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MICHAEL CHARLES HENRY WALTERS
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BISON HIDES AND BIOMECHANICS: EXPERIMENTAL BIOARCHAEOLOGY
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BY

____
Dr. Bonnie Pitblado, Chair

____
Dr. Lesley Rankin-Hill, Co-Chair

____
Dr. Sarah Trabert

____
Dr. Christopher Black

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Abstract

This study utilizes methodologies and theories from biological anthropology, archaeology, and kinesiology to conduct an experiment to test the effects of a change in Wichita scraping technologies during the Pre- and Post-Contact Periods on the musculo-skeletal system. During the Colonial Period, French Traders were increasing their requests of bison hides from trading with Plains Native American Tribes and the Wichita Nation facilitated this demand by changing how their scrapers were produced. Scrapers before trade with the French were smaller and uniformly made, after the French engaged the Wichita for bison hides, scrapers increased in size and were less uniform. To understand how the change in scraper technology affected the bodies of the Wichita women preparing hides, ten female participants scraped bison hides with the two types of scrapers, Pre- and Post-Contact scrapers, and in two positions, kneeling and crouching. Participants had electromyography (EMG) electrodes placed on muscle groups on their arm while scraping to measure the force output of the muscles. Based on the EMG signal, pathologies (i.e., osteoarthritis and enthesopathies) Wichita women might have experienced during this time were postulated. The results of this project indicate that more muscle force is required to scrape using the Post-Contact scraper compared to the Pre-Contact scraper. Because of the greater force, Post-Contact Wichita women are hypothesized to experience an increase in osteoarthritis, larger enthesopathies, and perhaps an earlier age of onset for these diseases. Furthermore, utilizing EMG in activity reconstruction can help to validate previous analyses of activity reconstruction from skeletal populations. Additionally, if a skeletal population is unavailable for analyses, conducting an experiment and recreating the activity in

question (i.e. scraping), can allow skeletal biologists to understand how past behaviors affected the musculo-skeletal system.

Chapter 1: Introduction

The purpose of this project is two-fold: 1) to determine if muscle activation is different when using a hafted or handheld scraper were different using electromyography (EMG) and 2) if a difference does exist, develop a hypothesis and model of activity related paleopathological indicators for women in a Post-Contact Wichita Society would have experienced. Analyzing a Post-Contact skeletal population and then comparing the results to a Pre-Contact site, such as 34Wa5 McLemore (Ellis 2015) would have been ideal. However, there are no available human remains from the Wichita dating to this time period available for research. Learning of the dramatic tool change associated with bison hide processing that occurred among the Wichita (Cleeland 2008), I was faced with a dilemma.

Drawing from my training as a skeletal biologist, anatomy, and kinesiology from undergraduate, I remembered that Electromyography measures muscle force exertion. With muscles attaching to bones, I designed a study to recreate Post-Contact hide scraping motions with modern technology. Have live people use both Pre- and Post-Contact scrapers, measure muscle innervation with EMG, and from there, compare muscle involvement and propose possible musculo-skeletal changes Post-Contact Wichita women might have experienced differently from a few generations ago. Focusing on paleopathologies related to activity, such as osteoarthritis and enthesopathies would be the focus of this study. Enthesopathies are enlarged muscle attachment sites. Osteoarthritis occurs when cartilage has deteriorated within a joint, in response the bone begins to form osteophytes (bony spurs) to accommodate the lack of cartilage. Eburnation is the final stage of osteoarthritis where the bones have polished each other, giving the joint a shiny appearance (Ortner 2012).

To answer these questions, the subsequent chapters are organized as described below. Chapter Two outlines the theoretical approaches employed, including a discussion of activity related paleopathologies, and musculo-skeletal biomechanics. Cultural descriptions of Post-Contact Wichita societal and technological differences from Pre-Contact Wichita society are highlighted.

Chapter Three outlines the methodology and techniques in constructing the experiment. These include scraper reproduction, preparing the bison hide for scraping, muscles measured with EMG, and EMG placement. The procedure and protocol for the experiment is also outlined.

Chapter Four presents the results of the experiment. Percentage of Maximum contractions were compared between tools and positions. Differences in muscle activation were noted between Pre- and Post-Contact scraper as well as scraping positions. This study potentially offers a new method of reconstructing activities and inference about human remains not available for study for a myriad of reasons.

Finally, Chapter Five concludes the study. Paleopathology of a Pre-Contact skeletal population from McLemore (34WA5) are outlined for comparison (Ellis 2015). From EMG signals, interpretations of Post-Contact activity related paleopathologies and where they could potentially develop are proposed. This chapter, also offers future research directions for the use of EMG in Biological Anthropology studies, especially those related to activity reconstruction. Potential muscles were identified for future

EMG testing for this project. Ending with how interdisciplinary collaboration is a fruitful and exciting endeavor that can open the past in ways that were obscured before.

Chapter 2: Background

Biocultural Theory and Bioarchaeology

Biological anthropology was a descriptive science before Sherwood Washburn's seminal piece, *The New Physical Anthropology* (1951), called for the discipline to engage in descriptive and comparative analogies as well as theoretical processes. One response had a significant, influential impact on biological anthropology. Cohen and Armelagos (1984) organized a seminar bringing international skeletal biologists with research from across the world based on a biocultural perspective. Instead of providing basic demographic profiles, age and sex distributions, the seminar was to explore physiological changes populations experienced as agriculture became the dominant subsistence strategy. The seminar was published as a book, *Paleopathology at the Origins of Agriculture*, and is essential to any biological anthropologist interested in human skeletal biology.

Additionally, Cohen and Armelagos (1984) proposed biocultural theory to conceptualize health and disease processes associated with subsistence strategies and changes across skeletal and living populations. Biocultural theory highlights the interaction between, biology, environment, and culture (Figure 2.1) Human remains provide insight into the life of the individual (i.e. activities undertaken and nutrients ingested) are recorded in the skeleton of the individual and skeletal biologists can infer population level patterns of stressors the population experienced (Beck 2006, Buikstra 1977, Goodman et al. 1984, Larsen 1997, 2002).

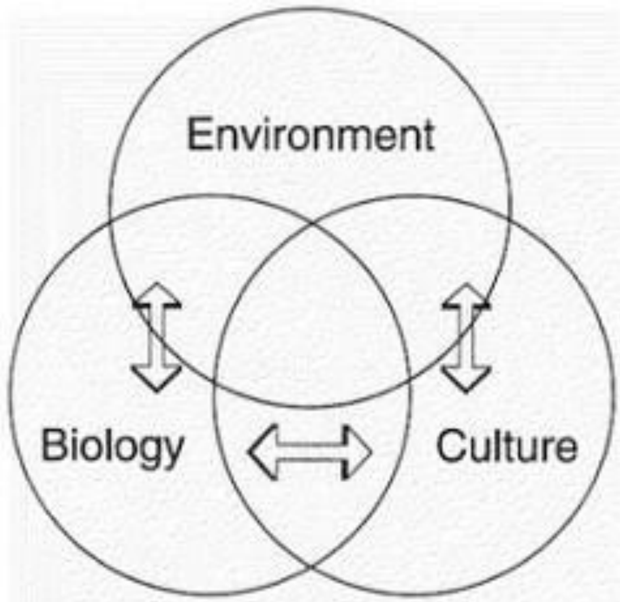

Figure 2.1 Figure depicting biocultural theory (Cohen and Armelagos 1984) and the interaction between, biology, culture, and environment.

Biocultural theory reinvigorated the field of skeletal biology and has been used in North American bioarchaeology to understand the effects of health and rank in the Southeastern United States (Powell 1991, 1998, Rose et al 1984, 1998), the transition to agriculture in the Southeast (Shuler 2012a, 2012b, Wilson 2012), indications of trauma, warfare, and activity patterns in the Plains (Owsley and Jantz 1994), and more generally the presence of diseases such as anemia, scurvy, syphilis, and oral diseases (Buikstra and Cook 1980, Larsen 2002, Ortner 2003, Ortner and Putschar 1981, Powell 1998).

Activity Reconstruction

In addition to studying the effects of agriculture and diet, skeletal biologists also look at paleopathologies associated with biomechanical stressors. Skeletal biologists have coined this type of research, activity reconstruction (Jurmain et al 2012). Due to bone remodeling and etiology (formation) of osteoarthritis and enthesopathies not being fully understood (Ruff et al 2006), activity reconstruction in skeletal biology has had differing views on what activities, if any, can be observed on skeletons (Jurmain 2012).

Despite this, skeletal biologists still analyze osteoarthritis and enthesopathies to investigate activity patterns. Also, when studying bones for activity reconstruction, skeletal biologists should be knowledgeable of archaeological contexts to make full use of biocultural theory (Cohen and Armelagos 1984, Powell 1991, 1998).

Common paleopathologies examined are osteoarthritis and enthesopathies, areas of robust muscle attachments (Jurmain et al 2012:534-535,539-542). Cross-sectional bone geometry is also researched and used to interpret activity; however, it is outside the scope of this research and will not be discussed. Osteoarthritis (Appendix N) is a degenerative joint disease that can occur in any joint that moves (Ortner and Putschar 1981, Ortner 2003: Waldron 2012). Osteoarthritis takes place once the articular cartilage of a joint wears down (Waldron 2012). Osteoarthritis is noted by lipping around the joint margins, osteophytes (bone spurs), pitting of the joint surface, alteration of joint function, and eburnation. Eburnation occurs when there is no more cartilage in the joint, therefore the bones are articulating against each other. This causes the bones to polish each other and creates grooves. In dry skeletons, eburnation is noted by its shiny appearance (Ortner 2003, Ortner and Putschar 1981, Waldron 2012).

As the joint is used and aging effects accrue, osteoarthritis is more likely to occur. Though the disease can occur in any joint, some appear to be more susceptible to osteoarthritic changes (Waldron 2012). Shoulders and ankles seem to be less affected unless an injury or other diseases affects the form of these joints (Waldron 2012). The knee is more affected at the patellofemoral (knee and thigh) compartment than the tibia. At the elbow, the radiohumeral joint is almost always afflicted with osteoarthritis, with the ulnohumeral joint rarely displaying osteoarthritis. Finally, the hand is also affected by osteoarthritis at the radial side of the joint (Waldron 2012: 515). Prevalence of the osteoarthritis increases with age and more common in females, especially in elder females (Waldron 2012: 514).

The appearance of enthesopathic (Appendix M) changes on the skeletal from repetitive or strenuous activity can manifest itself in a variety of ways (Jurmain et al 2012, Robb 1998). The two morphological forms of enthesopathies are Fibrous and Fribrocartilaginous. These exist on a spectrum and can mimic the other. Fibrous entheses are seen mainly on the diaphysis of long bones and the cranium. Firbrocartilaginous occur close to epiphysis of bones (near joint articulations) and it is associated with mechanical activity (Jurmain et al. 2012, Villotte and Knusel 2012). Less is known about fibrous enthesopathies, although there are hypotheses that transitioning from periosteal to bony attachments in young/middle adults and cellular degeneration in older adults could explain the presence of fibrous enthesopathies (Jurmain et al. 2012: 540).

Both osteoarthritis and enthesopathies are indications of activity, though there have been disputes over whether these paleopathologies can be linked to a specific activity (Jurmain 1991), the exact etiology of osteoarthritis (Jurmain 1977, Weiss and Jurmain 2007), and if osteoarthritis and enthesopathies are even indicators of biomechanical stress (Cardoso and Henderson 2010, Weiss 2003). Regarding the first two arguments, specific activity markers and etiology, (Jurmain 1991, 1977, Weiss 2003, Weiss and Jurmain 2007). Jurmain (1991, 1999) has argued that no one specific activity can be linked to the presence of either paleopathology. Recently, studies (Cardoso and Henderson 2010, Weiss 2003) have attempted to understand if enthesopathic changes are related to muscle activity or a result of advanced age. Cardoso and Henderson (2010) and Weiss (2003) both come to the conclusion that age is more correlated to enthesopathic changes than activity. However, both caution using only age as the etiological agent for either activity related paleopathologies. Other authors have also noted that if movement is happening, regardless of intensity or duration, it will be reflected on the skeleton (Godinho 2016, Ruff 2008, Ruff et al. 2006, Merbs 1983). Human activity can range day to day and in intensity rather the presence of osteoarthritis and enthesopathies are more likely representative of a lifetime of activities (Merbs 1983).

Biomechanics and Electromyography

Activity related paleopathologies have mechanical stress as a major factor in their etiology, Merbs (1983) states that a “disused joint never develops osteoarthritis” and enthesopathies can also be added to that statement (Jurmain 1991). Because osteoarthritis and enthesopathies are engaged with movement, and therefore muscles, a definition of biomechanics regarding bone and muscle will follow. Biomechanics is the application of mechanical principles applied to biological systems (Basmajian 1978, Robertson et al. 2014, Ruff 2008). The skeletal system reacts to loading as by either depositing more bone if the stress exceeds what the bone can handle or resorbing bone (Figure 2.2) (Godinho 2016, Lanyon 1982, Ruff 2008, Ruff et al. 2006). The intensity and duration of forces applied to the bone can change throughout the lifetime of an individual, regardless the bone is a living tissue and will respond accordingly to stressors applied to it (Ruff et al. 2006).

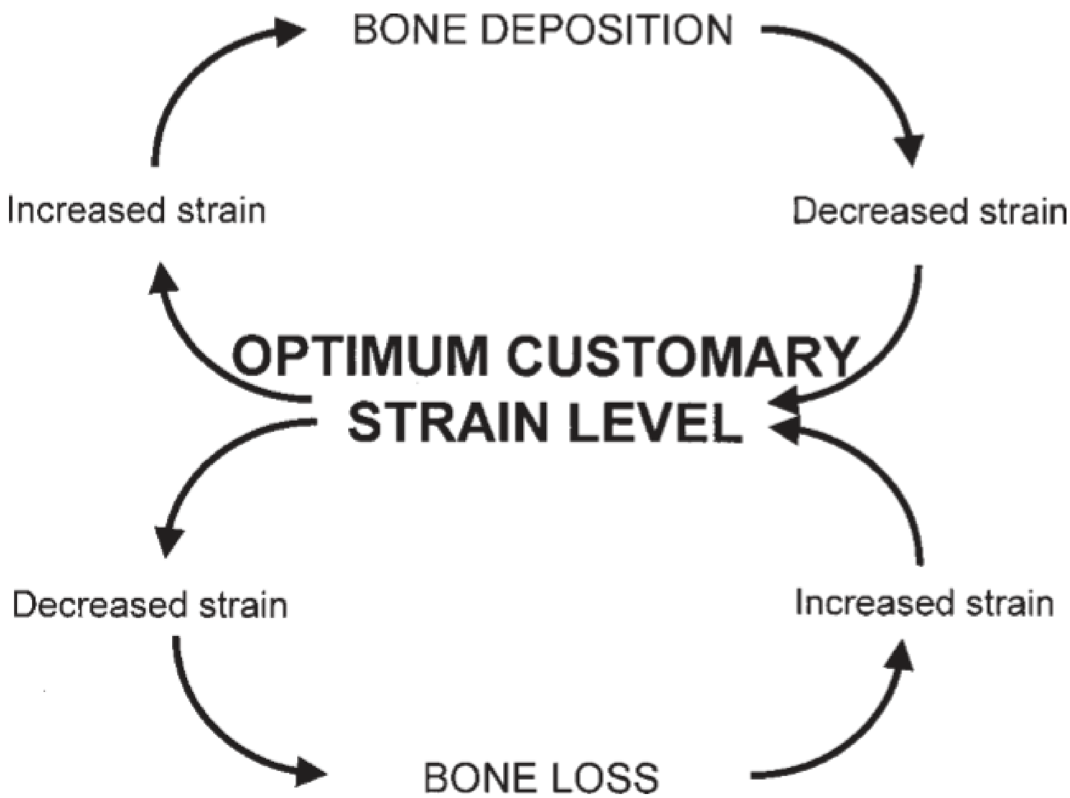

Figure 2.2. Model of functional bone adaptation (from Ruff et al. 2006:485).

The skeletal system supports the muscular system and helps support and stabilize movements: bones are levers, joints are fulcrums, and muscles are the strings that push and pull the levers (Basmajian 1978, Robertson et al. 2014). Because both systems are connected, force travelling through the muscle will reach the bone and both will physiologically adjust to accommodate for the forces being applied to them.

Muscle activation occurs when a signal from the nervous system reaches a muscle fiber. Once the action potential reaches the motor neuron, the muscle fibers in that motor unit are depolarized. Depolarization occurs among the entire muscle fiber through Sodium (Na) ions enter the cell and Potassium (K) ions leaving. This process generates an electromagnetic field eventually causing the muscle fiber, and muscle to contract (Basmajian 1978, Robertson et al. 2014).

Because contrasting muscles conduct electricity, kinesiologists and exercise physiologists developed a tool to measure muscle activation. Electromyography (EMG) is a method in biomechanics that measures the electrical output of muscle contraction. The EMG signal that is produced is a summation of all action potentials along the motor unit, or it measures the motor unit action potential (MUAP). Volts is the unit of measurement in EMG data since it is measuring electricity. The signal is correlated to the amount of force a muscle is producing. The greater the amplitude in the signal the more force being exerted, while the lower the signal, the less force. When more force is required, the muscle engages more motor units for a contraction to occur (Basmajian 1978, Beardsley, De Luca 1993, Konrad 2006, Robertson et al. 2014). A figure depicting muscle activation and the corresponding EMG signals is found below (Figure 2.3):

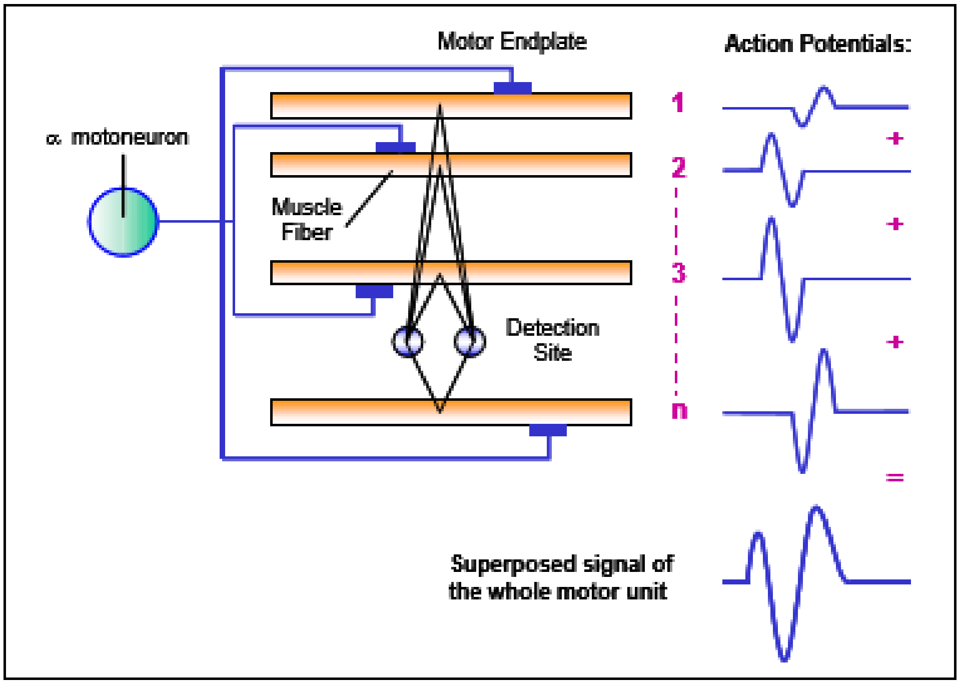

Figure 2.3. Muscle Activation and how EMG signals measures the summation of action potentials that travels along the muscle fibers (Konrad 2006: 9).

