biceps Brachii RB	rho	-0.167	0.242*	0.129
	Sig.	0.129	0.027	0.243
	N	84	84	84
Biceps Brachii OL	rho	-0.327**	0.096	0.351**
	Sig.	0.002	0.383	0.001
	N	84	84	84
Supinator RB	rho	0.186	0.517**	-0.243*
	Sig.	0.096	0	0.029
	N	81	81	81
Supinator OL	rho	.	.	.
	Sig.	.	.	.
	N	81	81	81
Pronator Teres RB	rho	-0.054	0.453**	0.009
	Sig.	0.635	0	0.94
	N	80	80	80

TABLE 6.27: Two-tailed Spearman Correlation Coefficients for Robusticity and Osteolytic Formations with Age, Sex and Body Size (continued)

Pronator Teres OL	rho	-0.124	-0.226*	0.18
	Sig.	0.275	0.044	0.11
	N	80	80	80
Extensor Carpi Ulnaris RB	rho	0.134	0.273*	-0.122
	Sig.	0.3	0.032	0.344
	N	62	62	62
Extensor Carpi Ulnaris OL	rho	-0.116	-0.183	-0.047
	Sig.	0.368	0.155	0.72
	N	62	62	62
Flexor Carpi Ulnaris RB	rho	0.251*	0.236	-0.293*
	Sig.	0.049	0.065	0.021
	N	62	62	62
Flexor Carpi Ulnaris OL	rho	0.141	0.198	-0.154
	Sig.	0.274	0.123	0.233
	N	62	62	62
Piriformis etc. RB	rho	0.153	0.594**	-0.212
	Sig.	0.201	0	0.074
	N	72	72	72
Piriformis etc. OL	rho	-0.083	0.143	0.106
	Sig.	0.487	0.232	0.378
	N	72	72	72
Gluteus Minimus RB	rho	-0.031	0.367**	0.022
	Sig.	0.787	0.001	0.85
	N	77	77	77
Gluteus Minimus OL	rho	-0.139	0.141	0.076
	Sig.	0.227	0.22	0.511
	N	77	77	77
Gluteus Medius RB	rho	-0.085	0.275*	0.008
	Sig.	0.464	0.016	0.942
	N	77	77	77
Gluteus Medius OL	rho	-0.076	0.055	0.123
	Sig.	0.513	0.637	0.285
	N	77	77	77
Quadratus Femoris RB	rho	0.064	0.26*	-0.052
	Sig.	0.598	0.028	0.666
	N	71	71	71
Quadratus Femoris OL	rho	-0.168	0.084	0.179
	Sig.	0.162	0.484	0.135
	N	71	71	71

TABLE 6.27: Two-tailed Spearman Correlation Coefficients for Robusticity and Osteolytic Formations with Age, Sex and Body Size (continued)

Gluteus Maximus RB	rho	0.001	0.509**	-0.047
	Sig.	0.993	0	0.669
	N	85	85	85
Gluteus Maximus OL	rho	-0.082	-0.262*	0.147
	Sig.	0.457	0.016	0.183
	N	84	84	84
Iliopsoas RB	rho	-0.241*	0.367**	0.24*
	Sig.	0.031	0.001	0.032
	N	80	80	80
Iliopsoas OL	rho	-0.031	0.083	0.072
	Sig.	0.784	0.464	0.523
	N	80	80	80
Adductor Magnus RB	rho	-0.065	0.49**	0.08
	Sig.	0.552	0	0.464
	N	85	85	85
Adductor Magnus OL	rho	0.005	0.089	-0.006
	Sig.	0.96	0.418	0.954
	N	85	85	85
Quadriceps RB	rho	-0.032	-0.03	-0.057
	Sig.	0.804	0.815	0.659
	N	63	63	63
Quadriceps OL	rho	.	.	.
	Sig.	.	.	.
	N	63	63	63
Popliteus RB	rho	-0.065	0.256*	-0.002
	Sig.	0.567	0.021	0.987
	N	81	81	81
Popliteus OL	rho	0.088	-0.228*	0.084
	Sig.	0.436	0.041	0.457
	N	81	81	81
Semimembranosus RB	rho	0.001	0.214	-0.018
	Sig.	0.995	0.067	0.876
	N	74	74	74
Semimembranosus OL	rho	-0.086	0.054	0.087
	Sig.	0.468	0.649	0.459
	N	74	74	74
Sartorius etc. RB	rho	-0.042	0.437**	-0.004
	Sig.	0.717	0	0.973
	N	77	77	77

TABLE 6.27: Two-tailed Spearman Correlation Coefficients for Robusticity and Osteolytic Formations with Age, Sex and Body Size (continued)

Sartorius etc. OL	rho	-0.11	0.065	0.17
	Sig.	0.339	0.576	0.139
	N	77	77	77
Soleus RB	rho	0.236	0.261*	-0.283*
	Sig.	0.063	0.039	0.025
	N	63	63	63
Soleus OL	rho	-0.117	0.191	-0.049
	Sig.	0.36	0.134	0.704
	N	63	63	63

**P* ≤0.05
***P* ≤ 0.01

Since age had the strongest as well as the highest number of correlations with entheseal robusticity and osteolytic formations, Partial Spearman correlations were carried out to re-examine correlations of the entheseal variables with age after sex and body size were controlled for. Table 6.28 presents the results of the partial correlations with age. After controlling for sex and body size, age correlated significantly with robusticity of the *supraspinatus* (*P* = 0.023), *pectoralis* (*P* = 0.018), *latissimus* (*P* = 0.015), *deltoideus* (*P* = 0.031), *triceps brachii* (*P* = 0.008), *brachialis* (*P* = 0.013), *biceps brachii* (*P* = 0.024), *supinator* (*P* = 0.000), *pronator teres* (*P* = 0.000), *extensor carpi ulnaris* (*P* = 0.035), *piriformis* (*P* = 0.000), *gluteus minimus* (*P* = 0.001), gluteus medius (*P* = 0.016), *quadratus femoris* (*P* = 0.031), *gluteus maximus* (*P* = 0.000), *iliopsoas* (*P* = 0.000), *adductor magnus* (*P* = 0.000), *popliteus* (*P* = 0.021), *sartorius* (*P* = 0.000) and *soleus* (*P* = 0.039) entheses. After controlling for sex and body size, age also correlated significantly with osteolytic formations of the *conoid* ligament (*P* = 0.007), *pectoralis* (*P* = 0.011), *pronator teres* (*P* = 0.047), *gluteus maximus* (*P* = 0.017) and *popliteus* (*P* = 0.035) entheses. Results of this test suggest that age has the greatest influence on entheseal robusticity.

TABLE 6.28: Partial Spearman Correlations of Robusticity and Osteolytic Formations With Age After Controlling for Sex and Body Size

Entheseal Variable	**rho**	**Significance**
Costoclavicular RB	0.208	0.07
Costoclavicular OL	-0.113	0.329
Conoid RB	0.067	0.591
Conoid OL	0.326**	0.007
Trapezoid RB	0.137	0.253
Trapezoid OL	0.131	0.275
Subscapularis RB	0.189	0.092
Subscapularis OL	0.105	0.349
Supraspinatus etc. RB	0.261*	0.023
Supraspinatus etc. OL	0.153	0.186
Pectoralis RB	0.268*	0.018
Pectoralis OL	-0.287*	0.011
Latissimus etc. RB	0.276*	0.015
Latissimus etc. OL	-0.101	0.382
Deltoideus RB	0.249*	0.031
Deltoideus OL	-0.121	0.303
Triceps Brachii RB	0.322**	0.008
Triceps Brachii OL	-0.166	0.183
Brachialis RB	0.281*	0.013
Brachialis OL	-0.101	0.379
Biceps Brachii RB	0.249*	0.024
Biceps Brachii OL	0.113	0.313
Supinator RB	0.528**	0
Supinator OL	.	.
Pronator Teres RB	0.455**	0
Pronator Teres OL	-0.226*	0.047
Extensor Carpi Ulnaris RB	0.272*	0.035
Extensor Carpi Ulnaris OL	-0.189	0.149
Flexor Carpi Ulnaris RB	0.24	0.065
Flexor Carpi Ulnaris OL	0.197	0.132
Piriformis etc. RB	0.603**	0
Piriformis etc. OL	0.146	0.228
Gluteus Minimus RB	0.368**	0.001
Gluteus Minimus OL	0.146	0.212
Gluteus Medius RB	0.279*	0.016
Gluteus Medius OL	0.058	0.623
Quadratus Femoris RB	0.259*	0.031

TABLE 6.28: Partial Spearman Correlations of Robusticity and Osteolytic Formations With Age After Controlling for Sex and Body Size (continued)

Quadratus Femoris OL	0.091	0.459
Gluteus Maximus RB	0.511**	0
Gluteus Maximus OL	-0.262*	0.017
Iliopsoas RB	0.386**	0
Iliopsoas OL	0.085	0.46
Adductor Magnus RB	0.494**	0
Adductor Magnus OL	0.089	0.424
Quadriceps RB	-0.031	0.814
Quadriceps OL	.	.
Popliteus RB	0.258*	0.021
Popliteus OL	-0.237*	0.035
Semimembranosus RB	0.214	0.071
Semimembranosus OL	0.056	0.639
Sartorius etc. RB	0.439**	0
Sartorius etc. OL	0.069	0.554
Soleus RB	0.266*	0.039
Soleus OL	0.199	0.124

*$P \leq 0.05$

**$P \leq 0.01$

"." = Cannot be computed because at least one variable is constant (0)

Comparison of these correlations with the correlations taken without controlling for sex or body size reveal limited differences in the strength of the correlations, suggesting that sex and body size have limited influence on these same variables, thus verifying a number of the significant differences found in the initial Kruskal-Wallis test run on the entire sample. Significant differences that were validated for the whole population but not for a specific sex include robusticity of the *supraspinatus* ($P = 0.017$), *latissimus* ($P = 0.049$), *biceps brachii* ($P = 0.010$), and *gluteus minimus* ($P = 0.017$) entheses, as well as for osteolytic formations of the *conoid* ligament ($P = 0.036$), *popliteus* ($P = 0.000$), and *gluteus maximus* ($P = 0.029$) entheses (Figures 6.49 and 6.50).

FIGURE 6.49: Significant Differences in Mean Rank of Robusticity and Osteolytic Formations Across Age Categories For the Upper Limb, Sexes Combined

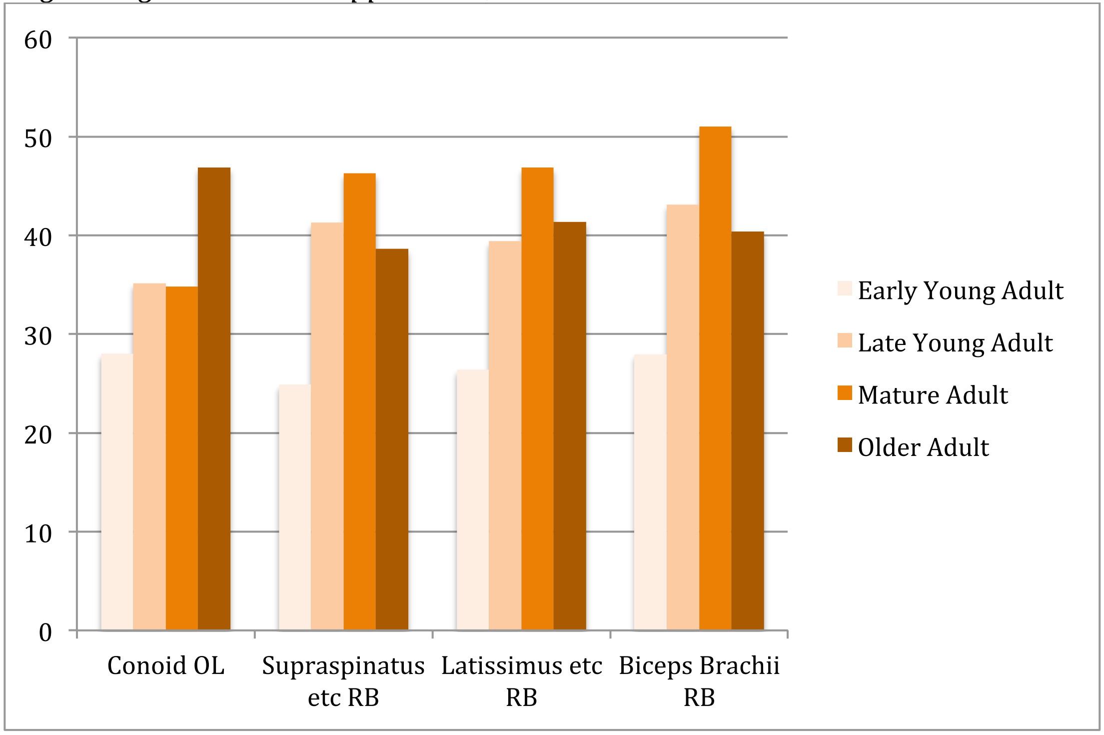
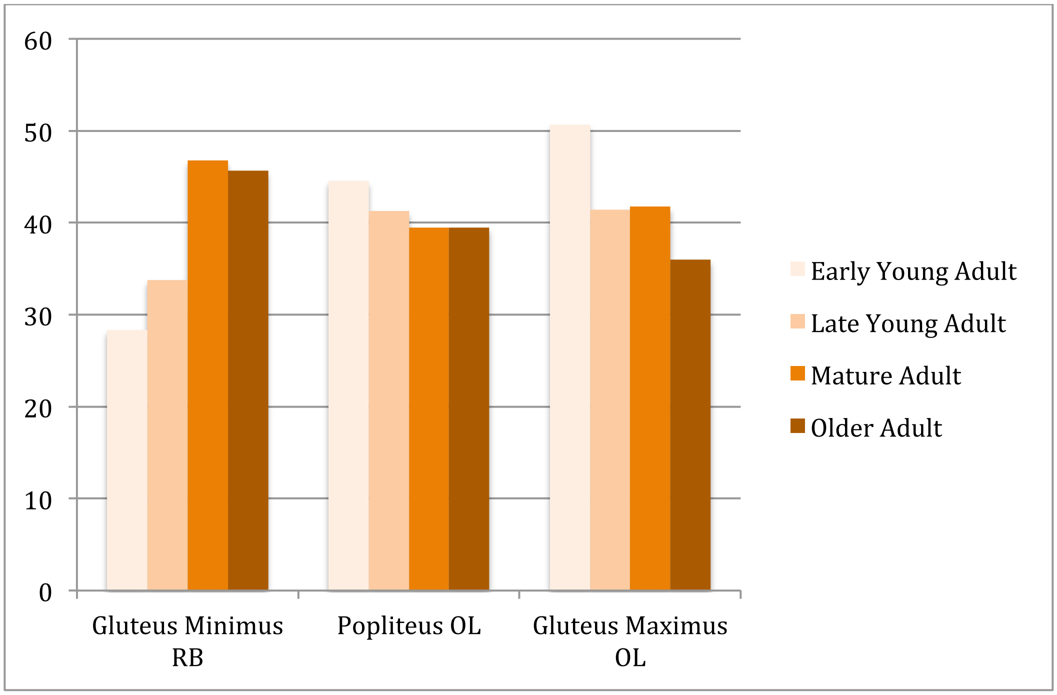


FIGURE 6.50: Significant Differences in Mean Rank of Robusticity and Osteolytic Formations Across Age Categories For the Lower Limb, Sexes Combined



Partial Spearman correlations were also carried out to re-examine correlations of the entheseal variables with sex after age and body size were controlled for. Table 6.29 presents the results of the partial correlations with sex. After controlling for age and body size, few significant correlations remained, however, sex did correlate significantly with robusticity of the *trapezoid* (*P* = 0.043) and osteolytic formations of the *costoclavicular* ligament (*P* = 0.001), *subscapularis* (*P* = 0.023), *latissimus* (*P* = 0.042), *extensor carpi ulnaris* (*P* = 0.043), *popliteus* (*P* = 0.016) and *soleus* (*P* = 0.035) entheses.

TABLE 6.29: Partial Spearman Correlations of Robusticity and Osteolytic Formations With Sex After Controlling for Age and Body Size

Entheseal Variable	**rho**	**Significance**
Costoclavicular RB	0.02	0.863
Costoclavicular OL	-0.358**	0.001
Conoid RB	0.115	0.354
Conoid OL	0.001	0.995
Trapezoid RB	0.241*	0.043
Trapezoid OL	-0.098	0.417
Subscapularis RB	0.029	0.8
Subscapularis OL	-0.252*	0.023
Supraspinatus etc. RB	-0.126	0.279
Supraspinatus etc. OL	-0.142	0.22
Pectoralis RB	0.042	0.716
Pectoralis OL	-0.08	0.488
Latissimus etc. RB	-0.223	0.051
Latissimus etc. OL	-0.233*	0.042
Deltoideus RB	0.092	0.431
Deltoideus OL	0.084	0.475
Triceps Brachii RB	0.194	0.118
Triceps Brachii OL	-0.026	0.836
Brachialis RB	0.072	0.531
Brachialis OL	-0.18	0.116
Biceps Brachii RB	-0.113	0.313
Biceps Brachii OL	-0.082	0.462
Supinator RB	-0.024	0.835
Supinator OL	.	.

TABLE 6.29: Partial Spearman Correlations of Robusticity and Osteolytic Formations With Sex After Controlling for Age and Body Size (continued)

Pronator Teres RB	-0.093	0.42
Pronator Teres OL	0.039	0.733
Extensor Carpi Ulnaris RB	0.06	0.648
Extensor Carpi Ulnaris OL	-0.262*	0.043
Flexor Carpi Ulnaris RB	0.026	0.844
Flexor Carpi Ulnaris OL	0.028	0.829
Piriformis etc. RB	-0.045	0.714
Piriformis etc. OL	0.002	0.989
Gluteus Minimus RB	-0.028	0.812
Gluteus Minimus OL	-0.135	0.249
Gluteus Medius RB	-0.139	0.235
Gluteus Medius OL	0.04	0.734
Quadratus Femoris RB	0.036	0.77
Quadratus Femoris OL	-0.042	0.735
Gluteus Maximus RB	-0.077	0.49
Gluteus Maximus OL	-0.066	0.559
Iliopsoas RB	-0.093	0.42
Iliopsoas OL	0.046	0.692
Adductor Magnus RB	-0.006	0.959
Adductor Magnus OL	0	1
Quadriceps RB	-0.131	0.315
Quadriceps OL	.	.
Popliteus RB	-0.117	0.304
Popliteus OL	0.271*	0.016
Semimembranosus RB	-0.026	0.828
Semimembranosus OL	-0.026	0.826
Sartorius etc. RB	-0.088	0.451
Sartorius etc. OL	0.045	0.699
Soleus RB	0.013	0.923
Soleus OL	-0.271*	0.035

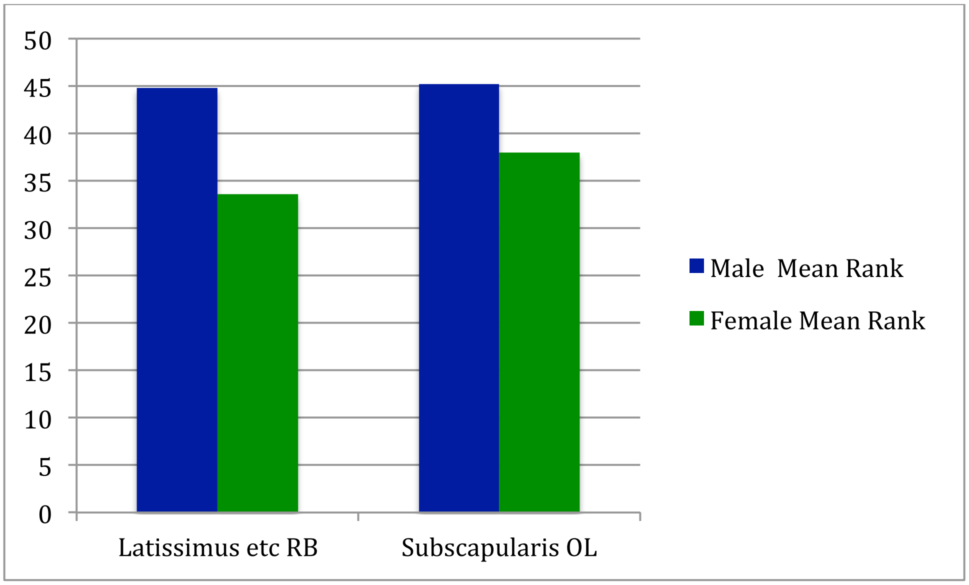
*$P \leq 0.05$

**$P \leq 0.01$

"." = Cannot be computed because at least one variable is constant (0)

Comparison of these correlations with the correlations taken without controlling for age or body size reveal substantial differences in the strength of many correlations, suggesting that age and body size are highly influential on these same variables, and nullifying many of the significant differences found in the initial Mann-Whitney U test run on the entire sample. Significant differences between the sexes that remain valid include robusticity of the *latissimus* (P = 0.021) and osteolytic formations of the *subscapularis* (P = 0.042) entheses (Figure 6.51).

FIGURE 6.51: Significant Differences in Mean Rank Between the Sexes After Accounting for Age and Body Size



To gain a clearer idea of the nature of the significant partial Spearman correlations, each variable was standardized by body size and, since age is the greatest predictor of robusticity in this sample, the data set was separated by age categories and Mann-Whitney U tests were conducted between the sexes for each age group; results are detailed in Table 6.30. Significant differences between the sexes were found in the Early Young Adult age group for robusticity of the *pectoralis* (P = 0.047), *deltoideus* (P = 0.010) and *triceps brachii* (P = 0.003) as well as osteolytic formations of the *costoclavicular* ligament (P = 0.002) *latissimus* (P = 0.033) and *extensor carpi ulnaris* (P = 0.021) entheses (Figure 6.52). Significant differences between the sexes were found in the Late Young Adult group for robusticity of the *latissimus* (P = 0.013) and *iliopsoas* entheses (P = 0.046) as well as osteolytic formations at the *costoclavicular* ligament (P = 0.047) (Figure 6.53). For the Mature Adult category, significant sex differences were found for robusticity of the *piriformis* (P = 0.013) and osteolytic formations of the *costoclavicular* ligament (P = 0.002) (Figure 6.54). Significant differences between the sexes were found in the Older Adult age group for robusticity of the *costoclavicular* ligament (P = 0.027), *pronator teres* (P = 0.015) and *soleus* (P = 0.041) as well as osteolytic formations of the *costoclavicular* ligament (P = 0.038) (Figure 6.55).

