December 2015

Entheses and Activities: The Multivariate Mechanisms of Entheseal Change for Individuals Represented By the 2013 Excavations of the Milwaukee County Institution Grounds Cemetery

Jessica L. Skinner
University of Wisconsin-Milwaukee

ENTHESES AND ACTIVITIES: THE MULTIVARIATE MECHANISMS OF ENTHESEAL CHANGE FOR INDIVIDUALS REPRESENTED BY THE 2013 EXCAVATIONS OF THE MILWAUKEE COUNTY INSTITUTION GROUNDS CEMETERY

by

Jessica L. Skinner

A Thesis Submitted in Partial
Fulfillment of the Requirements
for the Degree of

Master of Science
in Anthropology

at

The University of Wisconsin-Milwaukee

December 2015

ABSTRACT

ENTHESES AND ACTIVITIES: THE MULTIVARIATE MECHANISMS OF ENTHESEAL CHANGE FOR INDIVIDUALS REPRESENTED BY THE 2013 EXCAVATIONS OF THE MILWAUKEE COUNTY INSTITUTION GROUNDS CEMETERY

By

Jessica L. Skinner

The University of Wisconsin-Milwaukee, 2015
Under the Supervision of Professor Fred Anapol

The analysis of the features that mark tendon and muscle insertion sites on bone has been used in an attempt to reconstruct past life activity patterns of individuals and populations represented by skeletal remains. Many of these analyses have focused on comparing evidence from these individuals with known musculoskeletal and biomechanical data. Recent experimental tests have illustrated that defining these correlations is more complex than expected (Mariotti, 2007). Modern clinical data has expanded our understanding of the development of these markers as a result of enthesopathy and entheseal change, enabling further examination of the underlying forces affecting these changes, such as age and concurrent pathology. To further this study, an analysis of individuals from the Milwaukee County Institution Grounds Cemetery collection is conducted, using the enthesis-type-selection technique (Villotte, 2013) and an entheseal change scoring method proposed by Henderson et al. (2010). 3D morphometric analysis is also utilized. The shoulder complex of adult individuals exhibiting a range of skeletal health conditions is analyzed. This study examines the implications of age, concurrent pathology, and activity for skeletal and entheseal health, as well as the utility of entheseal change analysis for the purpose of determining past life activities.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

To begin, I am so grateful to my advisor, Dr. Fred Anapol, for his patience, advice, and the opportunities he has granted to me to further my education and experience. This support has helped me improve my research and professional experience incredibly. In addition, there aren't enough words to thank my wonderful committee. Dr. Patricia Richards, thank you so much for your constant kindness, encouragement, support, and impeccable counsel. I have learned so much about archaeology and research from you, and have finally broken the spell of those paragraph-long sentences. Dr. Joseph P Gray, thank you so much for your patience in the face of my constant questions and thank you for your excellent guidance through the world of R and statistics. My thesis would never have reached this point without all that each of you has contributed.

Thank you so much to Art Andersen and Peter Killoran for graciously allowing me access to the Microscribe G2 for the much extended period of data collection and research, as well as for the extensive advice and help in learning how to operate the Microscribe. Thank you so much to Dr. John Richards and the UWM CRM staff for allowing me access to the Archaeology Research Laboratory. Specifically, I am eternally grateful to Carrie Jones for her constant support, patience, help and advice. I am also grateful to Emily Epstein for her help and sunny disposition during data collection. I would also like to thank Brianne Charles, Eric Burant, Nick Richards, David Strange, and Brooke Drew for your kind support and advice about the project.

I would like to give special thanks to the amazing friends who have kept me company through long nights in the lab and who have definitely kept me sane. Shannon, Alexis, and Carrie, your belief in me and your encouragement, listening ears, bad puns, and bear strength have made all the difference and have sustained me through a truly busy year. I am so fortunate to have met you fantastic women.

Barbara, Sarah, Rachel, Helen, Kelly, and Cheri, thank you for always getting me out of my own head and giving me something to smile or laugh about. Lara and Lindsey, thank you for taking up your lofty two-part job of keeping me off the thesis ledge while also running Field Notes, and thank you to all my amazing friends in this whacky, wonderful department who have had my back and been by my side. You're all incredible.

I don't know what I would have done without my wonderful friends and family, especially you, Grandma. Nikki, Connie, and Jen, thank you for forcing me to have fun and also to never give up. Your support has made this so much better. Ashley, Stefani, and Magdalena, as you know, you are my triad of wise women and you've really earned the title. Thank you for the late night counsel, constant support and love, and of course, cat videos.

Mom and Dad, none of this would exist without you, both literally and because you are the most supportive, caring, and wonderful parents I could ask for. Mom, thank you for laughing and crying with me, passing down to me your passion and drive, not only to succeed, but to educate and help others to succeed. Dad, thank you for your support in so many ways and for passing onto me your curiosity and desire to figure out how things work. Thank you both for listening to me wax poetic about anthropology for eons on end, and for always believing in me and giving me the tools to be a pretty decent human being.

Zack, thank you for seeing all of my doubt, fear, and worry, and making sure that I took this leap anyway. Thank you for more than putting up with my busy schedule and late nights and time away so that I could strive towards a career that makes me happy. I am so lucky to have a husband who learns about my research and figures out puns related to it to make me laugh. Thank you for always knowing when it gets to be too much and doing something weird until I smile. I never could have done all of this without you.

CHAPTER ONE:

INTRODUCTION AND REVIEW OF LITERATURE

Utility of Osteological Change Analysis

The ability to read the inscription of life lived on the human skeleton can provide insight into identity and life experience, improve the life history understanding of groups, and illustrate the individual experience of the human condition. Often, osteological remains represent one of the very few links we retain between the present, and individuals or populations of the past. It is for this reason that methods of osteological investigation are continually evolving to better represent these individuals with whom we have been entrusted. This endeavor is at the core of the work of the Milwaukee County Poor Farm Cemetery Project (Richards et al., 2015). In line with that project, the purpose of this study is to further the work of representing and contextualizing the life experiences of those interred in the cemetery through the use of one of these recently expanding methods of osteological investigation: the study of entheseal change. Entheseal change analysis is the study of osteological change at the footprints that mark the interfaces between bone and muscle at different attachment sites throughout the body (Villotte, 2013; Henderson et al., 2013). This study undertakes the investigation of entheseal change of the rotator cuff by using a replicable non-metric scoring method and 3D geometric morphometric analysis.

In addition, this project validates a multi-factorial approach to understanding osteological change through the analysis of changes at the attachment sites of the primary rotator cuff muscles: subscapularis, supraspinatus, infraspinatus, and teres minor. These changes take place within the contexts of age, pathology, activity, and other individual factors. This multi-factorial approach aims

to enable a more accurate discussion about activity by beginning the process of distinguishing activity related changes from other changes such as concurrent pathology, trauma, and age.

Significance of Systemic Pathology

This study also strives to add depth to the discussion about pathology by illustrating the full extent to which some disorders affect non-adjacent areas of the body. For instance, in cases of spondyloarthropathies, periosteal infection, or traumatic injury, there are ramifications that radiate beyond the structures primarily affected by disease or trauma. The aim of entheseal change research, then, should not be simply to clarify the utility of activity-oriented entheseal change analysis, but to further illustrate and examine the dynamic and integrative nature of the human skeletal system and its role in the etiology of a myriad of illnesses. For instance, the periosteum plays a significant role in various lymphatic metastatic carcinomas, illustrating its communicative and connective interaction with other tissues and organ systems (Marchetta et al., 1964). In addition, current clinical literature reveals a link between spondyloarthropathy and joint pain, inflammation, and change at satellite locations throughout the body (McGonagal; 2005), and other studies (Eshed, et al., 2007) pose the possibility of a connection between injury to the periosteum and increased levels of degenerative joint change at satellite locations throughout the body.

Review of Literature

The human body, and the human skeleton in particular, has long been recognized as the last voice of the dead. What anthropologists often encounter while attempting to make sense of life and death are bones, often devoid of tendon, ligament, other soft tissue, and often out of context. These remains are not the sum of a human being, but may be the only remaining available means to understand and identify that individual.

In this way, anthropological analysis of human remains is often complicated. The concept of the inscription of life events on the human skeleton has been well investigated and documented (Henderson, 2010; Benjamin et al., 2006; Niinimäki, 2011), but examinations of living tissue and current clinical studies to understand skeletal remains has been underrepresented in the literature until recently (Mariotti et al., 2007).

The study of musculoskeletal interaction and dynamics has been a continuously expanding aspect of the field of osteology, particularly in recent years. The roots of this work, however, occur relatively early. Julius Wolff, in 1892, states that "Every change in the form and function of bone or of their function alone is followed by certain definite changes in their internal architecture, and equally definite alteration in their external conformation in accordance with mathematical laws" (Wolff 1892, 1986:23). This concept is a cornerstone of analyzing musculoskeletal dynamics and has given rise to other important principles regarding bone's reaction to external and internal stressors.

These principles include the idea that various stimuli, including mechanical ones, can cause bone formation or resorption, and that these reactions are not coupled biologically, but can act as separate agents (Frost, 2003:176). Seen in Figure 1 is a comparison of the trabecular architecture of the human proximal femur between (a) Wolff's original analytical trajectory (Wolff, 1892, 1986), (b) a natural proximal femur radiograph (Skedros and Baucom, 2007), and (c) a simulated radiograph based on the final computational results (Boyl and Kim, 2011).

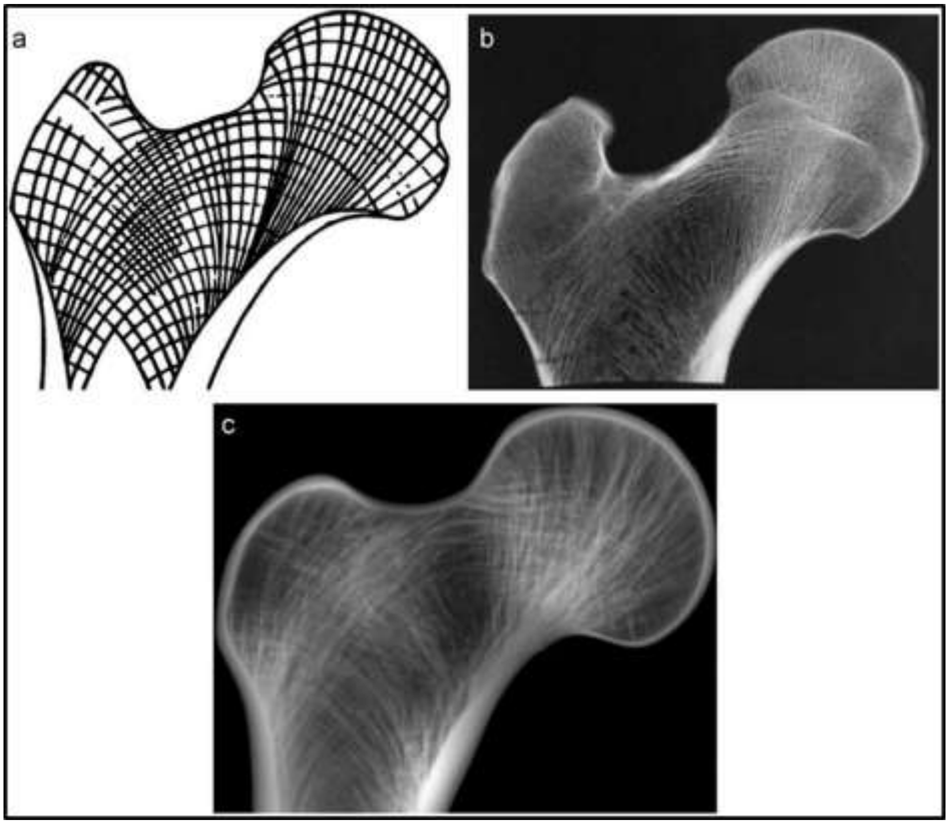

Figure 1. Wolff's law represented in theoretical sketch, in vivo radiograph, and radiographic simulation, adapted from Boyle and Kim 2011.

Closely related to this is the assertion that the internal architecture of trabecular bone undergoes adaptive changes, which are followed by secondary changes to the external cortical bone (Wolff, 1892), enabling a set of specific biogenic processes to be attributed to landmark formation. These processes, however, can be spurred, interrupted, and even uncoupled by factors such as aging, periosteal trauma or infection, and biomechanical stress (Bisseret et al., 2015).

Musculoskeletal Stress Marker Research and Beyond

The visibility of this marked and observable change to the areas of bone known to be associated with specific musculature has spurred the investigation of attachment sites in juxtaposition with the known biomechanical stressors attributed to various activities (Hawkey and

Merbs, 1995). This musculoskeletal stress marker research has been aimed at developing a widely accepted method of determining a direct correlation between markers on bone and past life activities and life histories (Merbs, 1998).

Counter to this goal, disparities of interpretation have arisen when conducting these analyses due to the dynamic nature of living bone and its multivariate interactions with muscular and connective tissues. The etiology of these changes has many underliers such as age, sex, pathology, physical activity, and individual variation, which need to be identified in order to fully evaluate entheseal change. Unfortunately these factors often overlap, making it difficult for researchers to make clear distinctions (Cardoso and Henderson, 2010). In addition, a need for increased standardization and improved analytical approaches for landmark scoring and interpretation is evident throughout the literature (Peterson and Merbs, 1998).

Despite these challenges, many recent works have begun to build a stronger framework in which to interpret entheseal change. Cardoso and Henderson call for an integration of age related changes into the discussion about entheseal change, which requires systematic and replicable age estimation methods (Cardoso and Henderson, 2013). Accurate standard estimation of the relative osteological age of the individual being examined is crucial to the process of delineating skeletal traits and change conditions. Particularly within the study of entheseal change, a key factor is to account for the change aging causes to the dynamics of bone cell populations, which can uncouple the normal process of bone resorption and formation, which alter the path of change to bone architecture (Kiebzak, 1991:178). The resulting elevated levels of entheseal change expression associated with age reflected in muscle attachment sites affect what can be asserted about the impact of biomechanical loading and change what inferences can be made about labor intensity (Niinimaki, 2011).

In August of 2015, Henderson et al (2015) proposed additional modifications to the 'Coimbra Method' entheseal change scoring system. Earlier versions of this system were used in this research, but unfortunately the August 2015 update of the method was unable to be used for this project as data collection had already taken place. However, there are a number of recommendations made in the 2015 paper that the researcher had already adopted: the use of strong natural and oblique lighting during analysis of entheseal change features, the classification of cavitations as pores with larger subcortical cavities, and the observation of the maximum extent of the fibrocartilaginous portion of the enthesis are all methods included in this research.