The correlation of EMG signal to force to muscle activation to functional bone adaptation is crucial to understanding archaeological skeletal populations. Though EMG provides a snapshot of muscle activation, skeletal biologists can use EMG to understand the muscle forces acting on the bone to explain what is being observed in a skeletal sample (Shaw et al. 2012, Sládek et al. 2016) or creating a hypothesis model of paleopathological changes (osteoarthritis and enthesopathies) a skeletal population would exhibit.

Experimental (Bio)Archaeology

Experimental archaeology arose as part of Middle Range Theory. The purpose of experimental archaeology was to propose frameworks to understand changes and use of material culture and put forth new hypotheses to be tested (Binford 1967, 1980). Analogies in archaeology have been criticized (Lyman and O’Brien 2001, Raab and

Goodyear 1984, Wylie 1985) however, the use of analogy and experimentation in archaeology has proven useful in explaining the past and proposing new research agendas. Experimental archaeology focuses on material culture (i.e. scrapers and ceramics). Considering the two studies mentioned above (Shaw et al. 2012, Sládek et al. 2016), and the goals of these projects focus on biocultural theory (Cohen and Armelagos 1984, Zuckerman and Martin 2016), the effects of material culture on the human body, throughout this paper I use the amended term, “experimental bioarchaeology”. The term differentiates what I have done from experimental archaeology proper because the focus of my study is not on artifacts, but rather the musculo-skeletal system. New research questions proposed at the end of Shaw et al. (2012) and Sládek et al. (2016) focus on the impacts of biomechanical stress on the skeletal system and less on artifacts.

EMG in Bioarchaeology Studies

To date two principal studies have employed electromyography in reconstructing past behavior (Shaw et al. 2012, Sládek et al. 2016). Both of these studies focused on understanding bone morphology, specifically the humerus. Shaw et al. (2012), is based on the work of Churchill (1996, 2002). Churchill (1996, 2002) theorized that spear thrusting caused the humeri of Neanderthals to have an anteroposterior elongation to adapt to the shock of spear thrusting (Churchill et al. 1996, Churchill 2002). Churchill et al. (1996) hypothesized that Neanderthal humeri adapted to spear thrusts by examining how military infantry thrusted with bayonets. Shaw et al. (2012) tested Churchill’s hypothesis that spear thrusting caused the morphology of the Neanderthal humeri to have the anteroposterior (front to back) adaptation.

To test this, Shaw et al. (2012) had participants recreate spear thrusting and hide scraping with EMG. Since the experiment was focused on overall morphology of the humerus and involved bilateral movement, the right and left anterior deltoid, posterior deltoid, infraspinatus, and pectoralis major were measured using EMG (2012: 5). All participants were right handed and EMG was applied to both left and right sides to measure the difference in muscle activity. These muscles were chosen based on their attachment sites to the humerus or involvement in moving the humerus. For the spear thrusting, they had participants undertake three trials: single thrust, repeated thrust, and strike hold (Shaw et al. 2012: 6). In the first trial, the participant thrusts the spear and withdraws with a two second interval. In the second trial, repeated strike, the participant struck the target three times in quick succession and rested afterwards. The final trial was done with the participant striking the target and holding the spear there. Each of these trials simulated what a Neanderthal would have done to kill their prey.

For scraping, carpet was used to imitate fur. Three trials were mimicked what Neanderthals might have done to scrape a hide: hacking, vertical pull down, and push or pull scraping. Hacking used a chisel, vertical pull down used a crowbar, and the push or pull scraping utilized a replicated Mousterian tool. In push scraping the tool is being moved away from the body and in pulling, the tool is drawn towards the participant's body (Shaw et al. 2012: 6).

Using EMG to compare the muscle activity during these tasks, the researchers found that the spear thrusting had less muscle activation in the dominant arm than in the scraping tasks. Leading the researchers to conclude that spear thrusting as a major factor in humerus shaft morphology was not as instrumental as hypothesized (Churchill et al. 1996, Churchill 2002). Instead of the dominant (right) arm supplying and taking the force required in spear thrusting, the non-dominant (left) arm took the brunt of the force in spear thrusting, as indicated by a higher EMG frequency. Instead, based on the signal produced by the muscles, one handed scraping might have had a larger role in humerus morphology since the EMG signal produced by the muscles were a higher frequency than in spear thrusting for the dominant arm (Shaw et al. 2012).

Sládek et al. (2016) also examined humerus asymmetry in Europe between Mesolithic and Neolithic periods. Females from these time periods displayed an increase in asymmetrical humeral strength during the later periods. The authors hypothesize the change in humeral morphology in European females were caused by a change in grinding technology, from the saddle quern grinding (metate style grinder) to the rotary quern grinding (a device with two stone slabs that are rotated over each to grind).

Muscles examined were pectoralis major, anterior deltoid, infraspinatus, and triceps brachii. Sixteen females participated in the study. The results were indicated muscle activity during the saddle quern grinding produced symmetrical muscle expenditure; however, the saddle quern produced asymmetrical forces regardless of whether one arm or both arms were used while grinding (Sládek et al. 2016:148).

Both of these studies used EMG to explain what is shown in the skeletal material available for study. In my project however, there is no skeletal population available for analysis, therefore I utilize EMG to propose a hypothetical model. The other two studies focused on the morphological changes of the humerus in response to different stressors and the strength of the humerus. Whereas, I am looking at specific muscle attachment sites and joints and hypothesizing the involvement of degenerative joint diseases and enthesopathies based on the EMG signal.

Pre- and Post-Contact Wichita Case Study

Many cultures have used both hafted and handheld scrapers throughout history. I have selected the Wichita as a case study in order to understand the muscle dynamics in using hafted and handheld scrapers. Wichita peoples used a uniform end scraper that was hafted to deer antler or a sturdy branch before they engaged with the French Hide trade (Cleeland 2008). After trade with the French began, scraper technology changed to a more expedient and basic handheld scraper (Cleeland 2008).

The Wichita, known today as Wichita and Affiliated Tribes, are a southern plains Native American Tribe whose territory encompassed the modern states of Texas, Oklahoma, Kansas, and Arkansas (Figure 2.4).

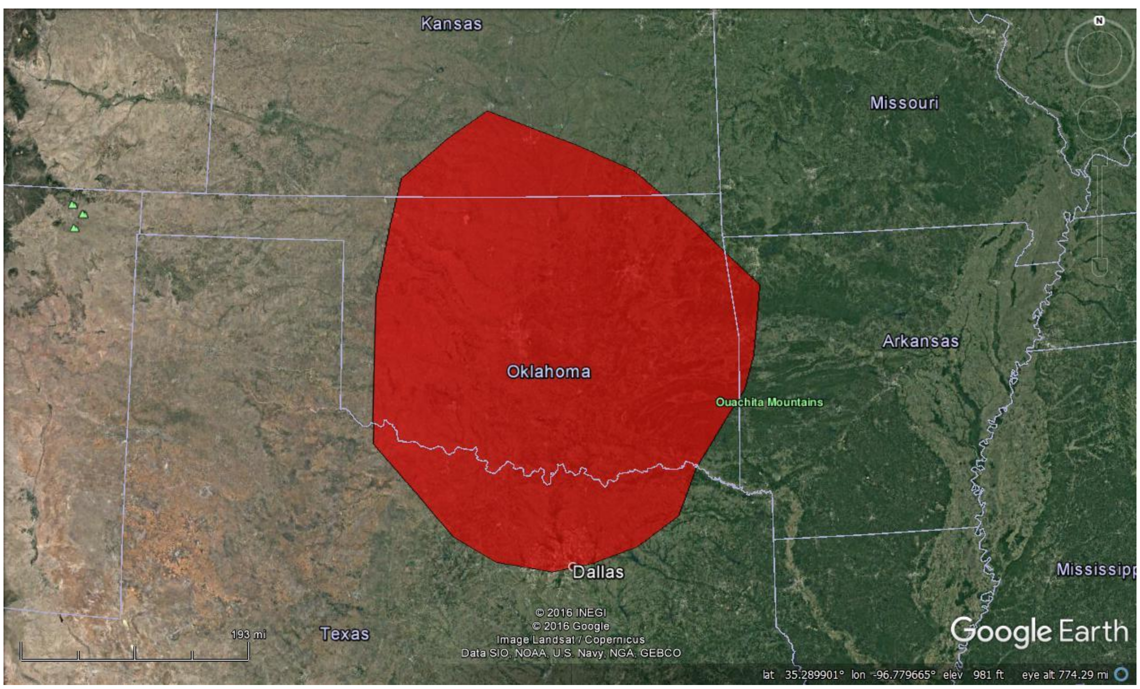

Figure 2.4. Map showing traditional Wichita Cultural territory in red.

Their subsistence strategies included both farming and hunting. In the summer and spring, they farmed near river drainages and lived in grass houses. During fall and winter, the Wichita left the area and followed bison herds across the plains with tipis for shelter. In addition to seasonal mobility, the Wichita lived in scattered villages (Smith 2000:3-4), as to not exhaust resources. Gender roles were established at a young age, with men hunting and going on raids while women farmed and processed hides (Smith 2000:4-5).

The Wichita have a long history of maintaining long distance trade networks. Some northern Rio Grande Pueblos were a consistent trade partner of the Wichita, as they provided bison products, bois d'arc wood, and other goods in exchange for Puebloan obsidian, turquoise, and various domesticates (Smith 2003:9). Wichita tradesmen were also knowledgeable of the southeastern tribes (Smith 2002:9, Vehik 2002:37-39). Vehik (2002) argued that population distribution and an increase in conflict provided Wichita chiefs the ability to expand their trade and prestige. As conflict increased in the region, before and after contact, nonlocal items increased in importance and were generally associated with a few distinct individuals (Vehik 2002).

In addition to increased violence and the movement of exotic goods, many Wichita groups were adjusting to their new trade partners, the Europeans (Cleeland 2008, Odell 2003, 2008, Smith 2003, Perkin et al. 2008). The French were demanding more bison products to ship to their colonies and back to France (Perkins, et al. 2008). Due to this high demand, Perkins and colleagues hypothesize that the Wichita began to engage in polygyny in order to have more wives to process more hides. Other studies on gender division of labor among the Wichita, combined with ethnohistories, corroborate that women were the ones to process hides, from initial skinning to the finished hide (Cleeland 2008:49, Odell 1999, 2008, Smith 2003:5, Weltfish 1965). To meet increased demands, Wichita men began to marry more wives in order to increase their income and their status in the village in the early 18th century (Perkins, et al. 2008). Although the Wichita and other Plains tribes were already practicing polygyny, it might have shifted from sororal polygyny, a man marrying sisters, to general polygyny/wealth-increasing polygyny (Perkins et al. 2008). Archaeological evidence for this shift in marriage practices can be seen in an increase of household size, although according to Perkins it is a working theory (2008).

Other lines of evidence for Wichita interaction with European trade strategies can be seen in the lithics, specifically scrapers (Cleeland 2008, Creel 1991, Odell 2003, 2008). The Wichita bison hide trade saw an increase in specialization as early as 1300 ACE, with the increased presence of endscrapers (Creel 1991). Early 18th century Wichita sites show an increase in the number of scrapers as well as a designated area for hide production (Creel 1991, Odell 2003, 2008). The increase in scrapers suggests that the Wichita understood what their trade partners needed and accordingly adjusted their production. The continued use of chipped stone tools into the Historic Period indicates that the Wichita resisted and sometimes modified European trade goods (Cleeland 2008, Creel 1991, Leith 2008, Odell 1991, 2003, 2008).

Specifically, the Wichita made larger handheld scrapers, shifting away from the small hafted endscrapers used before (Cleeland 2008). Figure 2.5 provides examples of Pre- and Post-Contact Wichita scrapers. These changes in lithic technology are best seen in the Bryson-Paddock handheld scraper (Post-Contact scraper), and the Tobias hafted endscraper (Pre-Contact scraper). Cleeland (2008) hypothesizes this change allowed the Wichita to increase efficiency in producing hides as it took less time to make the handheld scrapers.

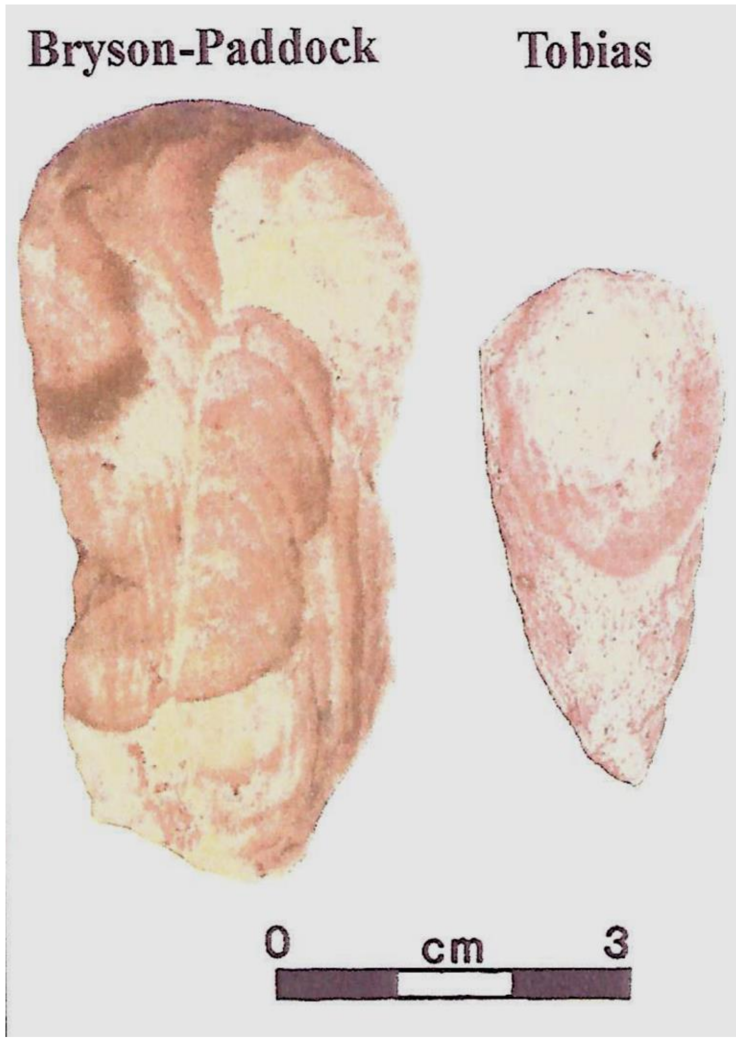

Figure 2.5. Depictions of Post-Contact Scraper (Bryson-Paddock) and Pre-Contact Scraper (Tobias) (from Cleeland 2008:85).

Cleeland (2008) notes the other changes made by the Wichita to increase their income and exchange with the French. More local lithic sources were used later in time, like Florence A chert, rather than utilizing more costly nonlocal materials. Cleeland (2008) hypothesizes the change was to decrease the time procuring nodes, as well as not waste exotic material (2008). Eighteenth-century sites provide less evidence for heat treating and scrapers retain more cortex suggesting less time was taken to produce them. Comparatively, earlier scrapers lacked cortex indicating that more time was spent knapping. Additionally, scrapers at Bryson-Paddock (18th Century) and other contemporary sites were not resharpened often (2008). Perhaps because a surplus of scrapers were made for hide processing. It is noted that Bryson-Paddock has an "unusually high number" of scrapers (Perkins et al. 2008), lending weight to Cleeland's (2008) hypothesis. The change in scraper technology to increase efficiency in bison hide production illustrates the Wichita's flexibility and willingness to adapt their technology and social organization to engage in new exchange opportunities.

Bison Hide Processing in the Plains

To create a supple, workable hide, bone or stone tools can be used to remove flesh, hair, muscle, and/or sinew. The process varies depending on the practices, from a few weeks to months if the hide requires decorations and embellishments (Cleeland 2008, Schultz 1989, 1992, Weltfish 1965). For French fur traders, bison hides were coveted trade items from Plains groups (Cleeland 2008). Many tribes traded hides with Europeans for guns, food, medicine and alliances (Smith 2000). Many Wichita bands were successful in their trade relations with the French and installed themselves as a go-between the French and other tribes to produce hundreds of bison hides for trade (Cleeland 2008, Odell 1999, 2003, 2008, Perkins et al 2008, Vehik 2002).

Schultz (1989, 1992) compiled ethnographies of Native North American Plains societies and the methods used to process hides. Seven steps were common among all these groups and most important to my research, scrapers were used in most of the steps. The first step is to prepare the hide for processing, which includes either lashing the hide to a wooden frame to have it upright, or stake it taught on the ground. Next the flesh was scraped to prevent rot (Schultz 1989, 1992, Weltfish 1965). Stripping the hide of hair, thinning the hide, and scraping the hide were next. Dehairing was performed on a dry hide and occurred if hide was destined for leather and not for a winter coat and can be done multiple ways, through scraping, pounded by stones, or soaked in an ash/lime/lye solution until the hair slipped off (Schultz 1992). For the purpose of this study, dehairing via scraper will be used to reduce health risks, such as bacterial infections if a participant is cut during the experiment. Scraping and thinning the hide were to ensure an even thickness and to prepare for the next step, braining. The brains and other organs were ground down and rubbed into the hide in order to make it soft and supple. After the hide had cured, several steps ensued: the hide was soaked, stretched a second time, the brain mixture removed and any leftover rough spots smoothed out. Sawing the hide between two poles helps to make the hide softer and to remove any excess water. Smoking was an optional step in the hide process. Placing the hide over a small fire caused the hide to tan and become water resistant. Once the hide was finished, it could be fashioned into clothing, tipi sides, or traded.

Based on historic photographs and paintings (figure 2.6), hides could be placed in two positions for dehairing (Catlin 1834, Schultz 1989, 1992, Weltfish 1965). There is an upright position where the hide is perpendicular to the ground and the woman kneels in front of it to work the hide (kneeling position). For the other position, the hide is staked to the ground and the woman crouched over or on the hide (crouching position). These different positions could affect what muscles are being activated, or if the same muscles are being used in both positions, and the intensity of the muscle activation could be affected.

Hypothesis

Trade with the French caused several dramatic shifts in Wichita culture. These include changes in marriage patterns, scraper technology (i.e. larger scrapers and no longer using hafts), and an increase in demand for bison hide production and thus an increase in the physical demands for Wichita women (Cleeland 2008, Perkins et al. 2008). Utilizing biocultural theory; and highlighting the interaction between culture and biology, (Cohen and Armelagos 1984), these changes in cultural patterns and activity, should be reflected on the musculo-skeletal system. Specifically, changes in scraper technology towards larger scrapers and away from hafted ones should be visible on the skeleton. My hypothesis is that more muscle force was required to use the handheld scraper (Post-Contact) than the hafted scraper (Pre-Contact), resulting in larger muscle attachments and perhaps early onset of osteoarthritis.

Figure 2.6. George Catlin's painting, *Comanche Village, Women Dressing Robes and Drying Meat,* depicts the two scraping positions, crouching and kneeling.

Chapter 3: Methods

To test if the change in scraper technology impacted the musculo-skeletal system of the arm, an experiment was designed that employed the use of electromyography (EMG) in biomechanics (Robertson et al. 2014, Ruff 2008, Ruff et al. 2006) to measure muscle activity in the arm, under a biocultural approach (Cohen and Armelagos 1984). Participants used reproduction Pre- and Post-Contact scrapers on a bison hide stretched on to a frame while EMG electrodes were affixed to the posterior deltoid, biceps brachii, and brachioradialis muscles. The experiment includes two independent variables, the scrapers (Pre-Contact/hafted and Post-Contact/handheld) and the two scraping positions (kneeling and crouching). Kneeling simulates the bison hide upright position and the participant is on their knees with their back more or less straight. The crouching positions mimics the hide staked into the ground, the participant is also on their knees but bent over the hide. The dependent variable is the amplitude of the EMG signal of the bicep, forearm, and posterior deltoid muscles of the participant's dominant hand while scraping on a bison hide. Due to time constraints, the intensity of bison hide production (how many hides were produced per month) were not tested. The study's protocol was approved by University of Oklahoma Institutional Review Board (IRB #7681).