TABLE 6.30: Mann-Whitney U Test Between the Sexes for Changes in Robusticity and Osteolytic Formations, Separated by Age and Standardized by Body Size

	Early Young Adult				Late Young Adult			
			Mean Rank				Mean Rank	
Variable	Mann-Whit U	Sig.	Male	Female	Mann-Whit U	Sig.	Male	Female
Costoclavicular RB	25	0.475	9	7.67	47	0.802	10.2	10.8
Costoclavicular OL	3.5	0.002**	11.15	4.08	25	0.047*	13	8
Conoid RB	18.5	0.823	7.65	7.13	45	0.706	10	10.91
Conoid OL	17	0.485	7.2	8.25	45.5	0.707	10.06	10.86
Trapezoid RB	21	0.603	8.4	7.2	27.5	0.381	8.06	10.06
Trapezoid OL	24	0.889	8.1	7.8	36	1	9	9
Subscapularis RB	27.5	0.721	8.25	8.92	67	0.683	12.92	12.08
Subscapularis OL	29.5	0.947	8.45	8.58	59.5	0.265	13.54	11.46
Supraspinatus etc. RB	19.5	0.933	7.45	7.63	65	0.946	12.08	11.91
Supraspinatus etc. OL	19.5	0.929	7.55	7.38	61	0.705	11.58	12.45
Pectoralis RB	7.5	0.047*	6.25	10.63	38	0.091	13.55	9.45
Pectoralis OL	19.5	0.934	7.55	7.38	55	0.317	12	11

TABLE 6.30: Mann-Whitney U Test Between the Sexes for Changes in Robusticity and Osteolytic Formations, Separated by Age and Standardized by Body Size (continued)

Latissimus etc. RB	15.5	0.469	7.95	6.38	22	0.013*	14	7.7
Latissimus etc. OL	6	0.033*	8.9	4	48.5	0.539	10.41	11.65
Deltoideus RB	5.5	0.01**	6.05	11.13	57	0.79	11.18	11.82
Deltoideus OL	17.5	0.656	7.25	8.13	60.5	1	11.5	11.5
Triceps Brachii RB	4.5	0.003**	5.95	12.1	25	0.069	7.78	12
Triceps Brachii OL	20	0.456	7.78	7	30	1	8.5	8.5
Brachialis RB	7.5	0.16	6.25	9.5	48	0.137	10.5	14.5
Brachialis OL	10.5	0.302	7.45	5.5	56	0.192	13.83	11.17
Biceps Brachii RB	23.5	0.836	8.15	7.7	55	0.128	14.92	11.23
Biceps Brachii OL	20	0.301	8.5	7	63.5	0.217	14.21	11.88
Supinator RB	19	0.867	7.6	7.25	46.5	0.182	10.38	13.77
Supinator OL	.	.	.	.	.	.	.	.
Pronator Teres RB	17	0.485	7.2	8.25	64.5	0.918	12.13	11.86
Pronator Teres OL	14	0.234	8.1	6	66	1	12	12
Extensor Carpi Ulnaris RB	7	0.179	7.22	4.33	30	0.601	8.29	9.5
Extensor Carpi Ulnaris OL	4	0.021*	7.56	3.33	38	0.805	9.25	9.7
Flexor Carpi Ulnaris RB	9	1	6	6	36	0.482	9	10.73
Flexor Carpi Ulnaris OL	4.5	1	5.5	5.5	24	1	7.5	7.5
Piriformis etc. RB	15	0.411	8	6.25	40.5	0.451	11.32	9.5
Piriformis etc. OL	20	1	7.5	7.5	36	0.099	11.73	9
Gluteus Minimus RB	28	0.796	8.7	8.17	53	0.876	11.2	10.82
Gluteus Minimus OL	30	1	8.5	8.5	43	0.217	12.2	9.91
Gluteus Medius RB	28.5	0.861	8.35	8.75	36.5	0.134	12.68	9.15

TABLE 6.30: Mann-Whitney U Test Between the Sexes for Changes in Robusticity and Osteolytic Formations, Separated by Age and Standardized by Body Size (continued)

Gluteus Medius OL	23	0.262	7.8	9.67	40	0.083	12.36	9.5
Quadratus Femoris RB	19.5	0.529	8.06	6.75	41	0.477	9.6	11.4
Quadratus Femoris OL	19	0.365	8.13	6.67	46	0.689	10.9	10.1
Gluteus Maximus RB	23	0.262	7.8	9.67	38.5	0.074	14.5	9.71
Gluteus Maximus OL	23	0.345	9.2	7.33	64	0.852	12.18	11.83
Iliopsoas RB	25.5	0.584	8.95	7.75	25	0.046*	13	8
Iliopsoas OL	30	1	8.5	8.5	40.5	0.168	9.55	11.45
Adductor Magnus RB	27	0.439	8.8	8	60	0.436	13.55	11.62
Adductor Magnus OL	30	1	8.5	8.5	71.5	1	12.5	12.5
Quadriceps RB	4	0.186	5.44	8.5	24	0.333	10.5	8.18
Quadriceps OL	.	.	.	.	.	.	.	.
Popliteus RB	23	0.679	7.8	8.4	42	0.101	14.18	10
Popliteus OL	18	0.147	8.7	6.6	60.5	0.338	11.5	12.46
Semimembranosus RB	20	0.674	7.22	8	46.5	0.809	10.17	10.77
Semimembranosus OL	21	0.743	7.33	7.8	37.5	0.258	11.83	9.41
Sartorius etc. RB	20	0.157	8.5	7	35.5	0.29	12.06	9.46
Sartorius etc. OL	20	1	7.5	7.5	48	1	10.5	10.5
Soleus RB	6	0.439	4.2	5	38.5	0.85	9.28	9.72
Soleus OL	7.5	1	4.5	4.5	31.5	0.145	8.5	10.5

	Mature Adult				Older Adult			
			Mean Rank				Mean Rank	
Variable	Mann-Whit U	Sig.	Male	Female	Mann-Whit U	Sig.	Male	Female
Costoclavicular RB	75.5	0.246	15.97	12.81	8	0.027*	5.14	9.86

TABLE 6.30: Mann-Whitney U Test Between the Sexes for Changes in Robusticity and Osteolytic Formations, Separated by Age and Standardized by Body Size (continued)

Costoclavicular OL	32.5	0.002**	18.83	9.5	9.5	0.038*	9.64	5.36
Conoid RB	69.5	0.611	13.65	12.29	7	0.583	5.67	4.67
Conoid OL	73	0.73	12.62	13.42	8	0.773	5.33	4.83
Trapezoid RB	93.5	0.432	14.5	16.81	7	0.247	6.33	4.25
Trapezoid OL	88.5	0.283	16.79	13.81	5	0.08	6.67	3.75
Subscapularis RB	78	0.25	16.41	13	15.5	0.409	7.79	6.08
Subscapularis OL	99	0.851	14.82	15.25	15.5	0.391	7.79	6.08
Supraspinatus etc. RB	71	0.124	16.27	12.46	13.5	0.479	7.07	5.7
Supraspinatus etc. OL	79	0.331	15.73	13.08	9	0.123	7.71	4.8
Pectoralis RB	96	0.696	15.5	14.38	16.5	0.275	6.36	8.64
Pectoralis OL	84	0.097	16.25	13.46	21	0.317	8	7
Latissimus etc. RB	65	0.083	17.18	11.92	21	0.64	8	7
Latissimus etc. OL	84	0.359	16.06	13.5	17	0.227	6.43	8.57
Deltoideus RB	78	0.511	13.2	15	16.5	0.455	7.64	6.25
Deltoideus OL	77	0.163	14.87	12.92	17.5	0.28	6.5	7.58
Triceps Brachii RB	36	0.213	9.77	13	13.5	0.438	5.75	7.25
Triceps Brachii OL	52	1	11	11	15	1	6	6
Brachialis RB	85.5	0.373	13.84	16.42	13	0.185	8.33	5.86
Brachialis OL	78	0.057	16.63	13	18.5	0.629	7.42	6.64
Biceps Brachii RB	92.5	0.645	15.56	14.21	22.5	0.776	7.79	7.21
Biceps Brachii OL	73	0.117	16.71	12.58	17.5	0.263	8.5	6.5
Supinator RB	84	0.389	13.94	16.5	19.5	0.475	6.79	8.21
Supinator OL	.	.	.	.	.	.	.	.
Pronator Teres RB	91.5	0.806	14.22	14.88	7.5	0.015*	9.93	5.07
Pronator Teres OL	90	0.386	14.13	15	21	0.317	8	7
Extensor Carpi Ulnaris RB	54.5	0.782	11.19	11.94	8.5	0.694	4.63	5.3

TABLE 6.30: Mann-Whitney U Test Between the Sexes for Changes in Robusticity and Osteolytic Formations, Separated by Age and Standardized by Body Size (continued)

Extensor Carpi Ulnaris OL	58	0.963	11.46	11.56	9.5	0.866	4.88	5.1
Flexor Carpi Ulnaris RB	41.5	0.238	10.19	13.39	9.5	0.866	5.13	4.9
Flexor Carpi Ulnaris OL	31.5	1	8.5	8.5	4.5	0.386	3.5	4.38
Piriformis etc. RB	47.5	0.013*	11.17	18.35	5	0.171	4	6.25
Piriformis etc. OL	88.5	0.563	15.1	13.81	10	1	5	5
Gluteus Minimus RB	88.5	0.69	14.97	13.88	12.5	0.614	5.5	6.42
Gluteus Minimus OL	92	0.781	14.75	14.17	14	0.787	6.2	5.83
Gluteus Medius RB	66.5	0.288	12.25	14.96	18	0.654	7.5	6.57
Gluteus Medius OL	80.5	0.807	13.25	13.79	18	0.561	6.5	7.43
Quadratus Femoris RB	57.5	0.388	11.42	13.77	15	0.662	6	6.86
Quadratus Femoris OL	62.5	0.487	11.81	13.32	12	0.17	7.6	5.71
Gluteus Maximus RB	110.5	0.698	15.5	16.61	19	0.459	6.71	8.29
Gluteus Maximus OL	104	0.608	15	16.07	21	0.53	8	7
Iliopsoas RB	89.5	0.321	16.74	13.88	11.5	0.15	8.58	5.64
Iliopsoas OL	87	0.159	16.88	13.69	20.5	0.909	6.92	7.07
Adductor Magnus RB	105	0.745	15.06	16	17.5	0.141	8.5	6.5
Adductor Magnus OL	111	0.923	15.44	15.57	24.5	1	7.5	7.5
Quadriceps RB	55.5	0.608	11.46	12.83	14.5	0.918	5.9	6.08
Quadriceps OL	.	.	.	.	.	.	.	.
Popliteus RB	100.5	0.647	16.09	14.73	13	0.428	5.86	7.4
Popliteus OL	110.5	1	15.5	15.5	17.5	1	6.5	6.5
Semimembranosus RB	72.5	0.411	14.97	12.59	14	0.54	5.8	7
Semimembranosus OL	84.5	0.752	14.22	13.68	13	0.337	7.4	5.86

TABLE 6.30: Mann-Whitney U Test Between the Sexes for Changes in Robusticity and Osteolytic Formations, Separated by Age and Standardized by Body Size (continued)

Sartorius etc. RB	90.5	0.521	15.84	13.96	12	0.299	5.5	7.5
Sartorius etc. OL	97.5	0.367	15.41	14.5	18	1	6.5	6.5
Soleus RB	57	0.253	11.8	14.8	5	0.041*	4	7.67
Soleus OL	60	0.077	14	11.5	12	0.273	6.6	5.5

*P ≤0.05

**P ≤ 0.01

"." = Cannot be computed because at least one variable is constant (0)

FIGURE 6.52: Significant Differences in Mean Ranks Between the Sexes for Early Young Adults, Standardized by Body Size

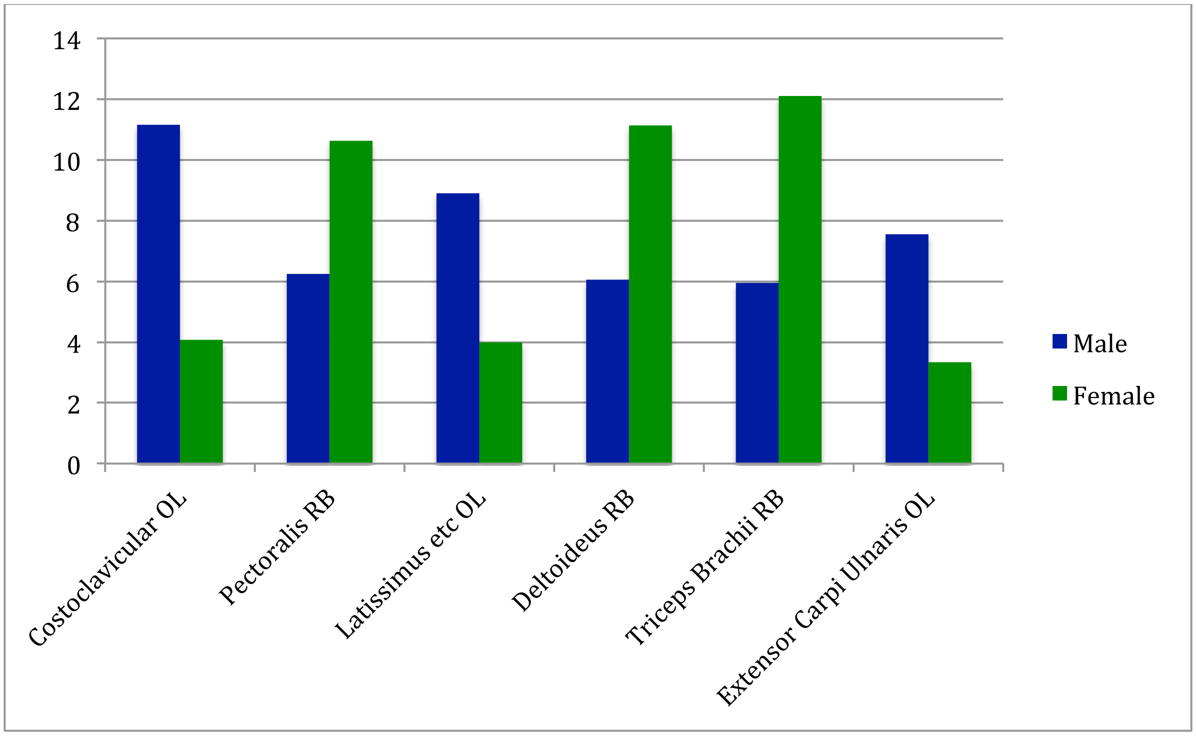


FIGURE 6.53: Significant Differences in Mean Ranks Between the Sexes for Late Young Adults, Standardized by Body Size

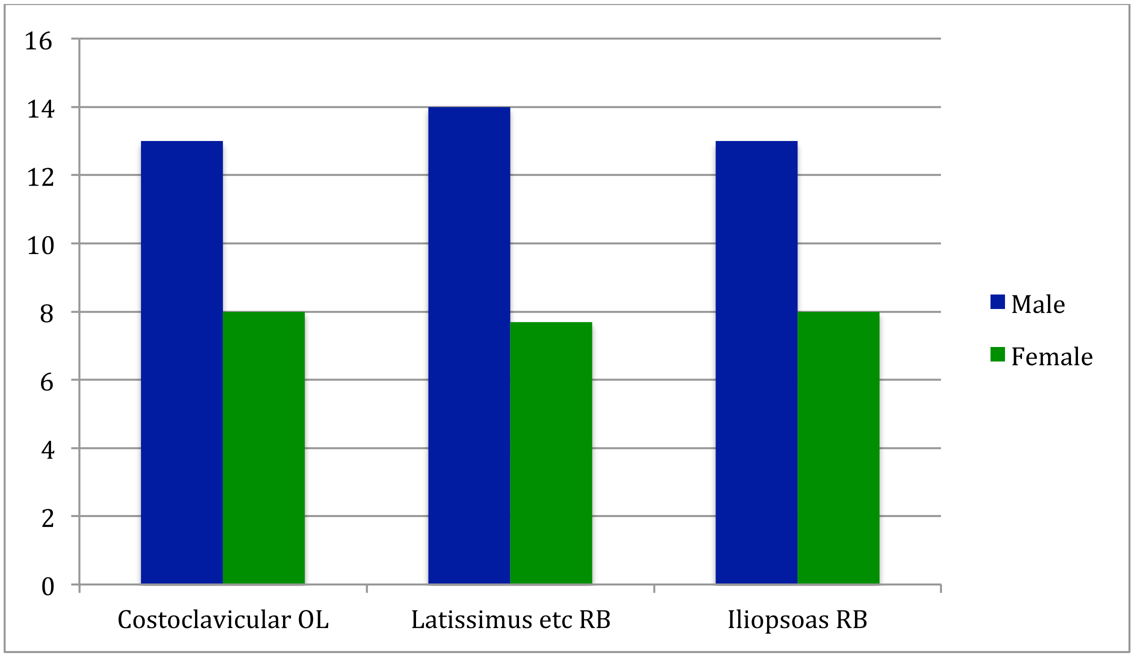


FIGURE 6.54: Significant Differences in Mean Ranks Between the Sexes for Mature Adults, Standardized by Body Size

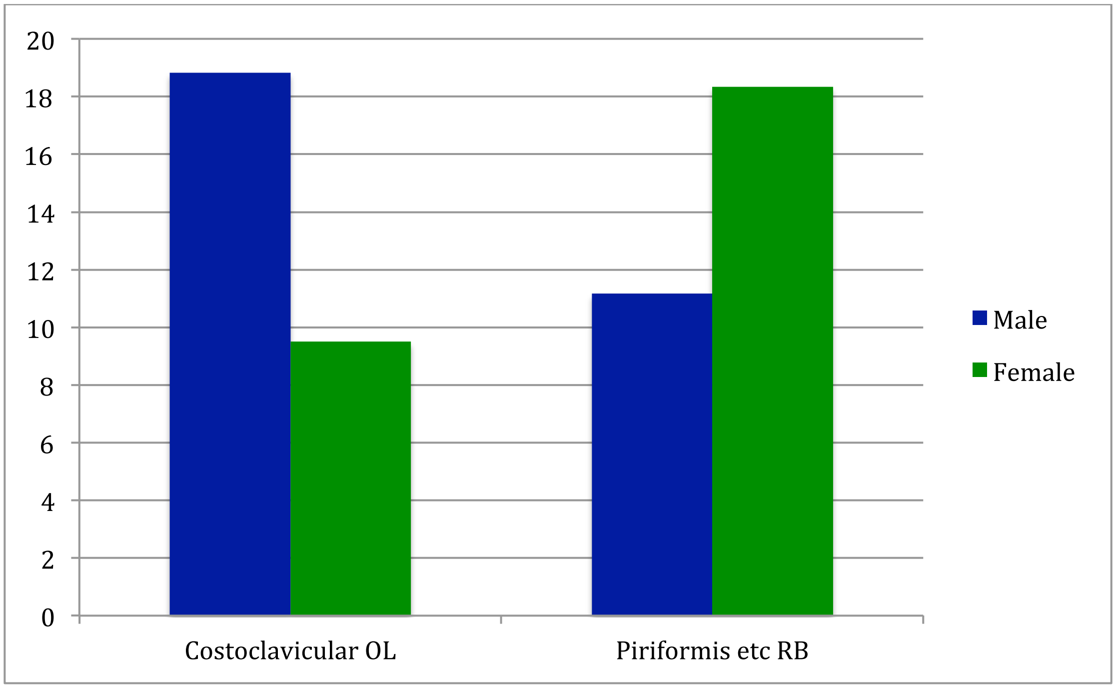
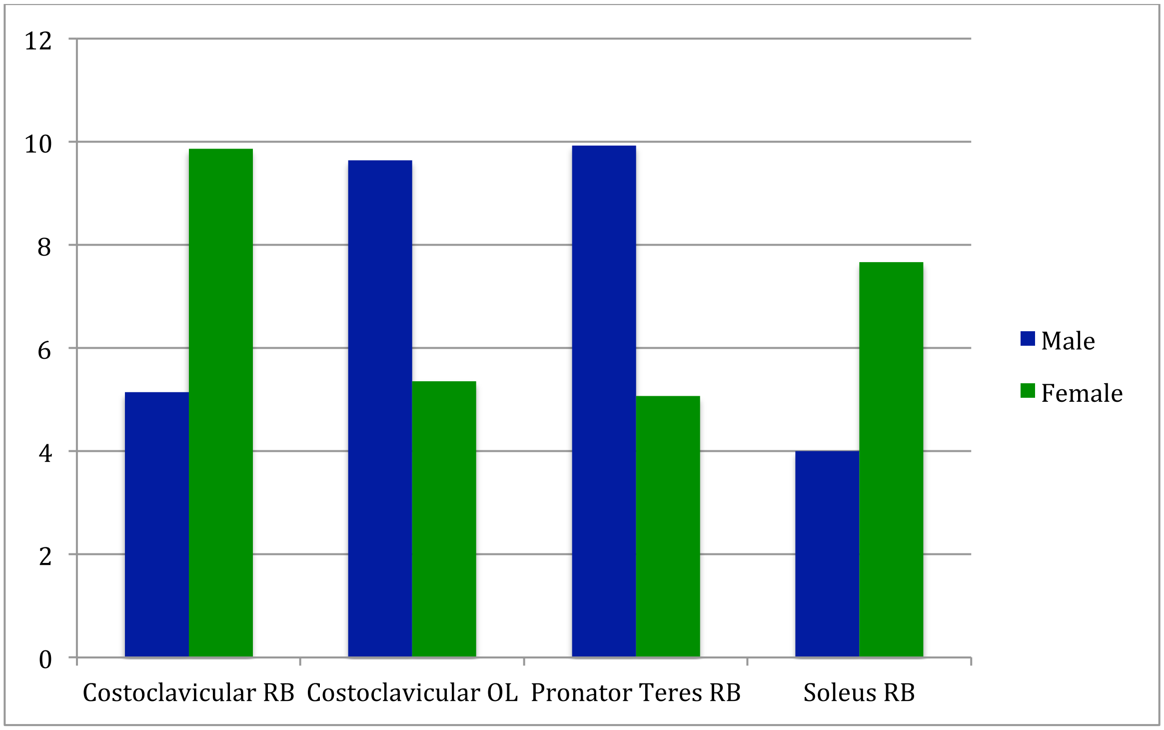


FIGURE 6.55: Significant Differences in Mean Ranks Between the Sexes for Older Adults, Standardized by Body Size



6.3.2 Osteophytic Formations

Mann-Whitney U tests were run on the entire sample to explore possible differences between the sexes for osteophytic formations. Table 6.31 presents the results of the Mann-Whitney U test which was performed on all of the entheseal osteophytic scores using sex as the grouping variable. Females had statistically significant higher scores than males for the left *conoid* ligament (*P* = 0.015), left *triceps brachii* (*P* = 0.004) and right *soleus* (*P* = 0.044) entheses.

TABLE 6.31: Mann-Whitney U Test Between the Sexes for Changes in Osteophytic Formations, Ages Combined

			Male		Female		Total
Entheseal Variable	Mann-Whitney U	Significance	Mean Rank	N	Mean Rank	N	N
Costoclavicular L	672.5	0.932	37.6	41	37.38	33	74
Costoclavicular R	577.5	0.523	36.39	37	34.5	33	70
Conoid L	366	0.015*	28.26	34	35.43	28	62
Conoid R	456	0.353	30.82	33	33.3	30	63
Trapezoid L	562.5	0.8	35.28	41	34.59	28	69
Trapezoid R	502	0.725	32.71	38	33.41	27	65
Subscapularis L	608.5	0.124	40.67	44	35.52	32	76
Subscapularis R	716	0.772	39.45	42	38.46	35	77
Supraspinatus etc. L	633	0.733	36.72	43	37.4	30	73
Supraspinatus etc. R	616.5	0.845	36.19	39	35.77	32	71
Pectoralis L	714	0.374	39.4	43	38.5	34	77
Pectoralis R	608	0.203	37.3	40	35.5	32	72
Latissimus etc. L	585	0.088	38.4	43	35	30	73
Latissimus etc. R	625.5	0.47	37.61	42	36.18	31	73
Deltoideus L	688.5	0.863	37.89	42	38.14	33	75
Deltoideus R	624	0.371	36.9	40	36	32	72
Triceps Brachii L	367.5	0.004**	28.5	35	35.39	27	62
Triceps Brachii R	452	0.267	30.79	34	33.41	29	63
Brachialis L	703	0.983	38.48	44	38.53	32	76
Brachialis R	750	0.909	39.36	42	39.67	36	78
Biceps Brachii L	688.5	0.177	42.11	42	37.61	37	79
Biceps Brachii R	767.5	0.866	40.23	42	39.74	37	79
Supinator L	787.5	1	40.5	45	40.5	35	80
Supinator R	765	1	40	45	40	34	79
Pronator Teres L	770	1	40	44	40	35	79
Pronator Teres R	663	1	37	39	37	34	73
Extensor Carpi Ulnaris L	280	0.248	24.5	28	25.67	21	49
Extensor Carpi Ulnaris R	280	0.248	24.5	28	25.67	21	49
Flexor Carpi Ulnaris L	270	0.257	24	27	25.14	21	48
Flexor Carpi Ulnaris R	280	0.248	24.5	28	25.67	21	49
Piriformis etc. L	494	0.624	32.22	36	33.97	29	65
Piriformis etc. R	504.5	0.965	33.06	39	32.9	26	65
Gluteus Minimus L	655	0.397	39.13	40	36.71	35	75
Gluteus Minimus R	484.5	0.133	35.91	37	31.65	30	67

TABLE 6.31: Mann-Whitney U Test Between the Sexes for Changes in Osteophytic Formations, Ages Combined (continued)

Gluteus Medius L	496	0.058	35.72	36	32	31	67
Gluteus Medius R	576	0.112	37.23	39	34.5	32	71
Quadratus Femoris L	406	1	29	29	29	28	57
Quadratus Femoris R	490	1	32	35	32	28	63
Gluteus Maximus L	774	0.938	39.93	42	40.08	37	79
Gluteus Maximus R	765	0.847	39.79	43	40.25	36	79
Iliopsoas L	643.5	0.522	36.59	40	38.57	34	74
Iliopsoas R	609.5	0.832	36.17	43	36.98	29	72
Adductor Magnus L	837	0.517	41.47	43	42.58	40	83
Adductor Magnus R	783	0.07	44.7	44	40.08	40	84
Quadriceps L	349	0.467	26.96	28	29.07	27	55
Quadriceps R	296	0.706	24.96	27	26.13	23	50
Popliteus L	785.5	0.968	40.54	45	40.44	35	80
Popliteus R	788	0.686	41.49	45	40.39	36	81
Semimembranosus L	528	0.332	33.97	34	33	32	66
Semimembranosus R	560	0.148	36.03	34	34	35	69
Sartorius etc. L	698	0.497	37.95	40	39.11	36	76
Sartorius etc. R	685.5	0.193	40.36	40	37.53	37	77
Soleus L	307.5	0.095	25.92	31	32.67	26	57
Soleus R	267.5	0.044*	25.11	33	33.37	23	56

*P ≤0.05
**P ≤ 0.01

Kruskal-Wallis tests were then run on the entire sample to explore potential differences between age groups. Table 6.32 presents the results of the Kruskal-Wallis test, which was performed on all of the entheseal osteophytic scores using age as the grouping variable. Statistically significant differences between age categories were returned for the right *latissimus* (P = 0.046), left *piriformis* (P = 0.008), right *iliopsoas* (P = 0.021), right *adductor magnus* (P = 0.017) and left and right *soleus* (P = 0.007, P = 0.046) entheses.