In addition, data gained from clinical studies of muscle, bone and joint interactions in living individuals reveals a connection between localized arthropathy (or specific joint inflammation) and enthesopathy of unrelated synovial joints, or capsule-type joints at various uncoupled points throughout the same individual (Eshed et al., 2007; Zytoon, et al., 2014). Periostalgia (noted in archaeological contexts as periostitis), or the inflammation of periosteal tissue, has also been found in clinical contexts to be associated with increased entheseal change at non-adjacent loci, as observed by Eshed: "On MRI, the [spondyloarthropathies] are associated with extensive inflammatory changes at a considerable distance from the enthesis, illustrated at the plantar fascia and Achilles' tendon where enthesitis is associated with marked osteitis or synovitis in the immediately adjacent tissues." (Eshed, 2005: 59). These MRI diagnostics have prompted researchers to test for the effect of concurrent osteopathologies on entheseal change. Finally, more accurate and expressive morphometric analysis is also available as evidenced by Nolder (2013), allowing for the bolstering of entheseal change research with multiple lines of evidence. These advancements create a multifaceted framework in which entheseal change may be studied.

CHAPTER TWO: HISTORICAL BACKGROUND

The sample for this study is drawn from individuals excavated from an abandoned cemetery in Wauwatosa, Wisconsin. Cemetery 2, also known as the Paupers Cemetery – Froedtert Tract (MI-0527, BMI-0076), is located on the Milwaukee County Institution Grounds (MCIG). This cemetery opened in 1882 and closed in 1925. Based on excavated burial density and Milwaukee County Death Certificates, Cemetery 2, if continually utilized until abandonment, may have held 7222 burials (Richards et al., 2015). Figure 2 illustrates the location of the cemetery and Milwaukee County Grounds within the State of Wisconsin.

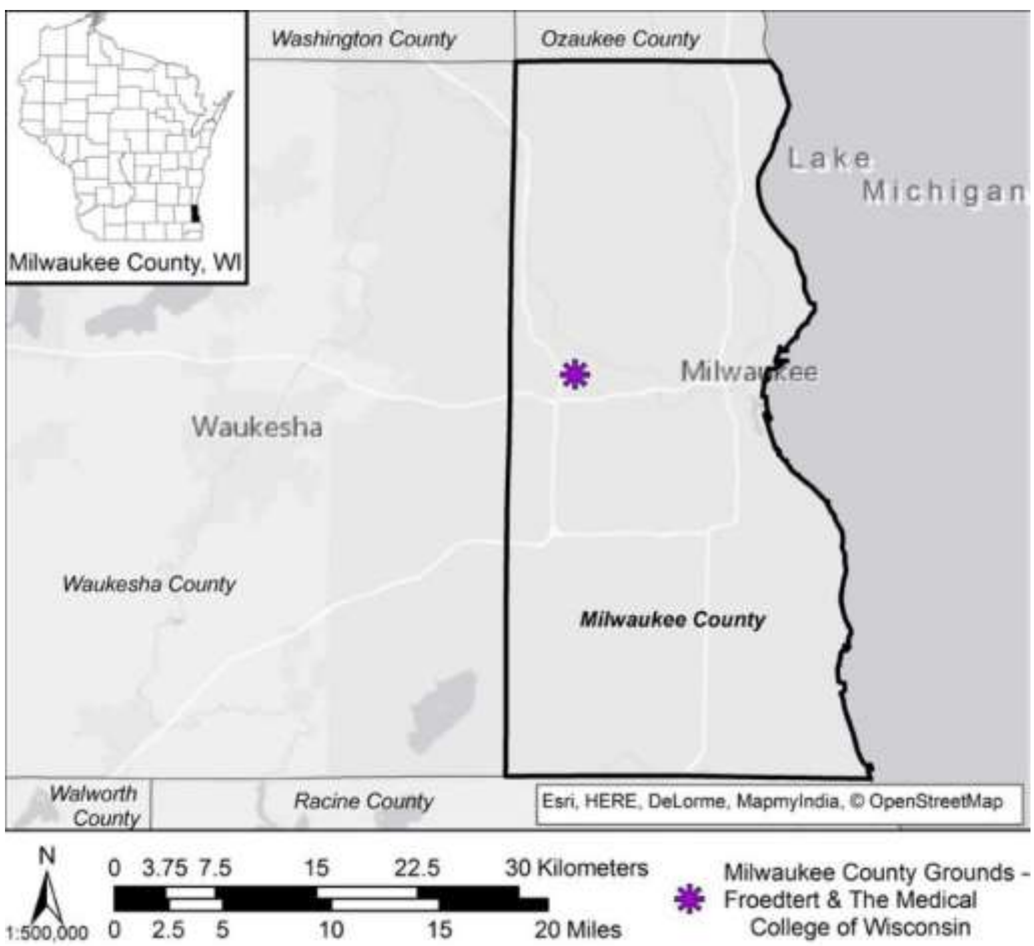

Figure 2. Location of Cemetery 2 and the project location for the Froedtert Tract (MI-0527, BMI-0076) excavations. (Adapted from Richards et al., 2015.)

In the spring and summer of 2013, approximately 0.5 acres of land in the area of Cemetery 2 was excavated in accordance with the Wisconsin Burial Site Preservation statute (Wis. Stat § 157.70). This statute requires proper protection and reporting of human remains when encountered during construction disturbances, and prohibits intentional disturbances of burial sites without express permission of the Burial Site Preservation Board and professional archaeological supervision. These excavations are recorded in the University of Wisconsin-Milwaukee Cultural Resource Management 2015 Report of Investigation (Richards et al., 2015). These excavations represent the second portion of the cemetery to be excavated to date. The first excavations took place in 1991 and 1992 (Richards and Kastell, 1993). The 2013 excavations facilitated the removal of 632 individual burial locations containing the remains of a minimum of 665 individuals, including 381 adults and 284 juveniles. The following age categories were determined for the adults: 40 young adults (20-34.9 years), 174 middle adults (35-49.9 years), 84 old adults (50+ years), and 83 individuals of indeterminate age. Of the adults for whom sex could be determined, 82 percent are males and 18 percent are females. There are 50 commingled lots in addition to the single adult lots. These represent a minimum number of individuals of 166, which brings the total number of potential individuals represented by this collection to 831 (Richards et al., 2015).

After the excavations, all recovered individuals and material culture items were brought to the University of Wisconsin-Milwaukee Archaeology Research Laboratory for stabilization and analysis. This collection is now temporarily curated at the University of Wisconsin-Milwaukee Archaeology Research Laboratory until final disposition is determined by the Wisconsin Historical Society.

Many individuals were buried in the cemetery over its long tenure. The poor, institutionalized, unknown, and unclaimed all found places there (Richards, 1997:11). Cemetery 2 was utilized by the Milwaukee County Institutions as a final resting place for residents of the county institutions, individuals who could not afford a plot, and for individuals who were unable to be identified (Richards et al., 2015). Cemetery 2 was not the only burial ground utilized by the Milwaukee County Institutions. There are three other cemeteries on the grounds that were used by the county institutions in both earlier and later periods. Figure 3 illustrates the locations of each cemetery.

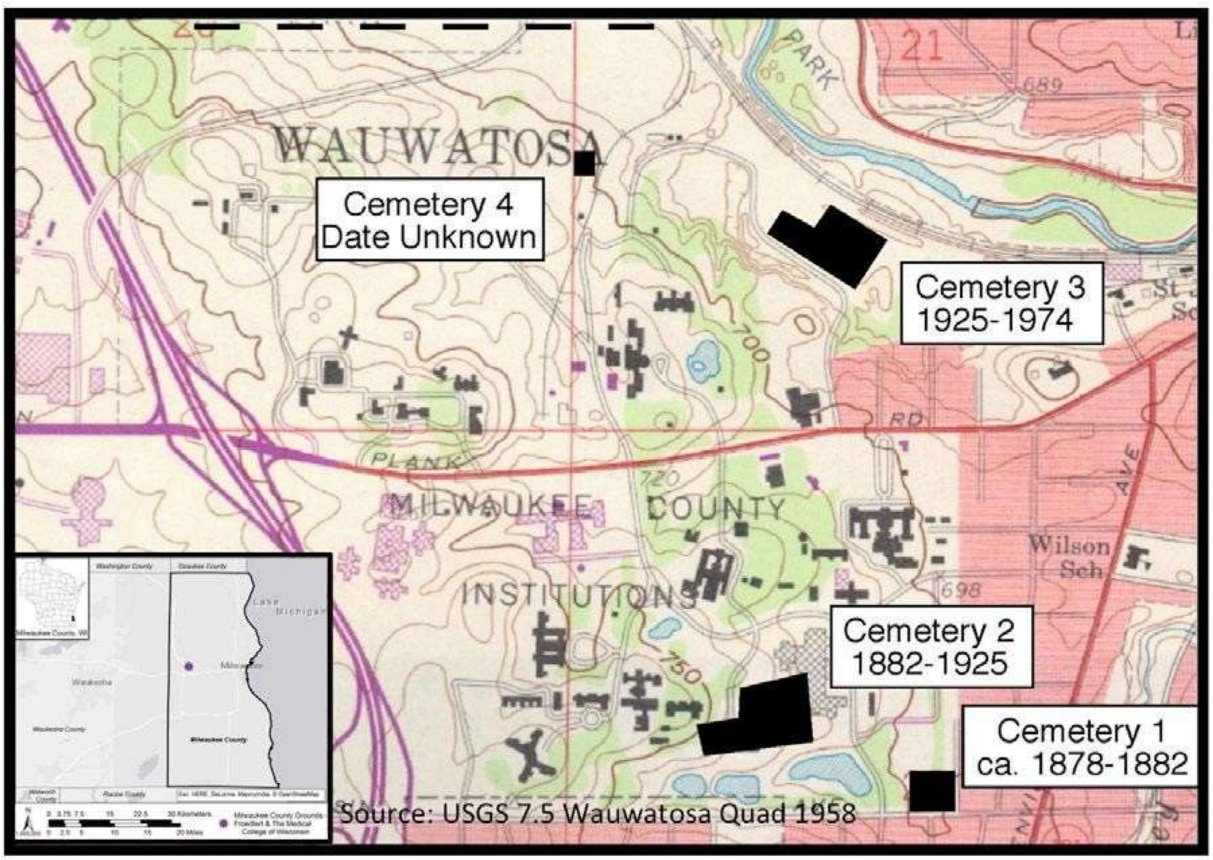

Figure 3. Cemetery Locations at the County Grounds including Cemetery 2. (Adapted from Richards et al., 2015)

The Milwaukee County Institution Grounds was first occupied in November of 1852 as a result of the burgeoning "Indoor Relief" program designed as a refuge for the poor (Richards et al.., 2015). The original purchase of land encompassed 160 acres approximately seven miles west of the City of Milwaukee. The number of people living at the Almshouse and Poor Farm grew, and the County built a school on the grounds. At this time, in 1856, the poor, the sick, orphans, and the insane all resided together in the Almshouse and Poor Farm (Richards et al., 2015).

The county grounds continued to expand as the County added a hospital in 1860, and by 1898 the county grounds and institutions included a larger General Hospital, the Milwaukee County Asylum for the Chronically Insane, the Home for Dependent Children, and a new Almshouse for the poor (Richards et al., 2015). It is reflected by institution records, death certificates, coroner's reports, and hospital data that the individuals recovered in the 2013 excavations, particularly males represented in these excavations, would have engaged in physical labor during a substantial portion of adult life. The Annual Report of the County Farm and Almshouse: 1896 demonstrates this: of the 592 almshouse occupants, the two most represented occupations were laborers (270 individuals), and farmers (83 individuals) (Richards, 1997:69).

Individuals who were residents of the almshouse would have partaken in intensive labor in their occupations prior to entering and while residing at the almshouse, participating in activities to sustain the running of the grounds and almshouse. Individuals who were not residents of the institutions but who were buried in the cemetery for other reasons often were documented to have labor intensive occupations. This lifelong engagement in physical activity places a great deal of strain on the condition of the physical body.

In addition, many Milwaukee residents of the time identified as immigrants or the descendants of immigrants. Though census data from 1910 reflects that by that time only 17 percent

of the population was German born, 53.5 percent of city residents identified themselves as of German heritage (Still, 1945; Richards, 1997:87).

It is possible that the struggles associated with immigration and settlement made their mark on these individuals. Leavitt (1996:9) reports on these struggles and the possible cultural and practical burdens associated with them.

> At the same time that public health activity lead to declining mortality rates and offered many Milwaukeeans increased life expectancy, it also put added burdens on people whose lives were already beset by hardships. In the culturally diverse setting of Milwaukee, health officers met resistance to their policies, not because people disagreed with the goals of bringing health to the community, but because some of the changes contradicted accustomed behaviors and added to personal suffering.

The encumbrance of health reform, particularly in the form of pressure to alter traditions and life choices appeared to particularly burden immigrants and the poor as they were reluctant to stay away from the sick and dying because of familial connections and mortuary customs (Leavitt, 1996:8). In addition, the costs of improved medical care and the distrust of some biomedical techniques practiced at this time period hampered the improvement of medical conditions for these individuals.

The intersection of these struggles is manifested in the osteology of these individuals, resulting in the expression of highly exacerbated osteological conditions due to long periods of continuing to perform labor-intensive activities while suffering from injury or disease. This hardship is only one facet of the lives of these individuals, but these factors in the lives of those represented by the remains recovered during the 2013 excavations have influenced their osteology, enabling investigators to better understand the impact of life activities and circumstances on these individuals.

CHAPTER THREE: THEORETICAL FRAMEWORK

Figure 4. A Milwaukee crew digging a trench and laying drain tile. Date unknown. (Courtesy of the Wisconsin Historical Society, WHS ID: 101470)

Osteological Change and Life Lived

Osteological change takes many forms, some of which have the potential to accurately represent the lived experience inscribed on the skeletal remains of an individual. However, unlike pathological or traumatic inscription, entheseal change represents the living body in motion and the dispositions, habits, and actions of the living individual.