Materials

Scrapers

For my experiment, I commissioned the production of 10 Pre-Contact Scrapers and 10 Pre-Contact Scrapers. I also procured two bison hides, attached them to a frame, and received access to EMG electrodes, and an EMG machine. Dr. Leland Bement at the Oklahoma Archeological Survey donated the bison hides for the experiment. Drs. Michael Bemben and Christopher Black at the University of Oklahoma Department of Health and Exercise Science donated EMG electrodes, EMG Machine, and allotted lab space to conduct the experiment. Bob Berg from Thunderbird Atlatl made the scrapers (http://www.thunderbirdatlatl.com).

Pre-Contact scrapers were generally uniform in shape and dimensions, whereas the Pre-Contact scrapers were more crudely made and highly variable in shape (Cleeland 2008: 84). Because of the variability in Pre-Contact scrapers, only one form (Figure 2.5) was reproduced because it was considered standard for Post-Contact scrapers (Dr. Susan Vehik personal communication 2016). Each scraper was arbitrarily numbered 1 through 10 for each Pre and Pre-Contact set. Figure 3.1-3.2 depict the replicated scrapers. The dimensions of each scraper for Pre and Pre-Contact are below in Tables 3.1-3.2. I measured dimensions using digital calipers and weights measured on a scale. Caliper measurements were done the same way that Dr. Lauren Cleeland used in her thesis (2008:53).

Figure 3.1. Reproduction Pre-Contact Scrapers.

Figure 3.2. Reproduction Post-Contact Scrapers.

Table 3.1 Pre-Contact Scraper Dimensions and Material Type					
Scraper No	Length (cm)	Width (cm)	Thickness (cm)	Weight (g)	Raw Material
1		3.2	0.97		Georgetown
2		3.72	1.07		Pedernales
3		3.2	1.02		Georgetown
4		3.28	1.23		Pedernales
5		3.02	0.74		Georgetown
6		3.05	1.4		Georgetown
7		3.47	0.9		Georgetown
8		3.02	1.33		Georgetown
9		4.14	0.8		Georgetown
10		2.96	1.07		Georgetown

Lengths and weights for the Pre-Contact scrapers could not be measured since they were sent already hafted. The average width is, 3.306 cm, and the average thickness is 1.053 cm.

Table 3.2 Pre-Contact Scraper Dimensions and Material Type					
Scraper No.	Length (cm)	Width (cm)	Thickness (cm)	Weight (g)	Raw Material
1	8.86	3.62	1.25	40.6	Georgetown
2	10.2	3.84	1.53	60.6	Georgetown
3	7.28	4.9	1.37	51.3	Pedernales
4	5.2	4.31	1.14	24.4	Georgetown
5	6.95	4.47	1.13	38.3	Georgetown
6	5.98	4.11	1.58	34.4	Pedernales
7	6.15	3.74	1.12	28.4	Georgetown
8	7.8	3.56	1.6	45.3	Georgetown
9	7.79	3.32	0.93	28.6	Georgetown
10	5.79	3.91	1.45	35.3	Georgetown

The average dimensions are: length 7.2 cm, width 3.98 cm, thickness 1.31 cm, and weight 38.72 g.

In experimental bioarchaeology, it is ideal to use the same materials and have them made similarly to how they would have been in the past (Ingersoll et al. 1977: xii). However, the flint-knapper reproducing the scrapers was unable to acquire the chert used by the Wichita during the French Fur trade (Florence A chert). Using the same material type that was used in the past is pertinent to an experiment if the hypothesis is concerned about the form and function of the tool itself. Since my experiment is concerned with the human body and the effect of using a hafted tool versus a handheld tool, the handle is more pertinent than Florence A Chert, as it will have a direct effect on the muscles engaged.

Chert is a sedimentary rock composed of silicon dioxide (SiO_2), or silica. It can be formed through a variety of ways but the most common formation happens when silica, both from organic matter or inorganic matter, is deposited and filtered through limestone (Hein et al. 1981, Laschet 1984, Meyers 1977). If enough silicates are concreted together, chert is formed. Chert occurs in a variety of colors depending on characteristics in the soil, red from iron and darker colors from organic matter. The Mohs Hardness scale of chert is 6.5-7 (Hein et al. 1981, Laschet 1984, Meyers 1977), the same hardness as quartz.

Because chert is formed in a similar manner, has the same hardness, and has the same qualities regardless of where it comes from, the chert used should perform similarly to the chert used by the Wichita. For future studies, tests can be run where participants use these different types of chert and see if there is a statistically or qualitatively different EMG signal. Furthermore, the effects of different classes of minerals (i.e. obsidian, chert, quartz) on biomechanics can also be tested. Also, the chert used to make the reproduction scrapers were not heat treated. Heat treatment is usually done to align the crystalline structure to make it easier to knap (Domanski and Webb 1992, 2007) and might not have an effect on the performance of the tool. Again, no research has been undertaken to study the effects of heat treatment versus no heat treatment on biomechanics and can be a possible avenue for future research.

Bison Hides

The hides were already cured and defleshed to reduce the chance of bacterial infection in case a participant experiences a cut while scraping. To mimic traditional Plains hide processing techniques, the hide was soaked in water for two days to make it pliable. Due to the confined space of the Neuromuscular Lab, the hide was cut to fit across an 18x24” canvas frame. The hides were stretched across the frame and stapled to the frame to imitate the tension Plains groups had while stretching the hide in either position, staked to the ground or upright in a frame.

Muscles and EMG Placement

Since paleopathologies like enthesopathies (enlarged muscle attachments) and osteoarthritis are being considered, the muscles chosen have a clear attachment site on the skeleton. I chose to measure the following muscles: biceps brachii which attaches to the radial tuberosity on the radius, the posterior deltoid which attaches to the deltoid tuberosity on the humerus, and the brachioradialis muscles. The brachioradialis was chosen because the Supinator muscle, which attaches to the supinator crest on the ulna, cannot be measured using surface EMG. However, both muscles aide in supinating the hand and so EMG measurement of the brachioradialis serves as a proxy for the supinator (Bowden and Bowden 2005, White et al. 2012). Appendices F-L have a reference picture of the muscle followed by the corresponding bone, starting with the posterior deltoid. A total of six (6) EMG electrodes are placed on the three muscles to measure the muscle activity during scraping. Data were collected using a BioPack MP 100 with a band pass filter of 10-100 mHz. AcKnowledge 3.8.1 software recorded and analyzed the EMG signals.

Each of these muscles are responsible for initiating a movement. Even though I only focused on 3 muscles, it is important to note that muscles do not move a joint or bone in singularity, rather many muscles are engaged when initiating movement. Due to available equipment and time constraints, I focused on easily identifiable and measurable muscles for this pilot study. The biceps brachii is the main muscle for flexion at the elbow, raising the hand to the shoulder (Bowden and Bowden 2005:166). The posterior deltoid is responsible for extension of the arm, or drawing the arm towards the body (2005:159). Brachioradialis muscles rotate the hand up to anatomical position and radius over the ulna, in conjunction with the supinator (2005:184). During scraping, there is a significant amount of flexion at the elbow to allow the arm to move freely over the hide and the posterior deltoid would be responsible for pulling the entire arm towards the body. The brachioradialis muscle was chosen to better understand muscle activation when using a hafted scraper versus a handheld scraper (Figure 3.6a-b).

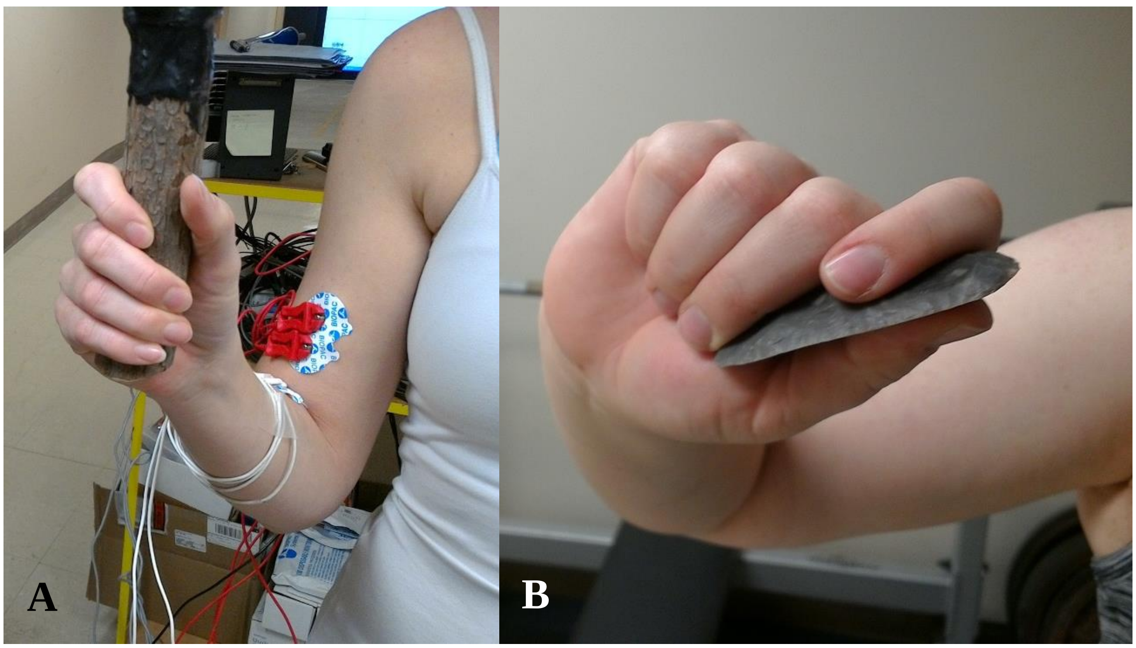

Figure 3.3A and 3.3B. Participants demonstrating the difference in rotation holding (A) a Pre-Contact Scraper and (B) a Post-Contact Scraper.

To understand how these muscles are activated during hide processing, using different tools, and in different positions, electromyography was used. Electromyography (EMG), is used to measure the amount of electricity (Volts) generated by the muscle (Basmajian 1978: 53). EMG electrodes are attached to the skin above the main portion of the muscle, or belly. Each muscle has a specific area where two (2) electrodes are attached. Electrode placements for the biceps, posterior deltoid, and brachioradialis muscles are shown in figure 3.7 below:

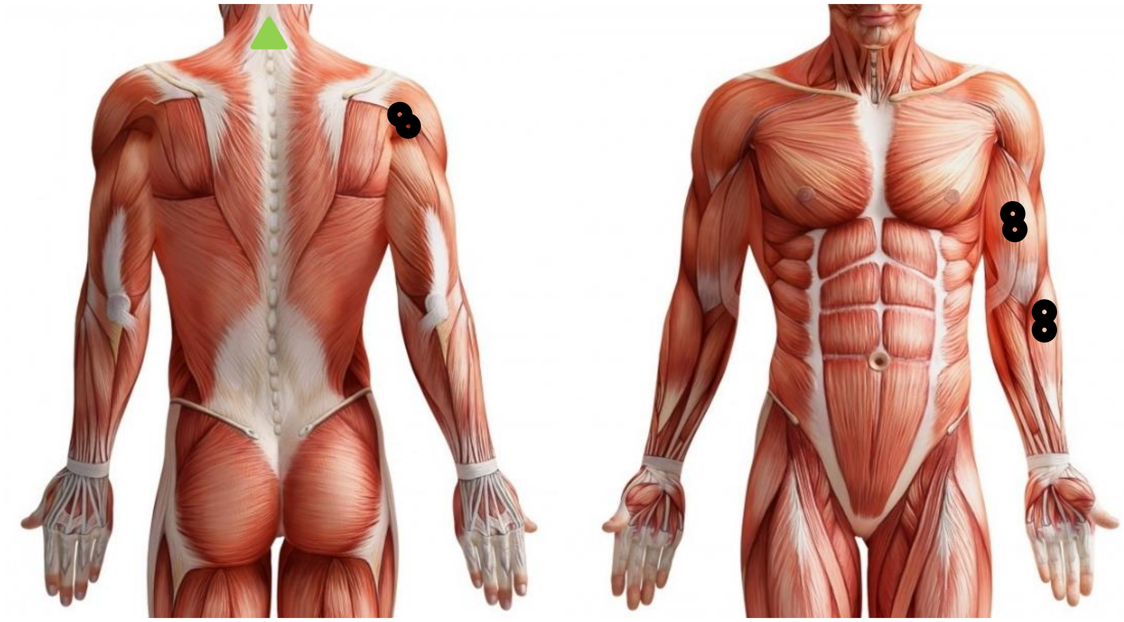

Figure 3.4. Electrode Placement on the posterior deltoid, biceps, and brachioradialis, depicted by the black circles. The Grounding Electrode placement is depicted by a green triangle (Based off Konrad 2006).

Grounding electrodes are placed opposite one of the three designated muscle placements. Grounding electrodes eliminate noise/ambient electricity in the surrounding environment (Basmajian 1978:38, De Luca 1993, Konrad 2006). The grounding electrode for this experiment was placed on the seventh cervical vertebrae, opposite the posterior deltoid.

Experiment Protocol

The experiment is a within subject design, meaning each participant is compared to themselves and they serve as their own control. Ten females participated in the experiment (9 right-hand dominant and 1 left-hand dominant). Because females historically were responsible for processing hides (Smith 2000:4-5, Weltfish 1965), only females participants were recruited. Average age 25.4, average height 1.67 meters, and average weight 75.16 kilograms. Participants were assigned a random number to provide anonymity.

The experiment was done in collaboration with the Department of Health and Exercise Science at the University of Oklahoma in the Neuromuscular Research Lab. The experiment consisted of two sessions in the course of one week, with a total time commitment of approximately 2-3 hours. The first session was a familiarization session, where the bison hide processing in the Plains was explained and demonstrated. Following the presentation, participants practiced scraping the bison hides with both types of scrapers and positions. Two hides allowed multiple participants to practice per hide. Once participants felt comfortable using the scrapers, they signed up for one of two days to come in for a 90-minute session to perform the experiment.

The second session, the participants did exercises to determine their maximum voluntary isometric strength (MVC) for each muscle. Each participant contracted to their full strength for three sets and held the contraction for three seconds each. The EMG signal for each participant served as their baseline. Following the isometric contractions, participants performed the four trials on hide scraping: hafted scraper while kneeling, hafted scraper while crouching, handheld scraper while kneeling, and handheld scraper while crouching. The trials were randomized for each participant, so that no participants performed the trials in the same order (Appendix E).

An exercise that emphasized each of the chosen muscles was performed by the participant the measure the MVC. For biceps brachii isometric contractions, participants stood over a bench press performing a single arm bicep curl (Figure 3.8). For the posterior deltoid, participants stood over a bench press lifting the bar with their elbows away from their bodies at a 90 degree angle (Figure 3.9). Finally, the forearm isometric contractions were performed by tightly gripping a handgrip dynamometer (Figure 3.10).

Figure 3.5. Participant during MVC of Bicep.


Figure 3.6. Participant during MVC of posterior deltoid.

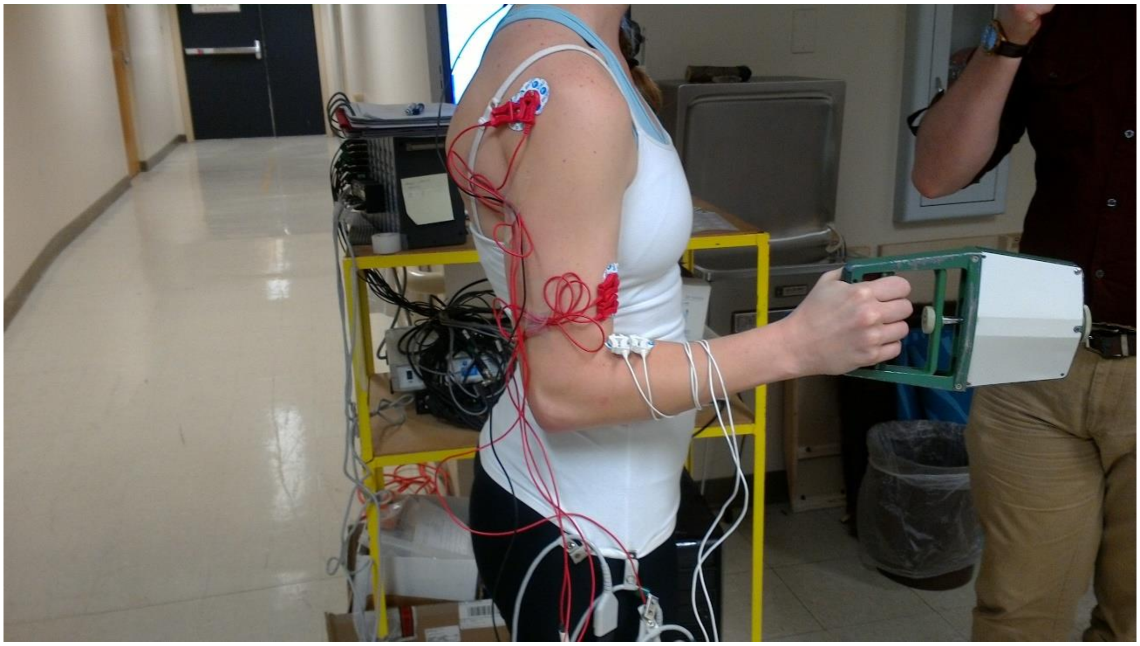

Figure 3.7. Participant during the MVC for the brachioradialis.

Also, during the second visit, I gave a review of the scrapers and positions. Afterwards, EMG electrodes were attached to the bicep, posterior deltoid, and brachioradialis. Once the hide and participant were in position, they scraped for three minutes without EMG data being collected as a warm-up and practice. After the three minutes, the participant rested for one minute and then scraped for ten minutes with EMG data being collected. The participant scraped towards them (pull scraper) followed by a short break and reset to the starting position, to help isolate the contractions. After measurements for each trial, the participant rested for 5-10 minutes. These steps were repeated 4 times until all four trials were completed. Following the end of the final test, the participant completed a survey/pain questionnaire (Appendix D) to describe where pain or discomfort was felt during the test. These data are useful to identify future areas of research.

Chapter 4: Results

Data collected during the experiments with 10 female participants was processed using AcKnowledge 3.8.1 software. EMG signals were filtered through a band pass filter to eliminate artifact movement, signal associated with wire movement and not from muscle activity. The parameters for the band pass filter are 10 Hertz (Hz) for the low filter and 500 Hz for the high filter. The Root Mean Square (RMS) was calculated for each channel: posterior deltoid, biceps brachii, and brachioradialis. The RMS is done to obtain a positive value along the EMG signal in order to get maximum, mean, and median values.

The maximum voluntary contraction (MVC) for each muscle will be presented with two values, the average value and the average maximum value. Each trial will be discussed chronologically in terms of tool use, hafted trials will be presented first followed by handheld trials. Values presented for each trial were the maximum and average values across all ten contractions.

Maximum Voluntary Contractions (MVC)

Tables 4.1-4.3 show the maximum contractions for each participant. By calculating the MVC, each participant provided their own baseline for each muscle that the trials will be compared to, in order to get the percentage of the maximum voluntary contraction (%MVC). The %MVC will demonstrate which tool and position combination exerted more force, which allowed me to generate predictions regarding where osteoarthritis and enthesopathies might develop over the life course of Wichita women in Pre- and Post-Contact periods.

