Biomechanical Modifications of a Danish Medieval Population

By

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A Thesis submitted to the Faculty of Graduate Studies,

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In partial fulfillment of the degree

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Department of Anthropology

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Abstract

This research focuses on the influences of shifts in agricultural practices on the patterns of daily repetitive activities and their associated reflections on the skeletal system. Denmark in particular experienced broad changes in agricultural production after the Black Death with a shift in the primary form of agricultural production from grain production to livestock rearing. These changes in lifestyle activities are hypothesized as being reflected in modification of the musculoskeletal system. Using metric analysis and musculoskeletal stress markers (MSM's) individuals are assessed for biomechanical modification to ascertain if the changes in agricultural production can be traced through the skeletal system by way of MSM's. Results suggest a decrease in robusticity and overall musculature from the grain producers to those who rear livestock, as well as more apparent trends such as differences in male and female musculature. Comparisons between the high and low status individuals illustrate that there is a distinct division of labour between the two, as well as within the groups.

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This work is dedicated to my Family, my strength , my rock, my encourager, and my motivator to be better and work harder no matter what I faced.

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Chapter 1 Introduction

The focus of this research is the premise that the skeletal system and auxiliary structures associated with its functions are malleable throughout an individual's lifetime and can therefore reflect certain changes in lifestyle, behavioural and growth patterns. It is not the purpose of this paper to assume any information about specific habitual activities of the individuals analyzed, but merely hypothesize that particular general forms of repetitive activity can be studied and analyzed over time.

The focus of this research is a population located in central Jutland, which is mainland Denmark, and from a Medieval Cistercian monastery and the surrounding village and rural areas. The Øm Kloster collections comprise two focus groups that are divided by time and agricultural practices. General trends in agricultural practice changed near the end of the medieval period due to environmental, ecological, and demographic influences from both within and without of the country. Prior to these influences the rural population of Denmark, those living outside of well populated urban areas, consisted of mainly grain-producing agriculturists. Afterwards the large majority of farming focused more on livestock than on grain crops. It is with this separation within the same population that a suggested change in habitual activity will occur, and this trend is the basis of analysis for the research conducted. The primary question for this study then, is whether there are marked differences in the evidence of habitual activities in the skeleton associated with the economic changes that are observed during this period.

The sample group was chosen based on age only, although several other controls were used during analysis; social class, age, and sex were used for comparison and control. Certain age groups were excluded from the study because of the effect they may have had on results (see the review in Chapter 2, as well as Chapter 3 for more information on the reasons for these exclusions). The original sample consisted of low status burials, which included both lay brothers and villagers of both sexes. An additional sample was created that was comprised of high status burials of both sexes for comparison. Individuals were included in the sample who showed trauma, infection, or chronic and acute disease. Samples were excluded if previous information for aging and sexing was not recorded; others were excluded due to a high degree of degradation or preservation; finally samples were excluded if burial position was unknown, this is because arm position during burial is popularly used as a method for located a burial temporally.

The actual analysis of the sample was conducted blind: neither sex, age or arm position were known when each burial was examined. This precluded researcher analysis of what results should be, and lessened preconceived suppositions about the outcome of the study. The two samples were divided into high and low status, but all other information was unknown until the data collected were input into a database for analysis. For each burial a series of metric analyses were taken, and a suite of specific musculoskeletal markers (MSM's) were examined. The series of metrics were taken to garner overall robusticity of the population and each individual for comparison between sex, age, status, and the agricultural groups. Likewise the suite of MSM's was taken incorporating areas that were likely to be altered for each agricultural trend. A focus was put upon the upper portion of the body, because the changes here are more likely to be attributable to behaviour changes rather than to locomotion patterns, although the lower limbs were not ignored. The femur was used for the calculation of stature, due to a lack of viable recorded data at the time of excavation. Descriptive notes as well as the metric analysis and scoring were also taken in order to provide a more holistic understanding of the element if needed. In some cases photographic and CT imaging were used to delineate a specific characteristic, when the characteristic was of interest for further examination.

Musculoskeletal markers are also defined as markers of habitual activity and occupational stress markers, but in this research never as enthesopathies. For the purposes of this research enthesopathic lesions are only used for the description of attachment sites that are traumatic in nature. A discussion of the definition and use of MSM's, the scoring and description of attachment sites, and the overall use of this information in skeletal biology can be found in the literature review in Chapter 2. Also in this chapter is a description of the patterns of change in Danish archaeological and anthropological theory which influenced the manner in which these burials were excavated and recorded over time. Likewise, differences between European and North American analysis and categorization of skeletons are also discussed, as is the impact that combination of these factors had on the research conducted.

The final portion of this thesis deals with the statistical analysis and discussion of the results. Comparisons between status groups, sex, age, and arm positions were undertaken using univariate statistical analysis. Comparisons between upper and lower limbs were also taken to compare the degree of change upon the bone. A discussion of the importance of the results and possible conclusions of this study follows. No definite answer can be given for why the observed changes have occurred, as a conclusion such as that is impossible to come to. A suggestion of the possibility of change can be offered, indicating trends in activity change between the sexes, or between populations located in different temporal locales. The purpose of this research is to discover if these trends existed and perhaps make a suggestion as to why they may exist in a higher degree in one group over another.

Chapter 2 Literature Review

Introduction

The question often arises of why do researchers study bones? The answer is simple, bones usually constitute the only direct evidence of fossil humans and past pre-historic populations; they are a means of biological comparison between modern populations and those that are no longer represented or have in some way changed due to contact with other groups; they bear evidence of ancient disease, often in the initial forms and can also illustrate the evolution of the modern forms; and finally, they are popularly the evidence for modern forensic cases (Bass: 1995). There are several uses for osteological knowledge outside of the areas of medical and anatomical sciences: the popular areas include the study and identification of the recently deceased, often in the area of legal science, known as forensic anthropology; another two areas are considered historical, involving the study of ancient remains, palaeoanthropology, and the study of the more recent remains under archaeology. All of these areas involve intimate knowledge of the human skeletal system, its structures, patterns of growth and pathologies. Although these areas of interest can operate alone they often work in tandem with other areas of study and knowledge: geology, history, biology, ecology, law and many more (White, 2000).

Being a skeletal biologist requires an understanding of the skeletal system that goes far beyond the labelling of elements; the utilization of osteology in the field often depends upon the specific questions being asked by the researcher. For that reason no study encompasses and answers every question possible about the skeletal remains of an individual or a population as the information obtained and required would be overwhelming. For the research presented here a basic and general understanding of the skeletal structure was needed, but specific information about bone growth, patterns of growth, pathological conditions, and the musculoskeletal system were necessary. Of particular importance was the understanding of what role bones play in the musculoskeletal system. Osteological knowledge of how muscle, ligaments and tendons interact with bones in the maintenance and daily function of life was required. This is a basic tenet that is necessary to almost any biological anthropologist who is using or plans to use the skeletal system as an element of evidence. This requires knowledge of how a bone functions individually and as part of the mechanical whole. Bone is one of the strongest biological materials in existence and comprises the main supporting tissues of the human body (White, 2000). Bone is a composite material formed of a protein known as collagen and a mineral known as hydroxyapatite, and as living tissue it can repair defects and malfunctions caused by trauma and illness. As well, it can reshape itself in response to external stress. It is a dynamic tissue that allows for growth during development, and can be reshaped during lifetime by cells contained within itself. This means that although shapes are similar within and between populations, overall morphology can differ greatly dependent upon many different factors. Initially, genetics play a large role in morphology, as do developmental factors such as nutrition and lifestyle, the latter being extrinsic or external forces that affect change in bone. There are myriad forces that exert pressure and influence growth development and morphology, including: *systemic*, which includes hormonal, nutritional, disease exposure and some mechanical forces; and *localized* which includes mechanical, traumatic, and disease (Ruff, 2000).

Bone Growth and Development

It is necessary to understand the composition and development of bones and their soft tissue counterparts, specifically how the bone develops and why the early stages of plasticity and malleability during bone development and growth must be taken into account, when research is being conducted. Initial stages of skeletal development are known as chondrogenesis; modifications made during this period of growth and development set the pace and parameters for later adjustments. Chondrogenesis involves the creation of the cartilage anlagen, an intermediate mode that will eventually lead to endochondral ossification. This process includes the migration of mesenchymal cells from three embryonic tissues (Goldring, 2006). Mesenchymal cells move to future skeletal locations only a few days after conception, they then differentiate into chondrocytes. In certain parts of the skeleton however, including parts of the skull and the clavicles, this step is skipped and the mesenchymal cells differentiate directly into osteoblasts without the need for an intermediate cartilage anlagen (Karsenty, 1999). This process is known as intramembranous ossification. It is the initial form of ossification to develop and it continues throughout life in the form of subperiosteal apposition. This form of ossification results in dense compact or diploic bone, but the process can also be sub-divided into two other distinct varieties of bone formations: dermal bones and perichondral bone.

The second major form of ossification is endochondral, which is responsible not only for the longitudinal growth of long bones, but also for the development of the long bone epiphyses, portions of the vertebral column, carpals, tarsals, and any skeletal element that has a large degree of cancellous bone composition. During this particular process, mesenchymal cells differentiate into chondrocytes which go on to form the cartilage anlagen of future bones. Osteoblasts then form from the cells contained within the periosteum, or periphery encasing of the long bones, and similarly composed elements. These cells which convert to the osteoblasts, actively contribute to bone growth by eventually invade the anlagen via cartilage canals; the cartilage calcifies and is consequently replaced by bone and bone marrow. This process lends the skeletal element a degree of plasticity because the sturdy outer cortex becomes malleable and open to external forces. As already mentioned, the periosteum contains the bone forming cells and due to this, it can add bone layers and formations onto the exterior cortex of the bone, thus creating the MSM sites where insertions pull at the outer cortex stimulating growth. After the formation of bone and marrow is completed, osteoclast differentiation occurs and the balanced process of bone resorption and formation begins (Malina & Bouchard, 1991).

After the primary centre of ossification forms, a region characterized by rapid growth develops between the epiphysis and diaphysis – this is known as the growth plate. It is discoid in shape, reflecting the role it plays in growth of the diaphysis longitudinally and diametrically. After birth and during development the skeleton increases in size and strength (Jee & Frost, 1992) and the influence of movement and activity become much more pronounced (Steele, 2000). However, it must be kept in mind that bone growth is also strongly influenced by environmental and hormonal factors. Developmental stability (homeostasis) refers to the ability of a biological organism to grow in an ordinary manner under a variety of environmental conditions and influences. Environmental perturbations are quite common, and usually cannot be avoided during development, therefore they can disturb developmental homeostasis, resulting in differential growth of skeletal elements, and quite commonly, bilateral asymmetry of one element or the entire skeleton (Albert & Greene, 1999). A great deal of the morphological change in the skeleton results from genetic and hormonal factors as well as the other environmental influences mentioned above, but mechanical influences play a significant role in development and the determination of skeletal form as well, and this is the primary focus of the research of this study. The specific skeletal influence that affects skeletal morphology is repetitive activity, and musculoskeletal stress markers (MSM's) are commonly used to infer information from the skeleton about either a population or an individual.