Entheses are defined as the areas where a tendon, capsule, or ligament attaches to bone (Villotte, 2013:3). There are two main types of entheses: fibrous entheses, which attach soft tissues to the bone directly or via the periosteum, and fibrocartilaginous entheses which interface with the bone in four zones. (Villotte, 2013:3). Fibrocartilaginous entheses are distinguished by four

histological zones and a tidemark, which is a regular calcification front that separates the calcified and uncalcified fibrocartilage. The tidemark (TM) between the calcified and uncalcified zones of articular cartilage (AC) is continuous with that at the insertion of the tendon. (Benjamin, et al., 2006; Cooper and Misol, 1970)

The cellular interactions between the tissues of bone, tendon, ligament, and cartilage at these attachment sites result in changes of the osseous structure both in terms of general size and rugosity as well as within the surface structure of the cortical bone. The changes made to the cortical bone are observable in the form of bone deposition, erosion, and porosity.

These factors add to the usefulness of entheseal change analysis, but it is important to remember that entheseal change is not simply the representation of only the living, moving body and individual repeated activity, but rather a result of praxis and embodiment at the intersection of health, trauma, and activity.

CHAPTER FOUR: MATERIALS AND METHODS

Osteological Sample

The investigation of the effects of age, pathology, and activity on the human skeleton in general, and entheses specifically, aids in further clarifying the biological processes associated with osteological change and deepens the representation of the individuals represented by the 2013 MCIG excavations, in which the high levels of expression of pathology, age, and external stressors reveal a biological representation of these individuals' life experiences. The sample of individuals (n=50) included in this study included those who died in the 19th and 20th centuries and were interred in Cemetery 2 of the MCIG. The individuals that were selected were analyzed to determine age at death, sex, stature, pathology and trauma, by the researcher and UWM CRM skeletal analyst staff using standard protocol. These pathology and trauma categories are defined in Table 1. Burial locations of these individuals are represented in Figure 5 on the following page.

Table 1. Pathology and trauma definitions. Adapted from Richards et al., 2015.

Pathology or Trauma Category	Characteristic Presentation
Osteogenic	Irregular and excessive bone deposition. This includes osteophytes, osteoblastic activity, and neoplastic growth.
Infection	Generalized osteolysis, periostitis, osteomyelitis, abscesses, or treponematosis.
Generalized Joint Disease	Generalized local and satellite joint disorder: collapsed bone, schmorl's nodes, osteophytic lipping, spondylolysis, and spondyloarthropathy.
Antemortem Trauma	Fractures and osteological wounds that show evidence of healing characterized by evidence of bone remodeling, calluses, and woven bone.
Vertebral Ankylosis	General abnormal fusion of vertebral joints.
Vertebral Degenerative Joint Disease	A degenerative porotic change in the subchondral bone and the formation of osteophytes at the margins of the articular surface of vertebrae.
Periostitis	Inflammatory periosteal reactive growth. When coupled with a cloaca, osteomyelitis is observed.

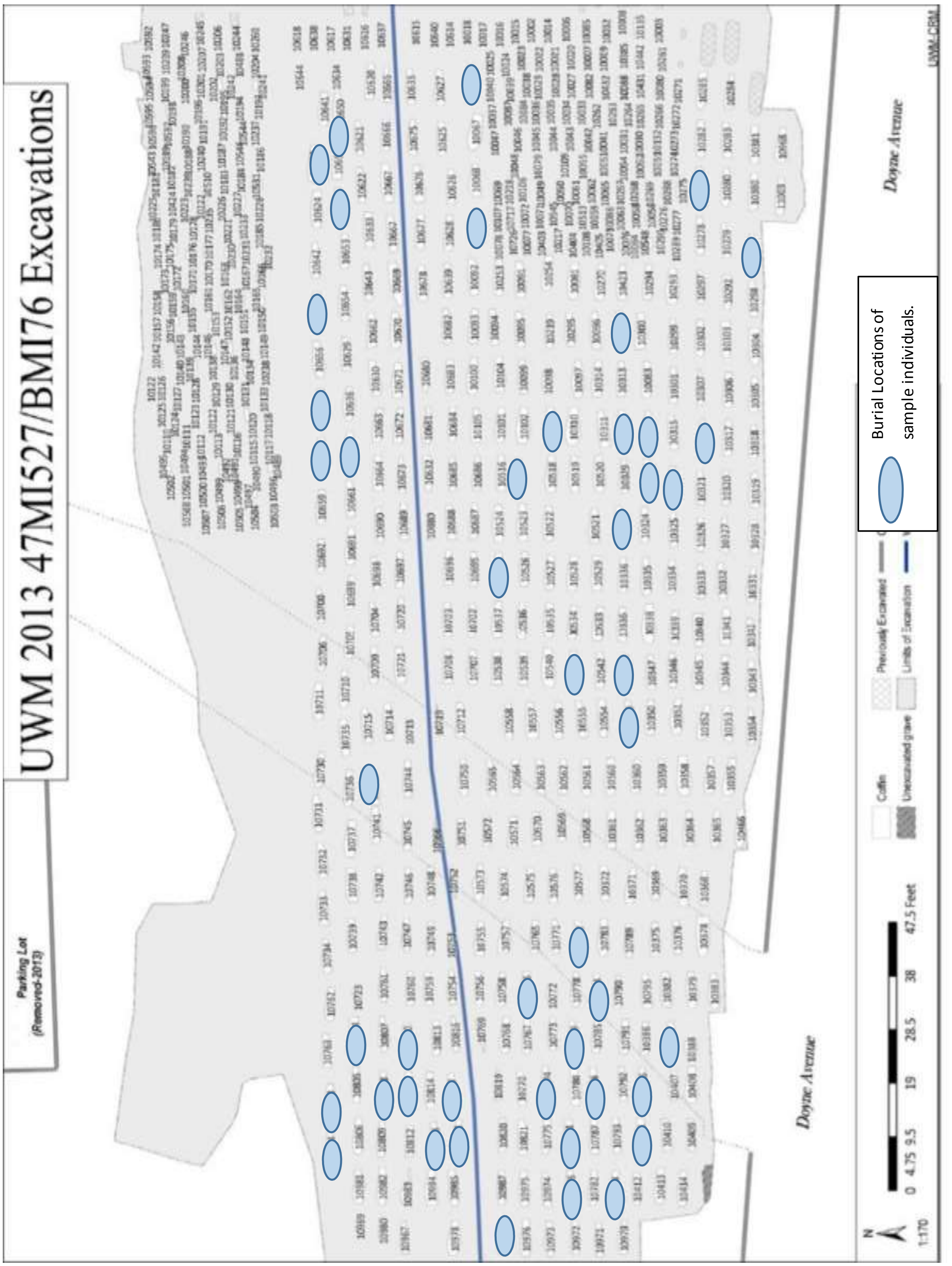

Figure 5. Burial Locations of sample individuals in UWM 2013 47MI527/BMI76 Excavation area. Adapted from Richards et al. (2015).

Non-metric sex estimation followed Phenice (1969) for the pelvis, and Acsadi and Nemeskeri (1970) for the cranium. Osteometric analysis of sex was also undertaken, using the left element as the preferred standard. These osteometric measurements included the length of the talus (after D. Gentry Steele 1970), the vertical diameter of the humeral head (following Stewart 1979; Spradley and Jantz 2011), and the maximum diameter of the femoral head, (following Stewart 1979; Spradley and Jantz 2011).

Age was assessed through standard non-metric analysis of the pubic symphysis (following Brooks and Suchey, 1990), the auricular surface (Osborne et al. (2004), a refinement of Lovejoy et al. (1985)), and cranial suture closure (following Meindl and Lovejoy (1985)).

The individuals selected for this study were those that had been assigned an estimated non-metric and metric sex of male. Males were selected to reduce error in two areas. The first area included the possible differences in the etiology of osteometabolic processes between males and females. The second was to mitigate the effects of the low number of recovered adult female single individuals within the 2013 excavated sample (57 females, or 15%) (Richards et al., 2015).

The individuals were divided into three age cohorts: 10 (20%) Young Adult Male (aged 20-34.9 yrs.), 28 (56%) Middle Adult Male (aged 35-49.9yrs), and 12 (24%) Old Adult Male (aged >=50yrs). This age distribution reflected the general age distribution of males recovered from the Milwaukee County Institution Grounds Cemetery during the 2013 excavations: 31 (12%) Young Adult Male (aged 20-34.9 yrs.), 130 (49%) Middle Adult Male (aged 35-49.9yrs), 67 (14%) Old Adult Male (aged >=50yrs), and 39 (14%) males for whom age could not be determined. The distribution of this sample is similar to the age distribution of Milwaukee residents during the early 1900s and 1920s. During this time, the City of Milwaukee population, as reflected in census reports, included a large number of middle adults, with fewer young and older adults (Richards, Richards and Drew,

2015: 24). The individuals represented within these age cohorts come from a wide variety of contexts. Based on holistic osteological, material culture, and medical intervention analysis, Richards (1997, 2015) developed context categories that represent the possible life pattern and residence of individuals. Each individual in the sample is represented in Figure 6 by age cohort. These data will help to better represent the significance of the entheseal change of individuals in each cohort.

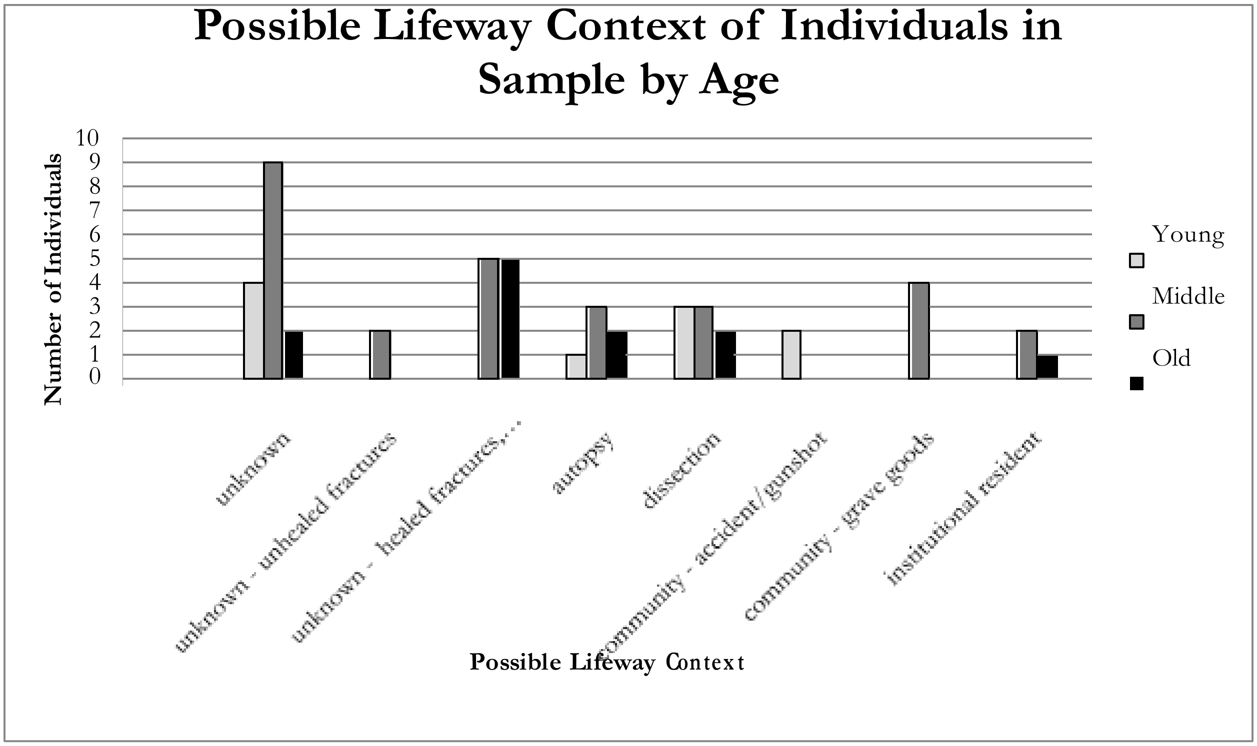

Figure 6. Possible Lifeway Context of Individuals in Sample by Age. (Adapted from Richards et al., 2015).

Within the age cohorts, each individual was assigned a mean osteological age based on three separate standard age assessments undertaken once an individual was determined to be an osteological adult via field assessment and fusion assessment in the lab, as well as once osteometric and non-metric sex assessment took place. The mean osteological age is composed of the result of pubic symphysis morphology analysis (Brooks and Suchey 1990), auricular surface assessment (Lovejoy, et al., 1985), and ectocranial suture closure assessment (Meindl and Lovejoy, 1985). These

mean ages enabled a more fine-grained analysis of the potential correlations between age and entheseal change and also enabled a clearer linear regression analysis.

Evidence of pathology and trauma was also recorded for each individual during UWM-CRM osteological analysis and confirmed during entheseal change analysis using standard osteopathology recording methods (Ortner, 2003; Luckas, 2012; Waldron, 2009). Nearly every individual represented in the 2013 excavations presented some osteopathology. "Three hundred seventy-five adult individuals (98.4%) exhibit some form of skeletal pathology; the six that do not were too damaged by the burial environment or by previous construction to make analysis possible." (Richards et al., 2015) This high rate of pathology enabled a spectrum of different pathological changes to be studied alongside entheseal change in the hopes of clarifying pathological conditions which may have more impact on joint complexes than others. However, the high rate of some pathologies across the sample did cause some statistical difficulty. In addition, the study of any individuals completely free from pathology was precluded with this collection. The details for each individual included in the sample is seen in Table 2, below.

Table 2. Demographic Information for all individuals in the sample. Adapted from Richards, et al., 2015

Lot Number	Sex	Mean Age	Bone Formation	Joint Pathology	Infection	Trauma
10066	Male	53.85	Present	Present	Present	Present
10073	Male	40.1	Present	Present	Absent	Present
10103	Male	47.8	Present	Present	Present	Absent
10281	Male	38.5	Absent	Present	Present	Absent
10285	Male	39.75	Present	Present	Present	Present
10291	Male	54.5	Present	Present	Absent	Present
10296	Male	58.9	Absent	Present	Absent	Absent
10308	Male	40	Absent	Present	Present	Absent
10312	Male	45	Present	Present	Present	Absent
10316	Male	39.15	Present	Present	Absent	Absent
10323	Male	47.2	Present	Present	Present	Present

Table 2, Continued. Demographic information for all individuals in the sample. Adapted from Richards, et al., 2015.