Table 4.1 MVC Values for Posterior Deltoid. Values in Hz.		
Participant Number	**Average RMS during MVC**	**Maximum RMS during MVC**
1	0.22	1.33
2	0.83	4.59
3	0.26	1.28
4	0.22	1.33
5	0.83	5.19
6	0.42	2.04
7	0.14	0.77
8	0.38	1.73
9	0.12	0.75
10	0.44	2.39

Table 4.2 MVC Values for Biceps Brachii. Values in Hz.		
Participant Number	**Average RMS during MVC**	**Maximum RMS during MVC**
1	0.88	4.81
2	0.44	2.56
3	0.17	0.95
4	0.24	1.26
5	0.37	2.04
6	0.3	2.12
7	0.13	0.73
8	0.21	0.97
9	0.43	2.53
10	0.94	3.59

Table 4.3 MVC Values for Brachioradialis. Values in Hz.		
Participant Number	**Average RMS during MVC**	**Maximum RMS during MVC**
1	0.07	0.48
2	0.14	0.84
3	0.15	0.76
4	0.13	0.73
5	0.23	1.29
6	0.22	1.81
7	0.18	0.85
8	0.22	1.15
9	0.12	0.75
10	0.20	1.23

Hafted Crouching

Hafted crouching results are presented below in Table 4.4. The average value is across all 10 contractions the participants did while scraping. The maximum value is the maximum value over the 10 contractions. These are raw values that have not been calculated as a percentage of the MVC. Table 4.4 presents the raw EMG data for each participant in millivolts (mv) for this trial. Table 4.5 presents the calculated %MVC for the trial. The data shown in table 4.5 are correlated to the amount of force being exerted by the muscle during the trial. These values will be the most useful in interpreting paleopathologies in Post-Contact Wichita women.

Table 4.4 Mean and Maximum Values for Hafted Crouching Trial.

Participant Number	Max Posterior Deltoid	Mean Posterior Deltoid	Max Bicep	Mean Bicep	Max Supinator	Mean Supinator
1	0.32	0.02	0.48	0.04	0.34	0.04
2	0.61	0.06	0.23	0.02	0.35	0.03
3	0.76	0.08	0.26	0.03	0.33	0.05
4	0.47	0.05	0.44	0.03	0.39	0.04
5	1.45	0.09	0.27	0.02	0.28	0.04
6	1.32	0.09	0.21	0.02	0.53	0.04
7	0.29	0.03	0.17	0.02	0.31	0.03
8	0.91	0.08	0.43	0.03	0.5	0.04
9	0.39	0.04	0.67	0.06	0.56	0.06
10	1.28	0.10	0.75	0.05	0.55	0.06

Table 4.5 Percentage of MVC for Hafted Crouching Trial.

Participant Number	% MVC Max Posterior Deltoid	% MVC Average Posterior Deltoid	% MVC Max Bicep	% MVC Average Bicep	% MVC Max Supinator	% MVC Average Supinator
1	24%	09%	10%	05%	71%	57%
2	14%	07%	09%	05%	42%	21%
3	59%	31%	27%	18%	43%	33%
4	35%	23%	35%	13%	53%	31%
5	28%	11%	13%	05%	22%	17%
6	65%	21%	10%	07%	23%	18%
7	38%	21%	23%	15%	36%	17%
8	53%	21%	44%	14%	43%	18%
9	52%	33%	26%	14%	75%	05%
10	54%	23%	21%	05%	45%	03%

Averaging the %MVC for the Hafted Crouching trials and all following trials (Table 4.6) provided an average muscle activation for the participants. Calculating this measurement facilitated drawing interpretations on muscle and skeletal activity as a population, rather than on an individual basis. This is because skeletal biologists interpret paleopathological patterns on a population level.

Table 4.6 Average %MVC for Hafted Crouching Trials		
Posterior Deltoid	**Bicep**	**Brachioradialis**
20% ± 9%	10.1% ± 5%	29.2% ± 14%

Based on the %MVC average for the three muscle groups measured, the posterior deltoid reached 20% of the MVC for the 10 participants. The biceps brachii 10.1% of the MVC and the brachioradialis was the highest %MVC with 29.2%. This indicates that the across the entire sample, the brachioradialis exerted more force than the other two muscles.

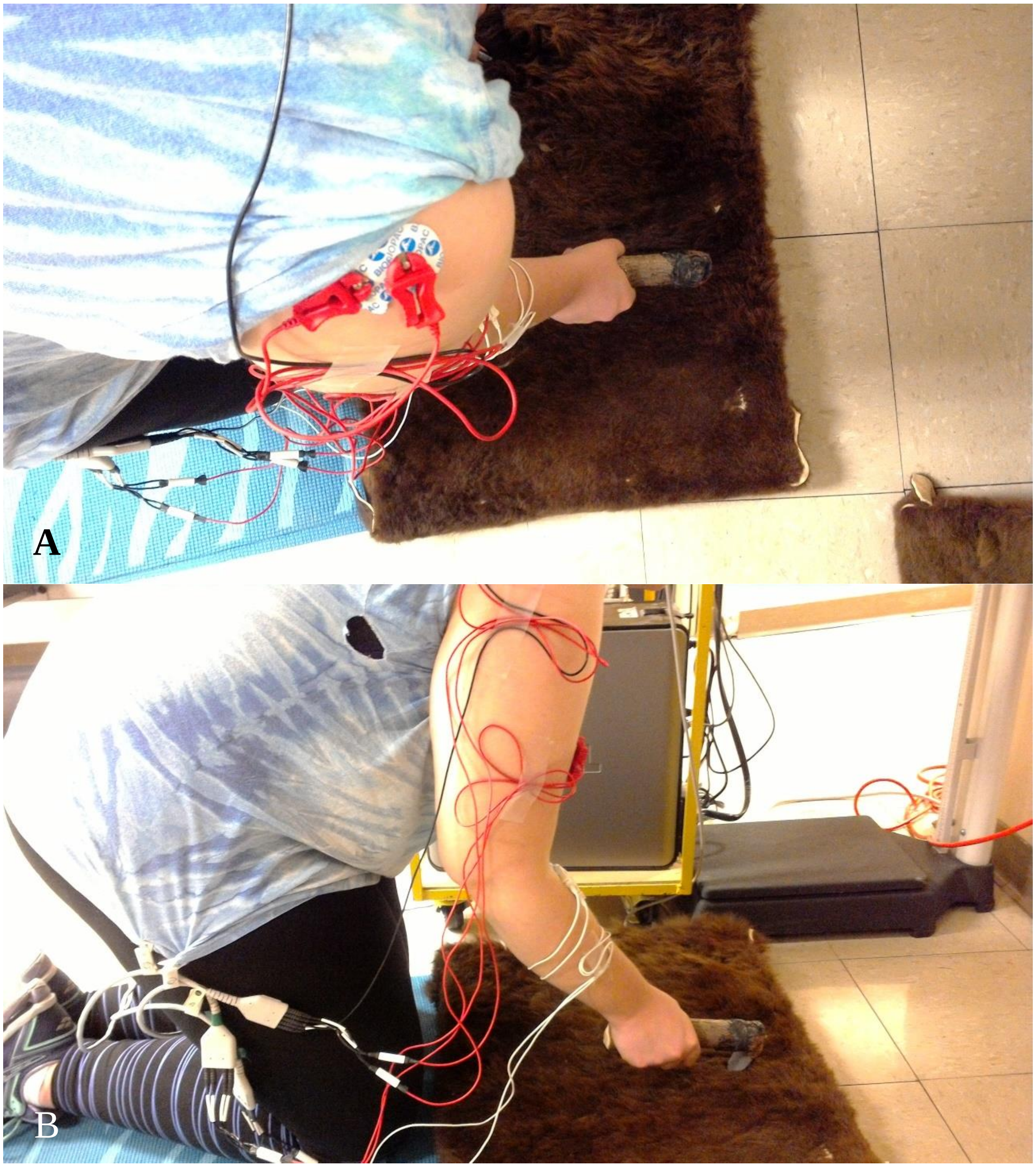

Figure 4.1A and 4.1B. Participant during the Hafted Crouching trial (A) view from above and (B) view from side.

Hafted Kneeling

Hafted kneeling values for each participant are presented below. This trial is using the hafted tool (Pre-Contact Scraper) while the hide is upright and the participant kneeling in front of the hide. Tables 4.7-4.9 report maximum and average values, %MCV, and average %MVC for this trial, respectively.

Table 4.7 Mean and Maximum Values for Hafted Kneeling Trial.

Participant Number	Max Posterior Deltoid	Mean Posterior Deltoid	Max Bicep	Mean Bicep	Max Brachioradialis	Mean Brachioradialis
1	0.22	0.03	0.93	0.07	0.26	0.03
2	1.07	0.06	0.84	0.04	0.59	0.06
3	0.49	0.05	0.48	0.04	0.47	0.06
4	0.34	0.03	0.83	0.07	0.45	0.04
5	0.66	0.06	0.43	0.03	0.61	0.06
6	1.19	0.1	0.38	0.03	1.15	0.07
7	0.2	0.03	0.34	0.03	0.44	0.03
8	0.75	0.06	0.55	0.04	0.49	0.05
9	0.3	0.04	0.57	0.06	0.62	0.05
10	1.26	0.09	2	0.09	1.11	0.07

Table 4.8 Percentage of MVC for Hafted Kneeling Trial.

Participant Number	% MVC Max Posterior Deltoid	% MVC Average Posterior Deltoid	% MVC Max Bicep	% Average Bicep	% MVC Max Supinator	% MVC Average Supinator
1	17%	14%	19%	08%	54%	43%
2	23%	07%	33%	09%	07%	43%
3	38%	19%	51%	24%	62%	04%
4	26%	14%	66%	29%	62%	31%
5	13%	07%	21%	08%	47%	26%
6	58%	24%	18%	01%	64%	32%
7	26%	21%	47%	23%	52%	17%
8	43%	16%	57%	19%	43%	23%
9	04%	33%	23%	14%	83%	42%
10	53%	02%	56%	01%	09%	35%

Table 4.9 Average %MVC for Hafted Kneeling Trial.		
Posterior Deltoid	**Bicep**	**Brachioradialis**
17.5% ± 8%	15.4% ± 8%	33.2% ± 9%

As with the Hafted Crouching, the brachioradialis average %MVC is highest among hafted kneelers, with posterior deltoid and biceps brachii.

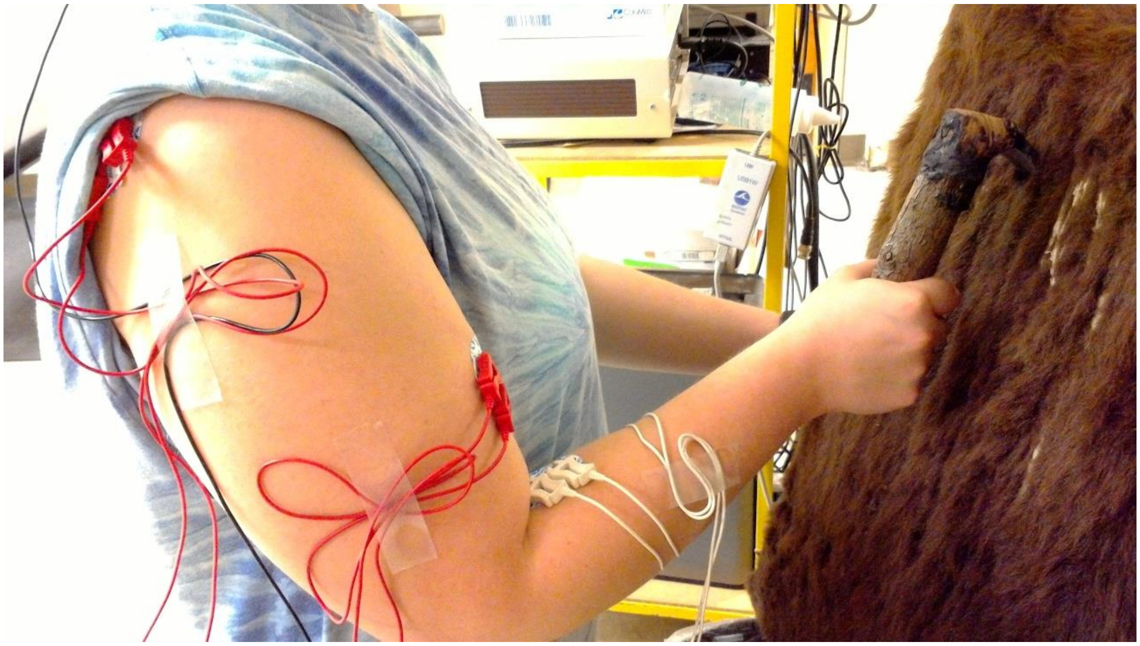

Figure 4.2. Participant during Hafted Kneeling Trial.

Handheld Crouch

Handheld crouching is using the replicated Post-Contact scraper, without a haft, and crouched over the bison hide to imitate the bison hide being staked to the ground. Tables 4.10-4.12 present the maximum and mean values, %MVC, and average %MVC.

Table 4.10 Mean and Maximum Values for Handheld Crouch Trial.

Participant Number	Max Posterior Deltoid	Mean Posterior Deltoid	Max Bicep	Mean Bicep	Max Brachioradialis	Mean Brachioradialis
1	0.24	0.02	0.5	0.02	0.96	0.09
2	1.18	0.14	0.24	0.02	0.31	0.04
3	1.16	0.13	0.44	0.04	0.47	0.07
4	0.41	0.04	0.29	0.02	0.47	0.03
5	1.29	0.1	0.33	0.03	0.42	0.05
6	0.99	0.08	0.48	0.04	1.08	0.11
7	0.23	0.03	0.24	0.03	0.38	0.04
8	0.91	0.09	0.65	0.06	0.51	0.06
9	0.49	0.04	0.16	0.02	0.45	0.06
10	1.21	0.11	0.65	0.04	0.73	0.08

Table 4.11 Percentage of MVC for Handheld Crouch Trial.

Participant Number	% MVC Max Posterior Deltoid	% MVC Average Posterior Deltoid	% MVC Max Bicep	% Average Bicep	% MVC Max Supinator	% MVC Average Supinator
1	18%	09%	01%	02%	02%	129%
2	26%	17%	09%	05%	37%	29%
3	91%	05%	46%	24%	62%	47%
4	31%	18%	23%	08%	64%	23%
5	25%	12%	16%	08%	33%	22%
6	49%	19%	23%	13%	06%	05%
7	03%	21%	33%	23%	45%	22%
8	63%	24%	67%	29%	44%	27%
9	65%	33%	06%	05%	06%	05%
10	51%	25%	18%	04%	59%	04%

Table 4.12 Average %MVC for Handheld Crouch Trial		
Posterior Deltoid	**Bicep**	**Brachioradialis**
22.8% ± 12%	12.1% ± 10%	43.9% ± 32.1%

Handheld Post-Contact Scrapers did not have a shaft, so I expected the brachioradialis would be more engaged. Because the forearm rotates more so the long side of the scraper would be in contact with the hide more force would be exerted to hold the scraper in place. Engagement of the biceps is low and could be due to the flexion at the elbow and minimal force being exerted by the muscle. The posterior deltoid is more engaged in handheld crouching position, again because it is pulling the arm towards the body during the scraping movement. However, it is also engaged to rotate the Humerus laterally (away from the body). Two other deltoid muscles are responsible for rotating the humerus laterally along with the pectoralis major. Further analysis of the deltoid in its entirety will have to be done as well as including the pectoralis major EMG data.

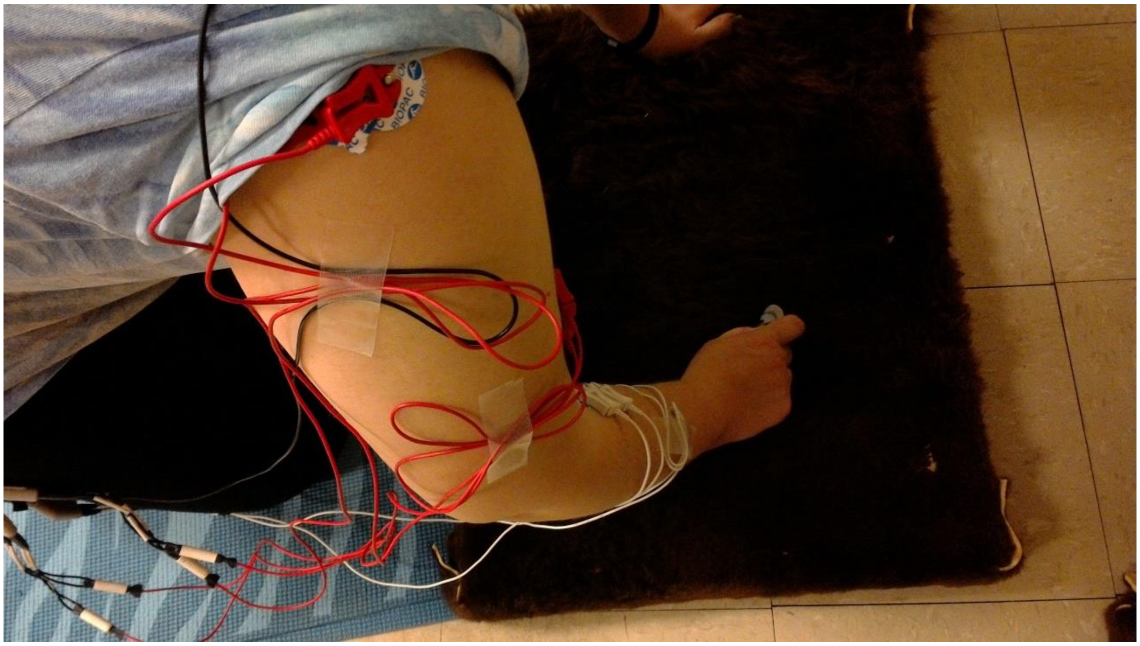

Figure 4.3. Participant during Handheld Crouching Trial.

Handheld Kneeling

The final trial results are the Handheld Kneeling. Wherein the Post-Contact scraper was used while the hide was upright and the participant in knelt in front of the hide. Tables 4.13-4.15 report the mean and maximum values, %MVC, and the average %MVC.

Table 4.13 Mean and Maximum Values for Handheld Kneeling

Participant Number	Max Posterior Deltoid	Mean Posterior Deltoid	Max Bicep	Mean Bicep	Max Brachioradialis	Mean Brachioradialis
1	0.37	0.03	0.41	0.03	0.8	0.06
2	1.42	0.14	0.41	0.03	0.45	0.04
3	0.81	0.12	0.53	0.06	0.44	0.05
4	0.46	0.05	0.27	0.03	0.45	0.04
5	1.72	0.11	0.6	0.06	0.35	0.05
6	1.67	0.11	0.52	0.05	0.64	0.08
7	0.34	0.04	0.48	0.04	0.29	0.03
8	1.25	0.13	1.16	0.14	0.96	0.06
9	0.45	0.06	0.2	0.02	0.86	0.06
10	1.14	0.12	1	0.04	0.92	0.1

Table 4.14 Percentage of MVC for Handheld Kneeling.

Participant Number	% MVC Max Posterior Deltoid	% MVC Average Posterior Deltoid	% MVC Max Bicep	% Average Bicep	% MVC Max Supinator	% MVC Average Supinator
1	28%	14%	31%	03%	167%	86%
2	31%	17%	09%	07%	54%	29%
3	63%	46%	41%	35%	58%	33%
4	35%	23%	02%	13%	62%	31%
5	33%	13%	12%	16%	27%	21%
6	82%	26%	25%	17%	35%	36%
7	44%	29%	62%	31%	34%	17%
8	72%	34%	67%	67%	83%	27%
9	06%	05%	27%	05%	115%	05%
10	48%	27%	42%	04%	75%	05%

Table 4.15 Average %MVC for Handheld Kneeling.		
Posterior Deltoid	**Bicep**	**Brachioradialis**
27.9% ± 12.5%	19.8% ± 19.9%	38.0% ± 20.0%

For the final trial, the posterior deltoid and brachioradialis muscles were more engaged than the Bicep. The Bicep was more engaged with the handheld scraper in the kneeling position than the crouching position, likely because due to the bicep exerted force outward from the body. Compared to the posterior deltoid in the crouching position which pushed the arm downward to apply pressure to dehair the hide. Handheld scraping in the kneeling position provided a similar view of muscle activity as its crouching counterpart. The Brachioradialis is more engaged due to the rotation of the Radius bone and holding the scraper while the posterior deltoid was supported the Humerus being extended laterally.