Most bones have a similar pattern of structure: a body and then one or several points of articulation with other bones. These points come in a variety of forms: heads, condyles, pedicles, complex sutures, or simple articulation facets. . Assuming the individual was in relatively good health at the time of death, i.e. not suffering from a major disease such as DISH, osteoporosis or other osteological diseases, the external surface of the bone will be smooth and dense, in cross-section this surface can be seen as a thick cortex of bone that has variable width, even within the same skeletal element. In long bones the cortex forms a hollow cylindrical shape; the hollow is referred to as a medullary cavity. At the ends of the shaft the bone is comprised of a spongy cortex known as cancellous or trabecular bone, which gradually fills the medullary cavity. Flat bones have similar composition with cortical bone overlapping cancellous bone, however there is no hollow in the centre of the bone; the medullary cavity that resides in the long bones is not present in flat bones. The external cortex is protected by a strong fibrous skin, the periosteum; this thin membrane contains cells that can manufacture bone. In the medullary cavity and the spaces of the trabeculae bone is red marrow which forms red blood cells. The medullary cavity may also be a storage area for yellow marrow or fat (Stele and Bramblett, 1988).

Musculoskeletal Stress Markers

The reconstruction of postures, behaviours and certain activity patterns used in life enables a better understanding and conception of lifestyle and living conditions of past populations (Boulle, 2001). There are myriad ways in which knowledge about past lifestyles and patterns can be obtained, but one focuses on the impact on the musculoskeletal system, where muscle and bone intersect. A large component of this thesis is the understanding of the role that these entheses or musculoskeletal stress sites, play in the analysis of individuals, and by association the overall population. For proper interpretation an appropriate definition must be used that encompasses the necessary information relevant to this research. In a clinical environment an enthesis is the region in which a tendon, ligament or joint capsule attaches to bone. Benjamin et al. (2004) believe that entheses sites are better understood by viewing them as not merely *focal* attachments, but as parts of an "enthesis organ complex". They forward the concept that the enthesis organ complex is a biological process in which stress is redirected away from the enthesis or insertion by the surrounding fibres, ligaments and cartilage. In the rheumatic and radiological study of enthesis sites, muscles insertions and origins are often considered more accurately termed enthesopathies, and are used to diagnose traumatic, degenerative, inflammatory, endocrine and metabolic conditions (Resnick and Niwayama, 1983). The difference between the anthropological and clinical definitions of an enthesis or insertion site is vastly different, and the two should not be confused. In the anthropological meaning, Chapman (1997) defines insertion sites or MSM's as the distinct skeletal markings that occur where muscle, tendon, or ligament inserts into the periosteum and the underlying bony cortex. When sites such as these are regularly subjected to a stress, such as physical exertion from habitual activity, the number of capillaries in the periosteum increases, thereby stimulating osteonal remodelling at the point of greatest stress. This results in hypertrophy of the bone, and the formation of rugose bony eminences on the exterior of the bone. Therefore a heavily used joint, limb, muscle, or tendon carries certain signs of behaviour, exhibiting traits such as enthesopathies, bone imprints and modifications, or supernumerary articular surfaces, to name a few (Boulle, 2001). Robusticity can be defined in many different manners dependent upon what is being described as robust. In the case of MSM's, the term robusticity refers to the increase in bony formations around an insertion or origin site; the development of osteophytes, lipping, cortical or shaft thickness, roughening of the cortical surface, callus not due to bone repair, in other words the normal response of bone to mechanical loading and repeated stress. This is to be separately defined from a stress lesion which is another way of describing the severity of MSM's. A stress lesion refers to a groove or furrow in the outer cortex of the bone, which can deepen into the inner cortex as the stress is repeated or increased. These furrows can artificially resemble lytic lesions (Chapman, 1997).

Numerous studies have been conducted which analyze the meaning of modifications of the musculoskeletal system. Al-Oumaoui et al. (2004) did a comparative study of five populations from the Iberian Peninsula dating from the early copper age until medieval times, from agricultural to mainly herding economies and from both flat and rugged environments. Results from the study showed that there was no significance of laterality between the left and the right sides in any of the population, although where there was asymmetry it was usually expressed in the upper limbs. Maturity of the skeleton was shown to have an effect on the frequency of the manifestation of asymmetry, but was not statistically significant. The study did however include both young adults and mature individuals. Sex differences were also observed for all five populations. The differences between the sexes were not uniform between the cultures. One population showed little difference while another had males being overall more robust and another still showed some limbs more developed for males but the upper limbs of both being equal in robusticity. The researchers concluded that overall asymmetry was seen more in the upper limbs than the lower, with a slight dominance of the right arm over the left. In general, despite cases were certain markers were more frequent or more rugose in the female, overall the males of all five populations were shown to be more robust and could be graded higher for most MSM's than the females.

Prehistoric populations have also been analyzed for MSM's and activity related skeletal modifications. Molnar (2006) looks at the repetitive activities at a specific site, that of Ajvide on the Island of Gotland, Sweden. The purpose of this study was to assess the prospects of identifying general levels of repetitive physical activity in the skeletal remains, and further examining other activity modifications and repetitive activity influences such as: sexual dimorphism, age-related enthesial change, and bilateral asymmetry. The sample came from a burial ground at Ajvide dated from 2750 to 2300 BCE. As of 2002, 73 grave sites had been excavated. The researcher has concluded that there were three plausible human activities at Ajvide: archery, harpooning, and kayaking, of course a number of everyday activities would also be performed. The researcher claims that a separate suite of muscles is needed for each of these activities, and that certain muscles are essentially needed to mechanically perform each movement. The archery movements, particularly the drawing of the bowstring is hypothesized to mainly be performed by the supraspinatus and infraspinatus muscles of the rotator cuff of the string arm, which would generally be the right arm. Flexors of the drawing arm would also be involved in the movement. The deltoideus and triceps brachii are affected in the opposite arm, or the bow arm. The supposition is that there should be marked bilateral asymmetry found in those who perform this activity. For harpooning the two primary muscles involved would be the deltoideus and pectoralis major muscles of the rotator cuffs: the teres minor, infraspinatus, supraspiantus, and subscapularis would also be involved. The final repetitive activity of kayaking involves the costoclavicular ligament, latissimus dorsi, triceps, and deltoideus for one arm, and the other used primarily for steering. The isolation of these muscle suites was obtained from clinical analysis of modern performers of the same tasks. Molnar (2006) describes general trends in which the highest scores for MSM's were seen at the costoclavicular ligament in males, teres major and pectoralis major. Females also received high scores for the teres major and pectoralis, but not for the costoclavicular ligament. Bilateral asymmetry appeared to be very low for all sites, and when pooled together the sites also did not result in any significant differences. Molnar concludes that some specific activities are not detectable through MSM analysis, due to the large variety of activity patterns and that instead of trying to isolate specific activities, MSM should be used to trace levels of activity instead.

Despite this conclusion, the study did relay interesting information about the sexual division of labour through the analysis of the MSM sites, specifically those muscles and ligaments used for kayaking.

Some studies involve the analysis of a joint, including MSM's and articular surfaces. Boulle (2001) discusses the skeletal markers involved with recognizing the squatting position. Instead of a repetitive activity the study focuses on a specific posture, which may correspond to a specific or general activity pattern. In squatting significant stress is placed upon the muscles, ligaments and tendons in the knee and ankle which would result in the bony modification of the bones involved with the posture. Although this particular repetitive posture is more likely to be manifested through facets, markers of stress can also be involved. The study is also interesting as it provides the same basic ideas about MSM studies but approaches the methods from a different angle. Instead of approaching the study with only the possibility of connecting a specific muscle to a specific activity, Boulle (2001) develops a lifestyle theory about the evolution of a skeletal modification and extrapolates that data to theorize about changes in habitation, daily life activity such as cooking. Boulle presents the wider picture, rather than the skeletal information alone. The paper concludes that skeletal markers can be utilized to assess the use of a posture because the difference in use is indicated by the presence and severity of certain markers. The activities are merely hypothesized rather than conclusively stated. Boulle suggests that perhaps the activity is that of squatting around a cooking fire and those changes throughout time are resultant from the evolution of the hearth and cooking fire. She stresses this repetitive activity as this suite of skeletal markers in the talus and tibia are more commonly found in the females of a population of then the males.

Chapman's (1997) study of the Spanish influence on agricultural activity in the Pecos Pueblo uses MSM analysis to observe repetitive activity changes and to reconstruct possible alterations in lifestyle and behaviour patterns. Chapman suggests that an increase in maize production would be expressed in changes to the robusticity of the latissimus dorsi, deltoideus, brachialis, brachioradialis, triceps brachialis, and anconeus muscles, all of which are muscles likely to be utilized in the planting and maintaining of crops in males, although not exclusively. These muscles perform a number of motor activities: deltoideus flexes the arm; latissimus dorsi extends the arm while the individual is making a motion similar to a hoeing movement; the brachialis and brachioradialis flex to pull the hoe back towards the body; triceps brachii is also active in flexing and extending the forearm. In females, Chapman hypothesized that there would be increased robusitcity for the insertion sites of deltoideus, teres major, and pectoralis major, which were utilized in processing maize with manos and metates. This created increased stress on the hand and wrist flexors and extensors, as well as the forearm supinators and pronators. Chapman found that the deltoideus attachment demonstrated statistically significant increase overtime and the latissimus dorsi increased in mean MSM expression but not statistically significant in the females. For males the latissimus dorsi and anconeus exhibit a statistically significant in crease in expression, but not in mean scores. The increase in triceps brachii and the anconeus may indicate wood chopping activities; the two work in tandem in short forceful movements of extension. The largest change in MSM expression between males and females at Pecos was found in the deltoideus and the trapezius. Chapman concludes that Spanish contactt did have an effect on some of daily activities in the culture, and analysis of these MSM's allowed for a more distinct illustration of the roles of men and women within the community pre and post Spanish contact.

Numerous researchers investigate MSM's as a form of evidence for reconstructing past behaviours, too numerous to discuss all of them with any great scope. Mays (1999) performed a biomechanical study of activity in medieval skeletons from the Fishergate site. Lai and Lovell (1992) performed an analysis of skeletal markers of occupational stress in the Fur Trade, examining a small set of burials from Rocky Mountain House, Alberta. Knusel (2000) studied the burials at Towton, UK for activity related skeletal change and concluded that MSM's and other biomechanical modifications suggest that the mass grave individuals were highly active individuals, and found some correlations to individuals from the sunken ship the *Mary Rose*. Knusel suggests that the modifications observed reflect a functional adjustment allowing for more power and a more efficient use of power. Additionally there are a number of more specific conclusions that can be taken from the range of human motions, including but not limited to throwing projectiles, grinding grain, knapping stone tools, horseback riding, rowing (Robb, 1998: 363), squatting in reference to the use of a central cooking fire within the domicile (Boulle, 2001: 53-4), hunting, (Weiss, 2003: 230), archery (Molnar, 2006: 13), harpooning and kayaking (Molnar, 2006: 14), foraging patterns (Churchill, et al. 1998) and various agricultural activities (Chapman, 1997 and al-Oumaoui, 2004). There are also myriad works that deal with associated research, such as clinical studies of MSM's with living samples. Logan's (1985) studied of the flatwater kayak stroke is an example of this. Logan studied what muscles were involved in the motions needed to reproduce the paddling action involved in kayaking. There are similar studies involved in analysing modern samples performing actions such as tennis, pitching, horseback riding, weight training, ballet, rock climbing, and marathon running.