TABLE 6.32: Kruskal-Wallis Test Between Age Groups for Osteophytic Formations, Sexes Combined

		Early Young Adult		Late Young Adult		Mature Adult		Older Adult		Total
Entheseal Variable	Sig.	Mean Rank	N	Mean Rank	N	Mean Rank	N	Mean Rank	N	N
Costoclavicular L	0.48	34	15	39.75	20	38	27	37	12	74
Costoclavicular R	0.913	34.94	16	35.71	19	36.63	24	33.5	11	70
Conoid L	0.114	31.12	13	36.5	19	29.23	22	26.5	8	62
Conoid R	0.647	32.71	14	31.44	18	33.39	23	28	8	63
Trapezoid L	0.656	36.07	14	34.94	17	35.93	28	31	10	69
Trapezoid R	0.448	31	15	34.82	17	33.71	24	31	9	65
Subscapularis L	0.671	34.5	15	39.76	25	39.81	24	38.25	12	76
Subscapularis R	0.549	34.43	15	38.96	23	40.11	27	42.29	12	77
Supraspinatus etc. L	0.619	35	14	38.36	22	36.38	26	38.27	11	73
Supraspinatus etc. R	0.312	33.5	13	36.95	21	34.85	26	39.86	11	71
Pectoralis L	0.212	41.25	14	38.5	23	38.5	27	38.5	13	77
Pectoralis R	0.552	38.07	14	35.5	21	37	24	35.5	13	72
Latissimus etc. L	0.174	37.61	14	39.98	22	35	24	35	13	73
Latissimus etc. R	0.046*	35	15	35	20	40.84	25	35	13	73
Deltoideus L	0.205	37	14	40.26	23	37	25	37	13	75
Deltoideus R	0.172	36	15	36	21	36	24	39	12	72
Triceps Brachii L	0.267	28.5	14	30.31	18	34.55	20	31.75	10	62
Triceps Brachii R	0.835	31.03	15	31.09	16	33.5	21	31.77	11	63
Brachialis L	0.524	40.46	14	40.07	23	37.7	27	35	12	76
Brachialis R	0.377	44.18	14	37.26	23	39.55	28	38.31	13	78
Biceps Brachii L	0.618	38.25	16	39.85	26	42.88	25	36.67	12	79
Biceps Brachii R	0.492	37.81	16	38.91	23	43.02	27	38.35	13	79
Supinator L	1	40.5	15	40.5	24	40.5	27	40.5	14	80
Supinator R	1	40	15	40	22	40	28	40	14	79
Pronator Teres L	1	40	15	40	24	40	26	40	14	79
Pronator Teres R	1	37	13	37	20	37	26	37	14	73
Extensor Carpi Ulnaris L	0.475	24.5	11	26.25	14	24.5	17	24.5	7	49
Extensor Carpi Ulnaris R	0.519	24.5	11	26.13	15	24.5	17	24.5	6	49
Flexor Carpi Ulnaris L	0.488	24	11	25.71	14	24	16	24	7	48
Flexor Carpi Ulnaris R	0.56	24.5	10	26.03	16	24.5	17	24.5	6	49
Piriformis etc. L	0.008**	26.97	15	27.08	18	38.63	24	40.75	8	65
Piriformis etc. R	0.089	29.12	13	28.53	17	34.81	27	42.69	8	65

TABLE 6.32: Kruskal-Wallis Test Between Age Groups for Osteophytic Formations, Sexes Combined (continued)

Gluteus Minimus L	0.301	33.5	17	38.86	21	40.65	26	37.05	11	75
Gluteus Minimus R	0.173	29.5	16	35.59	17	33.63	24	39.4	10	67
Gluteus Medius L	0.277	32	14	33.55	21	33.64	21	38.09	11	67
Gluteus Medius R	0.709	34.5	17	36.47	18	35.96	25	37.64	11	71
Quadratus Femoris L	1	29	12	29	17	29	17	29	11	57
Quadratus Femoris R	1	32	14	32	17	32	21	32	11	63
Gluteus Maximus L	0.348	38	17	39.74	23	42.21	28	38	11	79
Gluteus Maximus R	0.276	37	15	40.64	22	42.41	29	37	13	79
Iliopsoas L	0.125	32	17	37.73	20	41.71	26	35.64	11	74
Iliopsoas R	0.021*	27.5	15	35.69	18	42.89	28	33.82	11	72
Adductor Magnus L	0.52	40.5	17	42.16	25	43.57	27	40.5	14	83
Adductor Magnus R	0.017*	39	17	39	25	48.09	28	41.82	14	84
Quadriceps L	0.146	25.73	11	30.4	15	24.68	19	33.2	10	55
Quadriceps R	0.702	25.06	9	28.54	13	24.11	19	24.5	9	50
Popliteus L	0.97	39.6	15	40.25	24	41.28	29	40.25	12	80
Popliteus R	0.447	39.63	16	43.67	24	41.21	29	37	12	81
Semimembranosus L	0.373	33	14	35.06	16	33	25	33	11	66
Semimembranosus R	0.346	34	15	35.82	19	34	25	37.45	10	69
Sartorius etc. L	0.152	37	15	37	21	41.07	28	37	12	76
Sartorius etc. R	0.619	38.88	16	38.31	21	40.66	28	36.5	12	77
Soleus L	0.007**	15.5	9	25.63	16	33.93	21	35.55	11	57
Soleus R	0.025*	14.5	8	28.35	17	30.8	22	35.61	9	56

$^*P \leq 0.05$
$^{**}P \leq 0.01$

To gain a clearer idea of the nature of these potential differences, the data set was separated by sex and Kruskal-Wallis tests were conducted to look for significant differences across age categories for each sex (Table 6.33). Males had significant differences across age categories for the right *gluteus minimus* ($P = 0.025$) and right *adductor magnus* ($P = 0.037$) entheses. Females had significant differences across age categories for the left *biceps brachii* ($P = 0.016$), left *piriformis* ($P = 0.017$), left *iliopsoas* ($P = 0.040$) and both left and right *soleus* ($P = 0.005$, $P = 0.033$) entheses.

TABLE 6.33: Kruskal-Wallis Tests Between Age Categories By Sex for Osteophytic Formations

MALES:				
Entheseal Variable	Sig.	Age	N	Mean Rank
Costoclavicular L	0.405	EYA	9	19
		LYA	11	22.82
		MA	14	21.86
		OA	7	19
		Total	41	
Costoclavicular R	0.319	EYA	9	18.17
		LYA	10	17.65
		MA	13	21.77
		OA	5	16
		Total	37	
Conoid L	0.651	EYA	9	18.39
		LYA	10	18.2
		MA	12	16.5
		OA	3	16.5
		Total	34	
Conoid R	0.943	EYA	9	17.33
		LYA	9	17.33
		MA	12	16.88
		OA	3	15.5
		Total	33	
Trapezoid L	0.689	EYA	9	20.94
		LYA	10	20.45
		MA	16	22.31
		OA	6	18.5
		Total	41	
Trapezoid R	0.68	EYA	9	18.5
		LYA	9	20.61
		MA	14	19.86
		OA	6	18.5
		Total	38	
Subscapularis L	0.686	EYA	9	19.89
		LYA	13	24.5
		MA	15	21.8
		OA	7	23.64
		Total	44	

FEMALES:				
Entheseal Variable	Sig.	Age	N	Mean Rank
Costoclavicular L	0.725	EYA	6	15.5
		LYA	9	17.44
		MA	13	16.73
		OA	5	18.7
		Total	33	
Costoclavicular R	0.484	EYA	7	17.36
		LYA	9	18.67
		MA	11	15
		OA	6	17.75
		Total	33	
Conoid L	0.112	EYA	4	13.75
		LYA	9	18.61
		MA	10	13.1
		OA	5	10.5
		Total	28	
Conoid R	0.568	EYA	5	16.4
		LYA	9	14.61
		MA	11	16.95
		OA	5	13
		Total	30	
Trapezoid L	0.788	EYA	5	15.8
		LYA	7	15
		MA	12	14.17
		OA	4	13
		Total	28	
Trapezoid R	0.782	EYA	6	13
		LYA	8	14.69
		MA	10	14.35
		OA	3	13
		Total	27	
Subscapularis L	0.422	EYA	6	15
		LYA	12	16.33
		MA	9	18.56
		OA	5	15
		Total	32	

TABLE 6.33: Kruskal-Wallis Tests Between Age Categories By Sex for Osteophytic Formations (continued)

Subscapularis R	0.761	EYA	9	19.67
		LYA	11	21.41
		MA	15	21.4
		OA	7	24.21
		Total	42	
Supraspinatus etc. L	0.736	EYA	9	21
		LYA	12	22.83
		MA	15	22.4
		OA	7	21
		Total	43	
Supraspinatus etc. R	0.766	EYA	8	18.5
		LYA	10	20.45
		MA	14	19.89
		OA	7	21.29
		Total	39	
Pectoralis L	0.286	EYA	9	23.89
		LYA	12	21.5
		MA	15	21.5
		OA	7	21.5
		Total	43	
Pectoralis R	0.638	EYA	9	21.72
		LYA	10	19.5
		MA	14	20.93
		OA	7	19.5
		Total	40	
Latissimus etc. L	0.129	EYA	9	22.39
		LYA	12	25.38
		MA	15	20
		OA	7	20
		Total	43	
Latissimus etc. R	0.128	EYA	10	20
		LYA	10	20
		MA	15	24.2
		OA	7	20
		Total	42	

Subscapularis R	0.651	EYA	6	15
		LYA	12	18.08
		MA	12	19.25
		OA	5	18.4
		Total	35	
Supraspinatus etc. L	0.339	EYA	5	14.5
		LYA	10	16
		MA	11	14.5
		OA	4	18.25
		Total	30	
Supraspinatus etc. R	0.333	EYA	5	15.5
		LYA	11	17
		MA	12	15.5
		OA	4	19.38
		Total	32	
Pectoralis L	1	EYA	5	17.5
		LYA	11	17.5
		MA	12	17.5
		OA	6	17.5
		Total	34	
Pectoralis R	1	EYA	5	16.5
		LYA	11	16.5
		MA	10	16.5
		OA	6	16.5
		Total	32	
Latissimus etc. L	1	EYA	5	15.5
		LYA	10	15.5
		MA	9	15.5
		OA	6	15.5
		Total	30	
Latissimus etc. R	0.552	EYA	5	15.5
		LYA	10	15.5
		MA	10	17.05
		OA	6	15.5
		Total	31	

TABLE 6.33: Kruskal-Wallis Tests Between Age Categories By Sex for Osteophytic Formations (continued)

Deltoideus L	0.475	EYA	9	21
		LYA	12	22.75
		MA	14	21
		OA	7	21
		Total	42	
Deltoideus R	0.194	EYA	10	20
		LYA	10	20
		MA	13	20
		OA	7	22.86
		Total	40	
Triceps Brachii L	1	EYA	9	18
		LYA	8	18
		MA	12	18
		OA	6	18
		Total	35	
Triceps Brachii R	0.422	EYA	9	18.39
		LYA	6	16.5
		MA	13	16.5
		OA	6	19.33
		Total	34	
Brachialis L	0.544	EYA	10	24.9
		LYA	13	22.27
		MA	15	21.9
		OA	6	20.5
		Total	44	
Brachialis R	0.084	EYA	10	25.8
		LYA	11	19.5
		MA	15	20.9
		OA	6	19.5
		Total	42	
Biceps Brachii L	0.745	EYA	10	20.9
		LYA	13	23.69
		MA	14	20.11
		OA	5	20.9
		Total	42	

Deltoideus L	0.572	EYA	5	16.5
		LYA	11	18
		MA	11	16.5
		OA	6	16.5
		Total	33	
Deltoideus R	1	EYA	5	16.5
		LYA	11	16.5
		MA	11	16.5
		OA	5	16.5
		Total	32	
Triceps Brachii L	0.184	EYA	5	11
		LYA	10	12.5
		MA	8	17.38
		OA	4	14.75
		Total	27	
Triceps Brachii R	0.162	EYA	6	13
		LYA	10	14.55
		MA	8	18.31
		OA	5	13
		Total	29	
Brachialis L	0.497	EYA	4	15
		LYA	10	18.25
		MA	12	16.29
		OA	6	15
		Total	32	
Brachialis R	0.855	EYA	4	16.5
		LYA	12	18.13
		MA	13	19.19
		OA	7	19
		Total	36	
Biceps Brachii L	0.016*	EYA	6	17
		LYA	13	17
		MA	11	23.73
		OA	7	17
		Total	37	

TABLE 6.33: Kruskal-Wallis Tests Between Age Categories By Sex for Osteophytic Formations (continued)

Biceps Brachii R	0.583	EYA	10	20.95
		LYA	10	21.2
		MA	15	23.23
		OA	7	19
		Total	42	
Supinator L	1	EYA	10	23
		LYA	13	23
		MA	15	23
		OA	7	23
		Total	45	
Supinator R	1	EYA	10	23
		LYA	12	23
		MA	16	23
		OA	7	23
		Total	45	
Pronator Teres L	1	EYA	10	22.5
		LYA	13	22.5
		MA	14	22.5
		OA	7	22.5
		Total	44	
Pronator Teres R	1	EYA	8	20
		LYA	10	20
		MA	14	20
		OA	7	20
		Total	39	
Extensor Carpi Ulnaris L	1	EYA	9	14.5
		LYA	6	14.5
		MA	10	14.5
		OA	3	14.5
		Total	28	
Extensor Carpi Ulnaris R	1	EYA	8	14.5
		LYA	8	14.5
		MA	10	14.5
		OA	2	14.5
		Total	28	

Biceps Brachii R	0.667	EYA	6	17
		LYA	13	18.35
		MA	12	20.25
		OA	6	19.92
		Total	37	
Supinator L	1	EYA	5	18
		LYA	11	18
		MA	12	18
		OA	7	18
		Total	35	
Supinator R	1	EYA	5	17.5
		LYA	10	17.5
		MA	12	17.5
		OA	7	17.5
		Total	34	
Pronator Teres L	1	EYA	5	18
		LYA	11	18
		MA	12	18
		OA	7	18
		Total	35	
Pronator Teres R	1	EYA	5	17.5
		LYA	10	17.5
		MA	12	17.5
		OA	7	17.5
		Total	34	
Extensor Carpi Ulnaris L	0.654	EYA	2	10.5
		LYA	8	11.81
		MA	7	10.5
		OA	4	10.5
		Total	21	
Extensor Carpi Ulnaris R	0.572	EYA	3	10.5
		LYA	7	12
		MA	7	10.5
		OA	4	10.5
		Total	21	

TABLE 6.33: Kruskal-Wallis Tests Between Age Categories By Sex for Osteophytic Formations (continued)

Flexor Carpi Ulnaris L	1	EYA	9	14
		LYA	6	14
		MA	9	14
		OA	3	14
		Total	27	
Flexor Carpi Ulnaris R	1	EYA	8	14.5
		LYA	8	14.5
		MA	10	14.5
		OA	2	14.5
		Total	28	
Piriformis etc. L	0.4	EYA	10	16.15
		LYA	9	16.78
		MA	12	20.67
		OA	5	21.1
		Total	36	
Piriformis etc. R	0.384	EYA	10	16.75
		LYA	10	19
		MA	14	21.61
		OA	5	24
		Total	39	
Gluteus Minimus L	0.207	EYA	10	17.5
		LYA	10	23.5
		MA	15	21.5
		OA	5	17.5
		Total	40	
Gluteus Minimus R	0.025*	EYA	10	15.5
		LYA	9	21.83
		MA	13	16.96
		OA	5	26.2
		Total	37	

Flexor Carpi Ulnaris L	0.654	EYA	2	10.5
		LYA	8	11.81
		MA	7	10.5
		OA	4	10.5
		Total	21	
Flexor Carpi Ulnaris R	0.654	EYA	2	10.5
		LYA	8	11.81
		MA	7	10.5
		OA	4	10.5
		Total	21	
Piriformis etc. L	0.017*	EYA	5	11
		LYA	9	11
		MA	12	18.17
		OA	3	21
		Total	29	
Piriformis etc. R	0.132	EYA	3	14.17
		LYA	7	10
		MA	13	13.85
		OA	3	19.5
		Total	26	
Gluteus Minimus L	0.338	EYA	7	16.5
		LYA	11	16.5
		MA	11	19.64
		OA	6	19.5
		Total	35	
Gluteus Minimus R	0.311	EYA	6	14.5
		LYA	8	14.5
		MA	11	17.23
		OA	5	14.5
		Total	30	

TABLE 6.33: Kruskal-Wallis Tests Between Age Categories By Sex for Osteophytic Formations (continued)

Gluteus Medius L	0.153	EYA	9	16.5
		LYA	11	18.05
		MA	11	18.23
		OA	5	23.7
		Total	36	
Gluteus Medius R	0.699	EYA	10	18.5
		LYA	10	20.45
		MA	13	20.08
		OA	6	21.58
		Total	39	
Quadratus Femoris L	1	EYA	7	15
		LYA	9	15
		MA	8	15
		OA	5	15
		Total	29	
Quadratus Femoris R	1	EYA	8	18
		LYA	10	18
		MA	12	18
		OA	5	18
		Total	35	
Gluteus Maximus L	0.762	EYA	10	20.5
		LYA	12	22.21
		MA	15	21.93
		OA	5	20.5
		Total	42	
Gluteus Maximus R	0.344	EYA	10	20.5
		LYA	11	24.41
		MA	15	21.93
		OA	7	20.5
		Total	43	

Gluteus Medius L	1	EYA	5	16
		LYA	10	16
		MA	10	16
		OA	6	16
		Total	31	
Gluteus Medius R	1	EYA	7	16.5
		LYA	8	16.5
		MA	12	16.5
		OA	5	16.5
		Total	32	
Quadratus Femoris L	1	EYA	5	14.5
		LYA	8	14.5
		MA	9	14.5
		OA	6	14.5
		Total	28	
Quadratus Femoris R	1	EYA	6	14.5
		LYA	7	14.5
		MA	9	14.5
		OA	6	14.5
		Total	28	
Gluteus Maximus L	0.284	EYA	7	18
		LYA	11	18
		MA	13	20.85
		OA	6	18
		Total	37	
Gluteus Maximus R	0.172	EYA	5	17
		LYA	11	17
		MA	14	20.86
		OA	6	17
		Total	36	

TABLE 6.33: Kruskal-Wallis Tests Between Age Categories By Sex for Osteophytic Formations (continued)

Iliopsoas L	0.516	EYA	10	18
		LYA	10	22.05
		MA	15	20.53
		OA	5	22.3
		Total	40	
Iliopsoas R	0.196	EYA	10	17
		LYA	11	23.14
		MA	16	24.81
		OA	6	20.75
		Total	43	
Adductor Magnus L	0.558	EYA	10	21.5
		LYA	12	21.5
		MA	14	23.04
		OA	7	21.5
		Total	43	
Adductor Magnus R	0.037*	EYA	10	19.5
		LYA	12	19.5
		MA	15	26.97
		OA	7	22.36
		Total	44	
Quadriceps L	0.234	EYA	8	14.38
		LYA	5	18.1
		MA	10	12.5
		OA	5	15.1
		Total	28	
Quadriceps R	0.118	EYA	7	13.14
		LYA	4	20.38
		MA	11	12.45
		OA	5	13.5
		Total	27	
Popliteus L	0.807	EYA	10	23.2
		LYA	12	22.83
		MA	16	23.88
		OA	7	21
		Total	45	

Iliopsoas L	0.04*	EYA	7	14.5
		LYA	10	16.35
		MA	11	22.09
		OA	6	14.5
		Total	34	
Iliopsoas R	0.11	EYA	5	11
		LYA	7	12.86
		MA	12	18.5
		OA	5	13.6
		Total	29	
Adductor Magnus L	0.776	EYA	7	19.5
		LYA	13	21.04
		MA	13	21.04
		OA	7	19.5
		Total	40	
Adductor Magnus R	0.557	EYA	7	20
		LYA	13	20
		MA	13	21.54
		OA	7	20
		Total	40	
Quadriceps L	0.232	EYA	3	11
		LYA	10	13.75
		MA	9	12.78
		OA	5	18.5
		Total	27	
Quadriceps R	0.932	EYA	2	14
		LYA	9	11.5
		MA	8	12.31
		OA	4	11.5
		Total	23	
Popliteus L	0.755	EYA	5	16.5
		LYA	12	17.92
		MA	13	17.92
		OA	5	19.9
		Total	35	

TABLE 6.33: Kruskal-Wallis Tests Between Age Categories By Sex for Osteophytic Formations (continued)

Popliteus R	0.357	EYA	10	22.85
		LYA	12	25.96
		MA	16	21.97
		OA	7	20.5
		Total	45	
Semimembranosus L	0.198	EYA	9	17
		LYA	6	19.83
		MA	15	17
		OA	4	17
		Total	34	
Semimembranosus R	0.113	EYA	9	16.5
		LYA	8	18.63
		MA	14	16.5
		OA	3	22.17
		Total	34	
Sartorius etc. L	0.644	EYA	10	20
		LYA	9	20
		MA	15	21.33
		OA	6	20
		Total	40	
Sartorius etc. R	0.832	EYA	10	20.45
		LYA	9	20.67
		MA	15	21.23
		OA	6	18.5
		Total	40	
Soleus L	0.171	EYA	5	10
		LYA	7	16.57
		MA	14	18.71
		OA	5	13.6
		Total	31	
Soleus R	0.306	EYA	5	10.5
		LYA	9	18.83
		MA	14	17.96
		OA	5	17.5
		Total	9	

Popliteus R	0.627	EYA	6	17
		LYA	12	18.54
		MA	13	19.73
		OA	5	17
		Total	36	
Semimembranosus L	1	EYA	5	16.5
		LYA	10	16.5
		MA	10	16.5
		OA	7	16.5
		Total	32	
Semimembranosus R	1	EYA	6	18
		LYA	11	18
		MA	11	18
		OA	7	18
		Total	35	
Sartorius etc. L	0.303	EYA	5	17.5
		LYA	12	17.5
		MA	13	20.27
		OA	6	17.5
		Total	36	
Sartorius etc. R	0.605	EYA	6	18.5
		LYA	12	18.5
		MA	13	19.92
		OA	6	18.5
		Total	37	
Soleus L	0.005**	EYA	4	6
		LYA	9	9.89
		MA	7	17
		OA	6	19.83
		Total	26	
Soleus R	0.033*	EYA	3	4.5
		LYA	8	9.94
		MA	8	14
		OA	4	17.75
		Total	6	

*$P \leq 0.05$
**$P \leq 0.01$

Since a number of entheseal variables are statistically significantly different between the sexes as well as across age groups, Two-tailed Spearman correlations were calculated to see if the variables of age, sex or body size may be influencing the results. Table 6.34 presents the Two-tailed Spearman correlation coefficients of the entheseal variables with age, sex and body size. Sex significantly correlated with the left *conoid* ligament (*P* = 0.002), left *triceps brachii* (*P* = 0.003), and right *soleus* (*P* = 0.043) entheses. Age significantly correlated with the left and right *piriformis* (*P* = 0.001, *P* = 0.018), right *adductor magnus* (*P* = 0.047) and left and right *soleus* (*P* = 0.001, *P* = 0.007) entheses. Body size correlated significantly with the left *conoid* ligament (*P* = 0.006) and right *pectoralis* (*P* = 0.03) entheses. These results suggest that all variables play limited roles in the morphology of entheses.