Lot Number	Sex	Mean Age	Bone Formation	Joint Pathology	Infection	Trauma
10330	Male	29.4	Present	Present	Present	Absent
10349	Male	47.75	Present	Present	Present	Absent
10387	Male	47.9	Present	Present	Present	Present
10406	Male	45	Present	Present	Absent	Absent
10411	Male	50	Absent	Present	Absent	Absent
10451	Male	49.85	Present	Present	Absent	Absent
10467	Male	30.1	Present	Present	Present	Present
10517	Male	40	Present	Present	Absent	Absent
10523	Male	55	Present	Present	Present	Present
10541	Male	59.49	Present	Present	Present	Absent
10623	Male	55	Present	Present	Present	Absent
10650	Male	40	Absent	Present	Present	Absent
10652	Male	40	Present	Present	Present	Absent
10657	Male	49.95	Present	Present	Present	Present
10658	Male	40	Present	Present	Present	Absent
10660	Male	47.8	Present	Present	Present	Absent
10665	Male	49	Present	Present	Present	Present
10740	Male	45	Absent	Present	Present	Present
10745	Male	54.4	Present	Present	Absent	Absent
10760	Male	48.85	Present	Present	Present	Absent
10764	Male	53.1	Present	Present	Absent	Absent
10766	Male	42	Present	Present	Present	Absent
10774	Male	45.65	Present	Present	Absent	Present
10776	Male	29.5	Present	Present	Absent	Absent
10777	Male	30	Absent	Present	Present	Absent
10779	Male	45.65	Absent	Present	Present	Absent
10781	Male	29.5	Present	Present	Absent	Absent
10784	Male	45	Present	Present	Present	Absent
10786	Male	30.7	Present	Present	Absent	Absent
10794	Male	55.2	Present	Present	Absent	Present
10803	Male	52.5	Present	Present	Absent	Present
10804	Male	36.35	Present	Present	Present	Absent
10808	Male	29.5	Present	Present	Present	Absent
10810	Male	40	Present	Present	Absent	Absent
10811	Male	30.25	Present	Present	Present	Absent
10815	Male	53.85	Present	Present	Present	Present
10817	Male	33.85	Present	Present	Present	Absent
10818	Male	42.5	Present	Present	Absent	Absent
10977	Male	30	Present	Present	Present	Absent

Macroscopic and Histological Components of Fibrocartilaginous Entheses

To analyze entheseal change, it is important to first identify the features that distinguish fibrocartilaginous entheses from fibrous entheses. Fibrous entheses are relatively simple attachment sites that connect muscle or other soft tissues to the bone via the periosteum, resulting in a diffuse attachment with indeterminate borders (Henderson et al., 2010). Fibrocartilaginous entheses, which attach to the bone via a direct cartilaginous interface, leave distinct "footprints" that can be readily recognized and delineated, particularly when the histological components of the attachment are well understood. Figure 7 outlines the macroscopic components of this interface for the supraspinatus attachment site. Zone I is superficial and composed of fibers from the coracohumeral ligament, extending obliquely and posteriorly. Zone II is composed of densely packed tendon, while Zone III, at a 3 mm cross-sectional width, is composed of collagen bundles at a 45 degree angle to the tendon. Zone IV is the transitional area, composed of loose regular connective tissue and collagen bands that merge with the fibers of the coracohumeral ligament. Finally, Zone V represents the shoulder capsule (Stadnick, 2007).

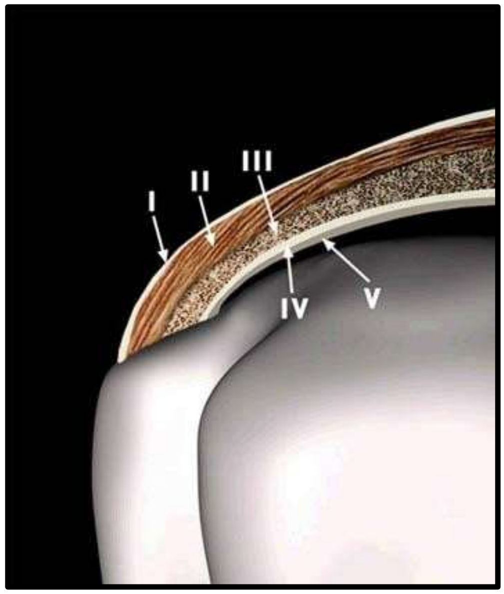

Figure 7: A 3D illustration of the supraspinatus insertion. I-V represent macroscopic tissue zones. (Adapted from Stadnick 2007)

These macroscopic zones correspond with the histological zones outlined by Jurmain and Villotte within a fibrocartilaginous enthesis (following Benjamin et al., 2006; Cooper and Misol, 1970). These zones are as follows: 1) tendon or ligament, 2) uncalcified fibrocartilage, 3) calcified fibrocartilage and 4) subchondral bone. "Zones 2 and 3 are avascular and separated from each other by a regular calcification front called the "tidemark" (Jurmain, 2010: 1). The tidemark is the transitional zone prior to which soft tissues exist that usually do not survive archaeological processes (Benjamin et al., 1986). However, zone 3, composed of calcified fibrocartilage, often survives in the archaeological context (Henderson and Gallant, 2005). These zones can be clearly viewed in the histological sample of Figure 8.

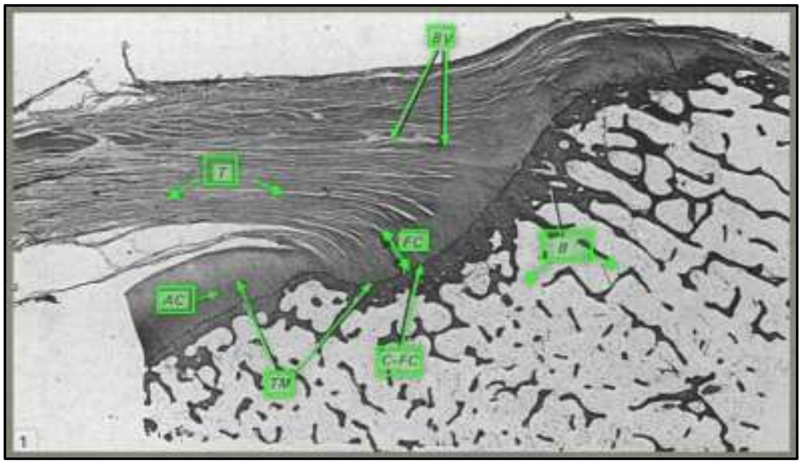

Figure 8. The Supraspinatus Insertion Prepared Slide (Adapted from Benjamin et al., 1986: 91)

The Rotator Cuff Muscles

The rotator cuff is primarily made up of four muscles: subscapularis, supraspinatus, infraspinatus, and teres minor. These muscles attach proximally on the scapula. The subscapularis attaches at the anterior surface of the subscapular fossa, the supraspinatus attaches at the medial portion of the supraspinous fossa, the infraspinatus attaches at the medial aspect of the infraspinous fossa, and the teres minor attaches at the posterior upper and middle aspects of the lateral border of the scapula (Curtis 2006). The rotator cuff muscles attach laterally on the greater and lesser tubercles of the humerus (Richards et al., 2007, Numura et al., 2012, and Lumsdaine et al., 2015). The subscapularis attachment covers the entire superior surface of the lesser tubercle (Richards et al., 2007),, the supraspinatus attachment is marked by the most anterior facet of the greater tubercle, the infraspinatus is marked by the medial, most superior facet of the greater tubercle, and the teres minor is marked by a facet on the most inferoposterior portion of the greater tubercle of the humerus (Numura et al., 2012, Lumsdaine et al., 2015).

The broad proximal scapular attachments, combined with the acute angle of the humeral attachments, as well as the comparatively small footprints of the humeral attachment sites,

contribute to a highly mobile yet stabilized glenohumeral joint (Richards et al., 2007:253). The tradeoff for such a highly mobile joint with a great degree of stabilization is the high impact mechanical loading transmitted to the humerus, and greater and lesser tubercles specifically, due to their position at the most mobile and mechanically impacted portion of this joint. As a result of this load transmission, as well as the multi-zone structure of a fibrocartilaginous enthesis (Villotte 2010), a distinct footprint is visible where the osseous tendon interface exists, and this remains visible long after maceration (Jurmain et al., 2010). Figure 9 illustrates the directionality and angle of each of the four rotator cuff muscles in situ, including a view of the glenohumeral capsule.

Figure 9. Directionality of the rotator cuff muscles. Note the acute angle of attachment at the humerus. (Adapted from Turkel et al., 1981)

The area of attachment and the angle of attachment for each of these muscles, as well as the biomechanical and biological stress applied to the bone and entheseal interface of these attachment sites contribute to the creation of a facet. This facet contains clearly delineated borders that can be recorded and measured with systematic methods so that it may be used to quantify the changes undergone by the entheseal interface in conjunction with mechanical and biological stressors in different contexts (Niinimaki et al., 2011, Villotte et al., 2013).

Figure 10 outlines the footprints and facets of subscapularis, supraspinatus, infraspinatus, and teres minor on the greater and lesser tubercles of the humerus.

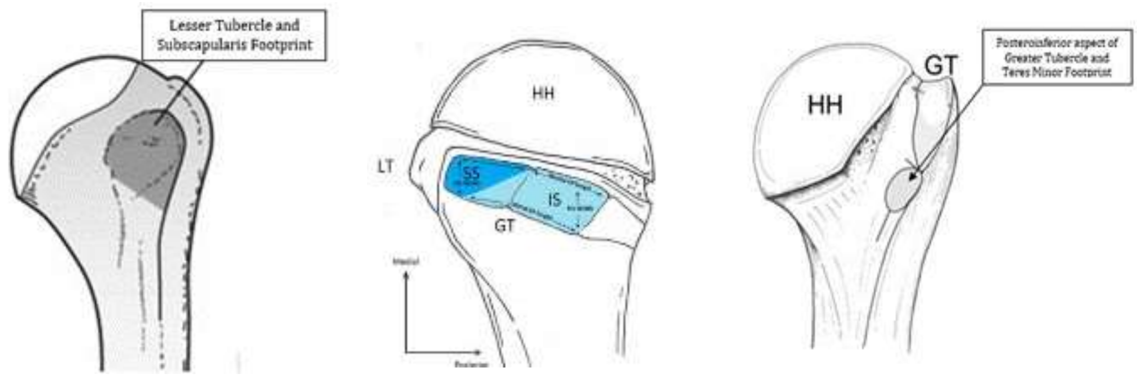

Figure 10. Footprint outlines of subscapularis, supraspinatus, infraspinatus, and teres minor. (Adapted from Richards et al., 2007, Nimura et al., 2012, and Lumsdaine et al., 2015.)

For the purpose of this study, the analyses of these footprints were conducted in two ways: first, non-metric visual entheseal change analysis via a scoring method (Villotte 2010, Henderson et al., 2012, Villotte et al., 2013). The second method employed a Microscribe G2 3D digitizer to conduct three dimensional shape analyses.

Data Collection Protocol

The non-metric entheseal change analysis conducted for this project encompassed the analysis of several main features of entheseal change in two separate zones of attachment on the greater and lesser tubercles of the humerus. Henderson et al. divide the enthesis into these two zones based on the following definitions: "… 'zone 1', [is] the contour opposite the acute angle at which the fibres attach (i.e. the more fibrous region) and 'zone 2' [is] the remaining surface and margin" (Henderson et al., 2013: 154). Within these zones there are several features that have been determined to coincide with the osseous factor of entheseal change.

These features are mainly connected to bone formation and resorption. These include bone formation (BF), erosion (ER), fine porosity (FPO), macroporosity (MPO), and cavitations (CA) (Henderson et al., 2013:154) (Henderson et al. 2013a). These disparate zones and the features scored are represented in Figure 11.

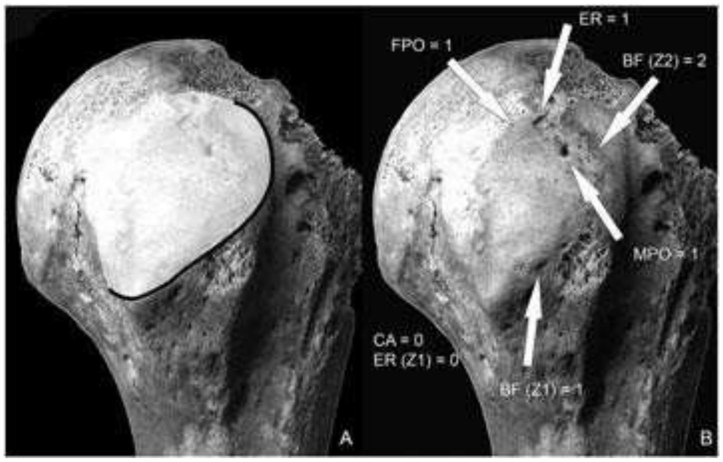

Figure 11. Subscapularis entheseal change assessment area. A) The area of Zone1 is represented by the black outline, while Zone 2 is represented by the gray area. B) Example scores for each feature. (Adapted from Henderson et al., 2013)

Visual analysis was conducted separately from the collection of age and pathology data, to avoid bias. The left side was used in this analysis as the preferred standard. Visual landmark data was scored using the proposed systematic data collection and scoring methods for fibrocartilaginous entheses put forth by Henderson et al in 2013. Consistent with these methods, the contour opposite the acute angle at which the fibers attach as well as the other areas of the surface and margin of the enthesis were observed. As recommended by Henderson et al. (2015), the visual non-metric analysis was conducted in strong natural light, using oblique lighting when necessary, and using magnification only to identify postmortem damage. Features seen on the entheses were scored through a 2 and 3 point degree of expression for each feature. This scale and the entheses examined are delineated in Tables 3-5 on the following pages.

Table 3. Analysis location form of Rotator Cuff Muscle Entheses.