Kennedy's (1989) recitation of what he refers to as marker's of occupational stress provides a list of skeletal manifestations of repetitive activities which are qualified as indicators of specific rather than the general trends in behaviour or activity patterns discussed above. His list includes everything from markers indicative of clarinet playing to indicators of occupation such as a milkman (Kennedy, 1989 quoting Lane 1887). While assumptions such as these are applicable with clinical evidence to augment their veracity, in the course of studying populations in which daily activities can at best be hypothesized but not substantiated by historical records, or personal identification, specificity can not and should not be shown or applied to MSM's. Kennedy (1989) is not the only author to apply specific behaviours to a suite of MSM's, and such reports should be taken as the author's supposition of specific activity, not the absolutely only answer. While particular activities can ascribe certain biomechanical changes, it is often impossible to isolate a muscle or skeletal element and suggest that a single activity contributed solely to its condition. When elements in the lower body are analyzed particular attention must be taken in order to ascertain changes, as a plethora of factors contribute to muscle and bone growth. Changes to the entheses of tendons, ligaments, and muscles might be attributed to processes outside of repetitive activity, as it is meant in the study.

Due to these factors it is necessary to understand the external and internal factors that may affect the structure of certain elements. The lower limbs in particular have muscles that are involved in repetitive activities of daily life that could skew assessments, due to their involvement with locomotor activities and weight bearing, which the upper skeletal elements are free from. These activities could contribute to increased muscle mass and bone thickness corresponding to these loads (Weiss, 2003).

Weiss (2004) concludes that lower limb MSM scores for males will be higher than females due to overall higher body size and weight overages in general. Therefore height, body mass, muscle, and fat content will contribute to lower limb robusticity and MSM attachment scores: due to the likelihood of men being taller with heavy builds, the load upon bones will be heavier and add more stress during activity and locomotion. Upper limb MSM's are not excluded from these tendencies, however the lower limb appears to be more susceptible (Weiss, 2004). For this reason, in this research, greater emphasis was put on the upper limb MSM's, particularly the scores and metrics of the humerus. Certain lower limb muscle attachments were chosen, which although not exempt from the eternal forces, could possibly illustrate significant information despite their involvement in locomotion and weight bearing. The gluteal muscle, minimus, medius, and maximus lines, which although are not insertion sites, are included as MSM's because they are a modification of a skeleton element manifested by a muscle through repetitive stress. This suite of muscles were included and examined both on the ilia and the femur because, although they indicate locomotor patterns, they can also be used to hypothesize squatting and straddling, such as in the increased use of horses for transportation or some type of agricultural activity.

There are many drawbacks to utilizing MSM's for inferring specific activity, although many others have done so. There are several problems created by age limitations when viewing MSM's. Age can often be the most important factor influencing the outcome of research. The very young, the sub-adult, juvenile and infant and the very old, have resorption rates that differ from those that comprise the middle age bulk of the population. Other variations in bone development and morphology are known as idiosyncratic variations - variations between individuals of the same population, age, and sex and these are often the focus of research (White, 2000). Robb (1998) suggest that because most studies show that juveniles have little to no surface markings, either in the form of robusticity, or ruggedness which describes the normal variation in areas where muscles attach, and describes generally the degree of rounding and cresting on the outer portion of the bone or stress lesion, that muscle markings only begin to accumulate after the bone has finished its growth pattern, regardless of lifestyle. This means that despite a rigorous lifestyle with heavy repetitive loading of the muscles, said lifestyle cannot be observed in the musculoskeletal system in the young. Biologically or osteologically this may be because during development when growth centres are expanding and epiphyses have yet to fuse, muscle insertion sites migrate across the bone's surface to accommodate changes in stature and structure (Robb, 1998) and because muscle markers accumulate due to increased habitual activity, and only occur when bone growth has ceased to occur and remodelling has taken over, many juvenile groups are excluded from studies similar to this. Bone growth obliterates signs of habitual activity, where as if overall bone size is stable, remodelling and bone re-growth are signs of stress placed on attachments and on the loading capacity of the element itself.

Therefore MSM's are not a viable source of information in juveniles or infant bones. Static bone growth is necessary because a muscle marker must be found in consistently the same area. During growth in juveniles the muscle insertion site travels across thin bone and therefore cannot be accurately utilized for scoring. At the opposite end of the spectrum, extreme age reflects a decrease in activity patterns and a lessening of the use of muscles. Remodelling slows, and the markers are resorbed into the overall structure of the bone, thus older age individuals do not accurately reflect lifetime activity (Robb, 1998). MSM's and signs of habitual activity including increased robusticity, are most likely to be reflected in individuals between the ages of 18, at the absolute youngest, and 60, although depending upon the population, this age limitation can be extended or further limited based on attitudes toward the elderly. This excludes a large portion of the population from overall study, hampering sample size. Although neither of the excluded portions are overly necessary to understanding overall habitual or repetitive activity within a population, MSM's are one way that lifestyle patterns cannot be recreated in the young and old (Robb, 1998).

Sex is also a limitation that must be taken into account when analysing MSM's, specifically since differences between the sexes such as overall body size, genetic and hormonal conditions specific to biological functions may create inaccurate results much in the same way that age can. Understanding sex differences in overall body size is important for evaluating those outside the normal range of variation within the population (Molnar, 2006). Results for these outlying individuals should be viewed as unique data, because they are not continuously represented within the overall population. Due to the fact that genetics and sex correlations are so important, the sexual dimorphism of a population should be recognized (Mays, 1999) so that it can be used as a comparative tool between the sexes. However, it can also affect overall results of inter-population comparisons, if a difference in population dimorphism is not accounted for in analysis. As stated above body size also plays an important part in the accumulation of repetitive markers. This however mostly affects between-population comparisons, where there are environmental, geographical or cultural differences (al-Oumaoui et al., 2004). This research is based on a single population, and due to a mostly static immigration flow, very little new genetic information was contributed to the overall pool. Therefore the composition was maintained in both temporal periods, and had approximately the same genetic pool to draw from. This similar genetic composition would not affect the biomechanical responses of either population, as musculoskeletal systems in both populations would hypothetically respond in the same manner. Instead, it is the effect of both cultural and environmental stresses, particularly those within the culture, which interest the researcher.

There are many mechanisms that must be taken into consideration when choosing the areas and attachment sites to be studied. The following requirements are necessary to ensure the repeatability and accuracy of the scoring of MSM's: 1) that they be easily distinguishable; 2) that they are of tendinous muscle sites, which are more easily identifiable and often found in the same generalized area of the bone; 3) they were used in the literature in lifestyle reconstruction (Weiss 2004). Boulle (2001) states that if a specific movement or posture is being analyzed then the associated skeletal elements and traits must be closely related or function within this repetitive movement, as well as be generally located on well preserved areas of the skeleton.

For this research a number of MSM's were chosen that accounted for these concerns. Collecting data from a number of resources, a list of MSM's appropriate for the study was compiled. Kennedy (1983) discussed the use of the triceps brachii for extension of the elbow joint, discussing that the motion affecting its use was more for speed than strength, like in the case of spear throwing, or possibly for the sowing of grain. Weiss (2004) discussed the use of a number of lower limb muscles that were affected by locomotion and were chosen because of their repeatability and because they are easy to distinguish. Eshed et al.'s (2003) list was helpful because it was used to analyze Neolithic farmers in the Levant, and similar activities might be presented in the sample populations used for this research.

There are a variety of ways to score MSM's, and they are often dependent upon the researcher and the research sample. Chapman (1991) uses three categories to score her research samples, specifically the Pecos Pueblo collection: robusticity markers, stress lesions, and ossification exostoses. Chapman utilized the system created by Hawkey (1988), in which visual observations are made and scored along a continuum of 0 to 3, absent to strong for each category. Chapman used this as the foundation of her analysis and created a scoring system in which scores were assigned a numerical value as follows: 1= grade 1 robusticity, 2= grade 2 robusticity, 3= grade 3 robusticity, 4= grade 1 stress lesion, 5= grade 2 stress lesion, 6= grade 3 stress lesion. Chapman defines these areas respectively as: the normal skeletal reaction to habitual activity and a display of a groove into the bony cortex of the bone. Ossification exostoses are bony "spurs" which project outward from the cortical surface, and can result in macrotrauma of the bone, or MSM site. Unobservable muscle sites, those not manifested, were coded as missing data and not included in the final statistical analysis.

Peterson (1998) scored only two, rather than three MSM expressions to determine changes: robusticity and stress lesions. She claims that robusticity refers to modifications of the cortex that appear as rugged markings at the site of muscle and ligament attachment, where as stress lesions are characterized by either pitting or furrowing in the cortex: what she calls superficial lytic lesions. Peterson's method is based on the visual reference system also devised by Hawkey and Merbs (1995), which identifies the threshold and disparate categories of each grading. This system is based on an amalgamation of the robusticity and stress lesion categories and is assigned on a scale as follows: 0= no expression of either robusticity or stress lesions; 1= faint robusticity; 2= moderate robusticity; 3= strong robusticity; 4= faint stress lesion combined with strong robusticity; 5= moderate stress lesion, 6= strong lesion. Half scores for those elements that share requirements for two scorings can also be applied with the researcher's discretion. This appears to be a revised form of the Hawkey methods utilized by Chapman above, the difference being that Peterson excludes the ossification exostoses from her criteria for scoring.

Weiss (2004) utilized a method also from Hawkey and Merbs (1995). She chose this method because the inter- and intra- observer error rates are low; the scoring categories and their associated meanings are clearly defined with definite thresholds; the descriptions of each stage of grading are clear and the guidelines for what a grading is, are clear-cut, many accompanied by photographic illustrations to make them even more distinguishable. Like Peterson a two threshold system was used in which robusticity and stress lesion were scored separately. Each dimension had four scoring levels with progression from 0=absence to 3. Afterward the scores were converted to a more continuum-like system with scoring from 0-6. Weiss (2004) provides a highly detailed description of each level, which was helpful for the overall scoring of this research. While these three versions of very similar systems were helpful, scoring is very much reliant upon the skeletal sample and the population variation within said sample.