TABLE 6.34: Two-tailed Spearman Correlation Coefficients for Osteophytic Formations with Age, Sex and Body Size

		Sex	Age	Body Size
Costoclavicular L	rho	-0.01	0.06	-0.047
	Sig.	0.932	0.614	0.688
	N	74	74	74
Costoclavicular R	rho	-0.077	-0.007	0.063
	Sig.	0.527	0.953	0.603
	N	70	70	70
Conoid L	rho	.312*	-0.195	-.349**
	Sig.	0.014	0.129	0.006
	N	62	62	62
Conoid R	rho	0.118	-0.057	-0.101
	Sig.	0.357	0.657	0.433
	N	63	63	63
Trapezoid L	rho	-0.031	-0.09	0.073
	Sig.	0.802	0.46	0.55
	N	69	69	69
Trapezoid R	rho	0.044	0.018	0.044
	Sig.	0.728	0.888	0.726
	N	65	65	65

TABLE 6.34: Two-tailed Spearman Correlation Coefficients for Osteophytic Formations with Age, Sex and Body Size (continued)

Subscapularis L	rho	-0.178	0.08	0.104
	Sig.	0.125	0.49	0.371
	N	76	76	76
Subscapularis R	rho	-0.033	0.156	-0.041
	Sig.	0.774	0.176	0.726
	N	77	77	77
Supraspinatus etc. L	rho	0.04	0.058	-0.086
	Sig.	0.736	0.623	0.472
	N	73	73	73
Supraspinatus etc. R	rho	-0.023	0.129	0.044
	Sig.	0.847	0.283	0.713
	N	71	71	71
Pectoralis L	rho	-0.102	-0.17	0.186
	Sig.	0.377	0.14	0.106
	N	77	77	77
Pectoralis R	rho	-0.151	-0.076	.256*
	Sig.	0.205	0.525	0.03
	N	72	72	72
Latissimus etc. L	rho	-0.201	-0.19	0.206
	Sig.	0.088	0.107	0.081
	N	73	73	73
Latissimus etc. R	rho	-0.085	0.131	0.089
	Sig.	0.474	0.27	0.456
	N	73	73	73
Deltoideus L	rho	0.02	-0.096	-0.08
	Sig.	0.865	0.415	0.494
	N	75	75	75
Deltoideus R	rho	-0.106	0.178	-0.066
	Sig.	0.375	0.134	0.584
	N	72	72	72
Triceps Brachii L	rho	.372**	0.195	-0.199
	Sig.	0.003	0.128	0.12
	N	62	62	62
Triceps Brachii R	rho	0.141	0.071	-0.036
	Sig.	0.27	0.582	0.779
	N	63	63	63
Brachialis L	rho	0.002	-0.166	0.151
	Sig.	0.983	0.152	0.193
	N	76	76	76

TABLE 6.34: Two-tailed Spearman Correlation Coefficients for Osteophytic Formations with Age, Sex and Body Size (continued)

Brachialis R	rho	0.013	-0.095	0.049
	Sig.	0.91	0.41	0.672
	N	78	78	78
Biceps Brachii L	rho	-0.153	0.026	0.047
	Sig.	0.179	0.819	0.678
	N	79	79	79
Biceps Brachii R	rho	-0.019	0.081	-0.103
	Sig.	0.867	0.48	0.368
	N	79	79	79
Supinator L	rho	.	.	.
	Sig.	.	.	.
	N	80	80	80
Supinator R	rho	.	.	.
	Sig.	.	.	.
	N	79	79	79
Pronator Teres L	rho	.	.	.
	Sig.	.	.	.
	N	79	79	79
Pronator Teres R	rho	.	.	.
	Sig.	.	.	.
	N	73	73	73
Extensor Carpi Ulnaris L	rho	0.167	-0.069	-0.225
	Sig.	0.252	0.637	0.121
	N	49	49	49
Extensor Carpi Ulnaris R	rho	0.167	-0.064	-0.214
	Sig.	0.252	0.662	0.139
	N	49	49	49
Flexor Carpi Ulnaris L	rho	0.165	-0.066	-0.226
	Sig.	0.261	0.657	0.122
	N	48	48	48
Flexor Carpi Ulnaris R	rho	0.167	-0.069	-0.225
	Sig.	0.252	0.636	0.121
	N	49	49	49
Piriformis etc. L	rho	0.061	.402**	-0.056
	Sig.	0.627	0.001	0.66
	N	65	65	65
Piriformis etc. R	rho	-0.005	.293*	0.079
	Sig.	0.966	0.018	0.53
	N	65	65	65

TABLE 6.34: Two-tailed Spearman Correlation Coefficients for Osteophytic Formations with Age, Sex and Body Size (continued)

Gluteus Minimus L	rho	-0.099	0.138	0.035
	Sig.	0.4	0.236	0.764
	N	75	75	75
Gluteus Minimus R	rho	-0.185	0.213	0.025
	Sig.	0.134	0.084	0.838
	N	67	67	67
Gluteus Medius L	rho	-0.234	0.202	0.119
	Sig.	0.057	0.101	0.337
	N	67	67	67
Gluteus Medius R	rho	-0.19	0.114	0.141
	Sig.	0.112	0.345	0.241
	N	71	71	71
Quadratus Femoris L	rho	.	.	.
	Sig.	.	.	.
	N	57	57	57
Quadratus Femoris R	rho	.	.	.
	Sig.	.	.	.
	N	63	63	63
Gluteus Maximus L	rho	0.009	0.085	0.022
	Sig.	0.939	0.456	0.849
	N	79	79	79
Gluteus Maximus R	rho	0.022	0.045	0.001
	Sig.	0.848	0.697	0.99
	N	79	79	79
Iliopsoas L	rho	0.075	0.17	-0.042
	Sig.	0.526	0.149	0.724
	N	74	74	74
Iliopsoas R	rho	0.025	0.226	0.067
	Sig.	0.834	0.056	0.579
	N	72	72	72
Adductor Magnus L	rho	0.072	0.045	-0.024
	Sig.	0.52	0.687	0.828
	N	83	83	83
Adductor Magnus R	rho	-0.199	.217*	0.135
	Sig.	0.07	0.047	0.221
	N	84	84	84
Quadriceps L	rho	0.099	0.1	-0.056
	Sig.	0.472	0.469	0.683
	N	55	55	55

TABLE 6.34: Two-tailed Spearman Correlation Coefficients for Osteophytic Formations with Age, Sex and Body Size (continued)

Quadriceps R	rho	0.054	-0.087	0.076
	Sig.	0.71	0.547	0.601
	N	50	50	50
Popliteus L	rho	-0.004	0.036	0.024
	Sig.	0.969	0.752	0.833
	N	80	80	80
Popliteus R	rho	-0.045	-0.076	-0.026
	Sig.	0.689	0.503	0.818
	N	81	81	81
Semimembranosus L	rho	-0.12	-0.075	0.055
	Sig.	0.336	0.551	0.659
	N	66	66	66
Semimembranosus R	rho	-0.175	0.088	0.03
	Sig.	0.15	0.471	0.804
	N	69	69	69
Sartorius etc. L	rho	0.078	0.116	-0.072
	Sig.	0.501	0.319	0.534
	N	76	76	76
Sartorius etc. R	rho	-0.149	-0.01	0.206
	Sig.	0.195	0.93	0.072
	N	77	77	77
Soleus L	rho	0.223	.438**	-0.245
	Sig.	0.095	0.001	0.066
	N	57	57	57
Soleus R	rho	.271*	.358**	-0.232
	Sig.	0.043	0.007	0.085
	N	56	56	56

*$P \leq 0.05$

**$P \leq 0.01$

"." = Cannot be computed because at least one variable is constant (0)

Partial Spearman correlations were carried out to re-examine correlations of the entheseal variables with age after sex and body size were controlled for. Table 6.35 presents the results of the partial correlations with age. After controlling for sex and body size, age correlated significantly with osteophytic formations of the left and right *piriformis* ($P = 0.001$, $P = 0.019$), the right *adductor magnus* ($P = 0.037$) and the left and right *soleus* ($P = 0.001$, $P = 0.007$) entheses. Results of this test suggest that age is only influential on a small number of osteophytic formations of the lower limb.

TABLE 6.35: Partial Spearman Correlations With Age After Sex and Body Size have been controlled for Osteophytic Formations

Entheseal Variable	rho	Significance
Costoclavicular L	0.062	0.606
Costoclavicular R	-0.004	0.971
Conoid L	-0.218	0.095
Conoid R	-0.062	0.637
Trapezoid L	-0.091	0.464
Trapezoid R	0.014	0.912
Subscapularis L	0.090	0.447
Subscapularis R	0.160	0.170
Supraspinatus etc. L	0.059	0.626
Supraspinatus etc. R	0.129	0.289
Pectoralis L	-0.172	0.139
Pectoralis R	-0.077	0.525
Latissimus etc. L	-0.189	0.115
Latissimus etc. R	0.134	0.266
Deltoideus L	-0.095	0.423
Deltoideus R	0.194	0.108
Triceps Brachii L	0.197	0.132
Triceps Brachii R	0.065	0.621
Brachialis L	-0.176	0.133
Brachialis R	-0.097	0.403
Biceps Brachii L	0.035	0.766
Biceps Brachii R	0.086	0.455
Supinator L	.	.
Supinator R	.	.
Pronator Teres L	.	.
Pronator Teres R	.	.
Extensor Carpi Ulnaris L	-0.075	0.618
Extensor Carpi Ulnaris R	-0.069	0.643
Flexor Carpi Ulnaris L	-0.071	0.639
Flexor Carpi Ulnaris R	-0.075	0.617
Piriformis etc. L	0.401	0.001**
Piriformis etc. R	0.294	0.019*

TABLE 6.35: Partial Spearman Correlations With Age After Sex and Body Size have been controlled for Osteophytic Formations (continued)

Gluteus Minimus L	0.144	0.223
Gluteus Minimus R	0.232	0.063
Gluteus Medius L	0.220	0.078
Gluteus Medius R	0.123	0.313
Quadratus Femoris L	.	.
Quadratus Femoris R	.	.
Gluteus Maximus L	0.084	0.467
Gluteus Maximus R	0.043	0.709
Iliopsoas L	0.167	0.161
Iliopsoas R	0.225	0.061
Adductor Magnus L	0.042	0.713
Adductor Magnus R	0.230	0.037*
Quadriceps L	0.096	0.494
Quadriceps R	-0.095	0.522
Popliteus L	0.036	0.757
Popliteus R	-0.073	0.524
Semimembranosus L	-0.70	0.583
Semimembranosus R	0.101	0.415
Sartorius etc. L	0.114	0.335
Sartorius etc. R	-0.007	0.950
Soleus L	0.446	0.001**
Soleus R	0.363	0.007**

*$P \leq 0.05$

**$P \leq 0.01$

"." = Cannot be computed because at least one variable is constant (0)

Comparison of these correlations with the correlations taken without controlling for sex or body size reveal little to no difference in the strength of the correlations. These results suggest that sex and body size have little to no influence on these same variables, thus verifying all of the significant differences found in the initial Kruskal-Wallis test run on the entire sample (Figures 6.56 and 6.57).

FIGURE 6.56: Significant Difference in Osteophytic Formations Across Age Categories For the Upper Limb, Sexes Combined

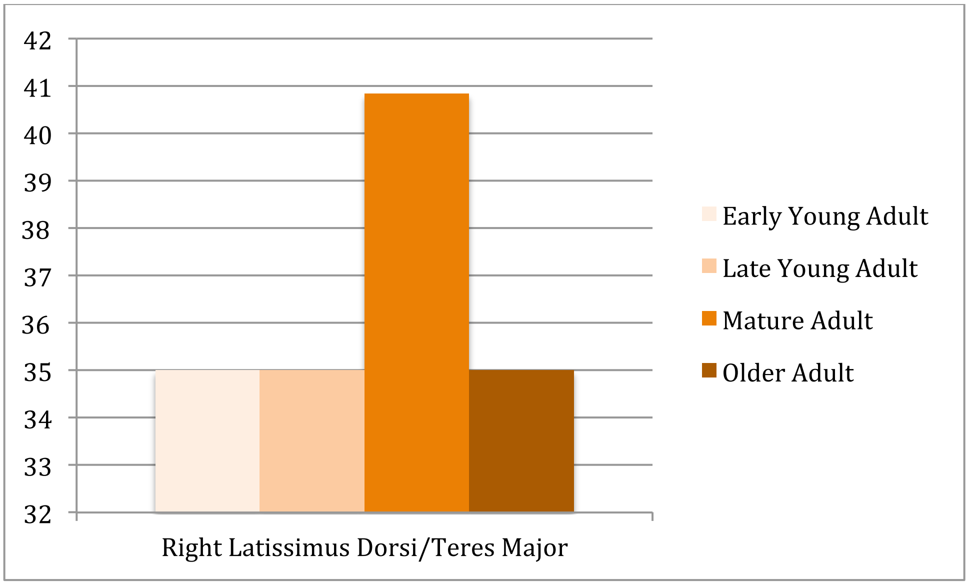
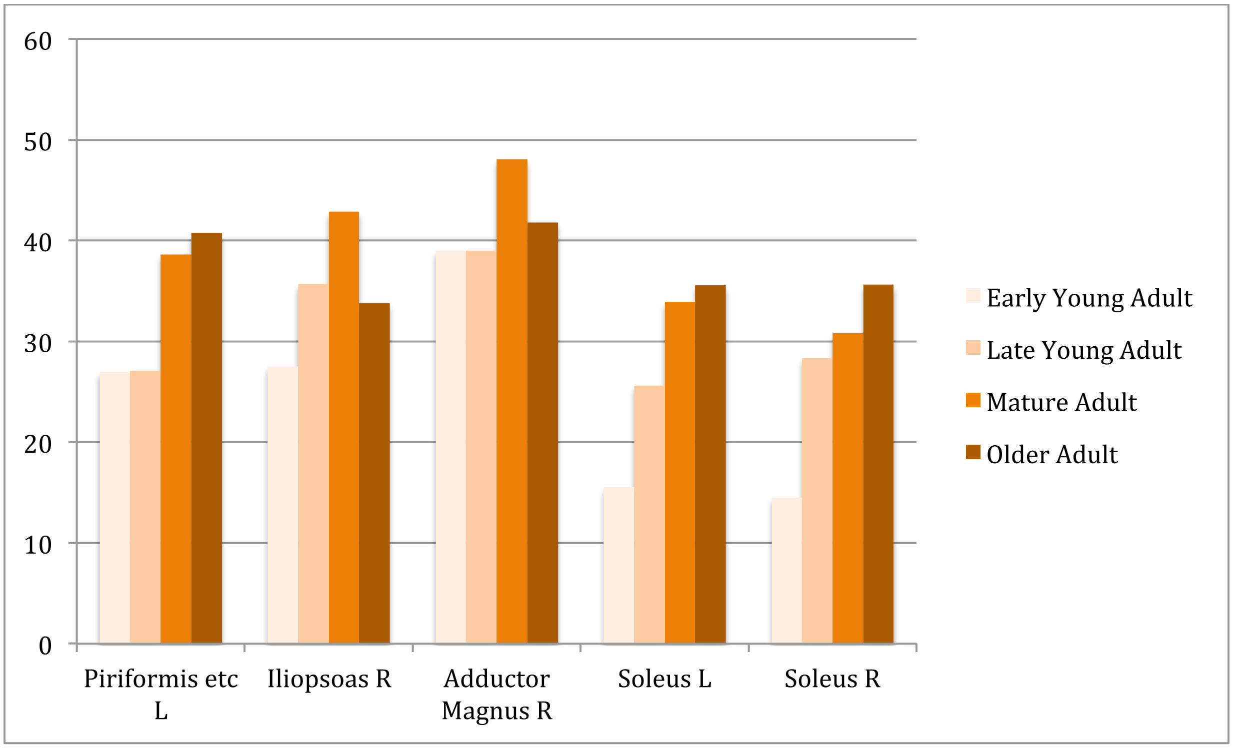


FIGURE 6.57: Significant Differences in Osteophytic Formations Across Age Categories For the Lower Limb, Sexes Combined



Partial Spearman correlations were also carried out to re-examine correlations of the entheseal variables with sex after age and body size were controlled for. Table 6.36 presents the results of the partial correlations with sex. After controlling for age and body size, few significant correlations remained, however, sex did correlate significantly with the right *deltoideus* (*P* = 0.019), left *triceps brachii* (*P* = 0.004), right *gluteus minimus* (*P* = 0.018), left *gluteus medius* (*P* = 0.048) and right *semimembranosus* (*P* = 0.035) entheses.

TABLE 6.36: Partial Spearman Correlations of Osteophytic Formations and Sex After Age and Body Size Have Been Controlled

Entheseal Variable	**rho**	**Significance**
Costoclavicular L	-0.084	.485
Costoclavicular R	-0.044	.724
Conoid L	.065	.620
Conoid R	.065	.618
Trapezoid L	.051	.681
Trapezoid R	.134	.295
Subscapularis L	-0.163	.166
Subscapularis R	-0.118	.313
Supraspinatus etc. L	-0.051	.675
Supraspinatus etc. R	.017	.893
Pectoralis L	.089	.449
Pectoralis R	.099	.415
Latissimus etc. L	-0.056	.645
Latissimus etc. R	-0.028	.815
Deltoideus L	-0.072	.542
Deltoideus R	-0.279	.019*
Triceps Brachii L	.365	0.004**
Triceps Brachii R	.187	.149
Brachialis L	.220	.059
Brachialis R	.092	.430
Biceps Brachii L	-0.195	.090
Biceps Brachii R	-0.176	.126
Supinator L	.	.
Supinator R	.	.
Pronator Teres L	.	.
Pronator Teres R	.	.

TABLE 6.36: Partial Spearman Correlations of Osteophytic Formations and Sex After Age and Body Size Have Been Controlled (continued)

Extensor Carpi Ulnaris L	-0.022	.884
Extensor Carpi Ulnaris R	-0.008	.959
Flexor Carpi Ulnaris L	-0.027	.860
Flexor Carpi Ulnaris R	-0.022	.884
Piriformis etc. L	.015	.906
Piriformis etc. R	.093	.470
Gluteus Minimus L	-0.125	.294
Gluteus Minimus R	-0.292	0.018*
Gluteus Medius L	-0.247	0.048*
Gluteus Medius R	-0.136	.266
Quadratus Femoris L	.	.
Quadratus Femoris R	.	.
Gluteus Maximus L	.041	.720
Gluteus Maximus R	.037	.748
Iliopsoas L	.065	.588
Iliopsoas R	.129	.289
Adductor Magnus L	.086	.443
Adductor Magnus R	-0.166	.136
Quadriceps L	.088	.533
Quadriceps R	.198	.177
Popliteus L	.024	.836
Popliteus R	-0.109	.338
Semimembranosus L	-0.126	.322
Semimembranosus R	-0.259	.035*
Sartorius etc. L	.030	.799
Sartorius etc. R	.029	.803
Soleus L	.033	.809
Soleus R	.143	.301

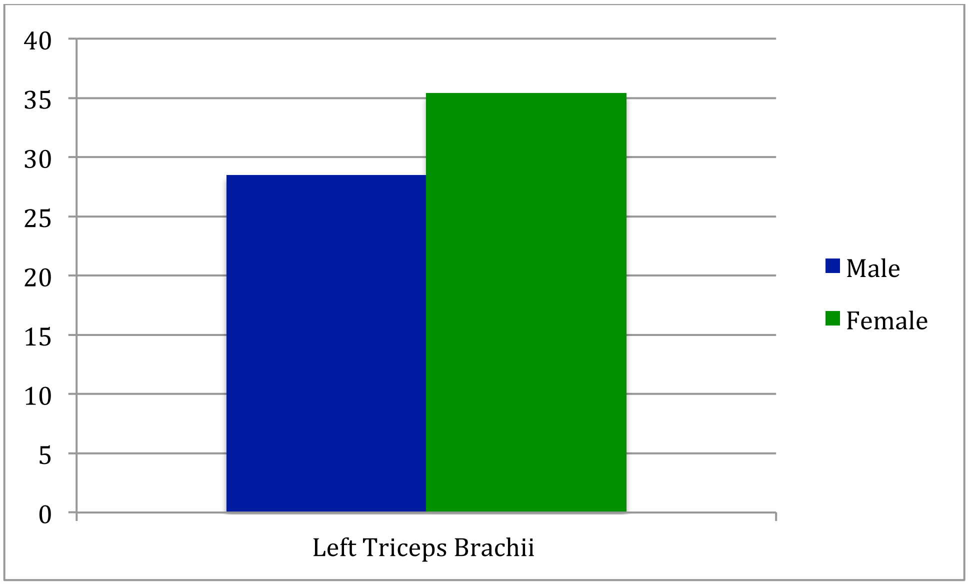
$*P \leq 0.05$

$**P \leq 0.01$

"." = Cannot be computed because at least one variable is constant (0)

Comparison of these correlations with the correlations taken without controlling for age or body size reveal substantial differences in the strength of many correlations, suggesting that age and body size are highly influential on these same variables, and nullifying two of the three significant differences found in the initial Mann-Whitney U test run on the entire sample. It should be noted that the two nullified differences each correlated significantly for another variable (age/body size), thus control of these influences definitively explains the difference. The significant difference between the sexes that remains valid is for the left *triceps brachii* ($P = 0.004$) enthesis (Figure 6.58).

FIGURE 6.58: Significant Difference in Mean Ranks of Osteophytic Formations Between the Sexes, Ages Combined



To gain a clearer idea of the nature of the significant partial Spearman correlations, each variable was standardized by body size, then the data set was separated by age categories and Mann-Whitney U tests were conducted to look for significant differences between the sexes of each age group; results are detailed in Table 6.37. No significant differences in osteophytic formations were found between the sexes in the Early Young Adult age group. Significant differences between the sexes were found in the Late Young Adult category for the left *conoid* ligament ($P = 0.044$) and left *gluteus minimus* ($P = 0.044$) (Figure 6.59) as well as in the Mature Adult category for the left and right *triceps brachii* ($P = 0.008$, $P = 0.020$) and *iliopsoas* ($P = 0.046$) entheses (Figure 6.60). The Older Adult age group results show significant differences between the sexes for both the left and right *soleus* entheses ($P = 0.018$, $P = 0.036$) (Figure 6.61).