<u>**Muscle**</u>	<u>**Abbreviation**</u>	<u>**Analyzed Attachment Sites**</u>
Subscapularis	SS	The attachment (attachment site borders and general rugosity) at the subscapularis facet on the Lesser Tubercle will be analyzed with a method adapted from the Coimbra method and digitized.
Supraspinatus	SPS	The attachment (attachment site borders and general rugosity) at the anteroproximal portion of the Greater Tubercle will be analyzed with a method adapted from the Coimbra method and digitized.
Infraspinatus	IS	The attachment (attachment site borders and general rugosity) at the superior posteroproximal portion of the greater tubercle will be analyzed with a method adapted from the Coimbra method and digitized.
Teres Minor	TM	The attachment (attachment site borders and general rugosity) at the inferior posteroproximal portion of the greater tubercle will be analyzed with a method adapted from the Coimbra method and digitized

Table 4. Zone 1 Scoring Criteria

Zone 1 **Margin opposite acute angle of fiber attachment**	Bone Formation	BF (Z1)	1 = Small, nodular or slightly raised margin < 1mm 2 = Distinctive sharp crests or other enthesophytes. ≥ 1mm but < 50% of margin 3 = Distinctive sharp crests or other enthesophytes ≥ 1mm but ≥ 50% of margin
	Erosion	ER (Z1)	1 = < 25% of margin 2 = 25 to 50% of margin 3 = > 50% of margin

Table 5. Zone 2 Scoring Criteria.

Zone 2	Bone Formation	BF	1="Roughness"/rugosity, change is diffuse, not a distinct structure 2= distinct structure measuring >1mm, affecting < 50% of the surface. 3= distinct structure measuring > 1mm, affecting ≥ 50% of surface
Remaining Margin And Surface	Erosion	ER	1 = < 25% of surface 2 = 25 to 50% of surface 3 = > 50% of surface
	Fine Porosity ≥ 1mm	FPO	1 = < 50% of margin 2 = > 50% of margin
	Macro-Porosity	MPO	1 = one or two pores 2 = > 2 pores
	Cavitation	CA	1 = one cavitation 2 = two or more cavitations

Three dimensional geometric morphometric landmark data was collected using 3D data capture with a Microscribe G2 3D digitizer (Figure 12). The Microscribe G2 allowed for points to be collected in three dimensional space with a stylus. These three dimensional points were entered into excel and saved as a comma separated values (.csv) document. These documents were then able to be read into R Studio (RStudio Team, 2015), an open-sourced statistical platform. From there, the points were rendered into a three dimensional shape in Geomorph, a package in R (Adams, et al., 2013). These represented a three dimensional outline of the muscle attachment footprint. This footprint could then be analyzed for shape changes that would be able to be more clearly observed in digitization. Figure 12 shows the setup for data collection with the Microscribe G2.

Figure 12. Microscribe G2 Digitizing Setup.

Statistical Background

This study seeks to evaluate the significance of the impact of age, pathology, and trauma on the process of entheseal change for the individuals recovered from the MCIG 2013 excavations. The type of data recovered for this study is considered bivariate. To determine the impact of age, pathology, and trauma on entheseal change scores, we assume that an increase or change in the predictor (age, pathology, and trauma) will correlate to an increase in the response variable (composite entheseal change scores.) To attempt to summarize the relationship between a response and a predictor, a simple linear regression model may be used. This model is represented by the following equation (Verzani 2014):

$$y_i = \beta_0 + \beta_1 x_i + \epsilon_i,$$

In this model, the y variable is the response variable, while the x variable is considered the predictor (Verzani 2014). While using this formula, it is understood that the value of y_i depends on the value of x_{ii}, the function of $\beta_0 + \beta_1 x$, and the value of the random error variable ϵ_i (Verzani, 2014).

Statistical Analysis

Linear regression as applied to age and each pathology category was performed on the composite scores of the left side for the subscapularis, supraspinatus, infraspinatus, and teres minor entheses. The composite score was designated as the dependent variable with age and pathology score as the predictor. Entheseal change scores were plotted against age and composite pathology presence scores.

To conduct a shape analysis, digitized entheseal footprints were rendered using open sourced statistical software: Geomorph (Adams and Otárola-Castillo 2013). Each enthesis was digitized individually and analyzed both within a Generalized Procrustes Alignment, and through

testing of shape disparity. A score for morphologic disparity was assigned to each digitized footprint. This system included a 5 point scale where 1=no morphological border change and 5=high morphological change in all axes. This scale takes into account change in only one axis, change in all three axes, and degrees of change based on the exemplar footprint illustrated by Richards et al (2007). Linear regression was performed with the shape change score as the response variable and age, pathology, and trauma as the predictor variables. An example of the three dimensional digitized enthesis is represented in Figure 13.

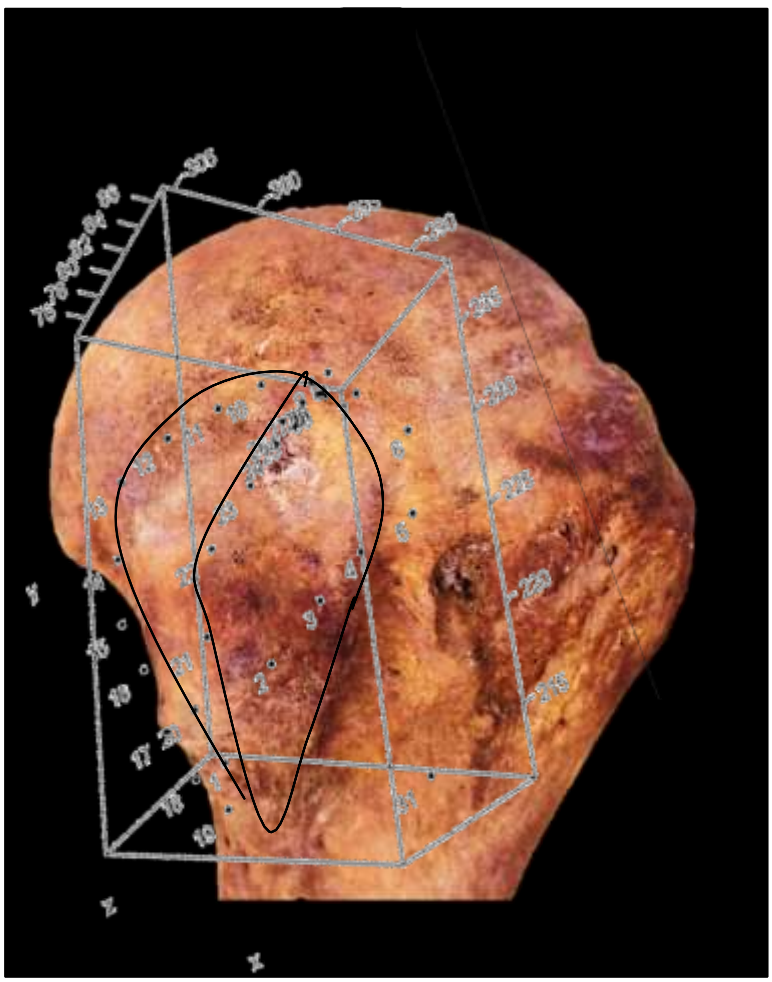

Figure 13. Three dimensional digitization of the left subscapularis enthesis superimpos d on the humerus. Lot #: MCIG 2013_47BMI_10810

CHAPTER FIVE: RESULTS AND DISCUSSION

Sample Distribution

The individuals (*n*=50) selected to test on the effect of age had a non-normal age distribution (a range of 30-55+ years, mean=43.7891 years, with a standard deviation of 8.6849, and Shapiro-Wilkes p-value of 1.595e-07), which was reflective of the age distribution of the 2013 overall excavated sample. The Normal Q-Q plot illustrating the Shapiro-Wilkes test is shown in Figure 14.

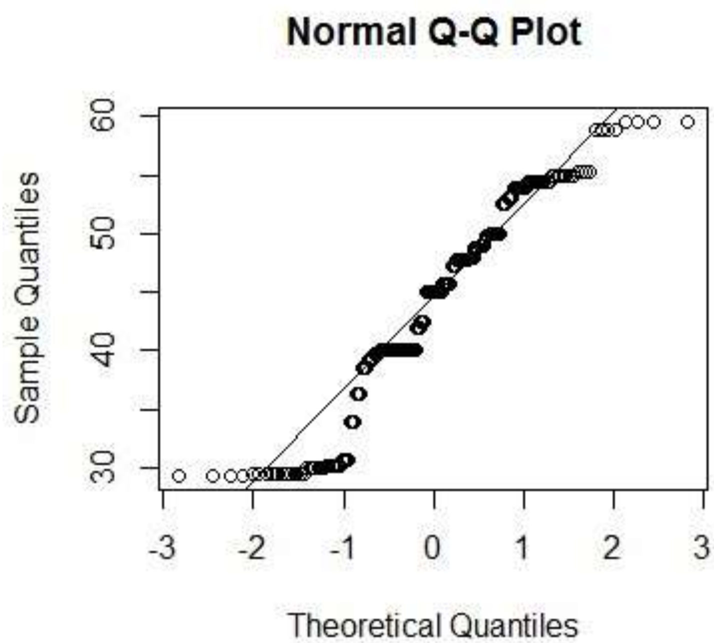

Figure 14. A Normal Q-Q plot representing the normality of the study sample.

The Effect of Age

The correlation between age and increased entheseal change scores was analyzed for all entheses using simple linear regression. The subscapularis enthesis exhibited a significant correlation between increased age and increased entheseal change scores ($p=0.0081$). Figure 15 illustrates entheseal change plotted against age.

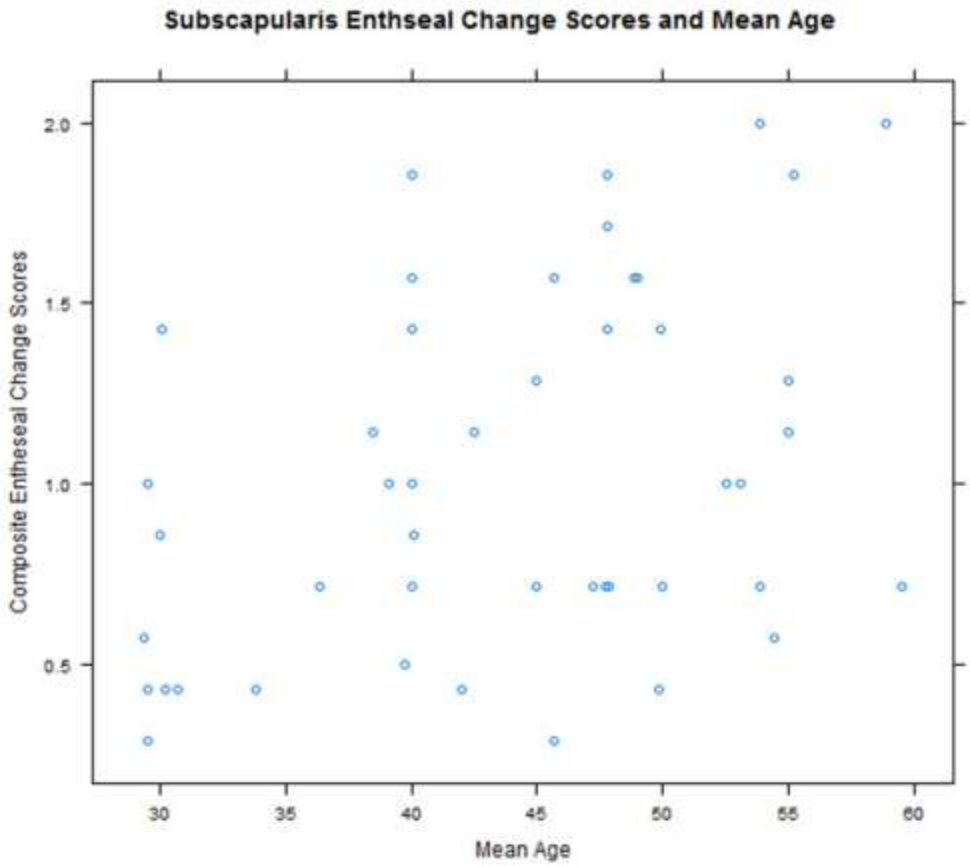

Figure 15. Plot representing age and composite entheseal change scores for the subscapularis.

Table 6 represents the results for the effect of age and entheseal change for all entheses of the left rotator cuff. P-values indicate that though significance was not assigned to supraspinatus, infraspinatus, or teres minor, subscapularis exhibits a significant correlation. The plot above illustrates the weakness of that correlation.

*Table 6. Results Table for Age and Entheseal Change Regression. * Denotes significance.*

Humeral Facet Muscle	**Number of Entheses Observed**	**Percent of Sample**	**Age and Entheseal Change P-Value**
Subscapularis	50/50	100.0	0.0081*
Supraspinatus	48/50	96.0	0.0119
Infraspinatus	45/50	90.0	0.1152
Teres Minor	34/50	68.0	0.7197

The Effect of Trauma and Pathology

Trauma was also found to have a significant correlation to increased entheseal change composite scores. Table 7 represents the results for the effect trauma, infection and entheseal change for all entheses of the left rotator cuff. P-values indicate that though significance was not assigned to subscapularis, infraspinatus, or teres minor, supraspinatus exhibits a significant correlation (*p=0.0476).*

*Table 7. Results Table for Infection, Trauma, and Entheseal Change. *Denotes significance.*

Humeral Facet Muscle	Number of Entheses Observed	Percent of Sample	Infection and Entheseal Change P-Value	Trauma and Entheseal Change P-Value
Subscapularis	50/50	100.0	0.8930	0.2510
Supraspinatus	48/50	96.0	0.3159	0.0476*
Infraspinatus	45/50	90.0	0.4300	0.0512
Teres Minor	34/50	68.0	0.5520	0.6567

Figure 16 represents the presence and absence of trauma plotted against entheseal change composite scores for the supraspinatus site.

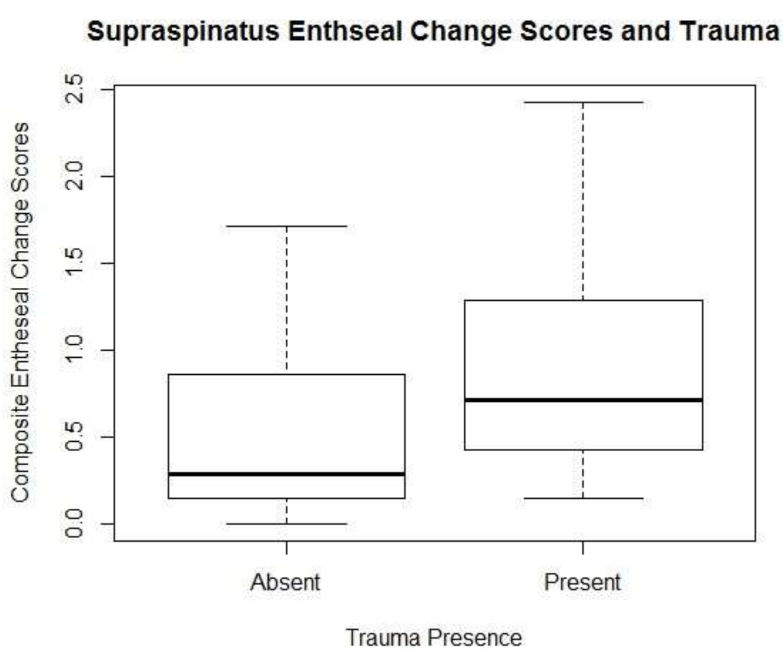

Figure 16. Composite entheseal change scores plotted against presence of trauma for the supraspinatus attachment.