Measurements, because they represent distance or quantity, have continuous distributions and presentations. Theoretically speaking, metric traits assume any value between fixed points that fall along and/or define a continuum (Pietruwsky, 2000). Metric analysis has several benefits including: precision and repeatability of measurements; their conservative nature in continuous variation, their usability as a direct link to the past, and for their demonstrability of heritability traits. All of these characteristics provide a sound theoretical foundation for the use of metric analysis in biological anthropology research, and due to this metrics are heavily relied upon for analyses. Multivariate analysis has provided skeletal biologists with useful perception about which measurements might be useful for inferring insight about a population or an individual. Measurement reliability or repeatability is extremely important and measurements used must be repeatable by the same researcher, allowing for a small margin of error, as well as by other researchers.

Estimation of Stature

Estimating stature is relevant because it can reveal overall size of individuals of a population and sample. Long bone lengths allow for a different view of robusticity, however due to normal variation within a population and between other geographical populations analysis of long bone lengths is a more appropriate tool for gauging robusticity. Problems with stature estimation can be compensated for, but if overall robusticity is being examined a comparison of each element independently is satisfactory.

Long bone measurements such as maximum length and anatomical length of the femur can be used for stature estimation (Bass, 1995). Waldron (1998) found that the confidence intervals for each of the long bones run with different methods for stature estimation were similarly close, but the femur alone had the smaller stature range than any bones. However, it has been shown that there are a number of difficulties that must be taken into account when dealing with stature estimation. Raxter et al. (2007) revised a formula for living stature from skeletal height which was based on Fully's (1956) anatomical technique on the Terry collection. It was adjusted to take into account the changes in living stature influenced by age. The femur is not the only skeletal element that can be measured to estimate stature; a pair of bones can be measured together and used to estimate stature. A more accepted method for direct reconstruction of stature is by measuring and adding together the lengths or heights of a series of contiguous skeletal elements from the skull through the foot, which incorporates and solves for differences in body proportions (Raxter et al. 2006).

There are a number of different methods for estimating living stature, but the most common is regression analysis, using long bone length. A number of univariate approaches to estimation include: regression of stature on long bone length; regression of long bone length on stature by solving for stature; major axis regression of stature on long bone length; reduced major axis regression of stature on long bone length

(Konigsberg et al. 1998); use of a long bone/ stature ratio (Feldsmen et al. 1990). The anatomical method used for this research was the White American formulae created by Trotter and Gleser (1952, 1958), which was used despite the fact that it consistently over estimates the height of Europeans in Europe born prior to the beginning of the twentieth century (Boldsen and Søgaard, 1998). It should also be noted that within the European population some of Denmark's population have body proportions that might affect the effectiveness of stature estimation formulas. An example is provided by the comparison of the Tirup men and the Sct. Mikkel men, both populations from mainland Denmark. A method developed by Boldsen at the Anthropological Database University of Odense (ADBOU) was used, which includes measuring the height of a once living human on a skeleton before it is excavated from the grave (Boldsen, 1984).Using this method on the Tirup and Sct. Mikkel men it was discovered that the Tirup men were on average 4.3 cm shorter than men excavated from the Sct. Mikkel site despite the fact that both samples had the same measured and recorded femoral lengths (Boldsen and Søgaard, 1998). Differing body proportions means that stature estimation is inaccurate for this population, but due to the early excavation dates of the sample (1930's), and the lack of a specific regression formula or anatomical method for estimating stature from the femur, stature estimations based on Trotter and Gleser were used.

Chapter 3: Materials and Methods

Materials

The sample examined for this research consisted of burials excavated during the 1930's from the archaeological site of Øm Kloster, Denmark. This site is a medieval Cistercian monastery located in central Jutland, mainland Denmark. The monastic community of Øm was founded in the 1160's although it was almost another decade before the existing monastic complex was begun (Buchwald, 1878; Gregersen and Jensen, 2003). The monastic complex itself was built in several phases and contained a courtyard surrounded by the cloisters and other religious buildings. The north wing of the square was formed by an impressive church, used for the burial of the founders and wealthy patrons and donors to the complex. Other important buildings include a "hospital", which was in actuality a hostel for guests and pilgrims traveling through the surrounding villages. The eastern portions of the monastic land, as well as the eastern portion of the cloister, were the burial grounds for the clergy and monks of the monastery. The northern portion was the commoner's cemetery, which served not only the lay brothers of the monastery but also the local peasants and lower class parishioners. Thus far, these sections of excavation have yielded over 1000 burials.

The majority of the research sample was taken from the local peasant cemetery and burial areas. Although this section contains both monastic and secular burials, the lay brothers that were interred here are those of a lower status, and often those used in the upkeep and menial labour of the monastery. This allows for comparable analysis of the skeletal sample due to the similarities in activity patterns. The religious presence also explains the somewhat disparate higher male: female ratio; the lay brothers were all men, and no female religious members are known to be interred here.

The population in Northern Europe declined significantly during the 14th century in many areas, largely due the Black Death. In Scandinavia in particular it appears that only half as many Danes were alive in AD 1400 as were recorded in AD 1300. This reduction in the population led to a dramatic change in post-Black Death agricultural practices. It is likely that as the population dwindled, rural inhabitants, particularly farmers, abandoned their land to relocate to more urban areas. This would impact on the manner in which agriculture was carried out in Denmark; now, uncultivated land could be used for livestock grazing and herding. This is reflected in the change of agricultural activities post plague. Before the bubonic plague struck Denmark in AD 1350 agricultural production was dominated by grain production and cultivation. After the severe reduction in population after the Black Death, and therefore a reduction in labour sources, beef and dairy production replaced grain production as the leading source of agricultural activity.

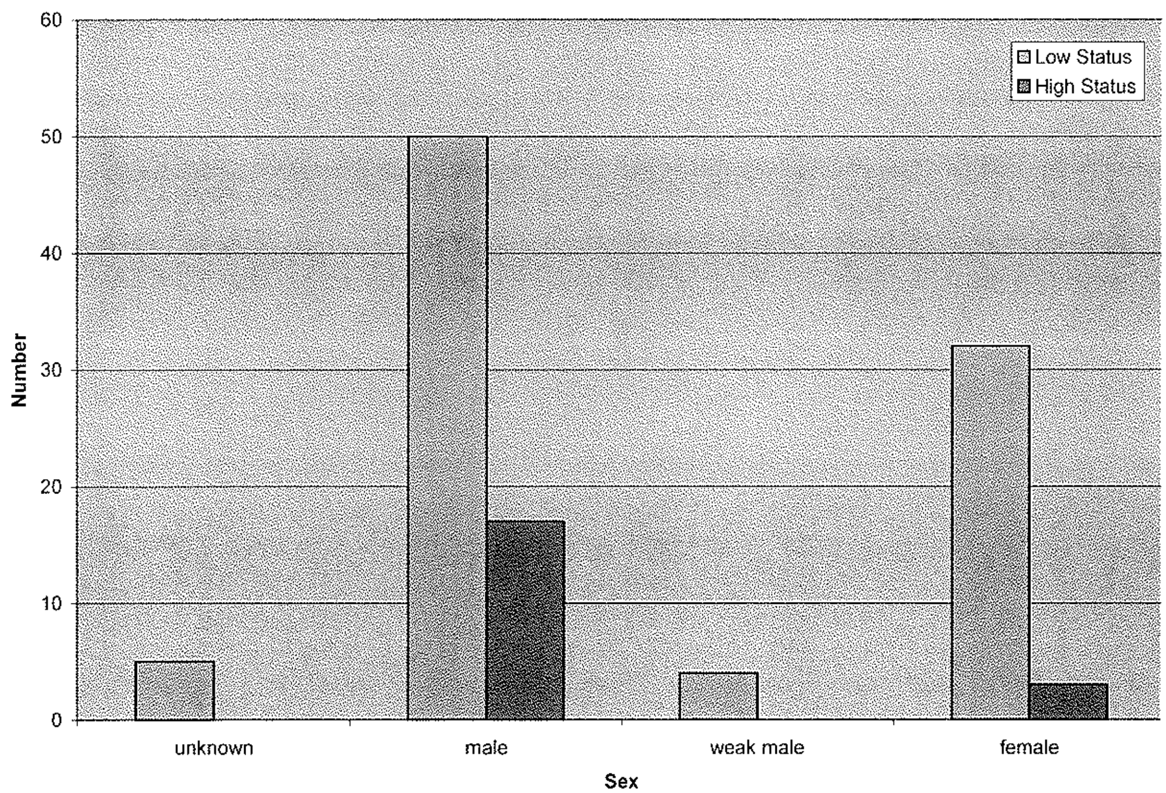
The site of Øm Kloster represents burials from the mid 12th to the late 16th century, and is comprised of the monastic order, local parishioners, and also a small number of visitors and pilgrims passing through. The burials are separated into four temporal categories based on burial positions. These time periods represent: prior to AD 1300, roughly 300 years; throughout the 14th century for roughly one hundred years; and finally after the decrease in population two time periods that blend into the final time category which ends sometime during the 16th century.

Of the one thousand burials already excavated, a total of 203 were examined, and 112 in total were analyzed for metric traits and predetermined musculoskeletal stress markers. The remaining 91 burials were excluded from the sample due to a lack of skeletal completeness, where less than 50% of the overall skeleton was preserved, or due to age restrictions.

There were certain specifications that each burial had to meet if it was to be used in the sample. Age restrictions were enforced for those under the age of 19 years due to the plasticity of growing bone. Complete epiphyseal fusion is necessary to accurately calculate robusticity indices and stature estimations. As well as epiphyseal fusion, there is the matter of the bone structure itself. When bone is still growing it is highly malleable and plastic; insertion sites and muscle markings move across the bone because of growth not only in length but diameter and to micro-architecture restructuring as the bone becomes more adult and mature. This constant change rarely allows for accurate assessment of musculoskeletal stress markers because the area that the muscle, tendon or ligament comes in contact with is constantly changing. Repetitive activity, even in general terms cannot be assessed proficiently when this occurs. Muscle markings can also be more easily manifested when bone is more plastic, which can also skew the scoring of MSM's. For this reason those under a certain age, generally under 18, are excluded from the sample in order to stabilize the results. At the polar opposite, older skeletons are more fragile, and due to the increasing fragility of the skeleton, activity markers can decrease because of disuse. This would skew the results due to lack of markers because of inactivity, which is different than lack of markers due to non-existence or a decrease in the activity.