TABLE 6.37: Mann-Whitney U Test of Osteophytic Formations Between the Sexes, Separated by Age and Standardized by Body Size

	Early Young Adult				Late Young Adult			
			Mean Rank				Mean Rank	
Variable	Mann-Whit U	Sig.	Male	Female	Mann-Whit U	Sig.	Male	Female
Costoclavicular L	22.5	1	7.5	7.5	41.5	0.652	10.35	9.61
Costoclavicular R	26	0.842	7.89	8.17	36	0.539	9	10
Conoid L	10.5	0.392	6.17	7.5	21.5	0.044*	7.39	11.61
Conoid R	15	0.462	6.67	7.75	35.5	0.931	9.06	8.94
Trapezoid L	16	0.624	6.78	7.5	30.5	0.854	8.39	8.64
Trapezoid R	22.5	1	7.5	7.5	32	1	8.5	8.5
Subscapularis L	20	0.456	7.78	7	53.5	0.131	14.04	10.96
Subscapularis R	20	0.456	7.78	7	58	0.844	11.7	11.33
Supraspinatus etc. L	18	1	7	7	59.5	0.947	11.46	11.55
Supraspinatus etc. R	16	1	6.5	6.5	55	1	11	11
Pectoralis L	16	0.505	7.22	6.5	60.5	1	11.5	11.5
Pectoralis R	16	0.505	7.22	6.5	49.5	1	10.5	10.5
Latissimus etc. L	16	0.505	7.22	6.5	40	0.082	12.36	9.5
Latissimus etc. R	20	1	7.5	7.5	45	1	10	10
Deltoideus L	18	1	7	7	60.5	1	11.5	11.5
Deltoideus R	20	1	7.5	7.5	49.5	1	10.5	10.5
Triceps Brachii L	18	1	7	7	36	0.371	9	9.9
Triceps Brachii R	20	0.456	7.78	7	27	0.439	8	8.8
Brachialis L	12	0.42	7.3	6	53.5	0.472	10.96	12.15
Brachialis R	10.5	0.299	7.45	5.5	55	0.361	11	11.92

TABLE 6.37: Mann-Whitney U Test of Osteophytic Formations Between the Sexes, Separated by Age and Standardized by Body Size (continued)

Biceps Brachii L	20	0.299	8.5	7	58.5	0.06	14.63	11.5
Biceps Brachii R	22.5	0.48	8.25	7.5	56	0.738	11.78	11.31
Supinator L	.	.	.	.	.	.	.	.
Supinator R	.	.	.	.	.	.	.	.
Pronator Teres L	.	.	.	.	.	.	.	.
Pronator Teres R	.	.	.	.	.	.	.	.
Extensor Carpi Ulnaris L	4.5	1	5.5	5.5	21	0.386	7	7.88
Extensor Carpi Ulnaris R	12	1	6	6	21	0.317	7	8
Flexor Carpi Ulnaris L	4.5	1	5.5	5.5	21	0.386	7	7.88
Flexor Carpi Ulnaris R	8	1	5.5	5.5	24.5	0.35	7.5	8.44
Piriformis etc. L	18	0.527	7.7	7	36	0.317	10	9
Piriformis etc. R	11.5	0.345	6.65	8.17	24.5	0.198	9.28	7.5
Gluteus Minimus L	30	1	8.5	8.5	33	0.044*	12.33	9
Gluteus Minimus R	25	1	8	8	20	0.063	10	7
Gluteus Medius L	18	1	7	7	45	0.317	11	10
Gluteus Medius R	30	1	8.5	8.5	32	0.346	9.44	8.5
Quadratus Femoris L	.	.	.	.	.	.	.	.
Quadratus Femoris R	.	.	.	.	.	.	.	.
Gluteus Maximus L	30	1	8.5	8.5	55	0.317	12	11
Gluteus Maximus R	20	1	7.5	7.5	44	0.128	12.1	10
Iliopsoas L	30	1	8.5	8.5	40	0.52	10.56	9.5
Iliopsoas R	20	1	7.5	7.5	28	0.357	9.7	8

TABLE 6.37: Mann-Whitney U Test of Osteophytic Formations Between the Sexes, Separated by Age and Standardized by Body Size (continued)

Adductor Magnus L	30	1	8.5	8.5	66	0.358	12	12.92
Adductor Magnus R	30	1	8.5	8.5	71.5	1	12.5	12.5
Quadriceps L	7	0.617	5.63	5	18.5	0.767	7.88	7.35
Quadriceps R	5	0.423	4.71	6	10	0.152	9	6.11
Popliteus L	18	0.527	7.7	7	65.5	0.95	12.05	11.96
Popliteus R	22.5	0.48	8.25	7.5	54.5	0.284	13.05	11.04
Semimembranosus L	18	1	7	7	25	0.197	9.33	8
Semimembranosus R	22.5	1	7.5	7.5	38.5	1	9.5	9.5
Sartorius etc. L	20	1	7.5	7.5	48	1	10.5	10.5
Sartorius etc. R	22.5	0.48	8.25	7.5	42	0.221	11.25	10
Soleus L	7.5	1	4.5	4.5	26	0.887	7.83	8.11
Soleus R	5	1	4	4	29	0.734	8.13	8.88

	Mature Adult				Older Adult			
			Mean Rank				Mean Rank	
Variable	Mann-Whit U	Sig.	Male	Female	Mann-Whit U	Sig.	Male	Female
Costoclavicular L	92	0.636	14.87	14.08	14	0.237	6	7.2
Costoclavicular R	55	0.059	14.57	11	12.5	0.361	5.5	6.42
Conoid L	52	0.099	11	13.3	7.5	1	4.5	4.5
Conoid R	57.5	0.209	11.42	13.77	7.5	1	4.5	4.5
Trapezoid L	92	0.46	15.59	14.17	12	1	5.5	5.5
Trapezoid R	72.5	0.768	12.83	13.25	9	1	5	5
Subscapularis L	69.5	0.838	12.84	13.28	12.5	0.21	7.21	5.5
Subscapularis R	90	0.695	14.13	15	15	0.593	6.86	6
Supraspinatus etc. L	77	0.392	13.87	13	10.5	0.186	5.5	6.88
Supraspinatus etc. R	78	0.355	13.93	13	12.5	0.673	5.79	6.38

TABLE 6.37: Mann-Whitney U Test of Osteophytic Formations Between the Sexes, Separated by Age and Standardized by Body Size (continued)

Pectoralis L	96	1	14.5	14.5	21	1	7	7
Pectoralis R	70	0.414	13.33	12.5	21	1	7	7
Latissimus etc. L	72	1	13	13	21	1	7	7
Latissimus etc. R	73	0.555	13.94	12.8	21	1	7	7
Deltoideus L	82.5	1	13.5	13.5	21	1	7	7
Deltoideus R	77	1	13	13	15	0.398	6.86	6
Triceps Brachii L	24	0.008**	8.5	13.5	9	0.221	5	6.25
Triceps Brachii R	32.5	0.02*	9.5	13.44	12.5	0.361	6.42	5.5
Brachialis L	94	0.835	14.38	14.67	18	1	6.5	6.5
Brachialis R	95.5	0.481	14.47	15.65	18	0.355	6.5	7.43
Biceps Brachii L	71	0.44	12.73	14.55	14	0.237	7.2	6
Biceps Brachii R	95	0.944	14.56	14.42	17.5	0.28	6.5	7.58
Supinator L	.	.	.	.	.	.	.	.
Supinator R	.	.	.	.	.	.	.	.
Pronator Teres L	.	.	.	.	.	.	.	.
Pronator Teres R	.	.	.	.	.	.	.	.
Extensor Carpi Ulnaris L	35	1	9	9	6	1	4	4
Extensor Carpi Ulnaris R	38.5	1	9.5	9.5	4	1	3.5	3.5
Flexor Carpi Ulnaris L	31.5	1	8.5	8.5	6	1	4	4
Flexor Carpi Ulnaris R	38.5	1	9.5	9.5	4	1	3.5	3.5
Piriformis etc. L	62	0.514	11.67	13.33	4.5	0.327	3.9	5.5
Piriformis etc. R	93	0.799	14.8	14.15	6.5	0.744	4.3	4.83
Gluteus Minimus L	87	0.942	14.06	13.91	12.5	0.361	5.5	6.42
Gluteus Minimus R	69	0.438	12.43	13.73	5	0.053	7	4

TABLE 6.37: Mann-Whitney U Test of Osteophytic Formations Between the Sexes, Separated by Age and Standardized by Body Size (continued)

Gluteus Medius L	55	0.361	11.92	11	9	0.104	7.2	5
Gluteus Medius R	78	0.355	13.93	13	12.5	0.361	6.42	5.5
Quadratus Femoris L	.	.	.	.	.	.	.	.
Quadratus Femoris R	.	.	.	.	.	.	.	.
Gluteus Maximus L	95.5	0.481	14.47	15.65	15	1	6	6
Gluteus Maximus R	95.5	0.245	14.47	16.68	21	1	7	7
Iliopsoas L	57	0.046*	12.06	16.82	12	0.273	6.6	5.5
Iliopsoas R	88	0.484	14.18	16.17	15	1	6	6
Adductor Magnus L	96.5	0.918	14.43	14.58	24.5	1	7.5	7.5
Adductor Magnus R	80	0.135	16.5	13.15	21	0.317	8	7
Quadriceps L	48	0.827	10.36	10.67	7.5	0.221	4.5	6.5
Quadriceps R	37.5	0.398	9.41	10.81	9.5	0.866	4.9	5.13
Popliteus L	106.5	0.748	15.74	15.19	14	0.237	6	7.2
Popliteus R	100.5	0.421	14.91	16.27	17.5	1	6.5	6.5
Semimembranosus L	75	1	13	13	14	1	6	6
Semimembranosus R	77	0.392	13.87	13	7	0.127	6.67	5
Sartorius etc. L	94.5	0.43	14.41	15.73	18	1	6.5	6.5
Sartorius etc. R	98.5	0.648	15.34	14.58	18	1	6.5	6.5
Soleus L	35.5	0.211	10.37	13.93	3	0.018*	3.6	8
Soleus R	36	0.106	10.4	15	2	0.036*	3.4	7

*$P \leq 0.05$

**$P \leq 0.01$

"." = Cannot be computed because at least one variable is constant (0)

FIGURE 6.59: Significant Differences in Mean Ranks of Osteophtyic Formations Between the Sexes in Late Young Adults, Standardized by Body Size

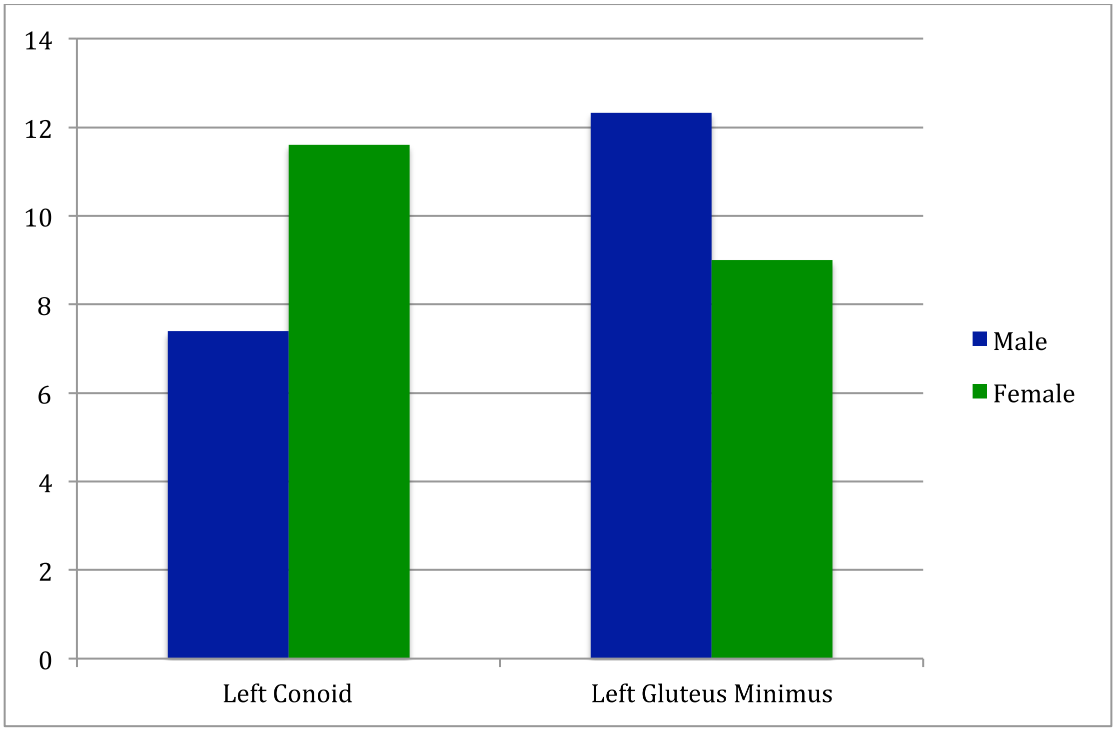


FIGURE 6.60: Significant Differences in Mean Ranks of Osteophtyic Formations Between the Sexes in Mature Adults, Standardized by Body Size

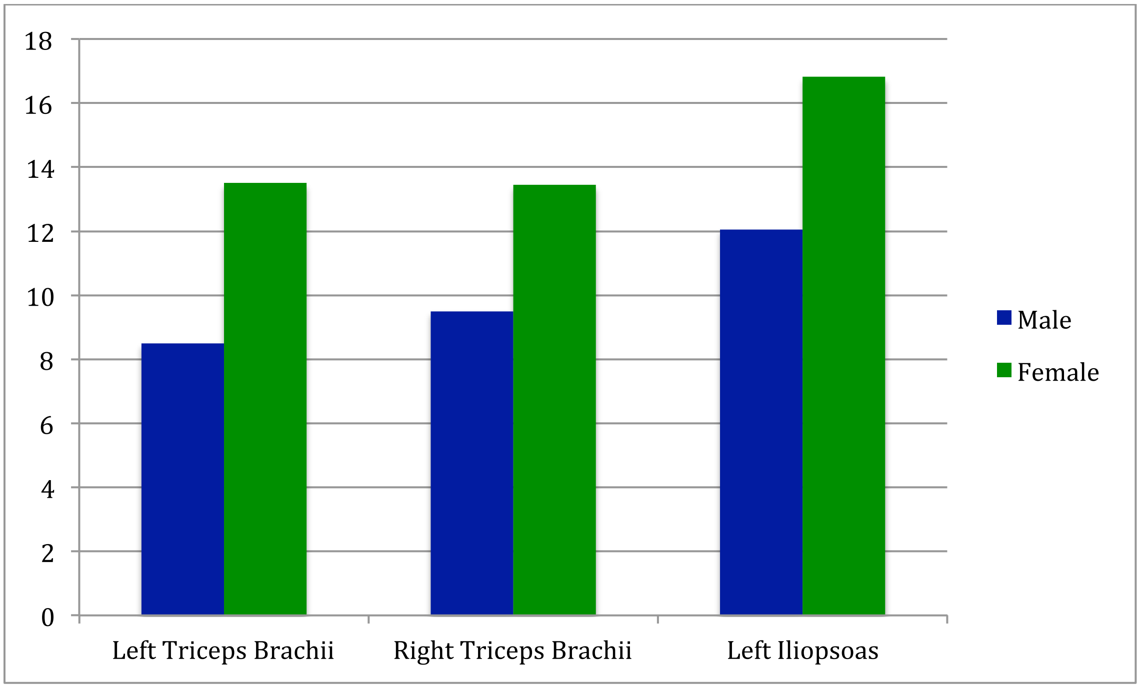
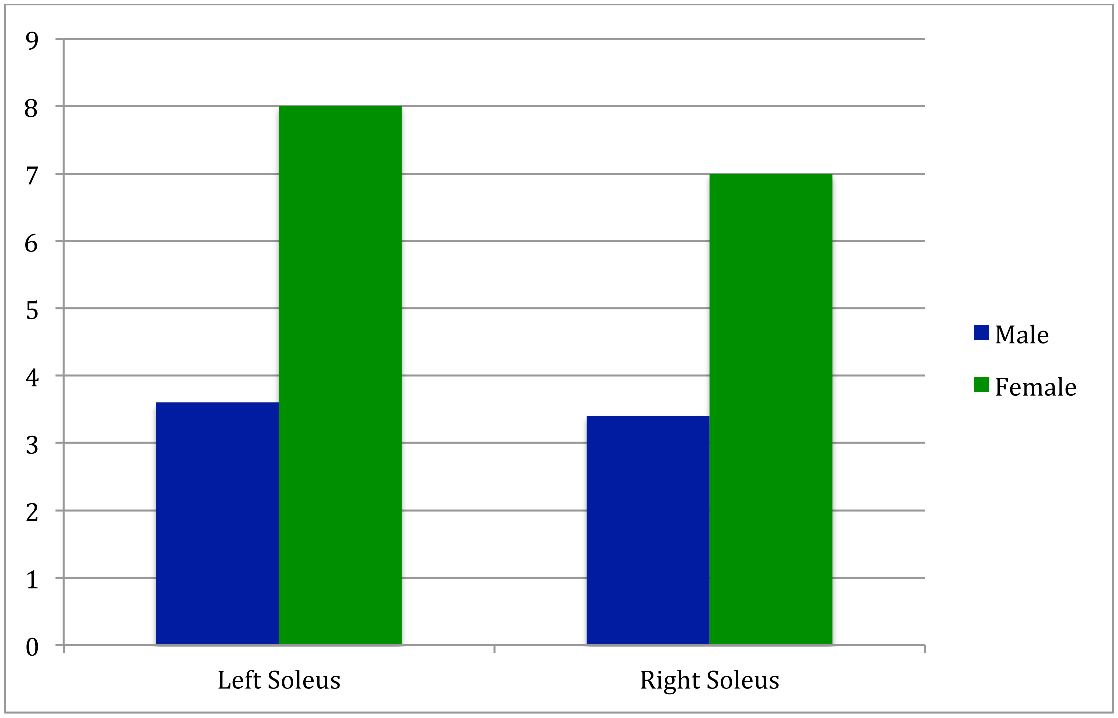


FIGURE 6.61: Significant Differences in Mean Ranks of Osteophtyic Formations Between the Sexes in Older Adults, Standardized by Body Size



6.4 OSTEOARTHRITIS

As mentioned previously, Spearman correlation coefficients were used to test for asymmetry in appendicular osteoarthritis. Results of the test are presented in Table 6.38, demonstrating a strong positive correlation between scores for the right and left sides. Based on these results the sides were combined, since there were more scores for the left side than the right, right side scores were substituted only in cases where the left side data were unavailable. No treatment was made for missing data; as such, sample sizes are listed per statistical analysis.

Mann-Whitney U tests were run on the entire sample to explore possible differences in location and severity of osteoarthritis between the sexes. Table 6.39 presents the results of the Mann-Whitney U test, which was performed using sex as the grouping variable. There were no statistically significant differences between the sexes for scores of osteoarthritis.

TABLE 6.38: Spearman's Rank Order Correlations for Asymmetry of Osteoarthritis

Variable	N	rho	Significance
Scapula	78	0.763**	0
Proximal Humerus	69	0.738**	0
Distal Humerus	71	0.753**	0
Proximal Ulna	75	0.860**	0
Proximal Radius	62	0.819**	0
Distal Ulna	58	0.474**	0
Distal Radius	74	0.778**	0
Innominate	84	0.790**	0
Proximal Femur	78	0.670**	0
Distal Femur	84	0.886**	0
Proximal Tibia	82	0.804**	0
Distal Tibia	85	0.769**	0
Proximal Talus	72	0.736**	0
Distal Talus	73	0.850**	0
Calcaneus	74	0.790**	0

**$P \leq 0.01$

TABLE 6.39: Mann-Whitney U Test Between the Sexes for Osteoarthritis, Ages Combined

			Male		Female		Total
Variable	**Mann-Whitney U**	**Significance**	**Mean Rank**	**N**	**Mean Rank**	**N**	**N**
Scapula	845.5	0.34	44.12	46	41.68	39	85
Proximal Humerus	799.5	0.845	40.88	46	41.16	35	81
Distal Humerus	758.5	0.187	41.36	43	39.5	37	80
Proximal Ulna	751	0.419	42.43	44	39.3	37	81
Distal Ulna	769.5	0.872	39.82	42	40.2	37	79
Proximal Radius	774	0.281	40	43	41.08	37	80
Distal Radius	826.5	0.305	41.37	45	43.81	39	84
Innominate	874.5	0.742	43.63	44	42.33	41	85
Proximal Femur	870	0.629	42.27	44	43.78	41	85
Distal Femur	913.5	0.897	43.3	45	43.72	41	86
Proximal Tibia	850.5	0.914	42.17	44	41.81	39	83
Distal Tibia	865	0.24	44.7	46	42.13	40	86
Proximal Talus	836	0.288	41.5	44	42.56	39	83
Distal Talus	836	0.288	41.5	44	42.56	39	83
Calcaneus	836	0.288	41.5	44	42.56	39	83

*$P \leq 0.05$

Kruskal-Wallis tests were then run on the entire sample to explore potential differences between age groups. Table 6.40 presents the results of the Kruskal-Wallis test, using age as the grouping variable with sexes combined. Statistically significant scores of osteoarthritis between age categories were returned for the scapula ($P = 0.041$), innominate ($P = 0.009$), and distal femur ($P = 0.014$).

TABLE 6.40: Kruskal-Wallis Test Between Age Groups for Osteoarthritis, Sexes Combined

		Early Young Adult		Late Young Adult		Mature Adult		Older Adult		Total
Variable	Sig.	Mean Rank	N	Mean Rank	N	Mean Rank	N	Mean Rank	N	N
Scapula	0.041*	39.5	17	39.5	24	44.98	31	49.31	13	85
Proximal Humerus	0.476	40	15	40	23	41.35	30	43.12	13	81
Distal Humerus	0.424	39.5	15	39.5	24	40.86	29	42.88	12	80
Proximal Ulna	0.068	34.7	15	36.5	25	45.93	28	46.31	13	81
Distal Ulna	0.147	37	13	37	23	42.45	29	42.64	14	79
Proximal Radius	0.624	40	14	40	24	41.38	29	40	13	80
Distal Radius	0.268	39.5	15	42.86	25	45.1	30	39.5	14	84
Innominate	0.009**	33	17	38.54	23	49.45	31	48.18	14	85
Proximal Femur	0.16	37.5	17	41	24	46.08	30	46.5	14	85
Distal Femur	0.014*	37.5	17	39.27	24	45.92	31	52.68	14	86
Proximal Tibia	0.157	35.5	17	40.85	23	45.62	29	44.29	14	83
Distal Tibia	0.164	41	17	41	24	45.19	31	47.07	14	86
Proximal Talus	0.622	41.5	17	41.5	23	42.88	30	41.5	13	83
Distal Talus	0.622	41.5	17	41.5	23	42.88	30	41.5	13	83
Calcaneus	0.642	41.5	17	41.5	22	42.84	31	41.5	13	83

*$P \leq 0.05$
**$P \leq 0.01$

To gain a clearer idea of the nature of these potential differences, the data set was separated by sex and Kruskal-Wallis tests were re-conducted to look for significant differences across age categories for each sex (Table 6.41). Males had significant differences across age categories for osteoarthritis of the innominate ($P = 0.048$). Females had no significant differences across age categories for any variable examined.