Vertebral Degenerative Joint Disease was also found to have a significant correlation with higher entheseal change composite scores. Table 8 represents the results for the effect of VDJD and entheseal change for all entheses of the left rotator cuff. P-values indicate that though significance was not assigned to subscapularis or teres minor, supraspinatus exhibits a significant correlation (*p=0.0217)*, as does infraspinatus *(p=0.0013).*

*Table 8. Vertebral Degenerative Joint Disease and Entheseal Change. * Denotes significance.*

Humeral Facet Muscle	**Number of Entheses Observed**	**Percent of Sample**	**Vertebral Ankylosis and Entheseal Change P-Value**	**Vertebral Degenerative Joint Disease and Entheseal Change P-Value**
Subscapularis	50/50	100.0	0.4980	0.8930
Supraspinatus	48/50	96.0	0.9410	0.0217*
Infraspinatus	45/50	90.0	0.5470	0.0013*
Teres Minor	34/50	68.0	0.5870	0.1300

Figure 17 illustrates the presence or absence of vertebral degenerative joint disease plotted against composite entheseal change scores for the subscapularis attachment site.

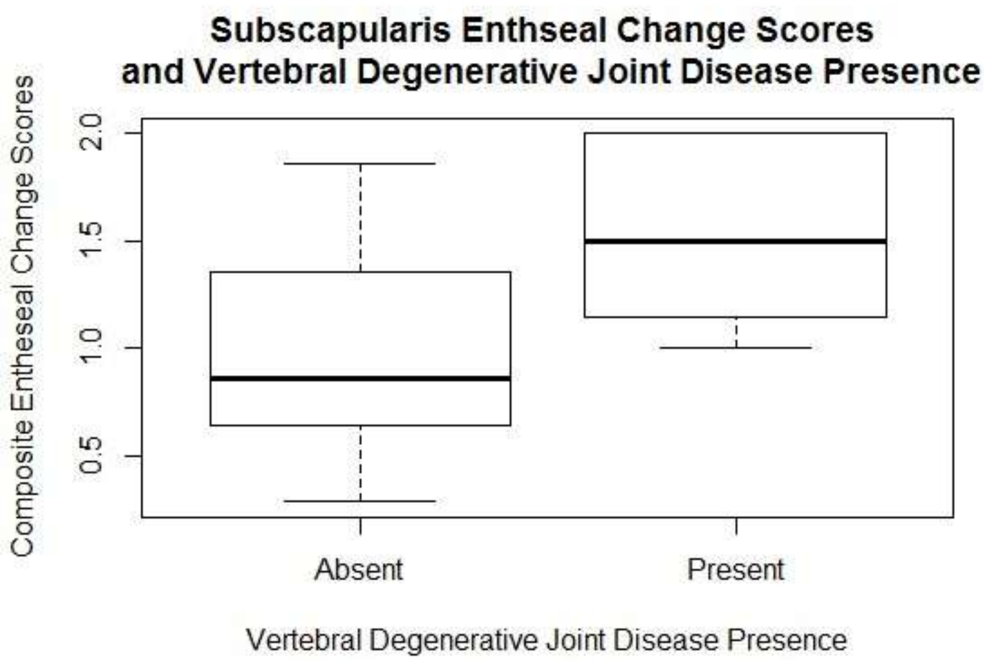

Figure 17. Composite entheseal change scores plotted against Vertebral DJD Presence or Absence for subscapularis.

The presence or absence of vertebral degenerative joint disease plotted against composite entheseal change scores for the infraspinatus attachment site is visualized in the plot in Figure 18.

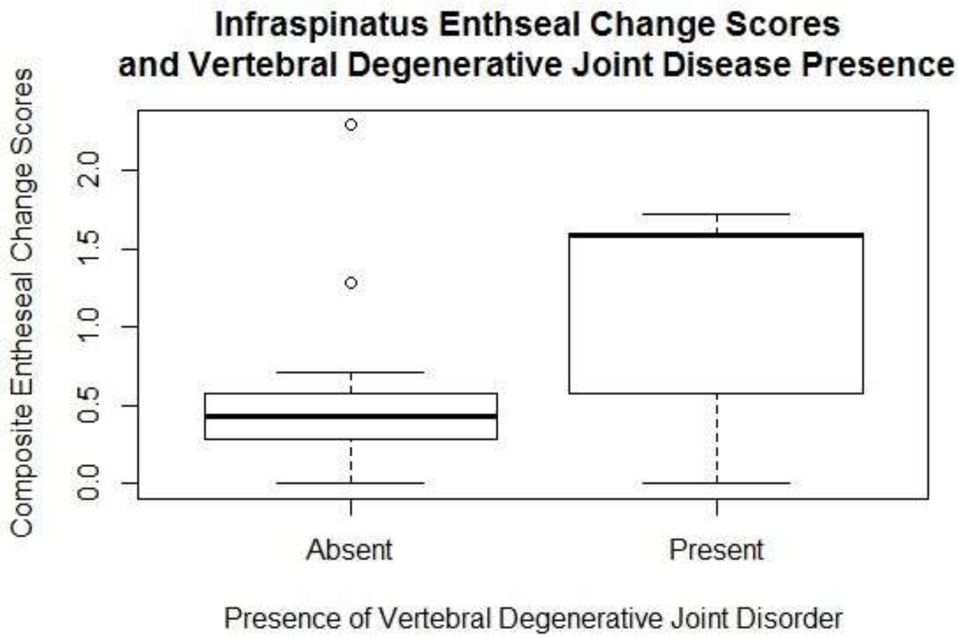

Figure 18. Infraspinatus entheseal change scores plotted against presence or absence of vertebral DJD.

To determine whether one of these factors is more of a driving force behind the observed entheseal changes than others, multiple linear regression was also performed for each muscle attachment site with age, pathology, and trauma as the predictors. In the multiple regression test, age and vertebral degenerative joint disease were the only two factors that had a significant impact (p= *<0.05).* Table 9, on the following page, contains the results of these tests, including the adjusted R-squared values.

*Table 9. Results and adjusted R-squared values for multiple regression for all attachment sites. *Denotes significance.*

Humeral Facet Muscle	Number of Entheses Observed	Percent of Sample	Age and Entheseal Change P-Value	VDJD and Entheseal Change P-Value	Adjusted R-Squared Value
Subscapularis	50/50	100.0	0.0227*	0.0341*	0.1139
Supraspinatus	48/50	96.0	0.1450	0.1670	0.0996
Infraspinatus	45/50	90.0	0.0527	0.0035*	0.3391
Teres Minor	34/50	68.0	0.1910	0.1030	-0.0024

As illustrated by Table 9, a number of variables fall away after a multiple regression analysis. Note that for the subscapularis attachment site, age and vertebral degenerative joint disease have a tendency to be associated with increased entheseal change scores and that for the infraspinatus muscle, vertebral degenerative joint disease tends to be associated with higher entheseal change scores. Important to note, however, is that the adjusted R-squared values are low overall (0.1139, or 11.39% and 0.3391, or 33.91%) and this reveals a weak association for these variables.

Though further analysis is required with an increased sample size, the age results, with the exception of subscapularis, do not fit to previous studies (Mariotti et al., 2004, 2007; Milella et al., 2012) that have connected age with differential deposition of bone and differences in the entheseal change process. Within the pathology category, the findings of increased entheseal change scores associated with positive identification of Vertebral Degenerative Joint Disease at the subscapularis and infraspinatus attachment sites illustrate the potential value in further researching VDJD and other impactful vertebral disorders which may impact satellite locations throughout the body.

Three-Dimensional Analysis

Figure 19 represents a Generalized Procrustes Alignment of all subscapularis footprints. This alignment constrains and places each recorded landmark into a relative three dimensional space to allow for comparison of shape changes. After this step was completed, the digitized border outlines recorded by the G2 digitizer and visualized by the Geomorph package were evaluated for shape change using a 5 point scale where 1=no morphological border change and 5=high morphological change in all axes. This scale takes into account change in only one axis, change in all three axes, and degrees of change based on the exemplar footprint illustrated by Richards et al (2007).

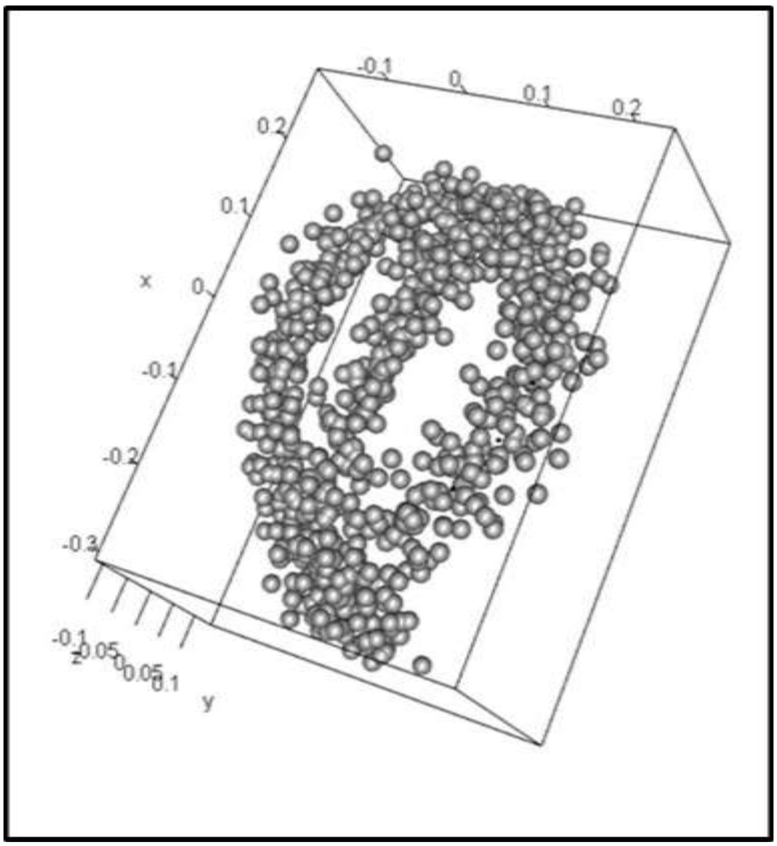

Figure 19. Generalized Procrustes Alignment of subscapularis footprint (All Specimens).

The results of geomorphometric shape change in concurrence with age do not yield statistical significance for entheseal border change (*p=0.227*). However, distortion with increased age at the subscapularis attachments is observable in some cases. This is visible in the shape comparison in Figure 20.

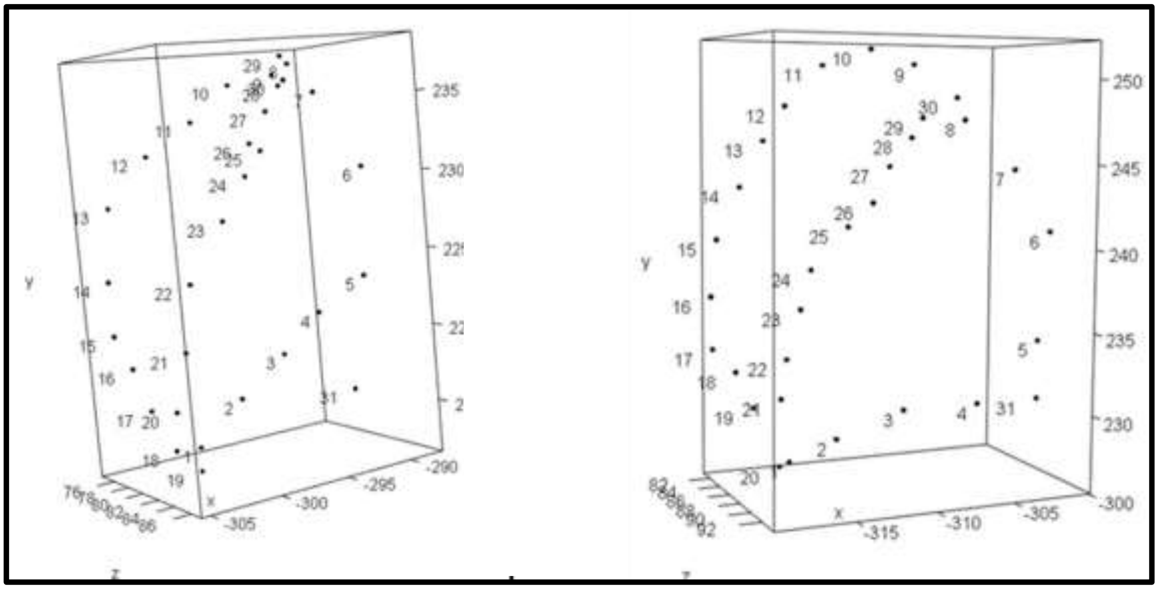

Figure 20. Shape change of the subscapularis attachment. A) individual of 29.9 yrs. B) Individual of 59.58 yrs.

Though statistical significance was not found with the three dimensional scoring system, further investigation into these shape changes with additional tests available in the Geomorph package will be conducted by the researcher and are promising for not only this type of analysis, but also for pair matching, cross-sectional analysis, and other useful applications.

CHAPTER SIX: CONCLUSIONS

The data gained from this research illustrate that the goal of reproducing the new non-metric entheseal scoring method developed by Henderson, Villotte, Cardoso, and others, was not achieved in this study. Though additional tests are required, a tendency for entheseal change to become more pronounced with advanced age was not statistically evident for all attachments, even though significant change was observed in conjunction with age for the subscapularis attachment site. Though it was not accomplished in this analysis, further delineating and understanding the connection between age and entheseal change is possible, and there are some factors that may have played a role these results. It is acknowledged that sample size for this study is a limiting factor. With a larger sample size, it is likely that the gradients of age and entheseal change will become more evident. In addition, the individuals from the 2013 excavated sample were found to survive in highly stressful conditions from even very early ages. The high percentage of young individuals in the excavated sample that exhibit schmorl's nodes (greater than 50%)(Richards et al., 2015:236), illustrates that a higher level of skeletal stress is being placed on the individuals from this sample at an earlier age, and may have affected the results of entheseal change analysis in conjunction with age.