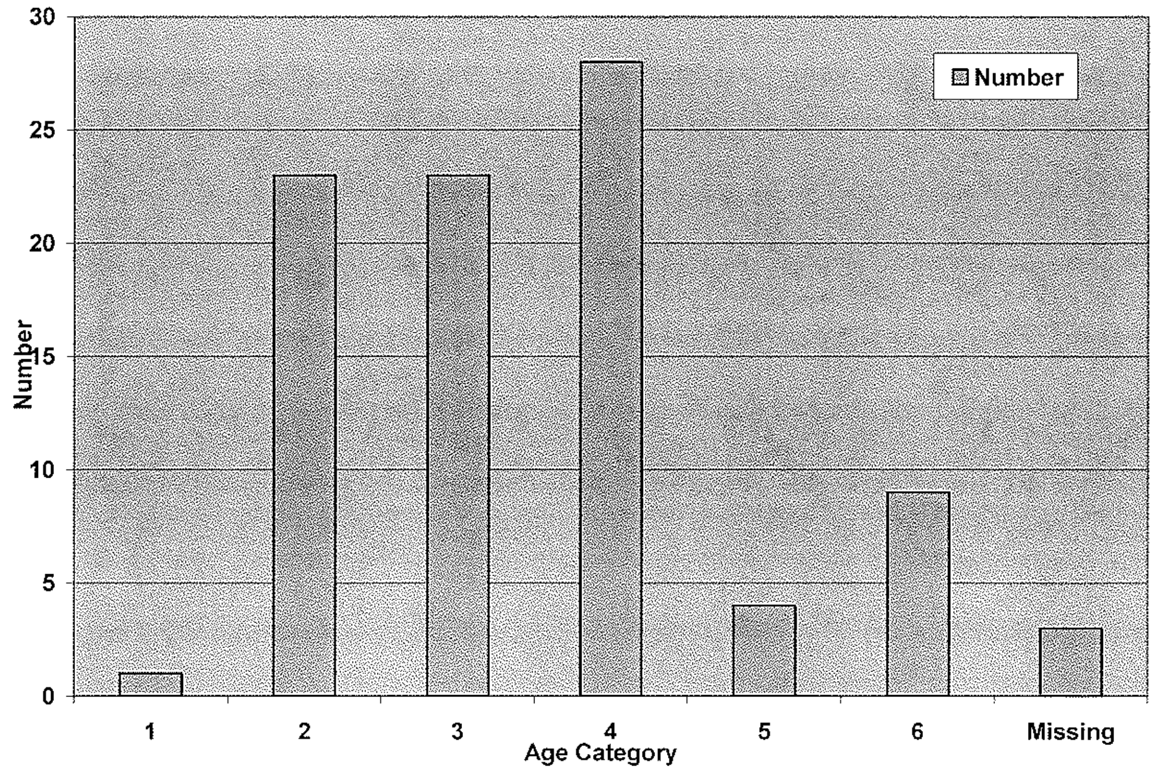
Of the 112 burials that were sufficiently complete and had the required records, a division based on class status was determined: 92 burials were extracted from the laypersons and peasant burials and 20 individuals were from the areas reserved for wealthy and high status individuals. This division was based upon predetermined categorization of the excavation site into areas where only the wealthy would be buried and those areas where the villagers and lay brothers were buried. Burials from these two areas were separated and categorized as high or low status in the official records for the site. Further division was recorded for age and sex, but a blind study was conducted.

Figure 3.1 Sex Frequency by Status



Knowledge of age and sex was excluded from skeletal analysis of individual burials; the only foreknowledge was the classification of status.

Figure 3.2 Low Status Age Frequency

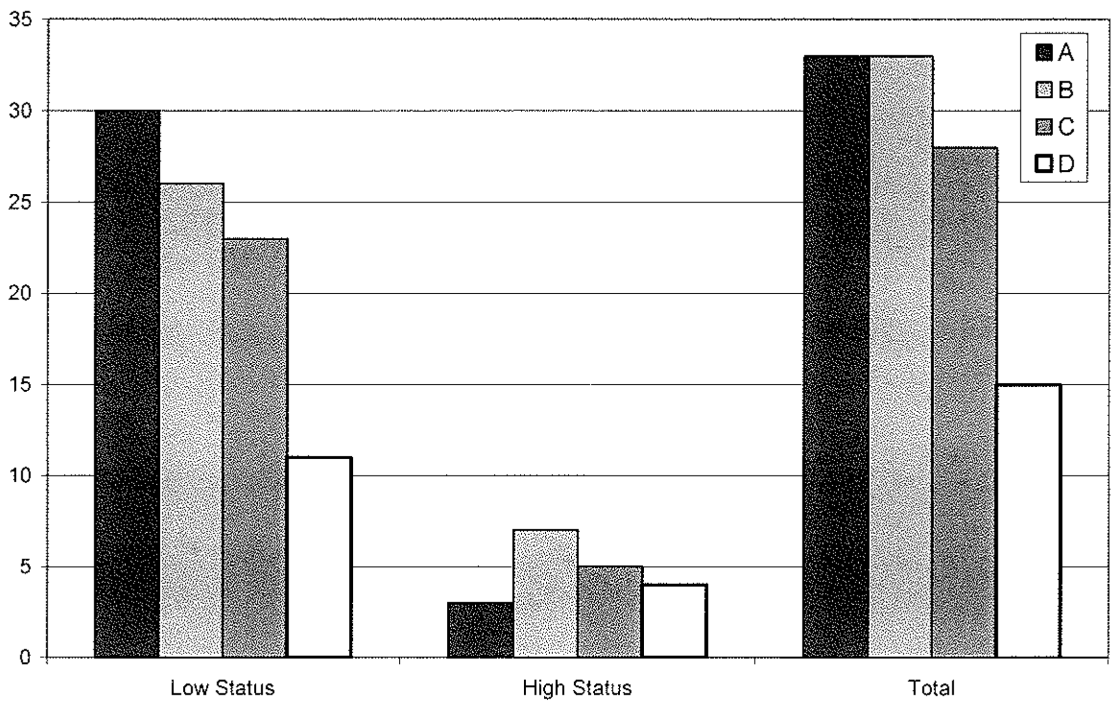


The 92 low status burials consisted of mainly male individuals, with the remainder of the burials being identified as either female, weak male, or unknown sex. For a complete distribution of the sex frequencies for low status burials please see Figure 3.1. The High status burials have a more disparate sex distribution due to the smaller sample size. For a comparison of the high and low status sex frequencies please see Figure 3.2. The high status burials do not contain any unknown sexes or any intermediate sexes, those categorized as weak male or female. The high male: female ratio is due to the fact that the burial area is found within a monastic complex, which would naturally have a higher population of males than females.

Besides the distribution of sex it is also imperative to know the age distribution as well. Although age was unavailable for the high status burials 97% of low status individuals had either subjective age estimation, or an age estimated by Transition

Analysis (Boldsen et al., 2002). Age categories were created by the researcher for statistical analysis, but have little meaning other than a completely subjective form of categorization. A table listing the category values can be found in the Methods chapter. For a complete distribution of ages please see Figure 3.2.

Figure 3.3 Arm Position Frequency by Status



Arm position frequencies are extremely important as they are the dividing factor between the two temporal populations. Distribution of sexes, ages, and results between the four categories will provide the overriding results for this study. The four categories are A=1, B=2, C=3, D=4, which correspond to the two temporal populations: A and B represent the grain producing populations prior to the Black Plague, and C and D represent the livestock producers after the devastation of the Black Plague. For a distribution of Low and High status arm positions please see Figure 3.3.

After arm position, sex, and age were established the rest of the research was conducted blindly. Age and sex, as well as arm position were not included in the information taken during skeletal analysis; the burials were merely divided between statuses. The blind study was conducted in order to avoid result bias, where gradings are assigned because of the expected result for a group. Analysis included metric analysis of the humerus and femur, as well as observation of musculoskeletal stress markers, and general overall health was also noted, if it might infringe on the scoring of MSM's. For an overview of these methods please see the below Methods section of this work.

Methods

Sample Collection

Using a list provided by the Øm Abbey Museum comprised of 930 of the partially analyzed excavations, burials were chosen that represented those of the higher and lower status groups, and met the required criteria of age, sex and arm position. A rough list was drawn up, and then cross referenced with existing data of age and sex and arm position provided by the Anthropological Database Odense University Laboratory (ADBOU) collections, which recorded skeletal age and sex. Using the above criteria the previous list was pared down to a total of 224 specimens, the majority (80%) coming from the commoners' section of the monastic complex.

As already stated 204 skeletons from the cemetery in Øm Kloster comprise the sample for this research. For 88% (180) of the skeletons, age and sex determination had already been established prior to analysis. These were established according to the ADBOU instructional manual, the University of Southern Denmark's Osteological

Methods Report Manual from 18 October 2004. Of the 204 skeletons that were subject to analysis, 112 or 55% met the required criteria of age and status, and completeness of remains. Of the remaining 112, 41% did not have enough skeletal material to analyze, and 59% were excluded due to age restrictions, many being either juveniles or infants. Some burials were included that met the majority of the criteria such as sex and arm position, but did not have age. All those without arm positions were excluded because this represents the primary division within the sample for comparison. Arm positions were unfortunately, not recorded at the time of excavation but were assigned at later dates based on a study done by Kieffer-Olsen in 1992 who studied several sites including the Abbey at Øm. Arm positions assigned for this sample are based on evaluations of site maps created in more recent times. These arm positions are one of four categories, A, B, C, D. As already discussed in the materials section, records indicated that many burials were recorded with a position with for each arm. For example, if each arm was positioned the same way, perhaps in position one a record would show A, A; if one arm position was unknown but the other was recognizable than that arm position would be recorded such as the case if one arm was in position one and the other was missing (A, O). Other positions were recorded dependent upon how the arms were positioned. It was decided if the arm could have plausibly fallen into that orientation and the other could not possibly have, such as in position 1 and 4 (A, D), then the arm position would be recorded as a 4. These positions each correspond to a specific burial position. Position A is an extended burial with arms straight at the sides of the main body; B extended burial with the arms crossed or placed over the pelvic region of the main body; c, extended burial with the arms crossed straight at the ribcage below the breastbone region; D, extended burial with the arms crossed across the ribcage with the hands towards the shoulder or head. Each of these positions was used at a specific time period which enabled later researchers to assign those using the arm positions to a burial period

Unknown sex was allowed in only 5% of the sample, and the remaining were categorized as female, male, weak male, and weak female. Likewise with age, the majority of the high status burials did not have ages recorded in the records provided, excluding them from comparison between statuses by age. However, only 2% of the lower status burials did not have an age associated with them in one form or another. The remaining 90 burials were categorized as age groups 1 through 6, a subjective categorization created by the author. For a listing of the categories see Table 3.1.

Table 3.1 Age Categories

Age Range	*Age Category*
<19.999	1
20 – 27.999	2
28 – 34.999	3
35 – 44.999	4
45 – 54.999	5
>55	6

Status was ascribed based upon predetermined burials positions within the monastic complex. A record with the burials already categorized as high or low status, along with their frequency, percent, valid percent and cumulative percent were provided upon request. Once all this information was correlated a list of possible burials were than extracted from storage and actual visual analysis could begin.

Analysis

The elements of the skeleton analyzed in this study include: the humerus, ulna and radius, the vertebral column, the pelvis, the femur and the tibia. For each of these elements measurements were taken, and specific MSM's were recorded and graded. Due to the large scale of the study and the limited time allowed, a full skeletal inventory was not plausible, and not necessary for the field of research being done.