TABLE 6.41: Kruskal-Wallis Tests Between Age Categories By Sex Osteoarthritis

MALES:				
Variable	Sig.	Age	N	Mean Rank
Scapula	0.131	EYA	10	21
		LYA	12	21
		MA	17	25.06
		OA	7	27.57
		Total	46	
Proximal Humerus	0.134	EYA	10	23
		LYA	12	23
		MA	17	23
		OA	7	26.29
		Total	46	
Distal Humerus	0.376	EYA	10	21
		LYA	11	21
		MA	16	22.31
		OA	6	24.67
		Total	43	
Proximal Ulna	0.087	EYA	10	19.2
		LYA	12	18.25
		MA	15	26.7
		OA	7	25.5
		Total	44	
Distal Ulna	0.103	EYA	8	20
		LYA	11	20
		MA	16	21.31
		OA	7	26
		Total	42	
Proximal Radius	1	EYA	10	22
		LYA	11	22
		MA	16	22
		OA	6	22
		Total	43	

FEMALES:				
Variable	Sig.	Age	N	Mean Rank
Scapula	0.438	EYA	7	19
		LYA	12	19
		MA	14	20.39
		OA	6	22.25
		Total	39	
Proximal Humerus	0.639	EYA	5	17.5
		LYA	11	17.5
		MA	13	18.85
		OA	6	17.5
		Total	35	
Distal Humerus	1	EYA	5	19
		LYA	13	19
		MA	13	19
		OA	6	19
		Total	37	
Proximal Ulna	0.583	EYA	5	15.5
		LYA	13	18.46
		MA	13	19.81
		OA	6	21.33
		Total	37	
Distal Ulna	0.118	EYA	5	17.5
		LYA	12	17.5
		MA	13	21.77
		OA	7	17.5
		Total	37	
Proximal Radius	0.605	EYA	4	18.5
		LYA	13	18.5
		MA	13	19.92
		OA	7	18.5
		Total	37	

TABLE 6.41: Kruskal-Wallis Tests Between Age Categories By Sex Osteoarthritis (continued)

Distal Radius	0.747	EYA	9	22
		LYA	12	23.88
		MA	17	23.32
		OA	7	22
		Total	45	
Innominate	0.048*	EYA	10	17
		LYA	10	19.2
		MA	17	26.06
		OA	7	26.43
		Total	44	
Proximal Femur	0.529	EYA	10	20
		LYA	11	22
		MA	16	24.13
		OA	7	23.14
		Total	44	
Distal Femur	0.113	EYA	10	20
		LYA	11	20
		MA	17	25.35
		OA	7	26.29
		Total	45	
Proximal Tibia	0.259	EYA	10	19
		LYA	11	20.95
		MA	16	24.59
		OA	7	25.14
		Total	44	
Distal Tibia	0.13	EYA	10	21.5
		LYA	12	21.5
		MA	17	24.21
		OA	7	28.07
		Total	46	
Proximal Talus	1	EYA	10	22.5
		LYA	11	22.5
		MA	17	22.5
		OA	6	22.5
		Total	44	

Distal Radius	0.284	EYA	6	18
		LYA	13	19.5
		MA	13	22.5
		OA	7	18
		Total	39	
Innominate	0.27	EYA	7	16.5
		LYA	13	19.65
		MA	14	23.82
		OA	7	22.36
		Total	41	
Proximal Femur	0.359	EYA	7	18
		LYA	13	19.54
		MA	14	22.5
		OA	7	23.71
		Total	41	
Distal Femur	0.111	EYA	7	18
		LYA	13	19.58
		MA	14	20.93
		OA	7	26.79
		Total	41	
Proximal Tibia	0.607	EYA	7	17
		LYA	12	20.25
		MA	13	21.5
		OA	7	19.79
		Total	39	
Distal Tibia	0.603	EYA	7	20
		LYA	12	20
		MA	14	21.43
		OA	7	20
		Total	40	
Proximal Talus	0.572	EYA	7	19.5
		LYA	12	19.5
		MA	13	21
		OA	7	19.5
		Total	39	

TABLE 6.41: Kruskal-Wallis Tests Between Age Categories By Sex Osteoarthritis (continued)

Distal Talus	1	EYA	10	22.5
		LYA	11	22.5
		MA	17	22.5
		OA	6	22.5
		Total	44	
Calcaneus	1	EYA	10	22.5
		LYA	10	22.5
		MA	17	22.5
		OA	7	22.5
		Total	44	

Distal Talus	0.572	EYA	7	19.5
		LYA	12	19.5
		MA	13	21
		OA	7	19.5
		Total	39	
Calcaneus	0.618	EYA	7	19.5
		LYA	12	19.5
		MA	14	20.89
		OA	6	19.5
		Total	39	

**P* ≤0.05
***P* ≤ 0.01

Since so few osteoarthritis variables are statistically significantly different between the sexes or across age groups, Two-tailed Spearman correlations were calculated to see the extent to which variables of age and sex may be influencing the results. Table 6.42 presents the Two-tailed Spearman correlation coefficients of the osteoarthritis scores with age and sex. Sex did not significantly correlate with osteoarthritis of any surface examined. Age significantly correlated with osteoarthritis of the scapula ($P = 0.006$), proximal ulna ($P = 0.011$), distal ulna ($P = 0.034$), innominate ($P = 0.001$), proximal femur ($P = 0.028$), distal femur ($P = 0.001$), proximal tibia ($P = 0.042$), and distal tibia ($P = 0.03$). These results suggest that age is the greatest predictor of osteoarthritis and influencing the results of the Mann-Whitney U tests.

TABLE 6.42: Two-tailed Spearman Correlation Coefficients for Osteoarthritis with Age and Sex

		Sex	Age
Scapula	rho	-0.104	0.299**
	Sig.	0.343	0.006
	N	85	85
Proximal Humerus	rho	0.022	0.165
	Sig.	0.847	0.14
	N	81	81
Distal Humerus	rho	-0.149	0.173
	Sig.	0.189	0.125
	N	80	80
Proximal Ulna	rho	-0.09	0.280*
	Sig.	0.422	0.011
	N	81	81

TABLE 6.42: Two-tailed Spearman Correlation Coefficients for Osteoarthritis with Age and Sex (continued)

Distal Ulna	rho	0.018	0.239*
	Sig.	0.874	0.034
	N	79	79
Proximal Radius	rho	0.121	0.064
	Sig.	0.284	0.575
	N	80	80
Distal Radius	rho	0.113	0.046
	Sig.	0.308	0.679
	N	84	84
Innominate	rho	-0.036	0.344**
	Sig.	0.744	0.001
	N	85	85
Proximal Femur	rho	0.053	0.238*
	Sig.	0.631	0.028
	N	85	85
Distal Femur	rho	0.014	0.347**
	Sig.	0.898	0.001
	N	86	86
Proximal Tibia	rho	-0.012	.224*
	Sig.	0.914	0.042
	N	83	83
Distal Tibia	rho	-0.127	0.234*
	Sig.	0.242	0.03
	N	86	86
Proximal Talus	rho	0.117	0.065
	Sig.	0.291	0.56
	N	83	83
Distal Talus	rho	0.117	0.065
	Sig.	0.291	0.56
	N	83	83
Calcaneus	rho	0.117	0.063
	Sig.	0.291	0.574
	N	83	83

*$P \leq 0.05$
**$P \leq 0.01$

Partial Spearman correlations were then carried out to re-examine correlations of osteoarthritis patterns with sex after age was controlled for. Table 6.43 presents the results of the partial correlations with sex. After controlling for age, there were still no significant correlations between sex and osteoarthritis of any surface examined. Comparison of these correlations with the correlations taken without controlling for age reveal only minor differences in the strength of the correlations. These results suggest that while age is clearly influential on scores of osteoarthritis, for many joints it does not obscure any differences between the sexes.

TABLE 6.43: Partial Spearman Correlations of Osteoarthritis With Sex After Age is Controlled

Variable	**rho**	**Significance**
Scapula	-0.116	0.292
Proximal Humerus	0.018	0.873
Distal Humerus	-0.155	0.173
Proximal Ulna	-0.101	0.372
Proximal Radius	0.013	0.91
Distal Ulna	0.12	0.292
Distal Radius	0.112	0.315
Innominate	-0.047	0.672
Proximal Femur	0.049	0.661
Distal Femur	0.006	0.954
Proximal Tibia	-0.018	0.875
Distal Tibia	-0.137	0.212
Proximal Talus	0.116	0.299
Distal Talus	0.116	0.299
Calcaneus	0.116	0.299

*$P \leq 0.05$
**$P \leq 0.01$

The data set was then separated by age categories and Mann-Whitney U tests were conducted to look for significant differences between the sexes of each age group; results are detailed in Table 6.44. No significant differences in osteoarthritis were found between the sexes in any of the age categories.

TABLE 6.44: Mann-Whitney U Test Between the Sexes for Changes in Osteoarthritis, Separated by Age

	Early Young Adult				Late Young Adult			
			Mean Rank				Mean Rank	
Variable	Mann-Whit U	Sig.	Male	Female	Mann-Whit U	Sig.	Male	Female
Scapula	35	1	9	9	72	1	12.5	12.5
Proximal Humerus	25	1	8	8	66	1	12	12
Distal Humerus	25	1	8	8	71.5	1	12.5	12.5

TABLE 6.44: Mann-Whitney U Test Between the Sexes for Changes in Osteoarthritis, Separated by Age (continued)

Proximal Ulna	22.5	0.48	8.25	7.5	72	0.563	12.5	13.46
Distal Ulna	20	1	7	7	66	1	12	12
Proximal Radius	20	1	7.5	7.5	71.5	1	12.5	12.5
Distal Radius	27	1	8	8	77.5	0.954	13.04	12.96
Innominate	35	1	9	9	61.5	0.71	11.65	12.27
Proximal Femur	35	1	9	9	70.5	0.904	12.59	12.42
Distal Femur	35	1	9	9	66	0.358	12	12.92
Proximal Tibia	35	1	9	9	61	0.598	11.55	12.42
Distal Tibia	35	1	9	9	72	1	12.5	12.5
Proximal Talus	35	1	9	9	66	1	12	12
Distal Talus	35	1	9	9	66	1	12	12
Calcaneus	35	1	9	9	60	1	11.5	11.5

	Mature Adult				Older Adult			
			Mean Rank				Mean Rank	
Variable	Mann-Whit U	Sig.	Male	Female	Mann-Whit U	Sig.	Male	Female
Scapula	106.5	0.393	16.74	15.11	18.5	0.626	7.36	6.58
Scapula	102	0.253	15	16.15	18	0.355	7.43	6.5
Proximal Humerus	97.5	0.367	15.41	14.5	15	0.317	7	6
Distal Humerus	76.5	0.251	15.9	12.88	19	0.735	7.29	6.67
Proximal Ulna	86.5	0.199	13.91	16.35	17.5	0.141	8.5	6.5
Distal Ulna	96	0.267	14.5	15.62	21	1	7	7
Proximal Radius	91.5	0.177	14.38	16.96	24.5	1	7.5	7.5
Distal Radius	112.5	0.76	16.38	15.54	21	0.591	8	7
Innominate	107.5	0.788	15.22	15.82	21	0.53	7	8
Proximal Femur	107	0.488	16.71	15.14	21	0.591	7	8
Distal Femur	100.5	0.837	15.22	14.73	21	0.53	8	7
Proximal Tibia	114.5	0.728	16.26	15.68	17.5	0.141	8.5	6.5
Distal Tibia	102	0.253	15	16.15	21	1	7	7
Proximal Talus	102	0.253	15	16.15	21	1	7	7
Distal Talus	110.5	0.27	15.5	16.61	21	1	7	7

$*P \leq 0.05$

6.5 NON-GENETIC NON-METRIC TRAITS

Spearman correlation coefficients were used to test for asymmetry in non-genetic non-metric traits. Results of the test are presented in Table 6.45, demonstrating a strong positive correlation between scores for the right and left sides. Based on these results sides were combined, since there were more scores for the left side than the right, right side scores were substituted only in cases where the left side data were unavailable. No treatment for missing data was performed, therefore, sample sizes are listed per statistical analysis. It should be noted that no incicdence of Osgood-Schlatter's disease was reported, and only one incidence of epicondylar exostoses was recorded (a stage 1 for an Older Adult male).

TABLE 6.45: Spearman's Rank Order Correlations for Asymmetry of Non-genetic Non-metric Traits

Variable	N	rho	Significance
Epicondylar Exostoses	50	.	.
Articular Border Convexity	69	0.681**	0
Poirier's Facet	70	0.639**	0
Tibial Imprint	82	0.725**	0
Martin's Facet	44	0.718**	0
Exostoses of the Trochanteric Fossa	82	0.610**	0
Tibial Squatting Facet	81	0.756**	0
Osgood-Schlatter	84	.	.

*$P \leq 0.05$

"." = Cannot be computed because at least one variable is constant (0)

Mann-Whitney U tests were run on the entire sample to explore possible differences in non-genetic non-metric traits between the sexes. Table 6.46 presents the results of the Mann-Whitney U test, which was performed using sex as the grouping variable. The only statistically significant result was that males had higher scores than females for Poirier's Facet ($P = 0.010$).

Kruskal-Wallis tests were then run on the entire sample to explore potential differences between age groups. Table 6.47 presents the results of the Kruskal-Wallis test, using age as the grouping variable with sexes combined. No statistically significant differences between age categories were returned for any non-genetic non-metric trait examined.

TABLE 6.46: Mann-Whitney U Test Between the Sexes for Non-genetic Non-metric Traits, Ages Combined

			Male		**Female**		**Total**
Variable	**Mann-Whitney U**	**Significance**	**Mean Rank**	**N**	**Mean Rank**	**N**	**N**
Epicondylar Exostoses	520	0.426	34.32	41	33.5	26	67
Articular Border Convexity	749	0.576	39.33	42	41.79	38	80
Poirier's Facet	589.5	0.01**	47.9	45	35.01	38	83
Tibial Imprint	839	0.436	41.64	45	45.54	41	86
Martin's Facet	444	0.469	33.44	34	30.31	29	63
Exostoses of the Trochanteric Fossa	810	0.357	41.11	46	45.23	39	85
Tibial Squatting Facet	848.5	0.655	41.95	46	44.24	39	85
Osgood Schlatter	897	1	43	46	43	39	85

**P ≤ 0.01

TABLE 6.47: Kruskal-Wallis Test Between Age Categories for Non-genetic Non-metric Traits, Sexes Combined

		Early Young Adult		Late Young Adult		Mature Adult		Older Adult		Total
Variable	Sig.	Mean Rank	N	Mean Rank	N	Mean Rank	N	Mean Rank	N	N
Epicondylar Exostoses	0.165	33.5	15	33.5	17	33.5	24	36.55	11	67
Articular Border Convexity	0.525	46.18	17	40.98	22	38.5	27	36.71	14	80
Poirier's Facet	0.101	29.75	16	43.02	24	46.88	30	43.92	13	83
Tibial Imprint	0.125	47.91	17	50.15	24	36.15	31	43.04	14	86
Martin's Facet	0.382	24.59	11	34.38	17	34.38	26	29.67	9	63
Exostoses of the Trochanteric Fossa	0.173	39.06	17	36.91	23	48.19	31	46.29	14	85
Tibial Squatting Facet	0.537	46.71	17	46.69	24	40.73	30	37.04	14	85
Osgood Schlatter	1	43	17	43	24	43	30	43	14	85

*P ≤0.05

The data set was then separated by sex and Kruskal-Wallis tests were re-conducted to look for significant differences across age categories per sex (Table 6.48). Males had significant differences across age categories for Articular Border Convexity (P = 0.018) and Poirier's Facet (P = 0.022). Females had significant differences across age categories for exostoses of the trochanteric fossa (P = 0.044).

TABLE 6.48: Kruskal-Wallis Tests Between Age Categories for Non-genetic Non-metric Traits, Sexes Separated

MALES:				
Variable	Sig.	Age	N	Mean Rank
Epicondylar Exostoses	0.12	EYA	10	20.5
		LYA	9	20.5
		MA	16	20.5
		OA	6	23.92
		Total	41	
Articular Border Convexity	0.018*	EYA	10	29.85
		LYA	11	21.27
		MA	14	17.64
		OA	7	17.64
		Total	42	
Poirier's Facet	0.022*	EYA	10	13.05
		LYA	11	27.59
		MA	17	23.47
		OA	7	28.86
		Total	45	
Tibial Imprint	0.284	EYA	10	26.75
		LYA	11	26.77
		MA	17	19.44
		OA	7	20.36
		Total	45	
Martin's Facet	0.267	EYA	7	13.57
		LYA	8	21.25
		MA	15	18.6
		OA	4	12.75
		Total	34	
Exostoses of Trochanteric Fossa	0.899	EYA	10	21.55
		LYA	12	23.54
		MA	17	24.71
		OA	7	23.29
		Total	46	

FEMALES:				
Variable	Sig.	Age	N	Mean Rank
Epicondylar Exostoses	1	EYA	5	13.5
		LYA	8	13.5
		MA	8	13.5
		OA	5	13.5
		Total	26	
Articular Border Convexity	0.402	EYA	7	14.21
		LYA	11	20.14
		MA	13	21.73
		OA	7	19.64
		Total	38	
Poirier's Facet	0.29	EYA	6	17.75
		LYA	13	17.73
		MA	13	23.81
		OA	6	15.75
		Total	38	
Tibial Imprint	0.47	EYA	7	21.64
		LYA	13	23.65
		MA	14	17.29
		OA	7	22.86
		Total	41	
Martin's Facet	0.656	EYA	4	10.5
		LYA	9	14.83
		MA	11	16.32
		OA	5	16
		Total	29	
Exostoses of Trochanteric Fossa	0.044*	EYA	7	18.21
		LYA	11	13.59
		MA	14	24.32
		OA	7	23.21
		Total	39	

TABLE 6.48: Kruskal-Wallis Tests Between Age Categories for Non-genetic Non-metric Traits, Sexes Separated (continued)

Tibial Squatting Facet	0.139	EYA	10	27.95
		LYA	12	27.17
		MA	17	21.82
		OA	7	14.93
		Total	46	
Osgood-Schlatter	1	EYA	10	23.5
		LYA	12	23.5
		MA	17	23.5
		OA	7	23.5
		Total	46	

Tibial Squatting Facet	0.916	EYA	7	18.43
		LYA	12	20.13
		MA	13	19.5
		OA	7	22.29
		Total	39	
Osgood-Schlatter	1	EYA	7	20
		LYA	12	20
		MA	13	20
		OA	7	20
		Total	39	

*$P \leq 0.05$
**$P \leq 0.01$

Since a number of traits are statistically significantly different between the sexes and across age groups, Two-tailed Spearman correlations were calculated to see the extent to which variables of age and sex may be influencing the results. Table 6.49 presents the Two-tailed Spearman correlation coefficients of the non-genetic non-metric traits with age and sex. Sex significantly correlated with Poirier's Facet ($P = 0.009$). Age did not significantly correlate with any non-genetic non-metric trait examined. These results suggest that neither sex nor age are significantly influencing the results of the Mann-Whitney U tests.

TABLE 6.49: Two-tailed Spearman Correlation Coefficients for Non-genetic Non-metric Traits with Age and Sex

		Sex	Age
Epicondylar Exostoses	rho	-0.098	0.186
	Sig.	0.43	0.133
	N	67	67
Articular Border Convexity	rho	0.063	-0.161
	Sig.	0.58	0.153
	N	80	80
Poirier's Facet	rho	-0.286**	0.212
	Sig.	0.009	0.054
	N	83	83
Tibial Imprint	rho	0.085	-0.173
	Sig.	0.439	0.112
	N	86	86
Martin's Facet	rho	-0.092	0.09
	Sig.	0.474	0.485
	N	63	63
Exostoses of the Trochanteric Fossa	rho	0.101	0.195
	Sig.	0.36	0.074
	N	85	85
Tibial Squatting Facet	rho	0.049	-0.154
	Sig.	0.657	0.16
	N	85	85
Osgood Schlatter	rho	.	.
	Sig.	.	.
	N	85	85

**$P \leq 0.01$

The data set was then separated by age categories and Mann-Whitney U tests were re-conducted to look for significant differences between the sexes of each age group; results are detailed in Table 6.50. Significant differences between the sexes were found in the Early Young Adult category for articular border convexity ($P = 0.024$) (Figure 6.62) and in the Late Young Adult category for Poirier's Facet ($P = 0.001$) (Figure 6.63). Significant differences between the sexes were also found in the Mature Adult category for articular border convexity ($P = 0.033$) (Figure 6.44). No significant differences in non-genetic non-metric traits were found between the sexes for the Older Adult age category.

TABLE 6.50: Mann-Whitney U Test Between the Sexes for Non-genetic Non-metric Traits, Separated by Age

	Early Young Adult				**Late Young Adult**			
			Mean Rank				Mean Rank	
Variable	Mann-Whit U	Sig.	Male	Female	Mann-Whit U	Sig.	Male	Female
Epicondylar Exostoses	25	1	8	8	36	1	9	9
Articular Border Convexity	14	0.024*	11.1	6	54.5	0.643	10.95	12.05
Poirier's Facet	27.5	0.762	8.25	8.92	21	0.001**	17.09	8.62
Tibial Imprint	34	0.917	9.1	8.86	69	0.877	12.27	12.69
Martin's Facet	9.5	0.322	6.64	4.88	24	0.22	10.5	7.67
Exostoses of the Trochanteric Fossa	31.5	0.646	8.65	9.5	54	0.263	13	10.91
Tibial Squatting Facet	27	0.409	9.8	7.86	64	0.631	13.17	11.83
Osgood Schlatter	35	1	9	9	72	1	12.5	12.5

	Mature Adult				Older Adult			
			Mean Rank				Mean Rank	
Variable	Mann-Whit U	Sig.	Male	Female	Mann-Whit U	Sig.	Male	Female
Epicondylar Exostoses	64	1	12.5	12.5	12.5	0.361	6.42	5.5
Articular Border Convexity	55	0.033*	11.43	16.77	17.5	0.254	6.5	8.5
Poirier's Facet	95.5	0.497	16.38	14.35	9	0.076	8.71	5
Tibial Imprint	111.5	0.736	15.56	16.54	17.5	0.343	6.5	8.5
Martin's Facet	76.5	0.735	13.9	12.95	8	0.61	4.5	5.4

TABLE 6.50: Mann-Whitney U Test Between the Sexes for Non-genetic Non-metric Traits, Separated by Age (continued)

Exostoses of the Trochanteric Fossa	94.5	0.283	14.56	17.75	18	0.351	6.57	8.43
Tibial Squatting Facet	99.5	0.628	14.85	16.35	10.5	0.06	5.5	9.5
Osgood Schlatter	110.5	1	15.5	15.5	24.5	1	7.5	7.5
Epicondylar Exostoses	64	1	12.5	12.5	12.5	0.361	6.42	5.5

**P* ≤0.05
***P* ≤ 0.01

FIGURE 6.62: Significant Differences in Mean Ranks Between the Sexes for Non-genetic Non-Metric Traits in Early Young Adults

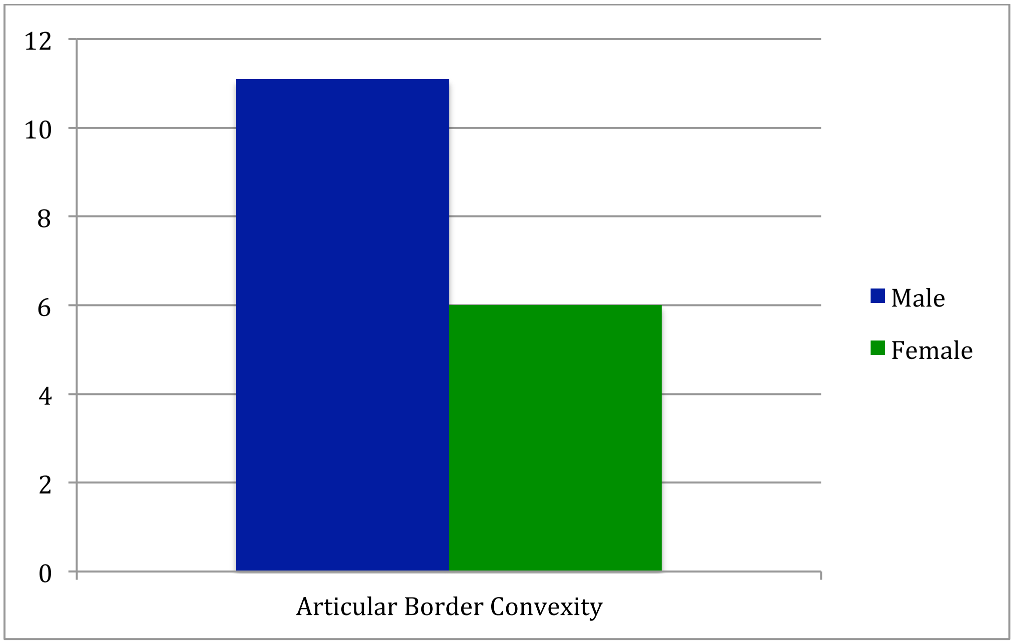


FIGURE 6.63: Significant Differences in Mean Ranks Between the Sexes for Non-genetic Non-Metric Traits in Late Young Adults