These data also illustrate that in most cases, a correlation cannot be determined between the general pathology of an individual and a relative rate of entheseal change. The lack of statistical significance in this area further underscores the implications of systemic pathology and importance of determining which pathologies may have the largest impact on entheseal change. This is necessitated by the fact that bone is one of many connective tissue organs that interact on many levels. An important impact to consider, besides sample size, which also affects this category of analysis, is the prevalence of pathology in this sample. First, all individuals in the excavated sample, except for the six that were too taphonomically damaged to be analyzed, exhibited some form of

pathology (Richards et al., 2015). Even when the categories of infection, irregular bone deposition, and joint disorders were broken down into their more specific components, the prevalence of these pathologies was still extremely high in the study sample. For example, all individuals in the sample exhibited vertebral osteophytic lipping. The pervasiveness of these pathologies highly impacted the effective delineation of correlation between these pathologies and increased entheseal change scores. A larger sample size with a selection of less pathologically expressive individuals may allow for a better investigation of this factor.

In addition, vertebral degenerative joint disease was found to have a statistically significant connection to increased entheseal change scores for both subscapularis and infraspinatus: the two most expressive and highly stressed attachment sites of the rotator cuff muscles, as well as the best preserved entheses in this sample. These data illustrate that there may be a correlation between VDJD and increased entheseal change, which would support clinical evidence of the disruption of stasis caused in the vertebral column in turn causing stress and disruption in satellite joints. These results have important implications for enthesopathy and the determination of the role of systemic pathology, particularly vertebral pathology.

These findings do not determine one source of entheseal change motivation; rather, they highlight the importance of a multifaceted approach, and underscore the strong effect of varied life impacts on the body, and the effect of this interaction on the skeletal system. This study also illustrates that further investigation and experimentation are required to fully understand the processes that inscribe the experiences of life on each individual.

Analyzed in concert with the osteology, material culture, and medical intervention data, these data represent a step towards better contextualizing the lives of the individuals represented by the 2013 excavations. For instance, the individual represented by burial lot 10291 exhibited relatively

low entheseal change scores on the left humerus despite the age of the individual and a healed amputation of the right humerus. This, coupled with the lack of grave goods for this individual, and the lack of postmortem intervention or medical school dissection allow for the hypothesis that this individual may have been a resident of the Almshouse and cared for there, as more old individuals are recorded as having passed away at the Almshouse than young or middle adults and often did and may not have been examined by the medical examiner or taken as a cadaver by the medical college. With the apparent and relatively low stress to the left humerus, it is possible to postulate that this individual was cared for by others. Though this small case study is only a start, the data represented in this study can be applied to all individuals in the sample and may represent an additional line of evidence when constructing life histories for these individuals.

Future aims for this research and additional application of the methods applied in this paper will contribute to the base of knowledge currently held about entheseal change, and can add an additional line of evidence for other osteological investigations. For instance, an increased engagement with the geometric morphometric analysis software, Geomorph, including additional tests of the sample data from this study will add to the understanding of entheseal change for these individuals by contributing another supporting line of evidence. Geometric morphometric analysis undertaken in this study may also be expanded to be applied to additional osteological elements to aid in pair matching. Finally, conducting entheseal change analysis on a larger sample size will contribute not only to the understanding of the individuals represented by this excavation, but will also contribute to the larger set of current entheseal change analysis data.

Finally, it is hoped that these findings represent a useful step towards fully manifesting the life experiences of the individuals represented in the 2013 excavations of the Milwaukee County Institution Grounds Cemetery.

REFERENCES CITED

Adams DC, and Otárola-Castillo E. 2013. geomorph: an r package for the collection and analysis of geometric morphometric shape data. Methods in Ecology and Evolution 4(4):393-399.

Acsádi, G. and Nemeskéri, J. 1970. History of human life span and mortality. Akadémiai Kiadó. Vancouver

Benjamin M, Toumi H, Ralphs JR, Bydder G, Best TM, and Milz S. 2006. Where tendons and ligaments meet bone: attachment sites ('entheses') in relation to exercise and/or mechanical load. Journal of Anatomy 208(4):471-490.

Benjamin, M., Evans, E.J. and Copp, L. 1986. The histology of tendon attachments to bone in man. Journal of Anatomy, 149, p.89. Vancouver.

Bisseret D, Kaci R, Lafage-Proust M-H, Alison M, Parlier-Cuau C, Laredo J-D, and Bousson V. 2015. Periosteum: Characteristic imaging findings with emphasis on radiologic-pathologic comparisons. Skeletal Radiology 44(3):321-338.

Boyle, C. and Kim, I.Y. 2011. Comparison of different hip prosthesis shapes considering micro-level bone remodeling and stress-shielding criteria using three-dimensional design space topology optimization. Journal of biomechanics, 44(9), pp.1722-1728.

Brooks S, and Suchey JM. 1990. Skeletal age determination based on the os pubis: a comparison of the Acsádi-Nemeskéri and Suchey-Brooks methods. Human evolution 5(3):227-238.

Cardoso FA, and Henderson C. 2010a. Enthesopathy formation in the humerus: Data from known age-at-death and known occupation skeletal collections. American Journal of Physical Anthropology 141(4):550-560.

Cardoso FA, and Henderson CY. 2010b. Enthesopathy formation in the humerus: Data from known age-at-death and known occupation skeletal collections. American Journal of Physical Anthropology 141(4):550-560.

Cooper RR, and Misol S. 1970. Tendon and ligament insertion. A light and electron microscopic study. The Journal of bone and joint surgeryAmerican volume 52(1):1-20.

Curtis AS, Burbank KM, Tierney JJ, Scheller AD, and Curran AR. 2006. The insertional footprint of the rotator cuff: An anatomic study. Arthroscopy: The Journal of Arthroscopic & Related Surgery 22(6):603-609.e601.

Eshed I, Bollow M, McGonagle DG, Tan AL, Althoff CE, Asbach P, and Hermann KG. 2007. MRI of enthesitis of the appendicular skeleton in spondyloarthritis. Annals of the Rheumatic Diseases 66(12):1553-1559.

Frost HM. 1998. From Wolff's law to the mechanostat: a new" face" of physiology. Journal of orthopaedic science 3(5):282-286.

Hawkey DE. 1998. Disability, compassion and the skeletal record: using musculoskeletal stress markers (MSM) to construct an osteobiography from early New Mexico. International Journal of Osteoarchaeology 8(5):326-340.

Hawkey DE, and Merbs CF. 1995. Activity-induced musculoskeletal stress markers (MSM) and subsistence strategy changes among ancient Hudson Bay Eskimos. International Journal of Osteoarchaeology 5(4):324-338.

Henderson C. 2008. When hard work is disease: the interpretation of enthesopathies. Bar International Series 1743:17.

Henderson C, Mariotti V, Pany-Kucera D, Villotte S, and Wilczak C. 2013. Recording specific entheseal changes of fibrocartilaginous entheses: initial tests using the Coimbra method. International Journal of Osteoarchaeology 23(2):152-162.

Henderson CY, and Alves Cardoso F. 2013. Special issue entheseal changes and occupation: technical and theoretical advances and their applications. International Journal of Osteoarchaeology 23(2):127-134.

Henderson CY, Craps DD, Caffell AC, Millard AR, and Gowland R. 2013b. Occupational mobility in 19th century Rural England: the interpretation of entheseal changes. International Journal of Osteoarchaeology 23(2):197-210.

Henderson CY, Mariotti V, Pany-Kucera D, Perréard-Lopreno G, Villotte S, and Wilczak C. 2012. The effect of age on entheseal changes at some fibrocartilaginous entheses. American Journal of Physical Anthropology 147(S54):163.

Henderson CY, Mariotti V, Pany-Kucera D, Villotte S, and Wilczak C. 2015. The New "Coimbra Method": A Biologically Appropriate Method for Recording Specific Features of Fibrocartilaginous Entheseal Changes. International Journal of Osteoarchaeology:n/a-n/a.

Jurmain R, and Villotte S. 2010. Terminology. Entheses in medical literature and physical anthropology: a brief review. Document published online in 4th February following the Workshop in Musculoskeletal Stress Markers (MSM): limitations and achievements in the reconstruction of past activity patterns. p 2-3.

Kiebzak GM. 1991. Age-related bone changes. Experimental gerontology 26(2):171-187.

Lovejoy C. 1985. Owen C. Lovejoy, Robert S. Meindl, Thomas R. Pryzbeck, Robert P. Mensforth, Chronological metamorphosis of the auricular surface of the ilium: A new method for the determination of age at death. American Journal of Physical Anthropology 68:15-28.

Lumsdaine W, Smith A, Walker RG, Benz D, Mohammed KD, and Stewart F. 2015. Morphology of the humeral insertion of the supraspinatus and infraspinatus tendons: Application to rotator cuff repair. Clinical Anatomy 28(6):767-773.

Marchetta FC, Sako K, and Badillo J. 1964. Periosteal lymphatics of the mandible and intraoral carcinoma. The American Journal of Surgery 108(4):505-507.

Mariotti V. 2007. The study of entheses: proposal of a standardised scoring method for twenty-three entheses of the postcranial skeleton. Collegium antropologicum 31(1):291.

McGonagle D. 2005. Imaging the joint and enthesis: insights into pathogenesis of psoriatic arthritis. Annals of the Rheumatic Diseases 64 Suppl 2:ii58-60.

McGonagle D, Gibbon W, O'Connor P, Green M, Pease C, and Emery P. 1998. Characteristic magnetic resonance imaging entheseal changes of knee synovitis in spondylarthropathy. Arthritis & Rheumatism 41(4):694-700.

Meindl RS, and Lovejoy CO. 1985. Ectocranial suture closure: A revised method for the determination of skeletal age at death based on the lateral? anterior sutures. American journal of physical anthropology 68(1):57-66.

Merbs CF. 1983. Patterns of activity-induced pathology in a Canadian Inuit population. Musée National de l'Homme Collection Mercure Commission Archéologique du Canada Publications d'Archéologie Dossier Ottawa(119):1-199.

Merbs, C. F. 1995. Incomplete Spondylolysis and Healing: A Study of Ancient Canadian Eskimo Skeletons. Spine, 20(21), 2328-2334.

Milella M, Giovanna Belcastro M, Zollikofer CP, and Mariotti V. 2012a. The effect of age, sex, and physical activity on entheseal morphology in a contemporary Italian skeletal collection. American journal of physical anthropology 148(3):379-388.

Niinimäki S. 2011. What do muscle marker ruggedness scores actually tell us? International Journal of Osteoarchaeology 21(3):292-299.

Nimura A, Kato A, Yamaguchi K, Mochizuki T, Okawa A, Sugaya H, and Akita K. 2012. The superior capsule of the shoulder joint complements the insertion of the rotator cuff. Journal of Shoulder and Elbow Surgery 21(7):867-872.

Noldner LK, and Edgar HJH. 2013. 3D representation and analysis of enthesis morphology. American Journal of Physical Anthropology 152(3):417-424.

Osborne D.N., Simmons T.L., and Nawrocki S.P. 2004. Reconsidering the auricular surface as an indicator of age at death. Journal of Forensic Science, 49: 1–7.

Phenice, T.W. 1969. A Newly developed visual method of sexing in the Os Pubis. American Journal of Physical Anthropology 30(2): 297-301.

Rana RS, Wu JS, and Eisenberg RL. 2009. Periosteal reaction. American Journal of Roentgenology 193(4):W259-W272.

Richards DP, Burkhart SS, Tehrany AM, and Wirth MA. 2007. The subscapularis footprint: an anatomic description of its insertion site. Arthroscopy: The Journal of Arthroscopic & Related Surgery 23(3):251-254.

Richards, PB, Kastell, MW. 1993. Archaeological Excavations at the Almshouse Burial Ground, Milwaukee County Poorhouse Wauwatosa, Wisconsin. *Reports of Investigation No. 333. Great Lakes Archaeological Research Center.*

Richards PB. 1997. Unknown Man No. 198: The Archaeology of the Milwaukee County Poor Farm Cemetery. Ph. D. Dissertation, University of Wisconsin-Milwaukee.

Richards PB, EE Burant, BL Drew, EM Epstein, CR Jones, NW Richards, TJ Zych. 2015. Nine for Mortal Men Doomed to Die: The Archaeology and Osteology of the 2013 Milwaukee County Poor Farm Cemetery Project (Froedtert Tract-47 MI 0527) *University of Wisconsin-Milwaukee Cultural Resource Management Report of investigations 381*. UWM CRM.

RStudio Core Team. 2015. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA URL http://www.rstudio.com/.

Skedros J, Baucom S. 2007. Mathematical analysis of trabecular 'trajectories' in apparent trajectorial structures: the unfortunate historical emphasis on the human proximal femur. *Journal of theoretical biology*, *244*(1), pp.15-45.

Turkel, SJ, Panio, MW, Marshall, JL, Girgis, FG. 1981. Stabilizing mechanisms preventing anterior dislocation of the glenohumeral joint. J Bone Joint Surg. 1981;63A:1208–1217.

Verzani J. 2014. Using R for introductory statistics. CRC Press.

Villotte, S. 2010. Enthesopathies as occupational stress markers: evidence from the upper limb. American Journal of Physical Anthropology 142.2 (2010): 224-234.

Villotte S, and Knüsel CJ. 2013. Understanding entheseal changes: definition and life course changes. International Journal of Osteoarchaeology 23(2):135-146.

Waldron, T. 2009. Paleopathology. Cambridge Manuals in Archaeology. Cambridge University Press, Cambridge.

Wisconsin Historical Society, Creator Unknown, View of a crew surveying land, digging a ditch, and laying drain tile, 101470. Viewed online at http://images.wisconsinhistory.org/700099991141/9999015983-l.jpg.

Wolff J. 1986. The law of bone remodelling: Springer.

Zytoon AA, Eid H, Sakr A, El Abbass HA, and Kamel M. 2014. Ultrasound assessment of elbow enthesitis in patients with seronegative arthropathies. Journal of ultrasound 17(1):33-40.