To begin with, a number of measurements were taken to track changes in growth between the two temporal populations. These include measurements that contribute to the overall calculation of robusticity. Using an osteometric board for the larger long bones was the easiest and most accurate instrument for metric analysis of post cranial elements. This instrument was used to evaluate maximum length and anatomical length of both the humeri and the femurs. A sliding caliper was utilized when reference points were relatively close together, such as in the epicondylar breadth measurement, or in a non-linear measurement, such as the antero-posterior diameter of the femoral shaft measurement. All measurements were taken, recorded or converted in centimeters. Only one measurement required a third instrument; the least circumference of the humeral shaft required the use of a standard flexible measuring tape, such as those used in textile manufacturing.

Of the two skeletal elements used for metric analysis, each element had a number of different measurements taken dependent upon its unique characteristics. For a full list of metrics analyzed please see Table 3.2 below.

Table 3.2 Metric Analysis

Skeletal Element	Measurement
Humerus	Maximum Length
Humerus	Anatomical Length
Humerus	Maximum shaft diameter
Humerus	Least Circumference of Shaft
Humerus	Maximum Diameter of Head
Humerus	Minimum Diameter of Head
Humerus	Epicondylar Breadth
Femur	Maximum Length
Femur	Anatomical Length

Femur	Medi-lateral diameter of shaft
Femur	Antero-posterior diameter of shaft
Femur	Maximum diameter of proximal shaft
Femur	Maximum diameter of head

For the femur several measurements were taken for both the right and left side, in order to observe if there was any bilateral asymmetry, or if specific traits were located on only one side. The maximum length, that is the greatest distance from the medial condyle at the distal end of the femur to the proximal point on the head, was taken using an osteometric board. The physiological length, or the length of the bone when it is in anatomical position was also taken; this measurement is taken from both distal condyles to the femoral head, with the posterior of the bone facing downwards on the osteometric board. These measurements are important because they were also utilized to estimate stature of the individual using Trotter and Gleser's (1952, 1958) European male and female formulae for stature estimation. For a discussion of the validation of this method please refer to Chapter 2.

Certain measurements were used to calculate indexes or other special information. In the case of the humerus, a measurement of the maximum length was taken, and a measurement of the least circumference of the shaft was also obtained. The least circumference is taken by locating the nutrient foramen on the distal portion of the shaft, sliding calipers are used to measure 1 (one) centimeter down from the posterior edge of the nutrient foramen, chalk is used to mark the area, and using a graduated measuring tape a measurement around the shaft is taken. A formula (least circumference of shaft X 100) / (maximum length of humerus) is used to establish the overall robusticity of the humerus (Bass, 1982). Similar to the femur, measurements were taken in order to record symmetry of the upper arm in both statuses. These measurements were taken with the osteometric board.

Also observed and recorded were a series of musculoskeletal stress markers, chosen depending upon what general activities they might represent within the two temporal populations. The attachment or insertion sites selected are those that are easily discernible on the skeletal element, not only for the researcher but for those not involved in the study; this is correlated with the repeatability of scoring as the MSM must be observable to all, and clearly definable. Sites are also chosen because they are found on bones that are usually represented within a burial, and largely well preserved; they represent specific activity patterns or the use of a specific muscle group and generally they will include the main articulation groups, elbow, hip, shoulder, knee (al-Oumaoui, 2004). A diverse series of markers were taken for the humerus and femur primarily, with secondary characteristics on the ulna, radius, tibia, vertebral column, and innominate, where available. The humerus and femur are the two elements most likely to be represented in an excavation, and can be easily used to examine general patterns of activity.

The humeral MSM's were those found on the lesser and greater tuberosities, and of particular interest those found on the crests of the two tuberosities as well. These two particular crests and the three muscles associated with them are often referred to in this text as the proximal MSM, as they are often integrated into one area of grading. The deltoid tuberosity was also an area that was analyzed for the robusticity of the deltoideus muscle. On the vertebral column the MSM known as Schmorl's nodes, a depression into the body of the vertebrae caused by pressure upon the column and displacement of the disc, was observed. The area of the vertebral column, Lumbar, Thoracic, and Cervical was noted, and a gradings of mild, moderate or severe was given. Lipping, more an indication of degenerative defects but also utilized for the grading of activity was also noted. The chosen MSM's often comprised a joint, in the case of those on the ulna and radius, or an element that would be used in a specific suite of motions, such as the vertebral column, pelvis, and femur and humerus. The clavicle was also analyzed, as was the tibia for several MSM's. For a complete list of the MSM's, skeletal elements and associated movement, please see Tables 3.3 and 3.4. as well as table 2.1 in the Literature review chapter. **Table 3.3 Musculoskeletal stress marker sites**

Humerus	***Ulna***	***Radius***	***Femur***	***Tibia***	***Vertebral Column***	***Inominate***
Crest of Greater Tubercle	Olecranon process	Radial Tuberosity	Greater Trochanter	Tibial tuberosity	Schmorl's Nodes	Iliac Crest
Crest of Lesser Tubercle	Ulnar Tuberosity	Midshaft tuberosity	Lesser trochanter	Soleal/Popiteal Line		Gluteal Line Inferior
Deltoid Tuberosity			Linea Aspera			Gluteal Line Medial
Greater Tubercle			Fovea capitis			Gluteal Line Superior
Lesser Tubercle						

There are several different manners in which scoring may be carried out. Drawing from two sources, Robb (1994, 1998) and Hawkey and Merbs (1995), an integrated version of scoring MSM's was created for this research. Due to the subjectivity of grading musculoskeletal stress markers, this study integrates several of these methods. Robb (1994) was particularly helpful, with the specific data from Øm Kloster and Denmark concerning skeletal characteristics and skeletal measurements. The gradings range from 0 which includes the following scores: cannot be scored due to postmortem damage, disease, or trowel, and cannot be graded because the element is not represented. These however are stricken from the statistical analysis and entered as missing. A grading of 1 is made when the characteristic is present but only to a degree that it is normally represented in the population; 2 is given to those that show a marked difference or increase in the trait compared to what the normal used or exercised trait would manifest; a 3 is rarely attributed because it represents a painful attachment or insertion site. This is generally attributed to over use of the element and is exhibited by severe pitting and furrowing of the cortical surface, and can result in degradation of that surface +2 mm. A grading of one is generally characterized by the presence of the trait, with minimal roughening and robusticity of the attachment area, however a grade of 1.5 can be given in cases where a portion, generally less than half of the site, exhibits some lipping, roughening, or one bony crest. A score of two manifests in a large roughened area with 2 or more bony outcroppings, severe lipping, generally larger than 2mm; a score of 2.5 is given if the MSM is severe enough to have the beginning of cortical damage, such as a depression alongside the attachment site without any pitting or osteophyte construction. The edges of the attachment are generally sharp and the surface is rough with a pimply feeling. A score of 3 exhibits all the characteristics of a 2 score only with cortical damage. This manifests as jagged bony crests, surrounding depressions or furrowing, and macroporosity of the attachment site. Small to medium sized pinholes are seen in the periosteum of the element, if the holes are larger the MSM site is excluded because the muscle would have been injured, generally not in the daily routine of repetitive activities. If possible where the attachment site has more than one insertion or origin, i.e. the greater trochanter, a specific muscle was delineated as the most extensive, usually this corresponded to the recording of the MSM for the crests of the humeral tuberosities, which contribute to the proximal MSM.

For each status group a number of skeletons were reanalyzed for the purpose of error evaluation. For the low status groups, roughly 10%, or ten skeletons were re-measured and rescored. For the high status group, due to the limited number in the original sample only 5 skeletons were reanalyzed. This, however, represents a larger percentage, roughly 25%. Using an error formula from White (2000), margin of error was calculated. The purpose of this is to calculate repeatability and reliability of the data (i.e. intra-observer error).

Finally, using Trotter and Gleser's (1952, 1958) formulae, the living stature of the burials was estimated. For a review of the deficiencies of this method in conjunction with this specific population please see Chapter 2.

Statistical analysis was performed using SPSS® v. 15. Scatterplots and boxplots were

Table 3.4 MSM Skeletal Elements and Associated Muscles

Skeletal Element	*Muscle, Ligament, Tendon*
Clavicle	Conoid Ligament
	Trapezoid Ligament
	Trapezius muscle
	Deltoideus muscle
	Costoclaciular ligament
Humerus	Subscapularis muscle
	Suprapinatus muscle
	Infraspinatus muscle
	Teres minor muscle
	Pectoralis major muscle
	Teres major muscle
	Deltoidues muscle
Radius	Biceps bracchi muscle
	Pronator teres
Ulna	Brachialis muscle
	Triceps Bracchi
Os coxae	Abdominal muscles
	Gluteal muscles
Femur	Gluteus maximus
	Gluteus medius
	Gluteus minimus
	Ligamentum teres
	Iliopsoas tendon
	Iliacus muscle
	Psoas major muscle
	Vastus muscles
	Longis magnus
	Longis brevis
Tibia	Quadriceps muscle
	Femoris muscle
	Popliteus muscle
	Popliteus fascia

used to compare distribution of two measurements. T- tests were used to compare differences in mean values between groups, and patterns of MSM traits were evaluated using Pearson χ_2 tests. Comparisons were made between sex, and arm position within each status group primarily and then between the two status groups secondarily. However of primary interest to this study were the differences between the arm positions as this represents changes throughout time; before the Black Death and after the Black Death, and this comparison realizes the bulk of the statistical analysis.

Chapter 4 Results

Upper Body

Asymmetry

Overall asymmetry was observed for the right side of the upper body with statistically significant results yielded for the right humerus length ($t= 10.813$; $df= 74$; $p< 0.001$), humerus shaft ($t= 6.460$; $df= 76$; $p< 0.001$), least circumference of the shaft ($t= 5.837$; $df= 76$; $p< 0.001$) and epicondylar breadth ($t= 3.321$; $df= 65$; $p= 0.001$). The maximum diameter of the head of the humerus did not yield statistical significant results although the right head was substantially larger than the left.

When the sample was controlled for sex, asymmetry was statistically significant in both sexes for the humerus length, shaft diameter and least circumference of the shaft; the males however also yielded statistically significant results for the epicondylar breadth. Similar results were yielded when controlled for status with the same measurements also exhibiting statistically significant results (shaft $t= 5.289$; $df= 58$; $p<0.001$, least circumference $t= 4.556$; $df= 63$; $p<0.001$, and epicondylar breadth $t= 3.178$; $df=52$; $p= 0.002$), with the results for high status maximum head diameter being slightly less significant than the others ($t= 2.354$; $df= 47$; $p=0.023$).