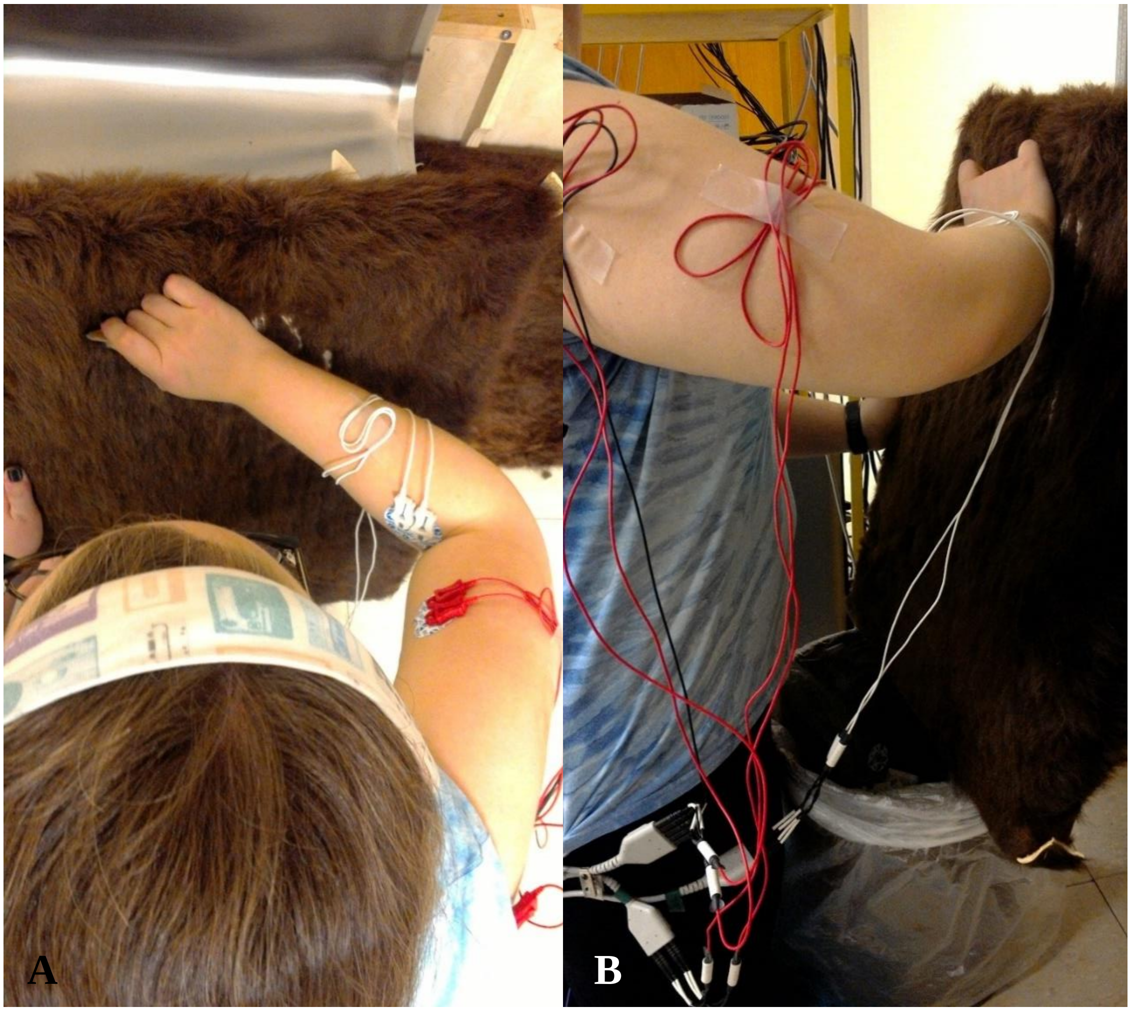

Figure 4.4A and 4.4B. Participant during Handheld Crouching Trail, (A) superior view and (B) lateral view.

Repeated Measures ANOVA

A 2x2 repeated measures ANOVA test was performed on each muscle, posterior deltoid, biceps brachii, and Brachioradialis, to test an interaction effect. An interaction effect compares between multiple levels of each factor to determine if there is a statistically significant difference for one or both factors. The factors chosen for the ANOVA test are Tool Type and Position. If the interaction effect is significant, then each trial will be compared to each other. If the interaction effect is not significant, then the effects of the tool or positions are tested to determine if one or the other has a significant effect on that muscle. Significance value is set as $p \leq 0.05$.

Posterior Deltoid ANOVA Results

For the posterior deltoid, the interaction effect had a p value of .003, a Bonferroni correction of <.0125 was added to the interaction effect for the posterior deltoid. Because the interaction effect was significant, meaning the tool type and position significantly affected the %MVC of the posterior deltoid, each trial was compared to each other. Handheld kneeling compared to hafted kneeling was significant (.003). Handheld crouching versus handheld kneeling was also significant (.023). Handheld kneeling versus hafted crouching was not significant (.230). Hafted crouching versus hafted kneeling was also not significant (.165). These values are presented below in Figure 4.5

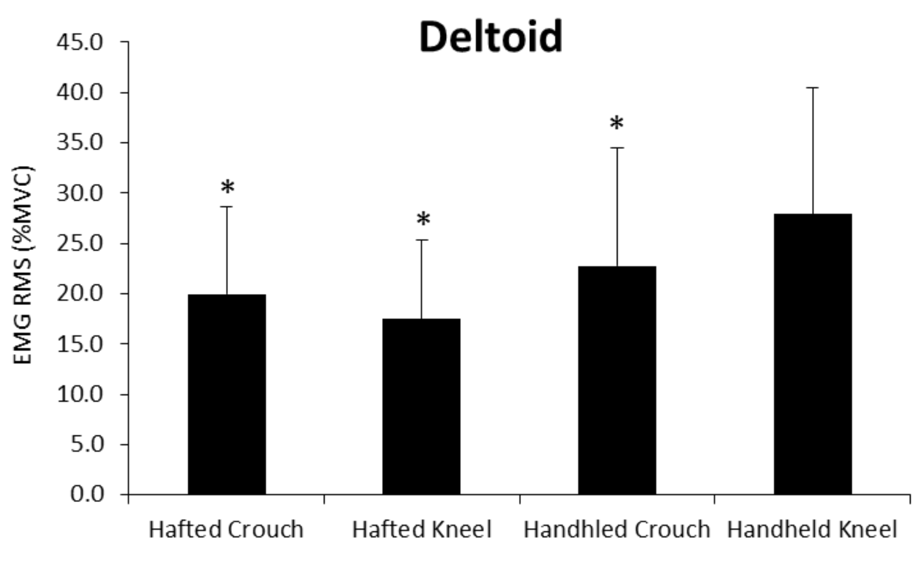

Figure 4.5 Mean EMG RMS of posterior deltoid for each trial. Asterisk"*" indicates significance

Biceps Brachii ANOVA Results

The interaction effect for biceps brachii is .53, meaning there is no significant effect between the trials. However, there is significance for the position ($p=.009$) but not the tool ($p=.425$). Meaning that the position had more of an effect on the innervation of the biceps brachii while scraping. Figures 4.2a and 4.2b depict the average EMG RMS values.

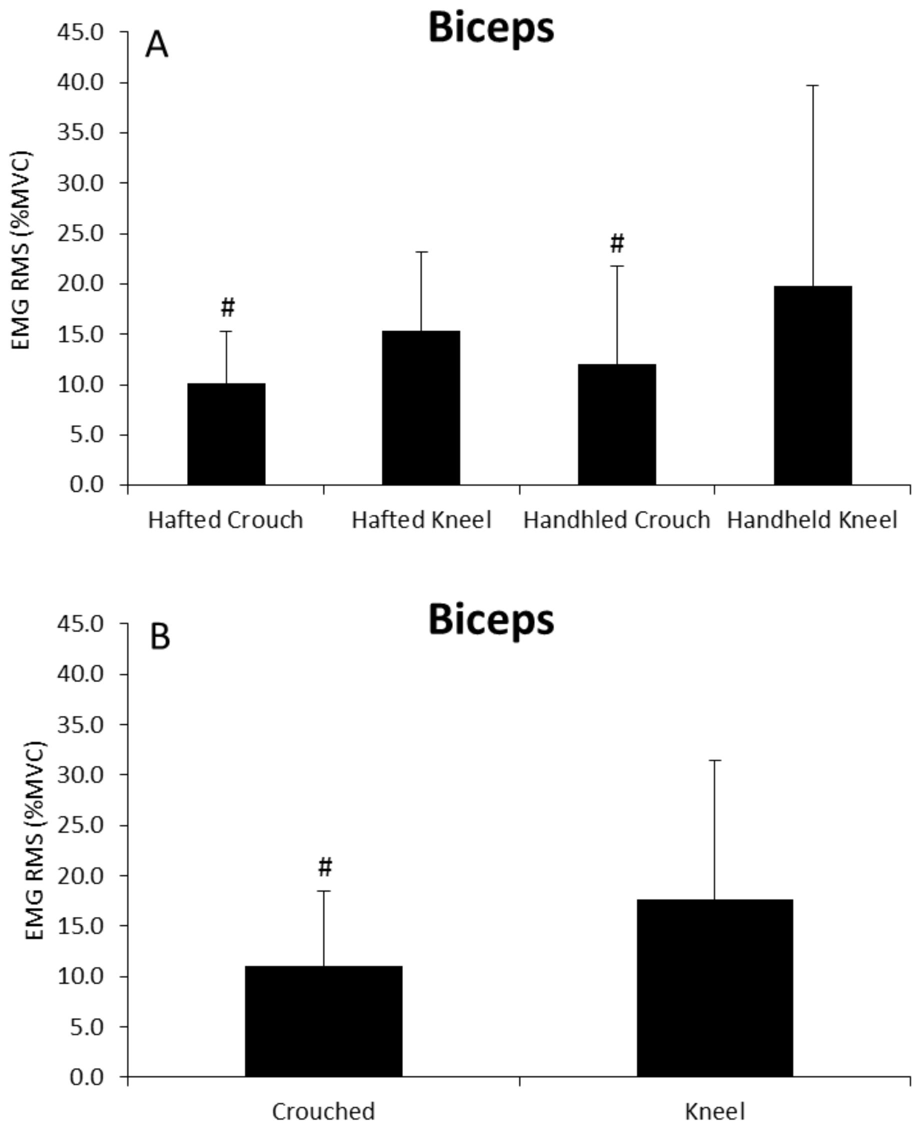

Figure 4.6A and 4.6B. Mean EMG RMS Values of biceps brachii during each trial. Pound "#" indicates the crouching position had a significant effect on the innervation of the biceps brachii

Brachioradialis ANOVA Results

The brachioradialis had an interaction effect of .058, neither the tool effect (p=0.122) or position effect (p=0.79) was significant. The brachioradialis was interesting in that there was not effect considering using the handheld tool requires more supination than when using the hafted tool. One reason is that a small sample size might have affected the statistical results. Another reason is that there was a participant whose %MVC value was over 100%. Meaning the participant when doing the MVC on the hand dynamometer did not contract to their full strength. So, when doing the trials the participant engaged their brachioradialis more than when doing the MVC.

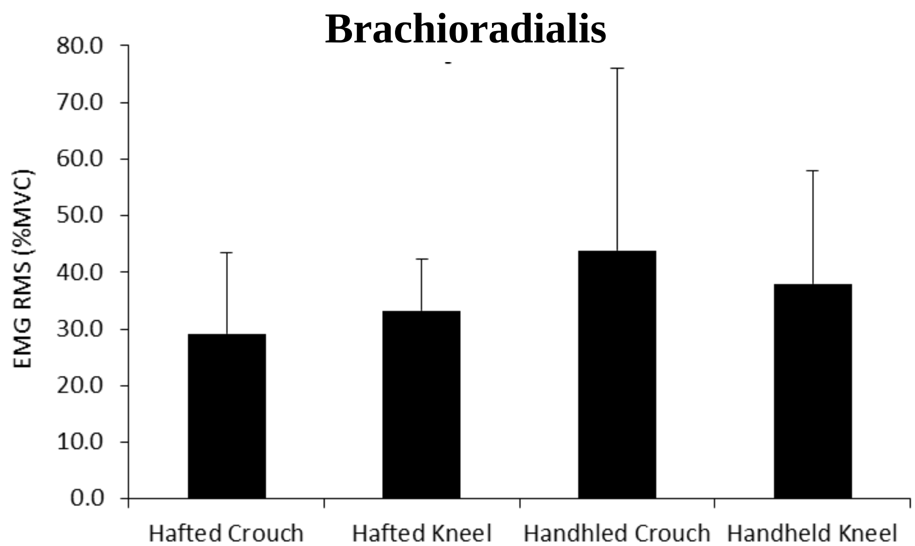

Figure 4.7. Mean EMG RMS values for brachioradialis during all trials.

Summary

Analyzing muscle activity during these four trials allowed a chance to understand how changes in Wichita hide scraping impacted the musculo-skeletal system. Though there is not a lot of statistical significance, there is a qualitative difference when looking at the graphs (Figure 4.1-4.3). As a pilot study, these results are promising and a larger sample size could help to highlight more of the difference between the two tools and positions.

Chapter 5: Discussions and Conclusion

In this final chapter, potential musculo-skeletal stresses Wichita women might have experienced while scraping hides during Pre- and Post-Contact Periods are proposed and discussed. Two questions guided this research: 1) is there a difference in muscle activity between using a hafted scraper or a handheld scraper, 2) If differences do exist, hypothesize what paleopathological indicators (i.e. enthesopathies, osteroarthritis) a Post-Contact Wichita skeletal population would have developed. The guiding theories driving the interest in this research is based on Ruff's article (2006), on bone functional adaptation and biocultural theory by Cohen and Armelagos (1984).

Bone is a living tissue that adapts throughout a lifetime to tribulations. Because bone is malleable and adaptive, skeletal biologists have used bone morphology and muscle attachment sites to investigate past activities (Ruff et al. 2006:484). Culture and environment also can cause changes in the skeleton. For example, spear thrusting (Churchill 2002, Churchill et al. 1996) and scraper technology changes, the body will reflect changes in activity patterns and changes in material culture. Therefore, cultural behaviors, patterns, and shifts, such as the dramatic changes highlighted in the Pre- and Post-Contact Wichita hide processing, are reflected in the skeleton (Cohen and Armelagos 1984, Larsen 1997, Zuckerman and Martin 2016).

Since no Pre- and Post-Contact Wichita skeletal populations were available to study, an experimental design was developed. Employing biocultural theory from Cohen and Armelagos (1984) and bone functional adaptation from Ruff (2006), it is known that the musculo-skeletal system will adapt to different mechanical stressors. Furthermore cultural patterns, such as hide scraping, spear thrusting, canoeing and other repetitive activities will also be recorded on the skeleton (Cohen and Armelagos 1984, Merbs 1983, Zuckerman and Martin 2016).

Wichita society changed dramatically between Pre- and Post- Contact Periods, especially when they engaged with French fur traders. With bison hides in high demand for French and European markets, the Wichita adapted scraper technology to take less time to make in order to have more time to prepare hides (Cleeland 2008). Post-Contact Period scrapers were produced in greater frequency than the Pre-Contact Period scrapers (Cleeland 2008, Perkins et al. 2008). A working hypothesis by Perkins and colleagues (2008) is that marriage patterns among the Wichita also changed, so that men were able to marry more wives to produce more hides and gain prestige through trade. These cultural changes to the demands of the French Fur Trade, the increase in bison hide production and a new scraper being held differently, would have an observable effect on the musculo-skeletal system.

Using EMG to measure muscle force in the posterior deltoid, biceps, and brachioradialis, a model is proposed of what variations would exist between Wichita women who lived during the Pre- and Post-Contact periods. If a muscle, or muscles, exert more force, the musculo-skeletal system will adapt (Ruff 2006) and develop paleopathologies that reflect the biomechanical use patterns. Muscle force exertion is used to propose a model of activity related paleopathologies (Jurmain et al. 2012, Waldron 2012), such as enthesopathies and osteoarthritis. Enthesopathies are enlarged muscle attachment sites that are used to indicate musculo-skeletal activity patterns in past populations (Jurmain et al. 2012). Osteoarthritis occurs when the cartilage in a joint degenerates and the bone reacts by forming osteophytes (bony spurs) and in severe cases, eburnation when the bones of the joint polish each other (Waldron 2012).

Analysis Interpretations

Based on the average %MVC (Maximum Voluntary Contractions) from hafted and handheld, reconfigured from Tables 4.6, 4.9, 4.12, and 4.15, indicating different forces produced by the muscles (Table 5.1). The bones would have adjusted to these differing forces and would have produced differences, in terms of location and intensity of paleopathological changes. The repeated measures ANOVA indicated the posterior deltoid was significantly different among each trial, the bicep was significant depending on positions, and the brachioradialis was not significant. Overall each muscle performed differently between the Pre- and Post-Contact scrapers, therefore differences are to be expected in frequency and intensity of observable paleopathological anomalies such as enthesopathies and osteoarthritis. But first interpretations of each muscle's performance during the trials will be discussed.

Table 5.1 %MVC of Hafted and Handheld Trials.

	Posterior Deltoid	Biceps Brachii	Brachioradialis
Hafted Crouching	20.0% ± 9.0%	10.1% ± 5.0%	29.2% ± 14.0%
Hafted Kneeling	17.5% ± 8.0%	15.4% ± 8.0%	33.2% ± 9.0%
Handheld Crouching	22.8% ± 12.0%	12.1% ± 10.0%	43.9% ± 32.1%
Handheld Kneeling	27.9% ± 12.5%	19.8% ± 19.9%	38.0% ± 20.0%

Posterior Deltoid Interpretation

Based on the average %MVC between the Pre-Contact (hafted) and Post-Contact (handheld), there is a difference in muscle exertion. The Posterior Deltoid is more activated using the handheld scraper than when using the hafted scraper. Due to the position of the arm while using the handheld scraper (Figure 3.6a), the posterior deltoid is holding the arm away from the body. With the hafted scraper, the arm is close to the side of the body and therefore the posterior deltoid does not have to be as highly innervated because it is not extending the arm away from the body. Comparing between the two positions, crouching and kneeling, the posterior deltoid is activated more in the crouching position. To remove hair, the arm was being pushed down, causing the posterior deltoid to exert more force on the entire arm than in the kneeling position.

Biceps Brachii Interpretation

Innervation of the biceps brachii between the two tool types was less than expected; however, interesting patterns arose. It was less engaged in the crouching than in the kneeling positions documented in table 5.1 frequencies. As with the posterior deltoid applying force in the crouching position, forces the arm downward, biceps brachii is most likely responsible for extending the arm outward and applying force in the kneeling position. The same pattern appeared regardless of whether the hafted or handheld scraper was used.

Brachioradialis Interpretation

For the brachioradialis muscle, overall, it was more activated when using the handheld scraper than when utilizing the hafted scraper (Table 5.1). Without the haft, the brachioradialis had to rotate the radius more for the scraper to be more functional while de-hairing hides. Even without, statistical significance in the interaction effect, the body would still respond to higher mechanical loadings. In this case, an enlarged supinator crest on the ulna. There seems to be no effect from the position on brachioradialis innervation.

Pre-Contact Wichita: What is known

There are several Pre-Contact skeletal populations but the largest Wichita cemetery. Indeed the largest cemetery in the southern plains, is McLemore (34WA5). McLemore is located among the Washita River and dates to the Washita River Phase 1100-1450 A.D. (Ellis 2015). Since the site is before contact, scrapers that would have been employed by the community would have been hafted scrapers of the style used in the experimental EMG study. Chelsea Ellis (2015), a Master's student at the University of Oklahoma, analyzed the human remains from the McLemore site and her analysis will be used as a comparison between paleopathologies between Pre- and Post-Contact Wichita skeletal populations.