Appendix A: Entheseal Change Analysis Protocol and Data Entry Form

Non-Metric Entheseal Scoring: Areas of Visual Observation Lot: ________________

Muscle	Abbreviation		Analyzed Insertion Site and Data Points	
Subscapularis	**SBS**		**Facet of Lesser Tubercle of Humerus**	
Zone 1 **Margin opposite acute angle of fiber attachment**	Bone Formation	BF (Z1)	Left	Right
	Erosion	ER (Z1)		
Zone 2	Bone Formation	BF		
	Erosion	ER		
Remaining Margin And Surface	Fine Porosity ≥ 1mm	FPO		
	Macro-Porosity	MPO		
	Cavitation	CA		

Supraspinatus	SPS		Anteroproximal Facet of Greater Tubercle of Humerus	
Zone 1 Margin opposite acute angle of fiber attachment	Bone Formation	BF (Z1)	Left	Right
	Erosion	ER (Z1)		
Zone 2	Bone Formation	BF		

			Left	Right
Remaining Margin And Surface	Erosion	ER		
	Fine Porosity ≥ 1mm	FPO		
	Macro-Porosity	MPO		
	Cavitation	CA		

Infraspinatus	**IS**		**Superior Posteroproximal Facet of Greater Tubercle of Humerus**	
Zone 1 Margin opposite acute angle of fiber attachment	Bone Formation	BF (Z1)	Left	Right
	Erosion	ER (Z1)		
Zone 2	Bone Formation	BF		
	Erosion	ER		
Remaining Margin And Surface	Fine Porosity ≥ 1mm	FPO		
	Macro-Porosity	MPO		
	Cavitation	CA		

Teres Minor	**TM**	**Inferior Posteroproximal Facet of Greater Tubercle of Humerus**		
Zone 1 Margin opposite **acute angle** of **fiber** attachment	Bone Formation	BF (Z1)	Left	Right
	Erosion	ER (Z1)		
Zone 2	Bone Formation	BF		
	Erosion	ER		
Remaining Margin And Surface	Fine Porosity ≥ 1mm	FPO		
	Macro-Porosity	MPO		
	Cavitation	CA		

Appendix B: Entheseal Change Scores for all Lots

Lot Number	Muscle	Z1 BF	Z1 ER	BF	ER	FPO	MPO	CA	COMP
10066	SBS L	3	0	0	1	1	0	0	5
10066	SPS L	1	2	1	1	1	2	1	9
10066	IS L	1	1	0	0	1	1	0	4
10066	TM L	NA	NA	NA	NA	NA	NA	NA	NA
10073	SBS L	1	1	1	2	1	0	0	6
10281	SPS L	1	1	0	2	1	1	0	6
10281	IS L	0	1	0	0	1	0	0	2
10281	TM L	1	0	1	0	1	0	0	3
10103	SBS L	2	2	3	1	2	1	1	12
10285	SPS L	NA	1	0	0	0	0	0	1
10285	IS L	0	0	0	0	0	0	0	0
10285	TM L	0	1	1	0	1	0	0	3
10103	SBS L	2	2	2	2	3	2	1	14
10296	SPS L	1	1	2	2	1	2	2	11
10296	IS L	1	2	2	2	1	2	2	12
10296	TM L	1	1	1	0	1	0	0	4
10281	SBS L	2	0	2	1	1	2	0	8
10308	SPS L	0	1	0	1	1	0	0	3
10308	IS L	1	0	1	0	0	0	0	2
10308	TM L	1	0	1	1	1	1	0	5
10285	SBS L	NA	1	1	0	1	0	0	3
10312	SPS L	0	1	2	1	0	0	0	4
10312	IS L	NA	NA	NA	NA	NA	NA	NA	NA
10312	TM L	NA	NA	NA	NA	NA	NA	NA	NA
10296	SBS L	2	1	3	2	2	2	2	14
10316	SPS L	1	1	1	0	0	0	0	3
10316	IS L	1	1	0	0	0	0	0	2
10316	TM L	0	0	0	0	0	0	0	0
10308	SBS L	0	3	1	3	2	2	2	13
10323	SPS L	0	1	0	0	0	0	0	1
10323	IS L	0	1	0	0	1	0	0	2
10323	TM L	0	1	1	0	0	0	0	2
10312	SBS L	0	2	1	1	1	2	2	9
10330	SPS L	0	2	0	0	0	0	0	2
10330	IS L	1	2	1	0	1	0	0	5
10330	TM L	1	2	1	1	1	0	0	6
10316	SBS L	3	1	2	0	0	1	0	7
10387	SPS L	1	1	0	0	0	0	0	2
10387	IS L	1	1	1	0	1	1	0	5
10387	TM L	NA	NA	NA	NA	NA	NA	NA	NA

10323	SBS L	1	1	2	0	1	0	0	5
10406	SPS L	1	2	0	1	2	0	0	6
10406	IS L	1	2	2	2	2	0	0	9
10406	TM L	1	2	1	0	0	0	0	4
10330	SBS L	0	2	1	0	1	0	0	4
10411	SPS L	0	1	1	0	2	0	0	4
10411	IS L	0	1	0	0	2	1	0	4
10411	TM L	1	0	1	1	2	2	1	8
10349	SBS L	1	2	1	0	1	0	0	5
10451	SPS L	0	1	0	0	0	0	0	1
10451	IS L	1	0	0	0	0	0	0	1
10451	TM L	1	1	1	0	1	0	0	4
10387	SBS L	1	1	1	1	1	0	0	5
10467	SPS L	3	2	3	3	2	2	2	17
10467	IS L	3	2	3	2	2	2	2	16
10467	TM L	2	1	2	1	1	1	0	8
10406	SBS L	1	1	2	1	1	2	1	9
10517	SPS L	0	0	0	0	1	0	0	1
10517	IS L	1	1	0	0	1	0	0	3
10517	TM L	0	1	0	1	1	2	1	6
10411	SBS L	0	0	1	1	2	1	0	5
10525	SPS L	1	0	1	0	2	0	0	4
10525	IS L	2	1	1	0	1	0	0	5
10525	TM L	1	1	1	0	0	2	1	6
10451	SBS L	0	1	1	1	0	0	0	3
10623	SPS L	1	1	2	0	1	1	0	6
10623	IS L	0	1	0	0	1	0	0	2
10623	TM L	1	0	1	0	1	1	0	4
10467	SBS L	1	2	3	1	2	1	0	10
10650	SPS L	0	0	1	0	1	0	0	2
10650	IS L	0	3	1	0	0	0	0	4
10650	TM L	NA	NA	NA	NA	NA	NA	NA	NA
10517	SBS L	1	1	0	0	1	1	1	5
10652	SPS L	0	1	0	0	0	0	0	1
10652	IS L	0	0	0	0	0	0	0	0
10652	TM L	0	0	0	0	0	0	0	0
10525	SBS L	2	1	3	0	0	2	0	8
10657	SPS L	0	1	0	1	0	2	2	6
10657	IS L	1	1	0	1	1	0	0	4
10657	TM L	0	1	1	0	1	0	0	3
10658	SPS L	2	1	2	1	2	2	0	10
10658	IS L	0	1	0	1	1	0	0	3
10658	TM L	0	1	0	1	0	2	1	5

10541	SBS L	1	1	1	0	1	1	0	5
10658	SPS L	2	1	2	1	2	2	0	10
10658	IS L	0	1	0	1	1	0	0	3
10658	TM L	0	1	0	1	0	2	1	5
10660	SPS L	1	3	1	2	1	2	2	12
10660	IS L	1	0	1	2	0	1	0	5
10660	TM L	1	0	1	0	1	0	0	3
10623	SBS L	2	1	2	1	1	2	0	9
10665	SPS L	2	1	2	2	2	2	1	12
10665	IS L	1	1	2	3	2	2	0	11
10665	TM L	NA	NA	NA	NA	NA	NA	NA	NA
10650	SBS L	1	2	1	3	1	2	0	10
10740	SPS L	0	1	0	0	1	2	0	4
10740	IS L	0	1	1	0	1	0	0	3
10740	TM L	NA	NA	NA	NA	NA	NA	NA	NA
10652	SBS L	1	1	2	1	1	1	0	7
10745	SPS L	1	1	0	0	0	0	0	2
10745	IS L	1	1	0	2	1	0	0	5
10745	TM L	1	0	1	0	1	0	0	3
10745	SPS L	1	1	0	0	0	0	0	2
10745	IS L	1	1	0	2	1	0	0	5
10745	TM L	1	0	1	0	1	0	0	3
10657	SBS L	3	0	2	1	2	2	0	10
10760	SPS L	0	1	0	0	0	0	1	2
10760	IS L	0	0	1	0	2	1	0	4
10760	TM L	1	1	0	1	2	1	0	6
10658	SBS L	1	1	3	2	1	2	1	11
10764	SPS L	0	0	0	0	0	0	0	0
10764	IS L	1	1	1	0	0	0	0	3
10764	TM L	1	1	0	0	1	1	0	4
10660	SBS L	2	2	2	0	2	2	0	10
10766	SPS L	1	1	1	0	0	0	0	3
10766	IS L	1	0	1	0	0	1	0	3
10766	TM L	1	0	1	0	1	0	0	3
10665	SBS L	1	2	2	2	1	2	1	11
10774	SPS L	NA	NA	NA	NA	NA	NA	NA	NA
10774	IS L	NA	NA	NA	NA	NA	NA	NA	NA
10774	TM L	NA	NA	NA	NA	NA	NA	NA	NA
10740	SBS L	1	1	1	0	2	0	0	5
10776	SPS L	0	0	1	0	0	0	0	1
10776	IS L	0	2	1	0	0	0	0	3
10776	TM L	1	2	0	1	1	0	0	5
10745	SBS L	0	1	1	0	1	1	0	4

10777	SPS L	0	3	0	1	0	0	0	4
10777	IS L	0	2	0	0	0	0	0	2
10777	TM L	0	2	1	0	1	2	1	7
10760	SBS L	2	3	2	1	1	1	1	11
10764	SBS L	1	1	0	1	1	2	1	7
10779	SPS L	0	0	0	0	0	0	0	0
10779	IS L	1	0	1	0	0	0	0	2
10779	TM L	NA	NA	NA	NA	NA	NA	NA	NA
10781	SPS L	0	1	0	0	0	0	0	1
10781	IS L	0	1	1	1	1	0	0	4
10781	TM L	0	0	0	0	0	0	0	0
10766	SBS L	1	0	1	0	0	1	0	3
10784	SPS L	0	0	0	0	0	1	0	1
10784	IS L	0	0	0	0	0	0	0	0
10784	TM L	NA	NA	NA	NA	NA	NA	NA	NA
10774	SBS L	1	2	3	1	1	2	1	11
10786	SPS L	0	0	0	0	0	0	0	0
10786	IS L	0	0	0	0	0	1	0	1
10786	TM L	NA	NA	NA	NA	NA	NA	NA	NA
10776	SBS L	0	2	1	0	1	2	1	7
10794	SPS L	NA	NA	1	1	1	1	0	4
10794	IS L	NA	NA	NA	NA	NA	NA	NA	NA
10794	TM L	NA	NA	NA	NA	NA	NA	NA	NA
10777	SBS L	0	2	1	1	1	1	0	6
10803	SPS L	2	1	0	0	0	0	0	3
10803	IS L	NA	NA	NA	NA	NA	NA	NA	NA
10803	TM L	NA	NA	NA	NA	NA	NA	NA	NA
10779	SBS L	1	0	1	0	0	0	0	2
10804	SPS L	1	0	0	0	0	0	0	1
10804	IS L	0	1	1	0	0	0	0	2
10804	TM L	NA	NA	NA	NA	NA	NA	NA	NA
10781	SBS L	1	0	1	0	0	0	0	2
10808	SPS L	0	1	0	0	0	0	0	1
10808	IS L	0	0	0	0	0	0	0	0
10808	TM L	1	1	0	1	1	0	0	4
10784	SBS L	1	1	2	0	1	0	0	5
10810	SPS L	2	1	2	1	1	2	0	9
10810	IS L	1	1	0	1	1	0	0	4
10810	TM L	1	1	0	1	1	1	0	5
10786	SBS L	0	0	0	1	1	1	0	3
10811	SPS L	0	0	0	0	0	0	0	0
10811	IS L	0	1	0	0	2	0	0	3
10811	TM L	NA	NA	NA	NA	NA	NA	NA	NA

10794	SBS L	2	1	3	2	1	2	2	13
10815	SPS L	NA	NA	1	2	2	2	1	8
10815	IS L	NA	NA	1	2	1	2	2	8
10815	TM L	NA	NA	NA	NA	NA	NA	NA	NA
10803	SBS L	2	1	2	1	1	0	0	7
10817	SPS L	0	0	1	0	0	0	0	1
10817	IS L	0	1	1	0	1	0	0	3
10817	TM L	1	0	0	0	1	0	0	2
10804	SBS L	1	1	1	0	1	1	0	5
10818	SPS L	NA	NA	NA	NA	NA	NA	NA	NA
10818	IS L	NA	NA	1	2	2	2	1	8
10818	TM L	1	1	0	1	1	0	0	4
10808	SBS L	1	1	0	1	0	0	0	3
10977	SPS L	0	0	0	0	0	0	0	0
10977	IS L	0	1	0	0	0	0	0	1
10977	TM L	0	2	0	1	1	1	0	5
10810	SBS L	1	2	2	1	1	1	2	10
10811	SBS L	1	2	0	0	0	0	0	3
10541	SPS L	0	1	0	0	1	0	0	2
10541	IS L	1	1	0	0	1	0	0	3
10541	TM L	1	1	2	2	1	1	1	9
10815	SBS L	NA	NA	3	2	2	2	1	10
10073	SPS L	1	2	1	0	0	1	0	5
10073	IS L	1	1	1	1	0	0	0	4
10073	TM L	2	1	1	0	2	0	0	6
10817	SBS L	1	0	0	1	1	0	0	3
10818	SBS L	1	1	1	2	1	2	0	8
10103	SPS L	1	2	1	2	2	2	2	12
10103	IS L	1	2	1	2	1	1	1	9
10349	TM L	1	1	1	0	0	0	1	4
10977	SBS L	1	1	1	1	1	1	0	6
10349	SPS L	1	0	1	1	2	1	0	6
10349	IS L	0	0	1	1	1	1	1	5
10291	TM L	0	2	1	0	1	0	0	4
10291	SPS L	1	2	0	1	1	0	0	5
10291	IS L	NA	NA	NA	NA	NA	NA	NA	NA
10291	TM L	NA	NA	NA	NA	NA	NA	NA	NA