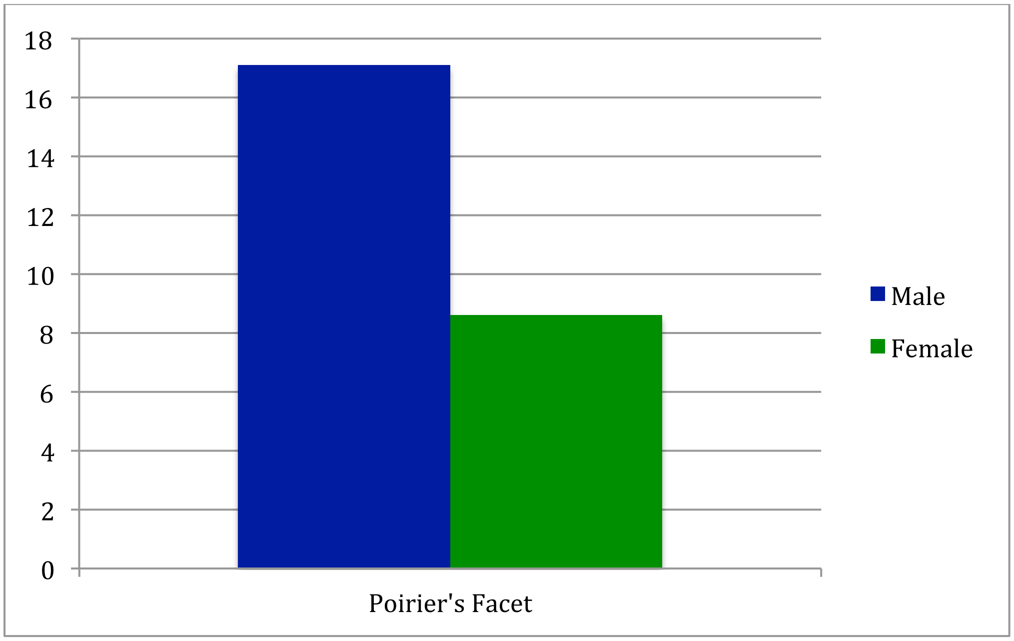
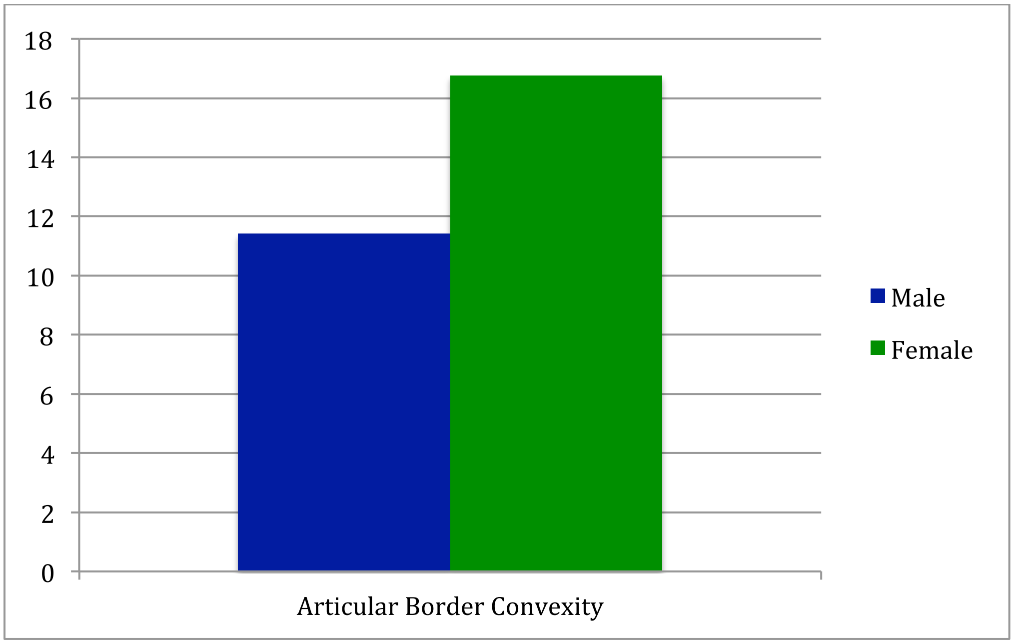


FIGURE 6.64: Significant Differences in Mean Ranks Between the Sexes for Non-genetic Non-Metric Traits in Mature Adults



6.6 INTRA-OBSERVER ERROR TESTS

The Wilcoxan Signed Rank Test was conducted to assess intra-observer error in the scoring of entheseal changes, osteoarthritis and non-genetic non-metric traits. The sub-sample chosen for this test consisted of ten individuals chosen specifically because they contained very complete skeletons. While this was not the most objective method of sampling it was important to be able to compare scores for all skeletal elements from which information was collected. The re-scoring of this sub-sample was taken after an elapsed time period of 17 months. Tables 6.51 - 6.53 detail the results of the intra-observer error tests. The only significant difference between the first and second observation times was for robustcity of the right *gluteus medius* (*P* = 0.046). These results suggest that, despite the subjective methodologies employed, there are extremely low intra-observer error rates, further supporting use of the Mariotti Method (2004, 2007) in studies of entheseal changes.

TABLE 6.51: Wilcoxan Signed Rank Test for Intra-Observer Error - Entheseal Changes

Side	Variable	Z	Significance
Left	Adductor Magnus OL	-1	0.317
Right	Adductor Magnus OL	-1	0.317
Left	Adductor Magnus OE	0	1
Right	Adductor Magnus OE	0	1
Left	Adductor Magnus RB	0	1
Right	Adductor Magnus RB	-0.447	0.655
Left	Biceps Brachii OL	-1.414	0.157
Right	Biceps Brachii OL	0	1
Left	Biceps Brachii OE	-1	0.317
Right	Biceps Brachii OE	-0.447	0.655
Left	Biceps Brachii RB	-1.414	0.157
Right	Biceps Brachii RB	0	1
Left	Brachialis OL	0	1
Right	Brachialis OL	-1	0.317
Left	Brachialis OE	0	1
Right	Brachialis OE	-1	0.317
Left	Brachialis RB	-1.732	0.083
Right	Brachialis RB	-1.732	0.083
Left	Costoclavicular OL	-1	0.317
Right	Costoclavicular OL	-0.577	0.564
Left	Costoclavicular OE	-1	0.317
Right	Costoclavicular OE	0	1
Left	Costoclavicular RB	-1.414	0.157
Right	Costoclavicular RB	-1.414	0.157

TABLE 6.51: Wilcoxan Signed Rank Test for Intra-Observer Error - Entheseal Changes (continued)

Left	Conoid OL	-1	0.317
Right	Conoid OL	-1	0.317
Left	Conoid OE	0	1
Right	Conoid OE	0	1
Left	Conoid RB	-0.577	0.564
Right	Conoid RB	-1.414	0.157
Left	Deltoideus OL	0	1
Right	Deltoideus OL	0	1
Left	Deltoideus OE	0	1
Right	Deltoideus OE	0	1
Left	Deltoideus RB	0	1
Right	Deltoideus RB	-1	0.317
Left	Extensor Carpi Ulnaris OL	0	1
Right	Extensor Carpi Ulnaris OL	0	1
Left	Extensor Carpi Ulnaris OE	0	1
Right	Extensor Carpi Ulnaris OE	0	1
Left	Extensor Carpi Ulnaris RB	-0.577	0.564
Right	Extensor Carpi Ulnaris RB	0	1
Left	Flexor Carpi Ulnaris OL	0	1
Right	Flexor Carpi Ulnaris OL	0	1
Left	Flexor Carpi Ulnaris OE	0	1
Right	Flexor Carpi Ulnaris OE	0	1
Left	Flexor Carpi Ulnaris RB	-1.633	0.102
Right	Flexor Carpi Ulnaris RB	-1.134	0.257
Left	Gluteus Maximus OL	0	1
Right	Gluteus Maximus OL	0	1

$^{*}P \leq 0.05$

TABLE 6.51: Wilcoxan Signed Rank Test for Intra-Observer Error - Entheseal Changes (continued)

Left	Gluteus Maximus OE	0	1
Right	Gluteus Maximus OE	-1	0.317
Left	Gluteus Maximus RB	-1	0.317
Right	Gluteus Maximus RB	-1	0.317
Left	Gluteus Medius OL	-1	0.317
Right	Gluteus Medius OL	0	1
Left	Gluteus Medius OE	-1	0.317
Right	Gluteus Medius OE	0	1
Left	Gluteus Medius RB	-1.732	0.083
Right	Gluteus Medius RB	-2	0.046*
Left	Gluteus Minimus OL	-0.816	0.414
Right	Gluteus Minimus OL	-0.447	0.655
Left	Gluteus Minimus OE	-1	0.317
Right	Gluteus Minimus OE	-0.447	0.655
Left	Gluteus Minimus RB	0	1
Right	Gluteus Minimus RB	-1	0.317
Left	Iliopsoas OL	0	1
Right	Iliopsoas OL	-1	0.317
Left	Iliopsoas OE	-1.633	0.102
Right	Iliopsoas OE	-1.414	0.157
Left	Iliopsoas RB	-1.414	0.157
Right	Iliopsoas RB	-1	0.317
Left	Supraspinatus etc. OL	-1	0.317
Right	Supraspinatus etc. OL	-0.816	0.414
Left	Supraspinatus etc. OE	-1	0.317
Right	Supraspinatus etc. OE	0	1
Left	Supraspinatus etc. RB	-1	0.317
Right	Supraspinatus etc. RB	-1	0.317
Left	Latissimus etc OL	0	1
Right	Latissimus etc OL	-1.732	0.083
Left	Latissimus etc OE	0	1
Right	Latissimus etc OE	0	1
Left	Latissimus etc RB	-1.342	0.18
Right	Latissimus etc RB	-1.633	0.102
Left	Pectoralis OL	0	1
Right	Pectoralis OL	0	1
Left	Pectoralis OE	0	1

*$P \leq 0.05$

TABLE 6.51: Wilcoxan Signed Rank Test for Intra-Observer Error - Entheseal Changes (continued)

Right	Pectoralis OE	0	1
Left	Pectoralis RB	-0.577	0.564
Right	Pectoralis RB	0	1
Left	Piriformis etc OL	-1	0.317
Right	Piriformis etc OL	-0.577	0.564
Left	Piriformis etc OE	-0.577	0.564
Right	Piriformis etc OE	0	1
Left	Piriformis etc RB	-0.577	0.564
Right	Piriformis etc RB	-0.447	0.655
Left	Popliteus OL	0	1
Right	Popliteus OL	-1	0.317
Left	Popliteus OE	-0.577	0.564
Right	Popliteus OE	-0.577	0.564
Left	Popliteus RB	-0.577	0.564
Right	Popliteus RB	-0.577	0.564
Left	Pronator Teres OL	0	1
Right	Pronator Teres OL	0	1
Left	Pronator Teres OE	0	1
Right	Pronator Teres OE	0	1
Left	Pronator Teres RB	-1.732	0.083
Right	Pronator Teres RB	-1.732	0.083
Left	Quadratus Femoris OL	0	1
Right	Quadratus Femoris OL	0	1
Left	Quadratus Femoris OL	0	1
Right	Quadratus Femoris OL	0	1
Left	Quadratus Femoris RB	0	1
Right	Quadratus Femoris RB	-1	0.317
Left	Quadriceps OL	0	1
Right	Quadriceps OL	0	1
Left	Quadriceps OE	0	1
Right	Quadriceps OE	0	1
Left	Quadriceps RB	-1.732	0.083
Right	Quadriceps RB	-1	0.317
Left	Semimembranosus OL	-1	0.317
Right	Semimembranosus OL	0	1
Left	Semimembranosus OE	0	1
Right	Semimembranosus OE	0	1

*$P \leq 0.05$

TABLE 6.51: Wilcoxan Signed Rank Test for Intra-Observer Error - Entheseal Changes (continued)

Left	Semimembranosus RB	-0.816	0.414
Right	Semimembranosus RB	-1.414	0.157
Left	Sartorius etc OL	0	1
Right	Sartorius etc OL	0	1
Left	Sartorius etc OE	0	1
Right	Sartorius etc OE	0	1
Left	Sartorius etc RB	-1.342	0.18
Right	Sartorius etc RB	-1	0.317
Left	Soleus OL	-1	0.317
Right	Soleus OL	-1	0.317
Left	Soleus OE	-1.732	0.083
Right	Soleus OE	-1	0.317
Left	Soleus RB	0	1
Right	Soleus RB	-1	0.317
Left	Subscapularis OL	0	1
Right	Subscapularis OL	0	1
Left	Subscapularis OE	-1	0.317
Right	Subscapularis OE	-1.414	0.157
Left	Subscapularis RB	0	1
Right	Subscapularis RB	0	1
Left	Supinator OL	0	1
Right	Supinator OL	0	1
Left	Supinator OE	0	1
Right	Supinator OE	0	1
Left	Supinator RB	0	1
Right	Supinator RB	-1.414	0.157
Left	Trapezoid OL	-1.732	0.083
Right	Trapezoid OL	-1.732	0.083
Left	Trapezoid OE	0	1
Right	Trapezoid OE	0	1
Left	Trapezoid RB	-1.414	0.157
Right	Trapezoid RB	-1	0.317
Left	Triceps Brachii OL	0	1
Right	Triceps Brachii OL	0	1
Left	Triceps Brachii OE	0	1
Right	Triceps Brachii OE	-1	0.317
Left	Triceps Brachii RB	-0.577	0.564
Right	Triceps Brachii RB	-0.577	0.564

*$P \leq 0.05$

TABLE 6.52: Wilcoxan Signed Rank Test for Intra-Observer Error - Osteoarthritis

Side	Variable	Z	Significance
Left	Calcaneus	-1.732	0.083
Right	Calcaneus	-1.732	0.083
Left	Distal Femur	0	1
Right	Distal Femur	0	1
Left	Proximal Femur	-1.732	0.083
Right	Proximal Femur	-1	0.317
Left	Distal Humerus	-1	0.317
Right	Distal Humerus	-0.577	0.564
Left	Proximal Humerus	-1	0.317
Right	Proximal Humerus	-1.414	0.157
Left	Innominate	-0.577	0.564
Right	Innominate	-1.414	0.157
Left	Distal Radius	0	1
Right	Distal Radius	-1	0.317
Left	Proximal Radius	-0.577	0.564
Right	Proximal Radius	-0.577	0.564
Left	Scapula	-1	0.317
Right	Scapula	-1.414	0.157
Left	Distal Talus	-1.732	0.083
Right	Distal Talus	-1.414	0.157
Left	Proximal Talus	-1.732	0.083
Right	Proximal Talus	-0.577	0.564
Left	Distal Tibia	-1	0.317
Right	Distal Tibia	0	1
Left	Proximal Tibia	0	1
Right	Proximal Tibia	0	1
Left	Distal Ulna	-1	0.317
Right	Distal Ulna	-1.414	0.157
Left	Proximal Ulna	-0.816	0.414
Right	Proximal Ulna	-0.333	0.739

$*P \leq 0.05$

TABLE 6.53: Wilcoxan Signed Rank Test for Intra-Observer Error - Non-genetic Non-metric Traits

Side	Variable	Z	Significance
Left	Articular Border Convexity	-1.732	0.083
Right	Articular Border Convexity	-1.414	0.157
Left	Epicondylar Exostoses	0	1
Right	Epicondylar Exostoses	0	1
Left	Exostoses of the Trochanteric Fossa	-1	0.317
Right	Exostoses of the Trochanteric Fossa	-0.577	0.564
Left	Martin's Facet	-1.732	0.083
Right	Martin's Facet	-0.577	0.564
Left	Osgood Schlatter	0	1
Right	Osgood Schlatter	0	1
Left	Poirier's Facet	-0.447	0.655
Right	Poirier's Facet	-0.378	0.705
Left	Tibial Squatting Facet	-1.414	0.157
Right	Tibial Squatting Facet	-1.414	0.157
Left	Tibial Imprint	-0.816	0.414
Right	Tibial Imprint	-0.378	0.705

$*P \leq 0.05$

CHAPTER 7: DISCUSSION

7.1 SUB-ADULT CROSS-SECTIONAL GEOMETRY

According to the results of the Kruskal-Wallis and Mann-Whitney U tests, significant differences in cross sectional geometry variables of the subadult sample were present for Iy, Ix/Iy, Imax and J. Iy, a measure of medio-lateral reinforcement, exhibits a significant decrease between the Young Child and Older Child categories. Imax, a measure of the direction of maximum bending rigidity, also has a significant decrease between the Young Child and Older Child categories. Ix/Iy, a shape index, exhibits a significant increase from the Perinate and Young Child age groups to the Older Child category. All three of these significant results are to be expected and can be explained by the onset and mastery of walking. The ontogeny of human locomotion has demonstrated a systematic development in which the ratio of bending rigidity between a toddler and an adult at the mid-shaft femur is similar- it is the orientation of the maximum bending rigidity that differs. Two to five month-olds have fairly circular femoral mid-shaft cross sections that become reinforced medio-laterally as they change forms of locomotion from crawling to 'waddling' (Cowgill et al. 2010:58-60; Schug and Goldman 2014:246). This medio-lateral reinforcement is greatest in children one to four years of age, and as they become more efficient bipeds the orientation of maximum bending rigidity eventually becomes an antero-posterior elongation (Cowgill et al. 2010; Gosman et al. 2013). In the Middenbeemster subadult sample, the perinates and young children (birth to five years old) exhibit slightly ovoid femoral cross section with reinforcement in the medio-lateral direction, which becomes a fairly circular cross section in middle childhood and finally is antero-posteriorly reinforced by older childhood.

An unexpected, and less easily explained, result for the Middenbeemster subadult sample is the significant decrease in J between the Young Child and Older Child categories. An index of the overall rigidity of a bone, J was expected to increase with maturation. Review of the distribution of mean scores and Spearman correlation coefficients of different cross-sectional areas do show a decrease in MA and increase in %CA with age, which are to be expected with a healthy growth trajectory; however, TA is actually smaller in the Older Child sample than it is in the Young or Middle Child samples. It is possible that this unexpected decrease in J and smaller TA in older childhood are the result of small sample sizes, un-diagnosed pathological conditions or simply the inherent mortality bias of any sample.

7.2 ADULT CROSS-SECTIONAL GEOMETRY

7.2.1 Femurs

According to the Pearson and one-way ANOVA tests, there are significant correlations between an increase in femoral MA and decrease in %CA with advancing age. Specifically, Older Adults have significantly higher MA and lower %CA than other ages categories. When the sample is separated by sex, however, and the ANOVA is re-run these age differences only remain significant for females, which is most likely explained by women's unique ageing processes and the significant hormonal effects of menopause on the female skeleton.

Results of the femoral T-tests suggested that males had significantly higher scores than females in Ix (antero-posterior reinforcement), Imax (maximum measure of bending rigidity) and J (overall rigidity). When the sample is separated by age, however, and the T-test is re-run the only sex differences which remain are in the Older Adult category, where males have significantly higher values for: %CA, Ix, Imin and J. Whether statistical significance was reached or not, a general pattern for all SMAs emerged in which males and females began in Early Young Adulthood with relatively similar values, after which women tended to either retain that value (ex. J) or steadily decline while men tended to experience a significant increase in each variable between Late Young and Mature Adulthood. These results, especially J, suggest that women maintained their activity pattern and activity strain levels throughout their life cycle, while beginning in Late Young Adulthood males began to participate in a more rigorous lower limb activity which affected the cross-sectional geometry of their femurs.

It should be noted that the femoral shape ratio Ix/Iy, also commonly used as a 'mobility index' was largely similar between the sexes, although the males did exhibit higher values than females especially in older age. What is remarkable is that for both sexes, and across all adult age categories, the mean Ix/Iy ratio is consistently close to but under a value of 1.0 which suggests a fairly circular but slightly medio-laterally reinforced femur; this is in concordance with conclusions reached by Saers (2017) on the same collection. As mentioned previously, adult femurs are usually reinforced antero-posteriorly as an effect of walking. The unusual shape found in the Middenbeemster adults may be the result of specific activities placing greater strain in a medio-lateral direction, or may simply be a result of the exceptionally flat terrain of the Low Countries and therefore an absence of strain in the antero-posterior direction commonly caused by variable terrain.

7.2.2 Humeri

According to the Pearson and ANOVA tests, there are significant correlations between an increase in humeral MA and decreases in CA and %CA with advancing age. Specifically, Older Adults are significantly different from all other ages categories for the variables of MA and %CA, but only significantly different from the Early Young and Late

Young Adults in CA. When the sample was separated by sex and the 1-way ANOVA tests were re-run, these age differences remained significant for both sexes.

Results of the humeral T-tests and 2-way ANOVA suggested significant differences between the sexes for all cross-sectional variables except for MA. When the sample was separated by age and the T-tests re-run a slightly different picture emerged. There are no significant differences between the sexes in Early Young Adulthood, but beginning in Late Young Adulthood there are significant differences between the sexes in all SMAs. Similar to the pattern found in femoral SMAs, males and females began in Early Young Adulthood with relatively similar humeral values, which deviated from each other as they grew older.

Overall, male humeri have higher values than women in CSAs and SMAs and experience a significant increase in each variable between Early Young and Late Young Adulthood. Notably, J remains relatively the same through Old Adulthood thus suggesting that beginning in Late Young Adulthood males began to participate in more rigorous upper limb activities the strain levels of which were maintained throughout their lifecycle. The shape ratios Ix/Iy and Imax/Imin for all age categories suggest an antero-posteriorly reinforced humeral shaft, however, there is a large (non-significant) decrease in these ratios between Late Young and Mature Adulthood, suggesting that while the strain level of their upper arm activities may have remained relatively the same throughout their life, the type of activities likely differed.

Overall, women's humeral MA increases while their %CA and J values tended to steadily decline with age. These results suggest that women did not maintain their activity strain levels throughout their life cycle, and notably exhibited a significant decline between Late Young and Mature Adulthood. Interestingly, women's SMAs and shape ratios suggest a change in types of activities during their life. Women have significantly higher shape ratios than men in all age categories, with a more antero-posteriorly reinforced humeral shaft, however, there is a decrease between Late Young and Mature Adulthood, followed by an increase in Older Adulthood. During Mature Adulthood, and the associated decrease in antero-posterior reinforcement, Iy and Imin remain relatively the same while Ix and Imax experience a decrease thus accounting for the reduction in anter-posterior reinforcement. Since the value nearly returns to that exhibited by Early and Late Young adults, it is possible that women stopped participating in an activity during Mature Adulthood that was resumed later in life.

7.3 ENTHESEAL CHANGES

According to the Mann-Whitney U test, significant differences in entheseal morphology between the sexes, regardless of age category or body size controls, were present for robusticity of the *latissimus dorsi /teres major* (P = 0.021), *triceps brachii* (P = 0.001), *flexor carpi ulnaris* (P = 0.05) and *iliopsoas* (P = 0.032) as well as for osteolytic formations at the *costoclavicular* (P = 0.000), *subscapularis* (P = 0.042) and *biceps brachii* (P = 0.003). Females had significantly greater scores for the *triceps brachii* and *flexor carpi ulnaris* while males had greater scores for the *costoclavicular, subscapularis, biceps brachii, latissimus dorsi /teres major* and *iliopsoas*. This suggests that females were frequently involved in bimanual repetitive activities involving intense extension of the arms and flexion of the hands. Males appear to have been involved in bimanual repetitive activities involving intense flexion and extension, medial rotation and adduction of the upper arms as well as flexion and medial rotation of the legs.

According to the Kruskal-Wallis test, significant differences in entheseal morphology between age categories, regardless of sex or body size controls, were present for a large number of both upper and lower limb entheses. Most robusticity and osteolytic formation scores demonstrate a general trend of increasing scores corresponding with increasing age, the most significant differences between age categories existing between the Early Young Adult category and the Mature Adult or Old Adult category. Notably, osteolytic formations at the insertion sites for the *pronator teres* and *pectoralis* show the Early Young Adult group as having significantly higher score than any other age group, suggesting early young adults were involved in an activity that involved overuse of the upper limb, especially for the actions of flexion, extension, adduction, medial rotation and pronation of the forearm.

As mentioned previously, in order to obtain a better understanding of the statistically significant test results, Two-tailed Spearman tests were conducted to assess potential influences of other variables in determining significant correlations. The results of the Two-tailed Spearman tests confirmed that body size, age and sex each correlated with a number of entheseal changes and thus were likely influencing the results of the Mann-Whitney U and Kruskal-Wallis tests. Partial Spearman correlations were then carried out to re-examine correlations of the entheseal variables with age after sex and body size were controlled for. Results of this test found that age continued to correlate with a large number of entheseal changes across the entire body. Partial Spearman correlations were also carried out to re-examine correlations of the entheseal variables with sex after age and body size were controlled for. Results of this test found that while few significant correlations remained, sex did correlate with robusticity of the *trapezoid* ($P = 0.043$) and osteolytic formations of the *costoclavicular* ligament ($P = 0.001$), *subscapularis* ($P = 0.023$), *latissimus* ($P = 0.042$), *extensor carpi ulnaris* ($P = 0.043$), *popliteus* ($P = 0.016$) and *soleus* ($P = 0.035$) entheses. In sum, results of the Partial Spearman tests found that while sex and body size did influence entheseal morphology, age was the single greatest predictor of entheseal robusticity in this skeletal sample.