Figure 4.1 Right Humerus Length Split by Arm and Compared between Sexes

Note: 1.00= Females, 2.00= Males

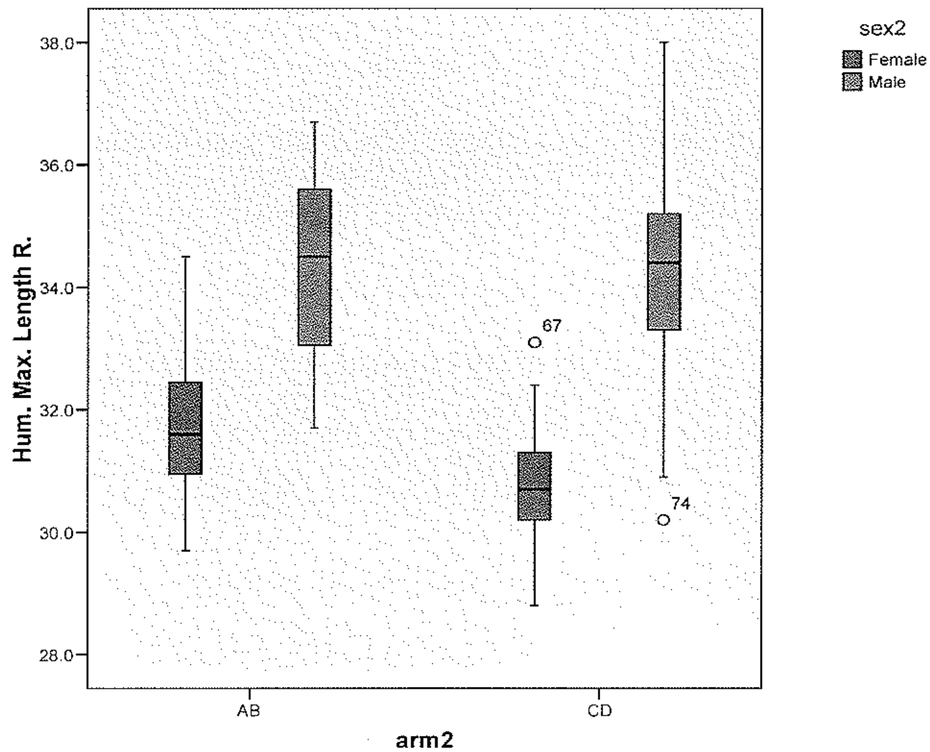


Figure 4.2 Left Humerus Length Split by Arm and Compared between Sexes

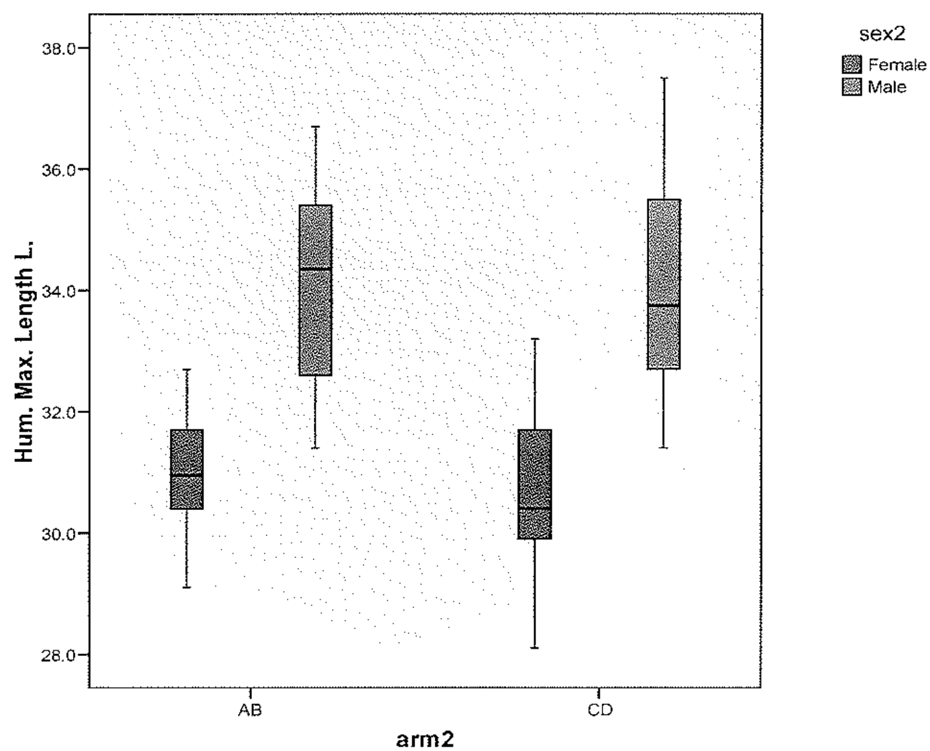


Figure 4.3 Left Epicondylar Breadth Arm by Sex

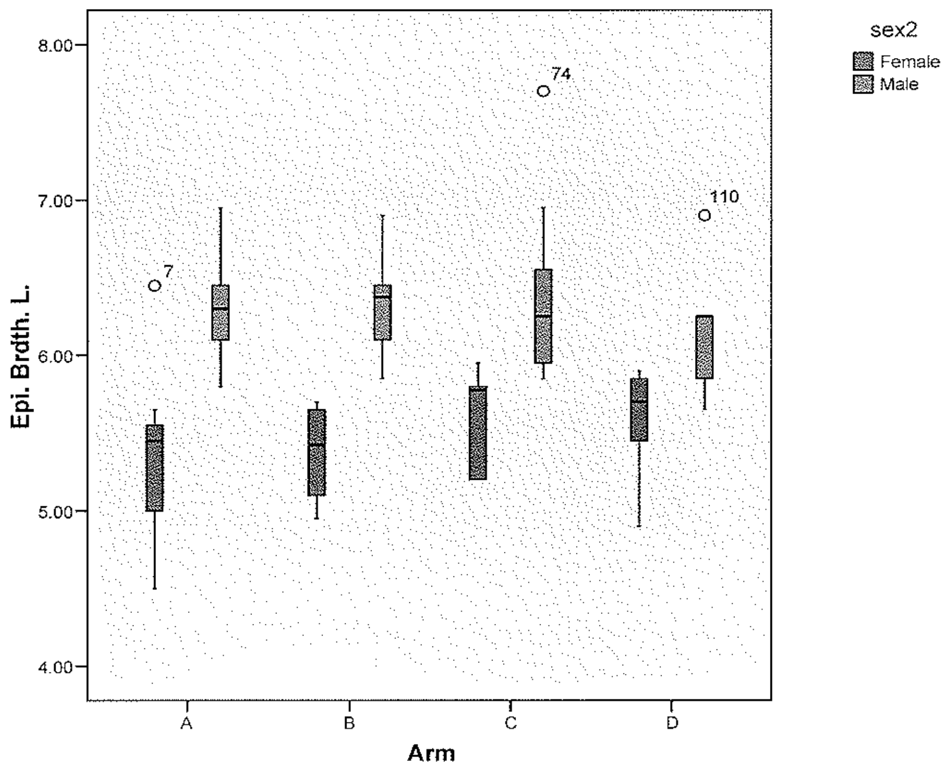


Figure 4.4 Right Epicondylar Breadth Arm by Sex

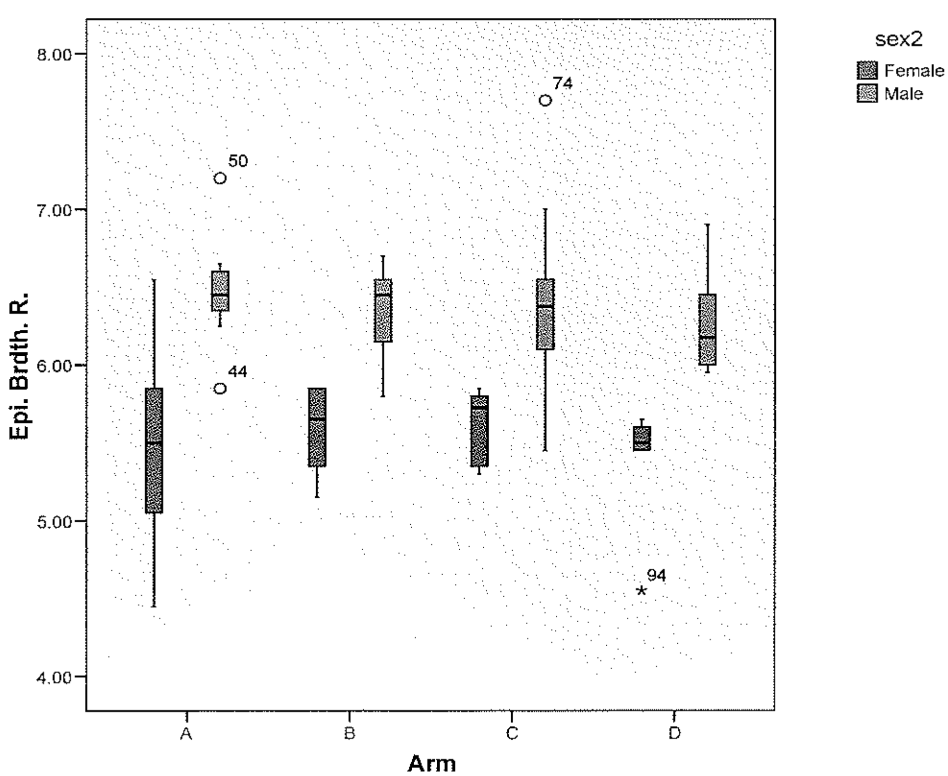


Figure 4.5 Right Least Circumference of Shaft Arm by Sex

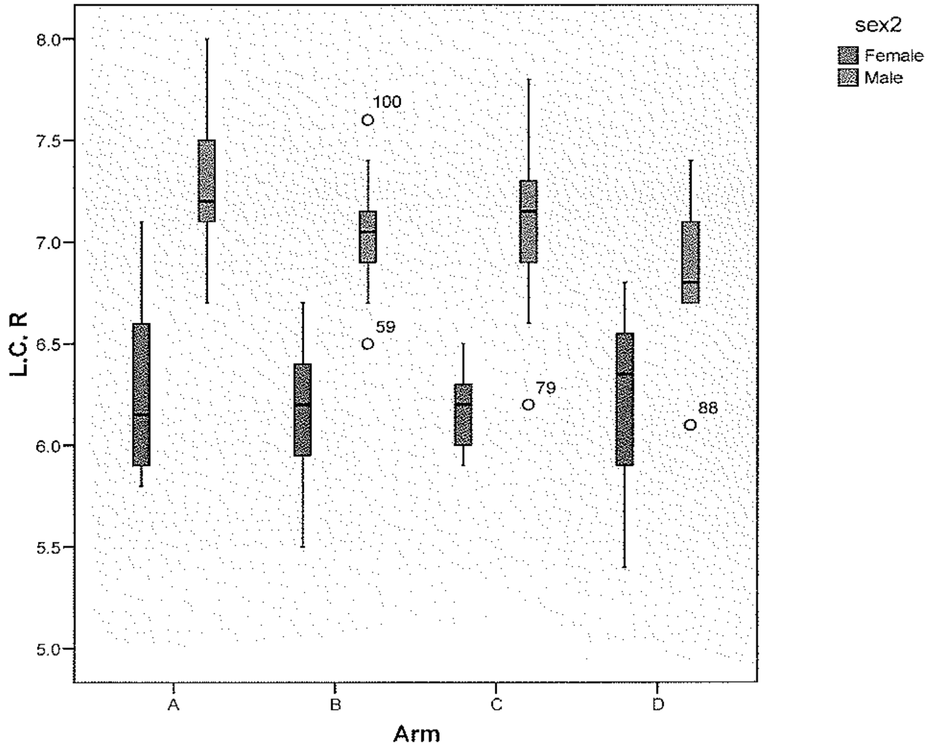
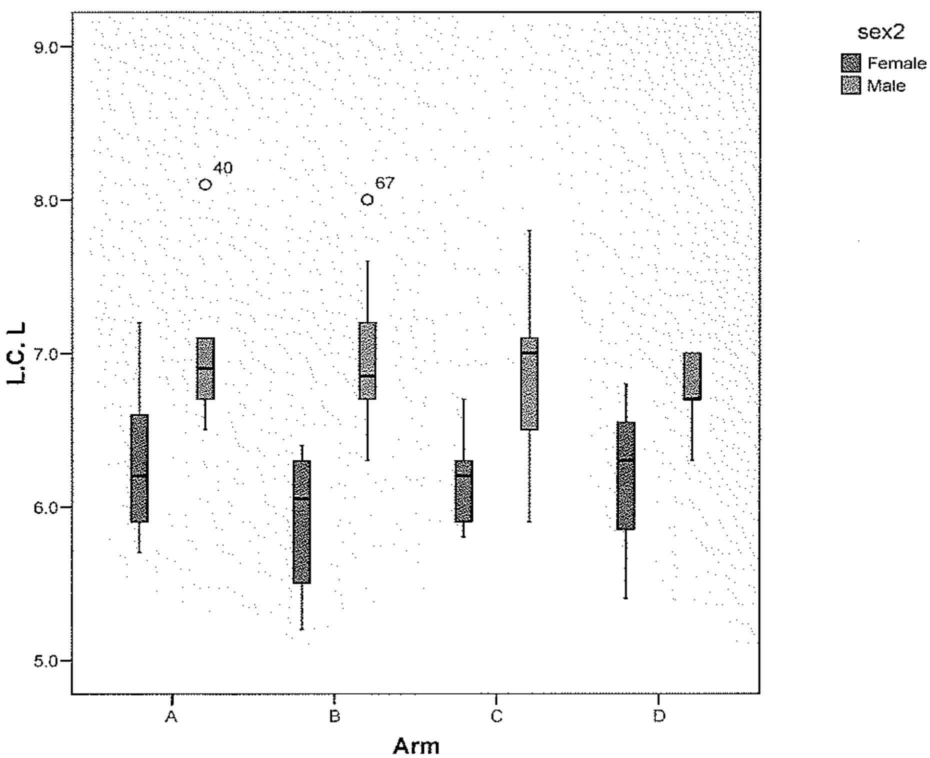


Figure 4.6 Left Least Circumference of Shaft Arm by Sex



When the sample was further controlled for arm positions acting as temporal indicators, the sample was split into two categories 1 for arm positions A and B and 2 for arm positions C and D. Figures 4.1 through 4.6 reveal the overall distribution of males and females in each temporal category, illustrating the significant difference between the two sexes for right and left side humerus maximum length, right and left least circumference, and right and left epicondylar breadth. The t-test revealed statistically significant results for both temporal periods for all of the measurements ($p<0.001$) with the right element always the dominant or larger for all.