Her analysis focused on determining why so many subadults were interred at McLemore, where she discovered that scurvy and otitis media (ear infections) were prevalent among the subadults at McLemore. Among the adults, observable indications of biomechanical stress and degenerative joint diseases were reported. Robust muscle attachments (enthesopathies) were found primarily on the humeri, femora, and tibiae, indicating that individuals utilized their arms and legs on a daily basis and strenuously enough to enact morphological changes on the skeleton (Ellis 2015). Other biomechanical stress markers were also noted, such as squatting facets and bilateral spondylolysis (stress fractures of the vertebrae) were present (2015). In the sample, osteoarthritis and osteophytosis (osteoarthritis of the spinal column) were also observed. A child of about nine or ten years old exhibited osteoarthritic changes (2015). All adults displayed degenerative joint disease: osteoarthritis in the knees, hips, shoulders, elbows, and wrists (Ellis 2015).

Post-Contact Wichita Hypotheses

Wichita women during the Post-Contact period using the handheld scrapers would more than likely exhibit paleopathologies different from their Pre-Contact ancestors. Although no statistical significanceswere found for every muscle measured, there was still a general trend of more force being exerted using the Post-Contact scrapers. Therefore, under functional bone adaptation (Ruff et al. 2006), changes would still occur. Overall, enlarged enthesopathies of the deltoid tuberosity on the humerus and supinator crest on the ulna compared to Pre-Contact Wichita populations. Increased osteoarthritis of all limbs due to increased intensity and duration of bison hide processing and perhaps an earlier onset of osteoarthritis. The spinal column would also exhibit osteophytosis, also at an earlier age.

Enthesopathy Interpretations

Attachment sites for the brachioradialis and posterior deltoid on the ulna and humerus, respectively, would be enlarged compared to Pre-Contact populations that used a hafted scraper. Because more force is being exerted by these muscles during scraping, the skeletal system would have adjusted to this change in force by depositing more bone to areas where more or different forces are being applied by the muscle(s) during scraping. Enthesopathies at the radial tuberosity due to increased and sustained use of the biceps brachii could also develop. The radial head would also showcase wear and tear due to rotating while using Post-Contact scrapers.

Elbow Joint Interpretation

Osteoarthritis at the radiohumeral joint (elbow) would be expected in a Post-Contact population. In order to use a handheld scraper, the radius via the brachioradialis and supinator muscles, is rotated more than when using a hafted scraper. Over time, the elbow joint would begin to wear down based on repetitive scraping with a handheld scraper. Other paleopathologies of the hand, wrist, and shoulder would have also afflicted Post-Contact Wichita women: such as, arthritis of the phalangeal joints (fingers), Carpal Tunnel, and arthritis of the shoulder girdle (clavicle, acromion process and glenoid cavity of the scapula).

Age of Onset for Osteoarthritis

In addition to different scrapers being used, Wichita society processed more bison hides and marriage patterns changed. According to Perkins et al. (2008), the prestige of Wichita men shifted from success in raids to successful hunts. Without successful hunts for hides, the men would not be able to engage with the hide trade with the French and have less opportunity for marriages. Men who were successful were more likely to have multiple wives to produce hides and therefore be more successful in trading with the French (Perkins et al. 2008). Because bison hide processing was no longer based on the needs of the community and instead produced for French fur trade as well as community needs (i.e. clothing), Wichita women may have begun processing hides at an earlier age. Determining if Wichita women engaged in bison hide processing earlier, would be to assess patterns of degenerative joint disorders and other anomalies such as os acromiale (unfused/partially fused acromion), osteoarthritis, and osteophytosis . Analyzing age of onset of osteoarthritis and a higher prevalence osteoarthritis among Wichita women, then compare it to osteoarthritis in a Pre-Contact Wichita population.

Common Paleopathologies of Pre- and Post-Contact Wichita Populations

A common trait I anticipate would be shared among Pre- and Post-Contact Wichita women, is the presence of squatting facets. Squatting facets occur if a person kneels or squats for long periods of time during a variety of activities (Ortner 2003) and manifest on the Talus and distal end of the Tibia. Considering hide scraping in either a kneeling or a crouching position, hide processing can vary in duration, and the amount of hides a woman processes, stress over a long period of time can be applied to the Talus and Tibia, causing squatting facets (Ortner 2003).

Cautions in Interpreting Activity Related Paleopathologies

As I propose this model of what paleopathologies a Post-Contact Wichita skeletal population would exhibit, it is important to reiterate the works of Robert Jurmain (1991, 1999), arguing that activity reconstruction is not clear cut. There are many factors that can influence what paleopathological anomalies and degeneration an individual will develop, from intensity of the activity and duration to genetics. Also, to keep in mind that humans do not engage in one activity in their daily lives and their skeleton will reflect a lifetime of differing uses of their bodies. Despite all this, without a Post-Contact Wichita associated skeletal population to physically assess and compare to a Pre-Contact population (i.e. McLemore), utilizing EMG can be useful in understanding past behaviors and how the musculo-skeletal system might have responded to different stressors. In addition, observations of other skeletal populations can be used to test the results and/or substantiate previous skeletal analyses.

Implications for Activity Reconstruction Studies

Activity reconstruction in Biological Anthropology has had a contentious past. Recent questions whether osteoarthritis and enthesopathies are indications of activity at all (Cardoso et al. 2010, Weiss 2003). One perspective argues that activity related paleopathologies are more indicative of age related deterioration instead of activity. On the other hand, Ruff and colleagues (2006) argue that the life history of an individual is reflected in their skeleton and these studies (Cardoso et al. 2010, Weiss 2003) appear to be viewing skeletal remains statically rather than taking into account the dynamic life of the skeletal system, individual and population. Utilizing EMG in activity reconstruction would allow a dynamic view of muscle involvement during past activities.

Shaw et al. (2012) and Sládek et al. (2016) used EMG to further their understanding of what can be observed in skeletal populations. The use of EMG in activity reconstructions can also be used in proposing models of ancient human activity when there are no skeletal populations to analyze. Furthermore, EMG use could potentially be used in describing the etiologies of osteoarthritis and enthesopathies. Measuring the force exerted by muscles and muscle groups, can help to understand how the skeletal system physiologically adapted to different stressors (intensity and duration). EMG can also help to verify or disprove previous analyses of activity related paleopathologies.

Future Research Directions

With EMG being a new area of research and methodology in skeletal biology and activity reconstruction increased data collection, standardization, and overall research production is possible. Only one other study has examined scraping using a chipped stone scraper and it was only used in one trial (Shaw et al. 2012).

Studying the effects of different material types of lithics (i.e. obsidian, chert, quartz) on muscle activation would be beneficial in understanding if the sharpness of these tools affect muscle innervation. Furthermore, when considering material sources, studying muscle activation among different sub-types of material (i.e. Georgetown chert, Pedernales chert, Florence A chert) and see if the different sub-types produce measurable differences in EMG signals. Overall, this is engaging and exciting research that can and should be used in studying the past and understanding other activities.

Indicating which scraper was used by participant would allow for more detailed analyses of the length, weight, circumference, and scraping edge of the Pre- and Post-Contact scrapers. Furthermore, including BMI and arm length as other variables could be able to help extrapolating the effect of past behaviors.

The experiment undertaken in this thesis research (pilot study) necessitates a larger sample size to help highlight the differences noted as well as provide greater statistical significance. Placing EMG electrodes on the other areas of the deltoid (anterior and middle), forearm muscles, the trapezius, pectoralis major, and latissimus dorsi to create a more holistic physiological profile of the body during scraping.

Measuring the muscles would be beneficial to understanding what changes the spine might have undergone in the different position, kneeling and crouching. For the spine, increase in osteophytes and deterioration of the spinal column (e.g. disc herniation, stenosis) can occur with intense mechanical loadings. Morphological changes in the humeri, radii, ulnae and clavicles can be affected by differing muscular use as demonstrated by two other EMG studies previously discussed (Shaw et al. 2012, Sládek et al. 2016). Bone morphology of the lower limbs are also affected by intense muscular innervation. EMG placement on the lower limbs would be interesting to measure their innervation during body position(s). For the crouching position, measuring the non-dominant arm, the arm supporting the body, and comparing it to the dominant arm scraping could prove interesting. It could have implications for handedness studies and might follow Shaw et al. (2012) where the non-dominant arm was supplying most of the force during spear thrusting.

These measurements could then be used to further hypothesize what paleopathologies a Post-Contact Wichita skeletal population would exhibit as well as furthering confirming the hypotheses presented here. As well as, comparing to previous studies of skeletal populations that have a detailed paleopathological assessment and description (Merbs 1983).

Conclusion

Activity reconstruction is a fascinating area of biological anthropology, offering many avenues to study the past. The use of EMG in biological anthropology studies has immense opportunities to expand and further the field. By providing a dynamic and real time view of muscle engagement during past activities, such as scraping and spear thrusting, EMG can shed light on the bodies of our ancestors and allow for a deeper look into the past. Furthermore, interdisciplinary collaboration with departments such as Health and Exercise Science and Kinesiology who study the physiology of human movement can aide in understanding the life history of skeletal populations. With this new area of study in biological anthropology, new avenues of research and new insights can be gained to further understand how our bodies react to the biocultural stresses of the world.

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Appendix A: Institutional Review Board Outcome Letter

The UNIVERSITY of OKLAHOMA

Institutional Review Board for the Protection of Human Subjects

Approval of Study Modification – Expedited Review – AP0

Date: March 09, 2017 **IRB#:** 7681

Principal Investigator: Michael Charles Henry Walters **Reference No:** 663435

Study Title: Bison Hides and Biomechanics: Experimental Bioarchaeology of Wichita Scraper Technologies

Approval Date: 03/08/2017

Modification Description:
Addition of assessments of the EMG signal from maximal voluntary contractions during the second testing session. They are currently assessed during the initial testing session (the familiarization session). We simply want to add a second assessment during the second session.

NOTE: Please be sure to re-consent participants coming in for Phase II that were already consented using the previously approved consent form.

The review and approval of this submission is based on the determination that the study, as amended, will continue to be conducted in a manner consistent with the requirements of 45 CFR 46.

To view the approved documents for this submission, open this study from the My Studies option, go to Submission History, go to Completed Submissions tab and then click the Details icon.

If the consent form(s) were revised as a part of this modification, discontinue use of all previous versions of the consent form.

If you have questions about this notification or using iRIS, contact the HRPP office at (405) 325-8110 or irb@ou.edu. The HRPP Administrator assigned for this submission: Nicole A Cunningham.

Cordially,

Ioana A. Cionea

Ioana Cionea, PhD
Vice Chair, Institutional Review Board

Appendix B: Informed Consent Letter

701-A-1

University of Oklahoma
Institutional Review Board
Informed Consent to Participate in a Research Study

Project Title:	Bison Hides and Biomechanics: Experimental Bioarchaeology of Wichita Scraper Technologies
Principal Investigator:	Michael Walters and Dr. Chris Black
Department:	Anthropology and Health and Exercise Science

You are being asked to volunteer for this research study. This study is being conducted at the Neuromuscular Laboratory (Department of Health and Exercise Science). You were selected as a possible participant because you fit the criteria to participate in this study (you are a woman, aged 18-35 and have not participated in heavy resistance training with your upper body in the last 6 months and are recreationally active and have no allergies or objections to working with a bison hide).
Please read this form and ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study
The purpose of this study is to determine and analyze if there is a difference in muscle activation between stone tools that were used during bison hide processing.

Number of Participants
About 15 people will take part in this study.

Procedures
If you agree to be in this study, you will be asked to visit the lab 2 times. You will complete a familiarization visit and a scraping day. During familiarization, you will be asked to perform an isometric (the maximum muscle flexion) test of the bicep, shoulder, and forearm. You will also be given a presentation of the two types of scrapers and how the Wichita would scrape and prepare bison hides via a PowerPoint presentation, along with demonstrations of how to use each type of scraper. The scraping day will occur the week of the familiarization. During this session you will again be asked to perform an isometric (the maximum muscle flexion) test of the bicep, shoulder, and forearm. Then you will use both types of scrapers in 2 positions—kneeling and crouching. During scraping, muscle activation data will be collected by electrodes placed over the biceps, shoulder, and forearm muscles. At the end of the scraping day, you will be asked to report if you felt pain or discomfort during the scraping.

Length of Participation
This study will consist of a familiarization visit lasting about 60 minutes, 1 scraper testing visits lasting about 90-120 minutes. The entire study will take place over 1 week.

Risks of being in the study are
When performing repetitive exercise like the scraping performed in this study, there is always a risk of injury to the muscle or joint. The exercise protocol employed in this study might cause temporary, reversible muscle damage and/or soreness as well as fatigue. Muscle swelling, soreness, and strength loss are the primary symptoms that could occur and typically dissipate within a week.
Cuts and scrapes from the stone tools are a possibility. Cured bison hides will be used for this study, so an allergic reaction to the hide is also possible.

If you are cut by the stone tools, a first aid kit will be available and antibiotic cream and a bandaid(s) will be applied to the wound. If you have an allergic reaction, antihistamine cream and pills will be on hand to administer.

701-A-1

Benefits of being in the study are
There are no direct benefits to participating in this study. However, you may, if you choose learn about your maximal strength in your bicep muscle, shoulder, and forearm. You will also learn about Wichita history and hide scraping techniques.

Compensation
You will reimbursed for your time at the end of the second visit ($10.00 gift card).

Injury
In the case of injury or illness resulting from this study, emergency medical treatment is available. No funds have been set aside by The University of Oklahoma-Norman, or the principle investigator to compensate you in the event of injury. If further medical treatment is required, the participant will have to pay for medical treatment themselves.

The current study involves low risk; however, there is always the possibility of a problem during exercise. Therefore, in case of a medical emergency the phone numbers for campus police (405-325-2864), Goddard Health Center (405-325-4611), Norman police (911), ambulance (911), and fire department (911) are posted in the testing room and research laboratory suite. Medical professionals are within minutes of the testing labs. The P.I. will be present at each experimental visit or immediately available if needed.

Confidentiality
In published reports, there will be no information included that will make it possible to identify you. Research records will be stored securely and only approved researchers will have access to the records.
The OU Institutional Review Board may inspect and/or copy your research records for quality assurance and data analysis.

Voluntary Nature of the Study
Participation in this study is voluntary. If you withdraw or decline participation, you will not be penalized or lose benefits or services unrelated to the study. If you decide to participate, you may decline to answer any question and may choose to withdraw at any time.

Waivers of Elements of Confidentiality
Your name will not be retained or linked with your responses unless you specifically agree to be identified. The data you provide will be destroyed unless you specifically agree for data retention or retention of contact information beyond the end of the study. Please check the option that you agree to:
I consent to having the information I provided retained for potential use in future studies by this researcher. ___Yes ___ No

Photographing of Study Participants/Activities
In order to preserve an image related to the research, photographs may be taken of participants. Photographs will be taken of you during the isometric maximum contractions, holding each type of scraper and you in each position, kneeling and crouching, using both types of scrapers. Your face will not be visible in any photographs. You have the right to refuse to allow photographs to be taken without penalty. If you refuse, you will still be allowed to participate in the study. Please select one of the following options:
I consent to photographs. ___ Yes ___ No

Videoing of Study Participants/Activities
In order to preserve a video related to the research, video may be taken of participants. Videos will be taken of you during each experiment trial, using a hafted scraper in the kneeling and crouching position and of you using the handheld scraper in the kneeling and crouching position. Your face will not be visible in the video. You have the right to refuse to allow video to be taken without penalty. If you refuse, you will still be allowed to participate in the study. Please select one of the following options.
I consent to videos. ___ Yes ___ No

Future Communications
The researcher would like to contact you again to recruit you into this study or to gather additional information.

_____ I give my permission for the researcher to contact me in the future.

_____ I do not wish to be contacted by the researcher again.

Contacts and Questions
If you have concerns or complaints about the research, Michael Walters can be contacted at 281-299-5458 or mchw1115@ou.edu and Dr. Chris Black can be contacted at 706-255-3750 or cblack@ou.edu. Contact the researcher(s) if you have questions, or if you have experienced a research-related injury.

If you have any questions about your rights as a research participant, concerns, or complaints about the research and wish to talk to someone other than individuals on the research team or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu.

You will be given a copy of this information to keep for your records. If you are not given a copy of this consent form, please request one.

Statement of Consent
I have read the above information. I have asked questions and have received satisfactory answers. I consent to participate in the study.

Participant Signature Print Name Date

Signature of Person Obtaining Consent Date

Print Name of Person Obtaining Consent

Appendix C: Par-Q Form

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____

SIGNATURE ____ DATE ________________________

SIGNATURE OF PARENT ________________________________ WITNESS ________________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

IRB NUMBER: 7681
IRB APPROVAL DATE: 02/21/2017

 Supported by: Health Canada Santé Canada

continued on other side...

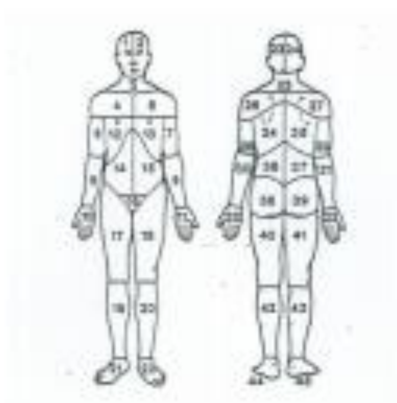
Appendix D: Pain Questionnaire

I.D. Number: ________________ Session Number: ________________ Date: ________________

PAIN QUESTIONNAIRE

1. Are you experiencing any pain whatsoever today? ______________ (Yes or No)

2. If you answered yes then draw on the figure below to indicate the locations on your body where you feel pain.



3. How much does the pain hurt? Use the scale below to indicate the overall intensity of the pain you are feeling. A score of 0 represents "no pain." A score of 10 represents "the highest possible pain intensity" that you can imagine.