Each variable was then standardized by body size, the data set was separated by age categories and Mann-Whitney U tests were conducted for each age group to look for significant differences between the sexes at each enthesis. Across all age groups there are significant differences in scores for osteolytic formations at the *costoclavicular* ligament; Early Young Adult ($P = 0.002$), Mature Adult ($P = 0.002$), Late Young Adult ($P = 0.047$) and Older Adult ($P = 0.038$) males all have significantly higher scores than females. The *costoclavicular* insertion is the primary restraint for the sterno-clavicular joint, specifically limiting anterior and posterior rotation of the long axis of the clavicle; clinical studies report that this is area is most commonly prone to overuse injury in painters, construction workers and kayakers (Rani et al. 2011). These results suggest that males were routinely involved in activities that placed unusually high amounts of stress on this insertion site, resulting in the formation of osteolytic lesions. It should also be noted that a significant difference between the sexes for robusticity of this insertion site was only returned for Older Adult females ($P = 0.027$). Comparison of the mean rank scores of this attachment site (between the sexes for each age group) suggest that the significantly higher scores for Older Adult females do not reflect a significant increase in women's *costoclavicular* use, but are actually a reflection of a significant decrease in the mean rank of men's scores in older age. In summation, this suggests that while men sustained the morphology of overuse injuries at this site, in older age they were no longer actively participating in the same stressful activity. Conversely, the maintenance of women's mean rank scores across all age groups suggests that they continued to be involved in activities that stressed this area throughout their life-course.

Early Young Adult males have significantly higher scores than females for osteolytic lesions of the *latissimus dorsi/teres major* ($P = 0.033$) and *extensor carpi ulnaris* ($P = 0.021$) entheses. The *latissimus dorsi/teres major* entheses are primarily responsible for the actions of horizontal extension, medial rotation and adduction of the arm while the *extensor carpi ulnaris* is responsible for extension of the hand/fingers. Late Young Adult males also have significantly higher scores for robusticity of the *latissimus dorsi/teres major* entheses ($P = 0.013$), further supporting the findings for the Early Young Adult males. These results suggest strenuous extension activities for the upper arm and hands as well as inward rotation and movement of the upper arm. Comparison of mean ranks for this enthesis across all age categories for males shows that scores for both robusticity and stress lesions peak in Late Young and Mature adulthood, and sharply decrease in older age suggesting a change in activity patterns during older age.

Significant results for Late Young Adult males were also found for robusticity of the *iliopsoas* ($P = 0.046$) and ossification exostoses of the left *gluteus minimus* ($P = 0.044$). The *iliopsoas* is primarily responsible for flexion and lateral rotation of the upper leg (raising the leg forward from the hip), however, it's origin in the lower back means that it is also responsible for flexion of the torso and therefore has been linked to back injuries caused by overuse (Thompson 1981). The *gluteus minimus* abducts and medially rotates the leg. Findings for the lower limb suggest a strenuous activity pattern that involves flexion of the thigh/outward rotation of leg, with traumatic injury resulting from the left leg being moved away from the midline of the body/rotated inward.

In the older adult categories, there were no further significant results for the lower limbs in males, however, for the Older Adult category there are significantly higher scores than the women for robusticity of the *pronator teres* ($P = 0.015$). The *pronator teres* is primarily responsible for pronation of the forearm, although it is also involved in forearm flexion. The lack of significant differences between the sexes for this enthesis in previous age categories is not the result of a change in activity patterns for males, but is in fact a result of a change for females; comparison of mean ranks across all age groups between the sexes show nearly equivalent scores until older age when the score for females dramatically decreases while the score for males only slightly decreases.

Higher scores for Early Young Adult women in robusticity of the *pectoralis* ($P = 0.047$), *deltoideus* ($P = 0.010$) and *triceps brachii* ($P = 0.003$) were also found. The *pectoralis major* is involved in flexion/extension, medial rotation and adduction. The *deltoideus* is the major abductor of the arm and is frequently used in conjunction with the *pectoralis major*. The *triceps brachii* is the major extensor of the forearm, most commonly used in any kind of pushing movement. The significantly higher robusticity scores for women for each of these entheses suggests that they were routinely involved in bimanual activities with repetitive and stressful flexion/extension, abduction/adduction of the arms as well as forearm extension. In Late Young adulthood, women have significantly higher scores than men in ossification exostoses of the left *conoid* ($P = 0.044$); this suggests severe unilateral injuries to a ligament which limits posterior rotation of the scapula.

Mature Adult women also have significantly higher scores than men for ossification exostoses of both the left and right *triceps brachii* ($P = 0.008$, $P = 0.020$). Exostoses of the *triceps* suggest that the activity responsible for such high scores at the same insertion site for younger women, continued through maturity and was both stressful and repetitive enough to cause traumatic injury. Mature Adult women also have significantly higher scores than men in robusticity of the *piriformis* ($P = 0.013$), as well as ossification exostoses of the left *iliopsoas* ($P = 0.046$). The *piriformis* is involved in the action of abduction when seated or lateral rotation when standing. The *iliopsoas* is also a lateral rotator, as well as a leg flexor. The significant results returned for both of these lower limb entheses suggest that mature adult women were participating in an activity involving extreme lateral rotation at the hip, especially on the left side.

As mentioned previously, Older Adult women have significantly higher scores than men for robusticity of the *costoclavicular* ligament, however, they also have significantly higher scores for robusticity of the *soleus* ($P = 0.041$) as well as ossification exostoses of both the left and right *soleus* ($P = 0.018$, $P = 0.036$). The *soleus* is involved primarily with plantar-flexion and is used in the actions of running, jumping, hopping, etc.; any movement which requires pointing your foot or raising your heel while in a standing position.

7.4 OSTEOARTHRITIS

Without breaking the sample down by age categories, Mann-Whitney U tests returned no statistically significant differences between the sexes for scores of osteoarthritis. Kruskal-Wallis tests were run on the entire sample to explore potential differences between age groups and returned statistically significant differences for the scapula ($P = 0.041$), innominate ($P = 0.009$), and distal femur ($P = 0.014$). As expected, there are significant differences between Early Young Adults and the Mature and Older Adult age categories. Kruskal-Wallis tests comparing differences between age groups for each sex found that the difference in age groups for osteoarthritis of the innominate was only for males. Two-tailed Spearman correlations were then calculated to see the extent to which variables of age and sex may be influencing the results, finding that sex did not significantly correlate with osteoarthritis of any area while age significantly correlated with osteoarthritis of the scapula ($P = 0.006$), proximal ulna ($P = 0.011$), distal ulna ($P = 0.034$), innominate ($P = 0.001$), proximal femur ($P = 0.028$), distal femur ($P = 0.001$), proximal tibia ($P = 0.042$), and distal tibia ($P = 0.03$). These results suggest that age is the greatest predictor of osteoarthritis and influencing the results of the Mann-Whitney U tests.

The data set was then separated by age categories and Mann-Whitney U tests were conducted to look for significant differences between the sexes of each age group. When comparing the sexes per age category, for Late Young Adults the results show that males have significantly higher scores than females for the proximal radius and calcaneus, while females have significantly higher scores for the distal humerus. Mature Adult males, however, have significantly higher scores than females for both the proximal and distal joint surfaces of the humerus. Interestingly, no significant differences between the sexes were found for osteoarthritis of any joint surface in older adults.

In general, for both sexes we see an increase in scores for osteoarthritis with advancing age; however, this sample has relatively low rates of appendicular osteoarthritis and when it is present is rarely more advanced than simple porosity. It should be noted that out of all surfaces and individuals analyzed, eburnation was only recorded a total of nine times in eight individuals. The highest incidence of eburnation (four times) was found at the proximal ulna, however, there is no associated pattern to sex or age category. This is especially interesting as we know that a large number of the individuals analyzed lived until extremely advanced older age. It is possible that these low rates of activity-related osteoarthritis are representative of stressful activities beginning early in life. As discussed previously, clinical studies on athletes have found an inverse relationship between osteoarthritis and biomechanical robusticity where athletes who began training early in life show little to no arthritis (Puranen et al. 1975; Lane et al. 1986; Panush and Brown 1987; Bridges 1989, 1991; Knüsel 2000).

7.5 NON-GENETIC NON-METRIC TRAITS

Results of the Mann-Whitney U tests to explore possible differences in non-genetic non-metric traits between the sexes returned only statistically significant result: males had higher scores than females for Poirier's Facet ($P = 0.010$). Results of the Kruskal-Wallis tests to explore potential differences between age groups returned no statistically significant differences between age categories for any non-genetic non-metric trait examined. Two-tailed Spearman correlations were then calculated to see the extent to which variables of age and sex may be influencing the results, finding that neither variable was significantly influencing the results.

The data set was then separated by age categories and Mann-Whitney U tests were conducted to look for significant differences between the sexes of each age group. Early Young Adult males had significantly higher scores ($P = 0.024$) than females for articular border convexity, which results from prolonged periods of time squatting or sitting cross-legged. Although squatting facets never reached any statistically significant difference between age or sex categories, it should be noted that they often co-occurred with the presence of the articular border convexity trait, suggesting that a squatting posture is more likely than a sartorial one. Mature Adult females had a significantly higher incidence ($P = 0.033$) of articular border convexity than males, however, they never scored over a stage one; the more extreme scores for this trait were recorded exclusively in young men. These findings suggest that men engaged more frequently/strenuously in squatting postures, and this activity was confined to early and late young adulthood.

Poirier's facet results from extreme extension of the legs and, as mentioned previously, was found to occur significantly more often in men than women. When the sexes are compared per age category, this finding is specifically statistically significant for Late Young Adult males ($P = 0.001$). Results of a Kruskal-Wallis test between the age categories for males show that the mean rank scores of Poirier's facet doubles between Early Young and Late Young adulthood, and is maintained throughout the duration of the life-course. This suggests that in Late Young Adulthood, men began to participate in a frequent/strenuous activity that involved extreme extension of the lower limbs.

7.6 TIEING IT ALL TOGETHER

In summation, Early Young Adult males and, to a certain degree Late Young Adult males, seem to be participating in an activity that involves a flexed, 'squatting-like' position as well as extension/adduction and medial rotation of the arms with continuing extension through the hands. Beginning in Late Young adulthood, there is an increase in activity induced strain levels as well as a shift in activity patterns in both upper and lower limbs. This flexed 'squatting-like' posture is eventually replaced by extreme leg flexion and extension with traumatic injury to the upper left leg caused by medial rotation, abduction (stepping to the side) or a combination of the two. Throughout the life-course, there is evidence for severe stress caused by anterior-posterior movement of the clavicle and anterior-posteriorly reinforced humeral shafts. Taken together this evidence suggests that men were participating in an activity that involved extreme leg flexion/extension and rotation while pushing/pulling something very heavy.

In reviewing the limited historical literature, it is quite possible that these changes in types of activities for males reflect an age-associated change in duties of daily farm life. As mentioned previously, boys were expected to begin contributing to farm work as early as age four and such duties included both helping with the herd and the twice daily milking of each cow (Schenkeveld 2008; de Groot 1917; van Berkhey 1811). The pattern of movements associated with a milking posture could help to explain the pattern we see in Early Young Adult males: squatting with extension and anterior-posterior reinforcement of the upper limbs. The significant differences in both activity level and type of activity that begins between Early Young and Late Young Adulthood likely reflects a change in duties as with increasing age comes increasing experience and knowledge of the inner-workings of running the farm. Historical records suggest that male adult duties in a Dutch dairy during this time commonly included such activities as driving the cattle to a corral to be milked, feeding, washing and currying the cattle, cleaning the barn stalls, digging/dredging turf for heat and cooking fuel, fertilizing the fields and ditch dredging (van Berkhey 1811; de Groot 1917; Falger et al. 2012). A number of these activities likely contributed to the suite of morphological features seen in Late Young, Mature and Older Adults- especially shoveling. No doubt a great deal of shoveling was required since large amounts of hay and manure (Figure 7.1) would have had to be moved on a daily basis and turf had to be dug for fuel. Figure 7.2 depicts the main tools used in maintaining the fields, which lend further support to the amount of shoveling/digging that were taking place on a regular basis. The flexion/extension, rotation and slight medio-lateral reinforcement of the lower limbs accompanied with antero-posteriorly reinforced humeri and antero-posteriorly strained clavicles could all be explained by the habitual and strenuous activity of shoveling.

FIGURE 7.1: 19th Century Dutch Farmers

Image taken from van Berkhey 1811

FIGURE 7.2: 19th Century Dutch Farming Tools

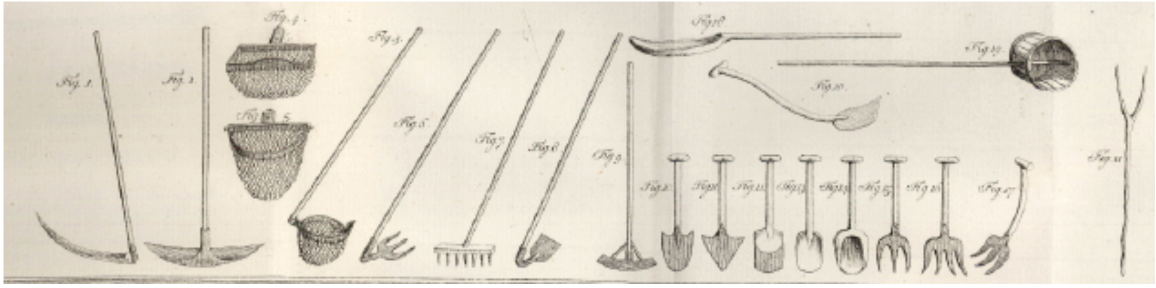
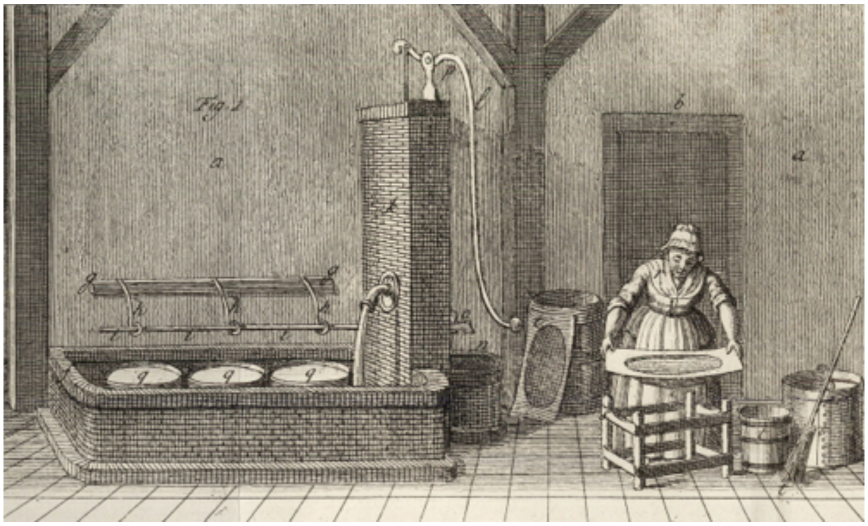


Image taken from van Berkhey 1811

For women, the level of overall activity gradually reduced across their life-cycle, however, there appear to be two major changes in type of activity. When comparing the mean rank scores across age categories for women the significant results for the upper limb suggest a pattern of activity that began early in life, continued until older age, and involved the strenuous raising and lowering of their arms along with forearm extension. This pattern of activity appears to have decreased dramatically in old age perhaps due to discomfort caused by overuse injuries, as evidenced by the increased presence of ossification exostoses with advancing age, or perhaps simply because the younger generation discreetly replaced the older women in this activity(s). Cross-sectional data suggests that women's lower limb rigidity and shape are maintained throughout their lifecycle and are medio-laterally reinforced. Significant results from the entheseal data suggest that women in the Mature and Older Adult age categories were participating in a strenuous activity involving intense lateral rotation of the left leg when standing as well as plantar-flexion of both feet. Taken together, data from the upper and lower limb may provide evidence for an age-related change in type of activity beginning between Late Young and Mature Adulthood.

Historical literature suggests that the duties of Dutch farmer's wives fell into two main categories: housekeeping and making the dairy products. The strenuous upper limb pattern seen in the Middenbeemster females is likely the result of a combination of both of these duties. In de Groot's (1917) autobiography she speaks of the housewives' constant battle against mildew, which involved the daily scrubbing and polishing of floors and brick pavements, as well as scouring the enormous amount of brass and copper pails, pans and utensils used everyday in the dairy. Once a week women were also responsible for scrubbing the tiled walls, woodwork, windows, casements, sills and rugs, polishing all of the wooden furniture, polishing all of the brass and copper as well as washing, boiling and bleaching the household's laundry (de Groot 1917). Mokyr has suggested that this intensive cleaning coincides with an increase in knowledge about the causes and transmission of diseases (2000). Labor intensive dairy making responsibilities included the carrying of large buckets of milk, either by hand or with a shoulder yoke, to pour into the separating trays for skimming (Figure 7.3) and then either the churning and molding process for butter (Figure 7.4) or the curd cutting (Figure 7.5), forming and pressing processes for cheese making (Figure 7.6) (van Berkhey 1811; de Groot 1917).

FIGURE 7.3: Skimming Process of Cheesemaking



Images taken from van Berkhey 1811

FIGURE 7.4: Traditional Dutch Butter Churning

Image taken from Lami 1888

FIGURE 7.5: Curd Cutting Process of Cheesemaking

Image taken from www.zuivelmuseum.be/pdf/info-map.pdf

FIGURE 7.6: Dutch Cheese Molding Process

Image taken from van Berkhey 1811

There is no singular activity that explains the habitual and strenuous antero-posterior movement of the upper arms in Middenbeemster women; instead, almost all of the responsibilities documented would involve the pattern described above. Unexplained, is the type of activity responsible for the change in women's lower limb morphology (lateral rotation and toe-pointing) however, it is worth noting that the timing of this in Mature and Older Adulthood would have likely coincided with becoming a grandmother and thus duties associated with caretaking of the younger children.

CHAPTER 8: CONCLUSION

8.1 SUMMARY

In many cultures, one’s constructed identity is heavily influenced by the contemporary normative social values and expectations based on sex, gender, age, occupation, economic status, etc. Social identity is not just a fluid and ephemeral concept, through the application of theories of practice and *hexis* it is possible to interpret the skeletal body as a contextually dependent materiality that has embodied its social identity. In the historic Netherlands, no matter what one’s occupation, economic standing or family size women were expected to take on the identity of ‘housewife’ while the men were expected to become the ‘breadwinner’. There is gravely little literature on the rural Netherlands of the 18th and 19th centuries, however, this sex-based division of labor is supported by census data (Schmidt and van Nederveen Meerkerk 2012).

The identity of ‘housewife’ on a 19th century rural Dutch dairy farm, however, was vastly different from what that same term implied to a woman of the 19th century Dutch urban upper class, or even to a 20th century rural Dutch dairy farmer. Cleanliness reigned supreme, and with the low altitude the threat of mildew to food, clothes and furniture was unending, thus, scrubbing, washing and polishing were unending and intensely laborious when living and working on a dairy farm. Housekeeping, however, did not make up the entirety of the ‘housewife’s’ responsibilities; several biographies, the Labor Act of 1889 and the research of two prominent feminist economists all suggest that women were much more involved on the dairy farm than census data alone would suggest.

By understanding the patterns of types of activities and their associated strain levels, applying biological characteristics of individuals in a life-course perspective, it becomes possible to frame biological and cultural data within a social narrative. At the site of historical Middenbeemster, musculoskeletal development analyses provide strong support for a sex-based division of labor with several changes in activity patterns over the life-course for both sexes. Men from Middenbeemster exhibited changes in types of activities that likely reflect an age-associated change in duties of daily farm life. Significant differences in both activity level and type of activity begin between Early Young and Late Young Adulthood and most likely reflect the change from an apprentice-like position involving milking the herd to the more strenuous activities which commonly involved the shoveling and moving of a variety of materials.

Women from Middenbeemster also exhibited changes in types of activities associated with age. There is a pattern of intense upper arm activity that began early in life and continued until older age, with strain levels beginning to decline between Late Young and Mature Adulthood, but remaining more antero-posteriorly enforced than men's arms at all ages. Conversely, women's legs showed consistent lower limb strain throughout life, with a change in type of activity beginning in Mature Adulthood suggested by the entheseal data. Overall, the pattern of the results suggest that younger women especially were involved not only in the intense cleaning/caretaking of the home, but also potentially support the role of women in the dairy production process, and therefore as important contributors to the economic success of the dairy farms.

8.2 SUGGESTIONS FOR FUTURE RESEARCH

Future research with the Middenbeemster collection could include the study of bone remodeling and morphology in areas of the skeleton (such as the metacarpals or ribs) to enhance our understanding of age and sex-related differences in bone growth and loss over the life-cycle, including its potential role with gendered activity patterns. The sample could also be substantially expanded after the completion of historical record identification to provide age/sex estimates for those individuals who were assigned an 'indeterminate' estimate.

Another interesting avenue to pursue with the Middenbeemster collection would be more in depth studies of individual skeletons with osteobiographies. There were a number of non-pathological individuals who were outliers for various data points and may represent individuals who practiced different occupations, emigrated from another area, or simply lived outside of the social norms. Comparison of these individuals with the average Middenbeemster population may provide better insight into the variety of identities found in historic Middenbeemster society.

From a bioarchaeological perspective, the methodologies employed in reconstructing patterns of activity from the human skeleton are still being refined. The strongest approaches to reconstructing past life-ways through the analysis of skeletal morphological variants are those which utilize a holistic methodology employing cross-sectional geometry, entheseal changes, osteoarthritis and non-genetic non-metric traits. By incorporating numerous types of activity pattern analyses, along with the direct examination of the growth and development of bone strength, this study was able to provide a fuller examination of activity related markers over the life-course, and a nuanced approach to the gender and age related identity in the Middenbeemster population. This multi-methodological approach allows for methods that have been widely criticized for being too subjective to be incorporated with objective methods. In this study, the cross-sectional geometry data largely complemented the ordinal data, thus validating the application and continued development of the latter in the field of bioarchaeology.

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APPENDIX

A.1: PHOTOGRAPHS OF GRADES OF EXPRESSION FOR ENTHESEAL CHANGES

SUPRASPINATUS; INFRASPINATUS/TERES MINOR:

Left to Right: Score = 1, 2, 3

SUPINATOR:

Left to Right: Score = 1, 2, 3

PIRIFORMIS:

Left to Right: Score = 1, 2, 3

GLUTEUS MINIMUS:

Left to Right: Score = 1, 2, 3

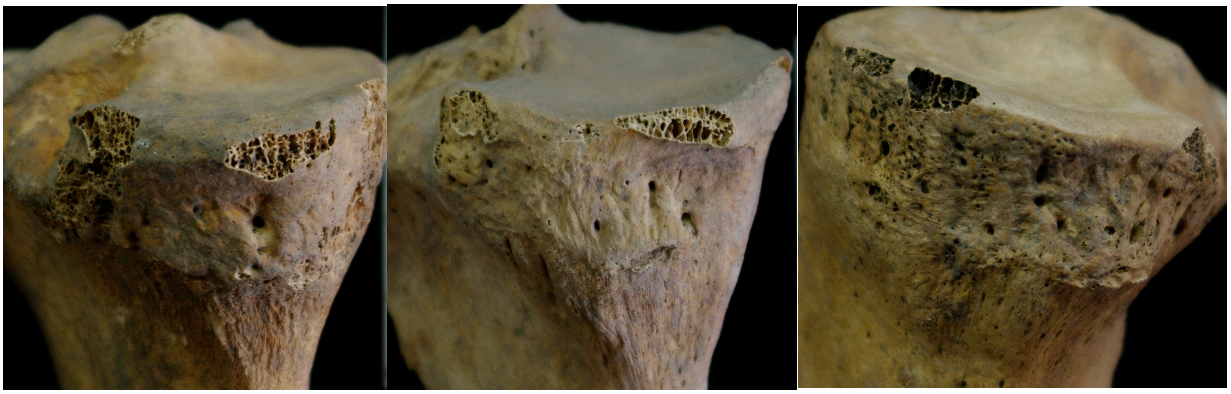
ADDUCTOR MAGNUS:

Left to Right: Score = 1, 2, 3

POPLITEUS:

Left to Right: Score = 1, 2, 3

SEMIMBRANOSUS:



Left to Right: Scores = 1, 2, 3

SARTORIUS/GRACILIS:

Left to Right: Scores = 1, 2, 3