No Pain 0 1 2 3 4 5 6 7 8 9 10 Highest Possible Pain

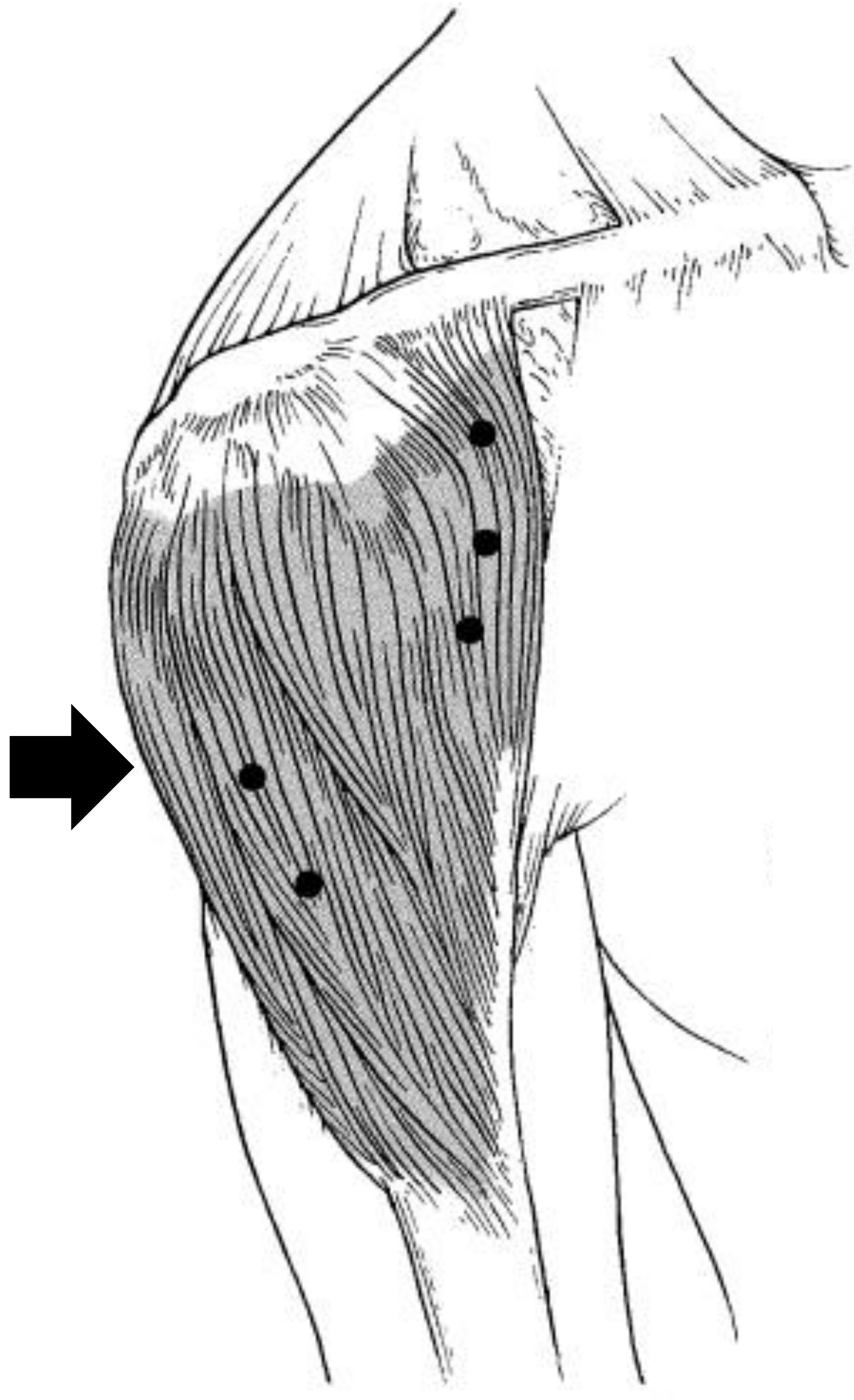
4. Use the scale below to report the highest intensity pain that you have ever experiencedHow much does the pain hurt? A score of 0 represents "no pain." A score of 10 represents "the highest pain intensity" that you can imagine.

No Pain 0 1 2 3 4 5 6 7 8 9 10 Highest Possible Pain

Appendix E: Participant Trials

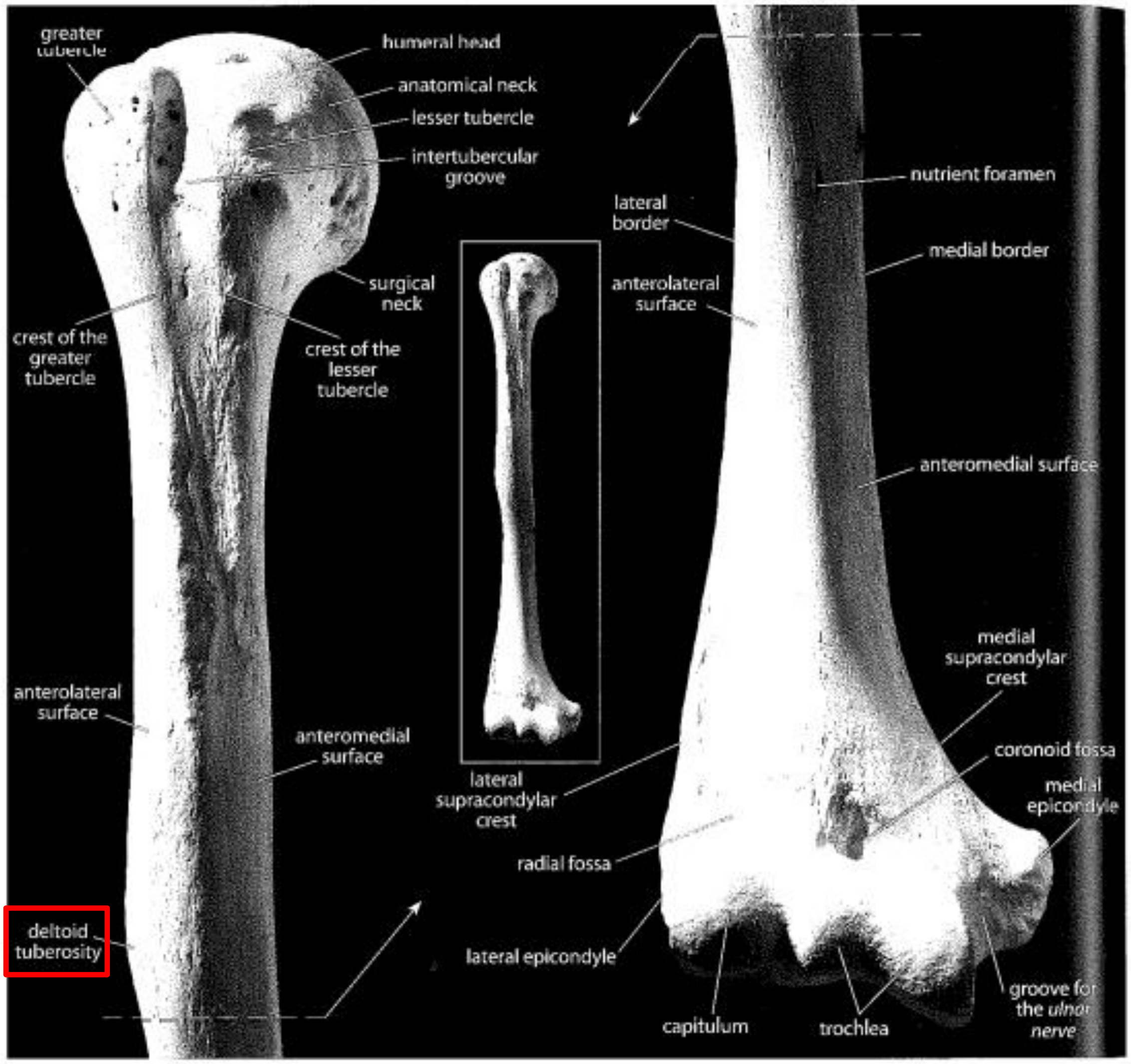
Participant Number	Trial 1	Trial 2	Trial 3	Trial 4
1	Hafted Kneel	Hafted Crouch	Handheld Kneel	Handheld Crouch
2	Hafted Crouch	Handheld Kneel	Handheld Crouch	Hafted Kneel
3	Handheld Kneel	Handheld Crouch	Hafted Kneel	Hafted Crouch
4	Handheld Crouch	Hafted Kneel	Hafted Crouch	Handheld Kneel
5	Hafted Kneel	Handheld Kneel	Handheld Crouch	Hafted Crouch
6	Hafted Crouch	Handheld Crouch	Hafted Kneel	Handheld Kneel
7	Handheld Kneel	Hafted Kneel	Hafted Crouch	Handheld Crouch
8	Handheld Crouch	Hafted Crouch	Handheld Kneel	Hafted Kneel
9	Hafted Kneel	Handheld Crouch	Hafted Crouch	Handheld Kneel
10	Hafted Crouch	Hafted Kneel	Handheld Crouch	Handheld Kneel

Appendix F: Posterior Deltoid Muscle

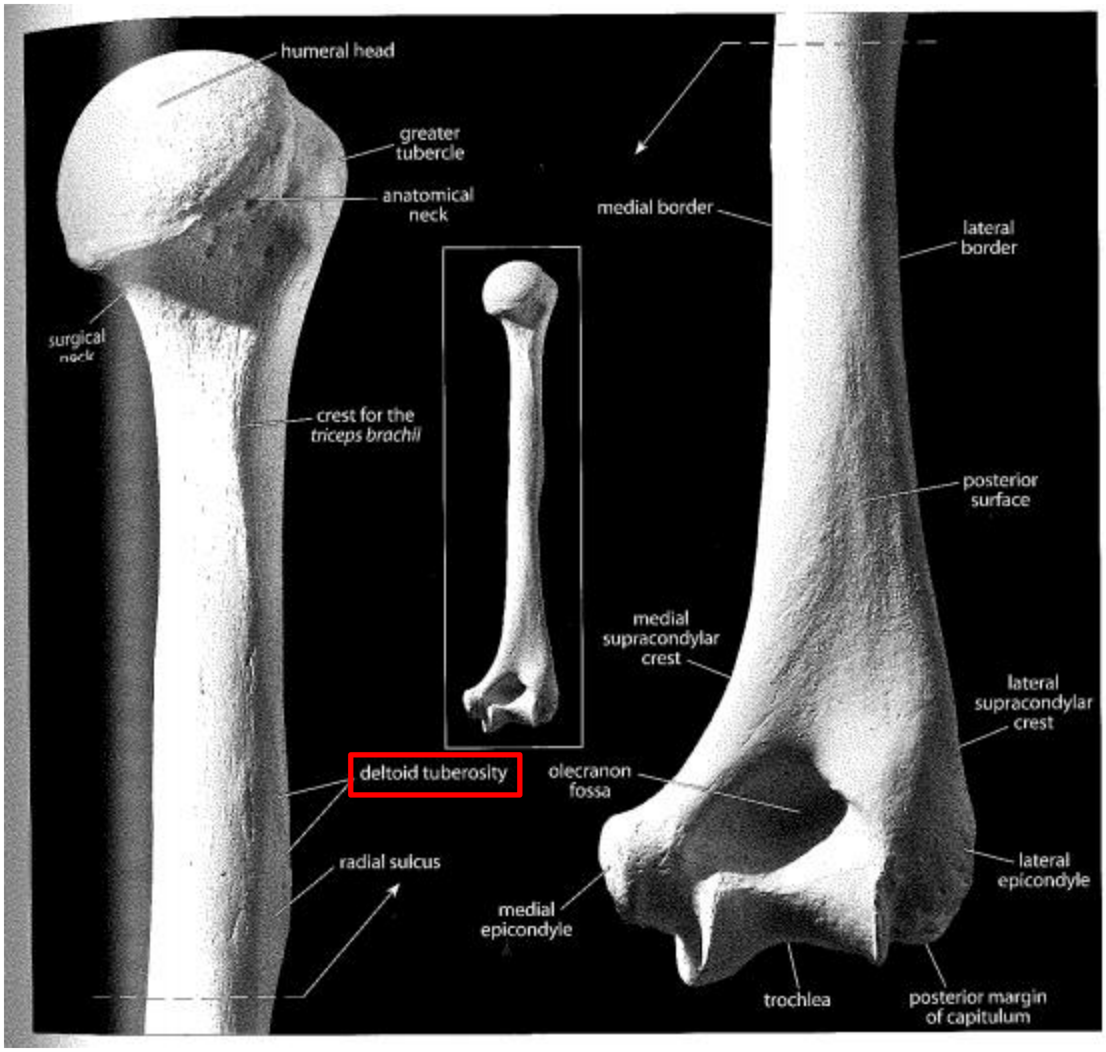


From Bowden and Bowden 2005. Arrow indicates location of posterior deltoid.

Appendix G: Humerus with Anatomical Landmarks

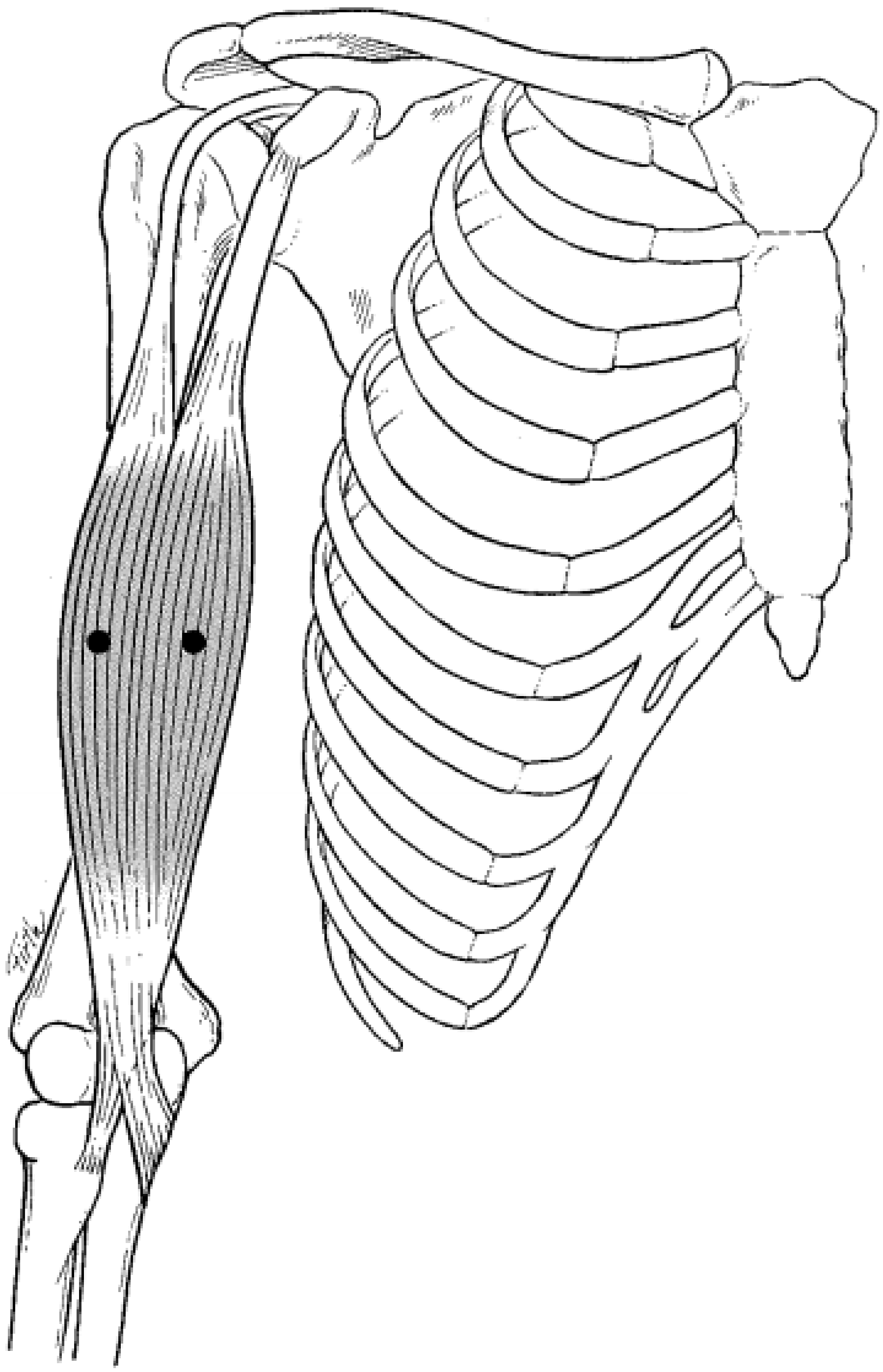


Adapted from White et al. 2012: 176. Right humerus, anterior view. Deltoid Tuberosity is outlined.



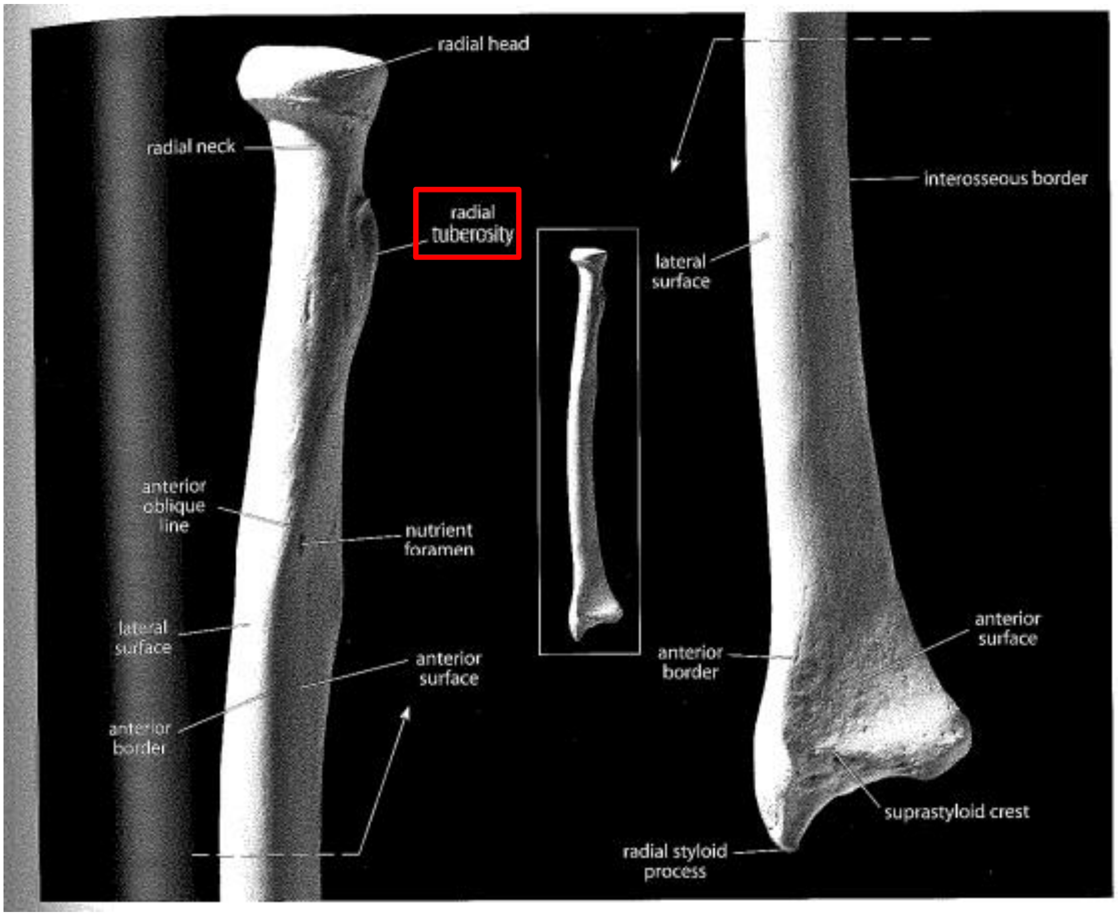
Adapted from White et al. 2012: 177. Right humerus, posterior view. Deltoid Tuberosity outlined.

Appendix H: Biceps Brachii

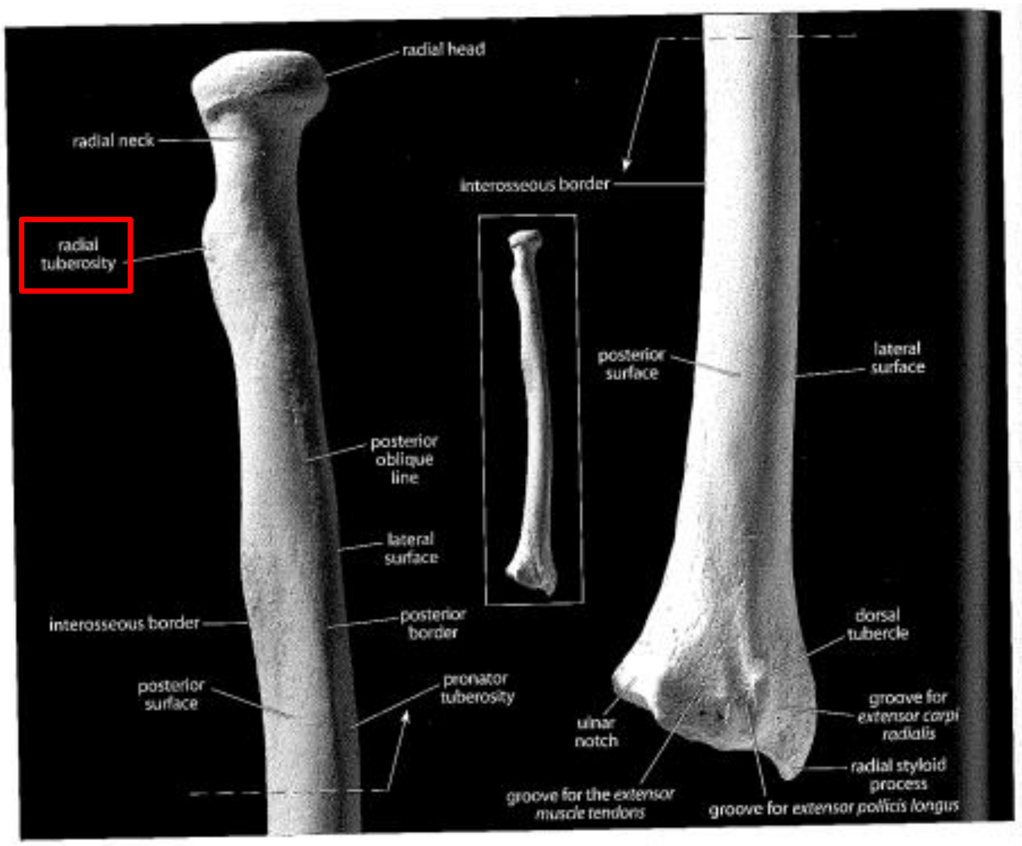


From Bowden and Bowden 2005: 166.

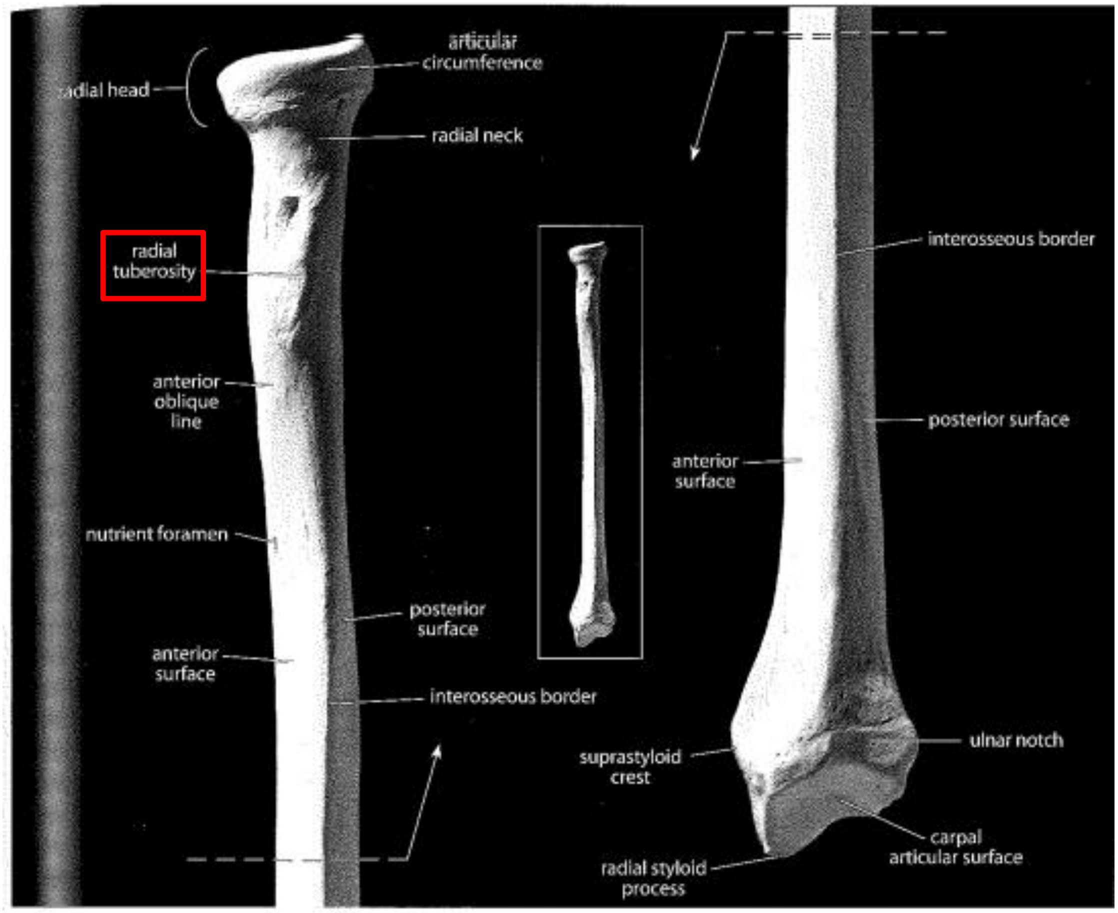
Appendix I: Radius with Anatomical Landmarks



Adapted from White et al 2012: 185. Right Radius, anterior view. Radial Tuberosity (where biceps attach to radius) outlined

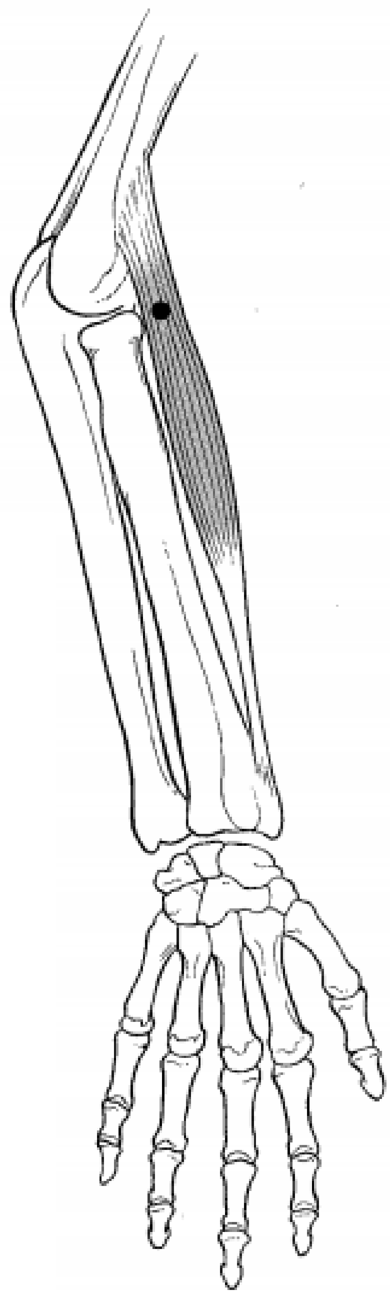


Adapted from White et al 2012: 186. Right radius, posterior view. Radial Tuberosity outlined.



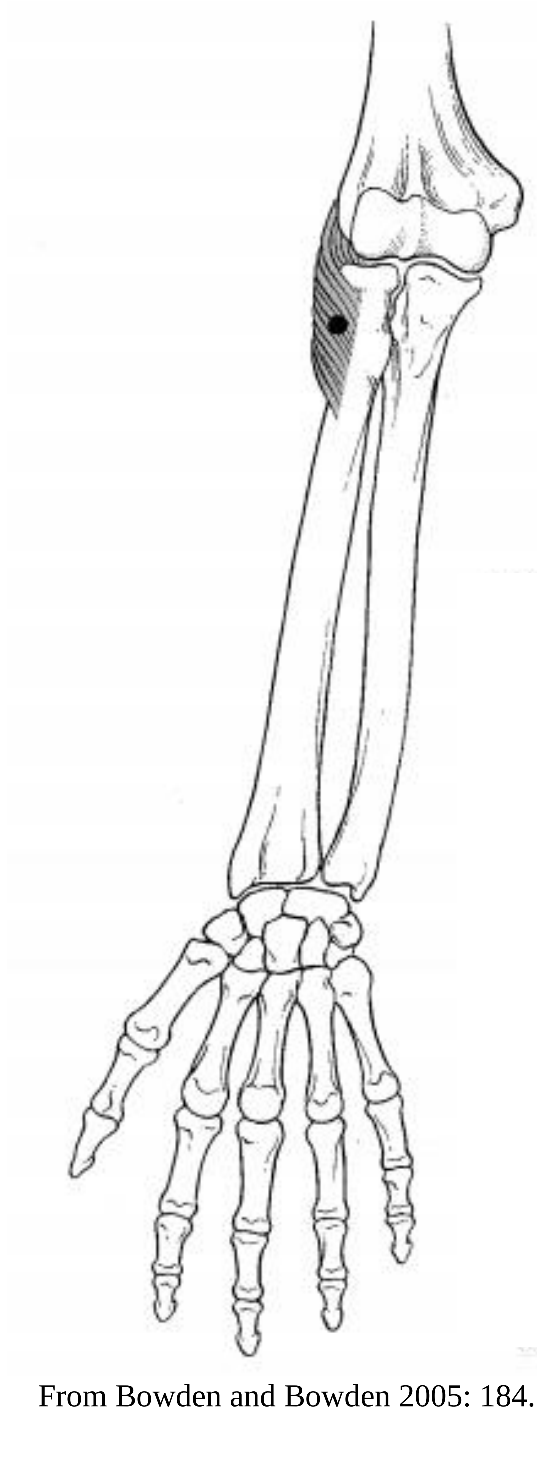
Adapted from White et al 2012: 187. Right Radius, medial view. Radial Tuberosity outlined

Appendix J: Brachioradialis



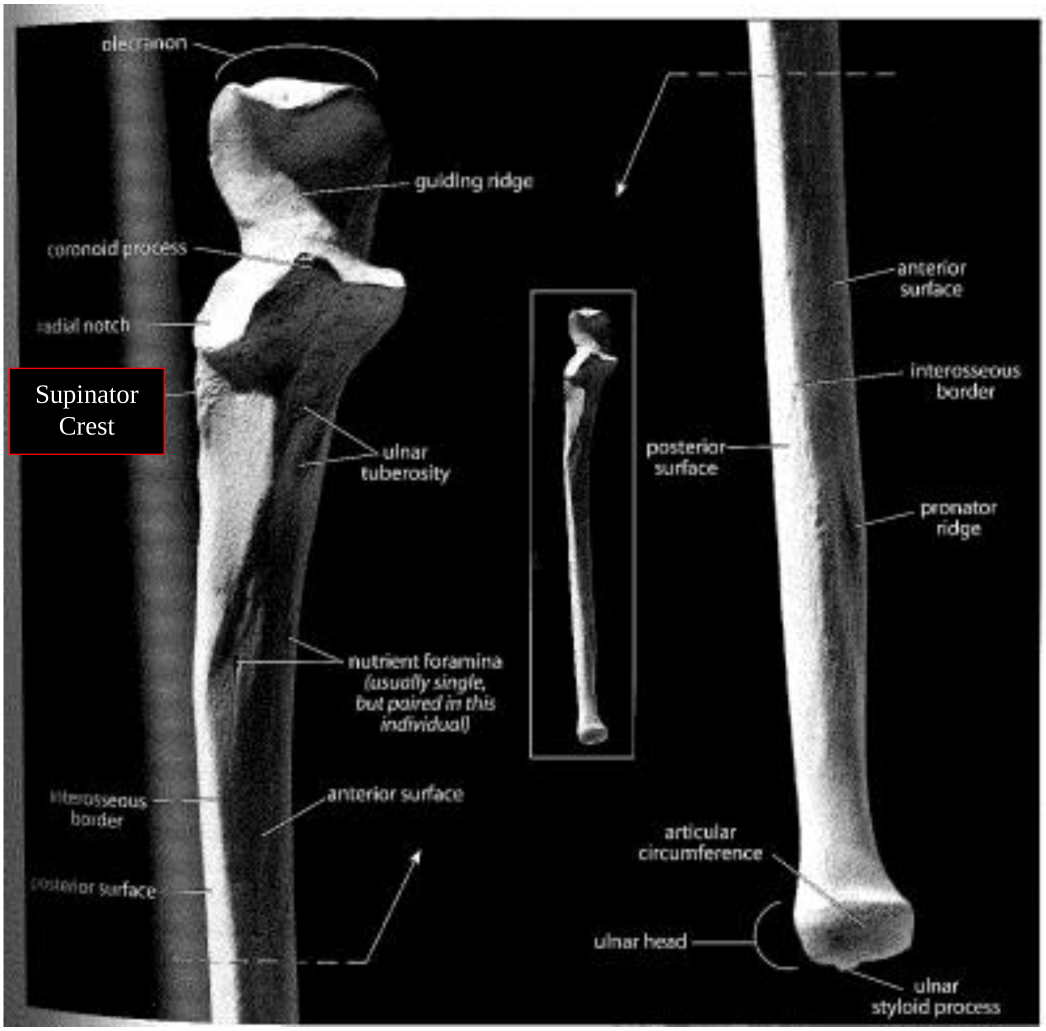
From Bowden and Bowden 2005: 168.

Appendix K: Supinator

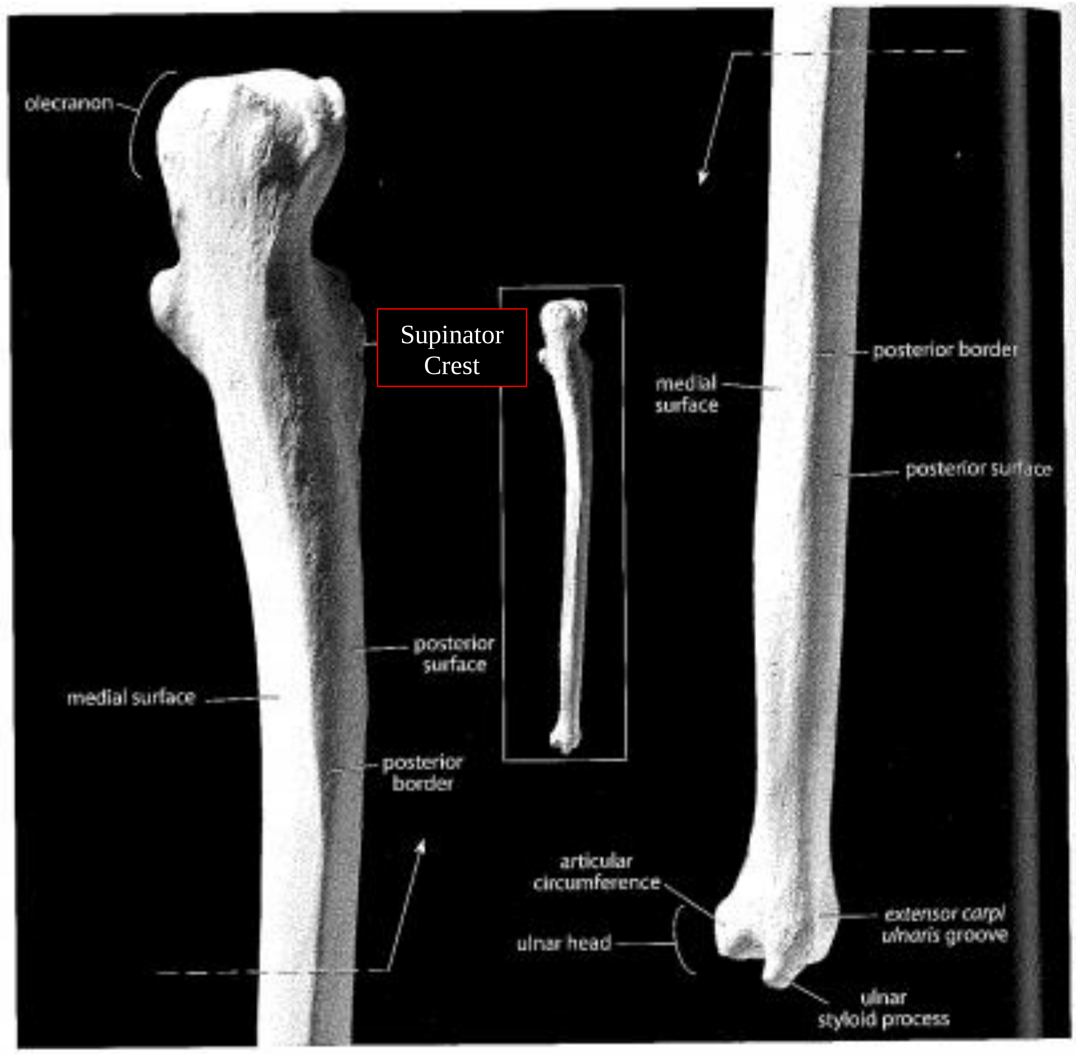


From Bowden and Bowden 2005: 184.

Appendix L: Ulna with Anatomical Landmarks



Adapted from White et al. 2012: 191. Right Ulna, anterior view. Supinator crest (attachment site fur supinator muscle) outlined.



Adapted from White et al. 2012: 192. Right Ulna, posterior view. Supinator crest (attachment site fur supinator muscle) outlined.

Appendix M: Enthesopathy

Image depicting enthesopathic changes on the ulnae at triceps brachii insertion. Figure A has an exostosis with enthesopathies. Figure B portrays enthesopathies with no exostosis. (Henderson et al. 2013:202).

Appendix N: Osteoarthritis

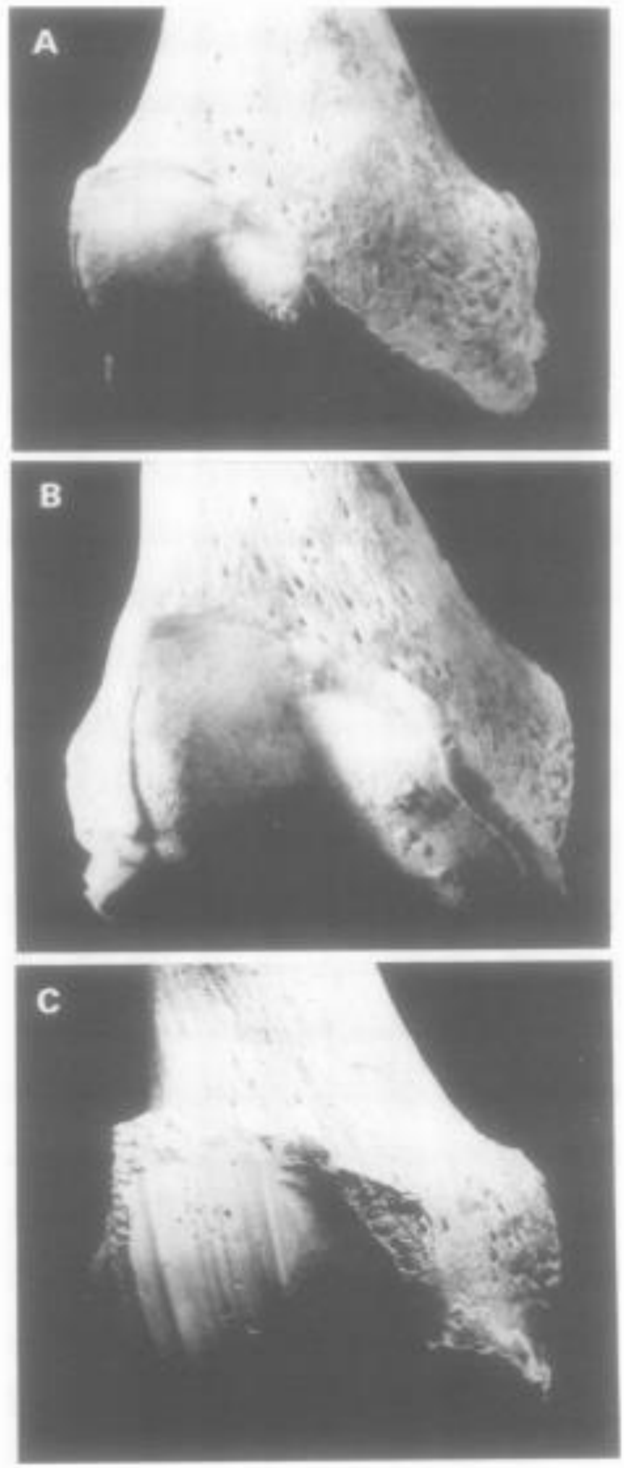


Image depicting stages of osteoarthritis. A shows minimal involvement and C shows severe osteoarthritis with eburnation and groves on the joint. (From Jurmain and Kilgore 1995: 44)