Using humerus maximum length as an indicator of asymmetry the sample was controlled for arm positions and statistically significant results were seen for both temporal categories: 1 (A and B) $t= 9.779$; $df= 41$; $p< 0.001$ and 2 (C and D) ($t=5.543$; $df= 31$; $p<0.001$).

Asymmetry is therefore present across a long stretch of time and varies little between the two groups. The final control for status yielded the same results with both the high and the low groups manifesting asymmetry of the right arm over the left arm ($p<0.001$). Figures 4.7-4.14 illustrate the distributions of each measurement between the two status groups for each arm position. Low status individuals have a wider range of lengths than high status individuals.

Figure 4.7 Right Humerus Maximum Length, Status by Arm

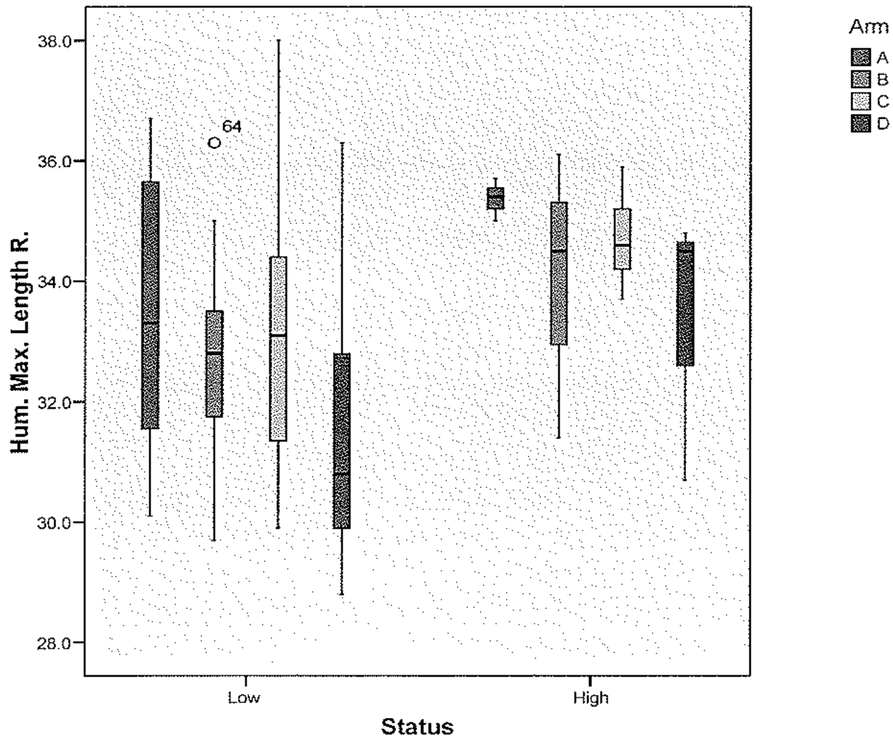


Figure 4.8 Left Humerus Maximum Length, Status by Arm

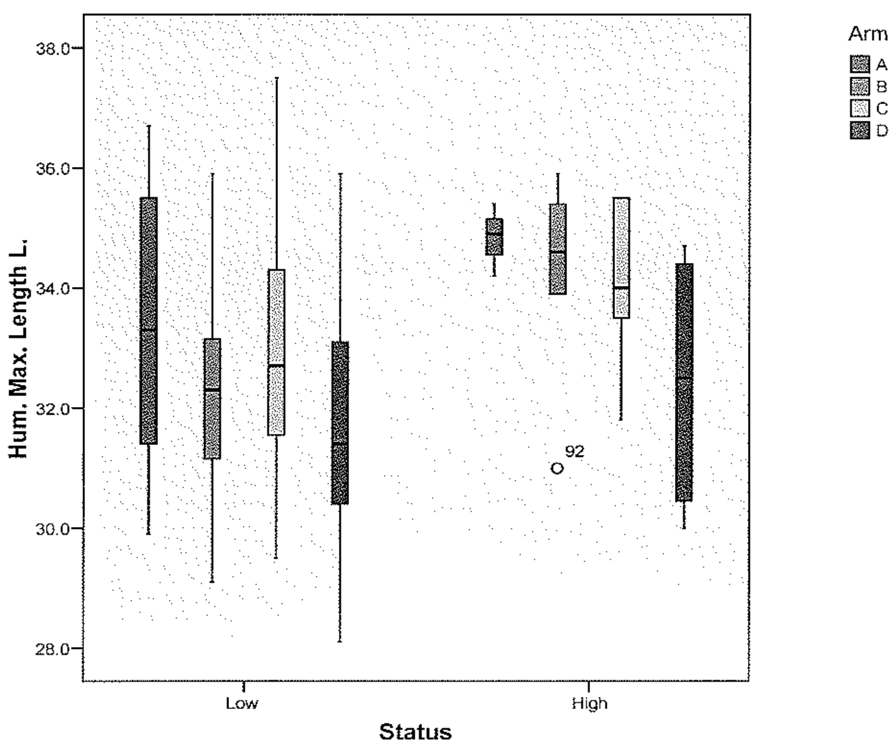


Figure 4.9 Left Least Circumference of the Shaft, Status by Arm

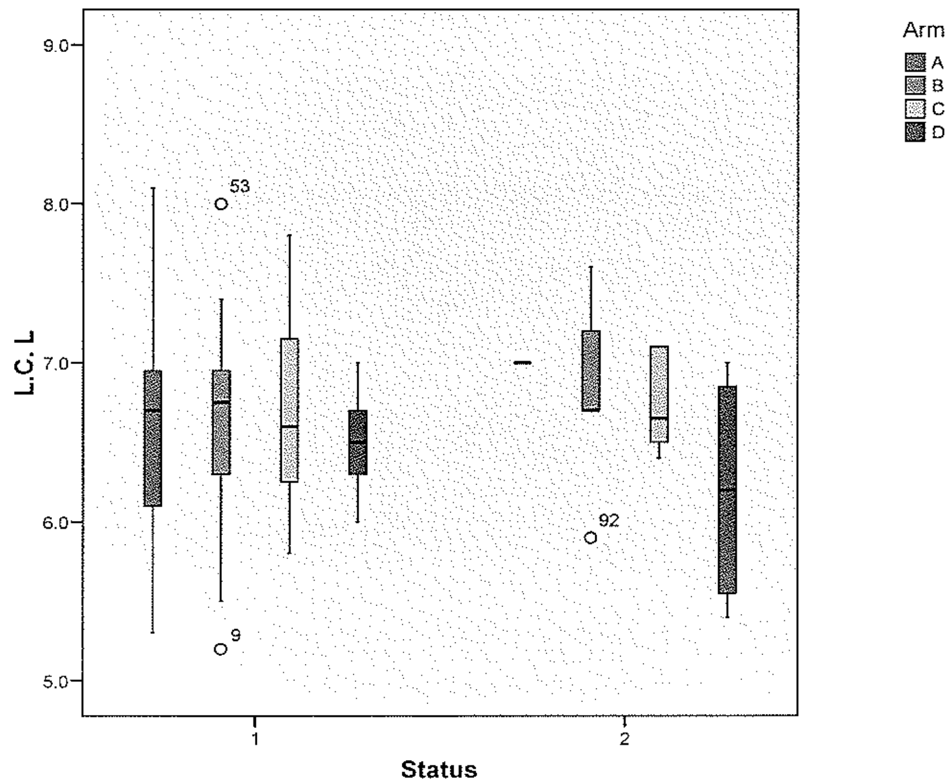


Figure 4.10 Right Least Circumference of the Shaft Status by Arm

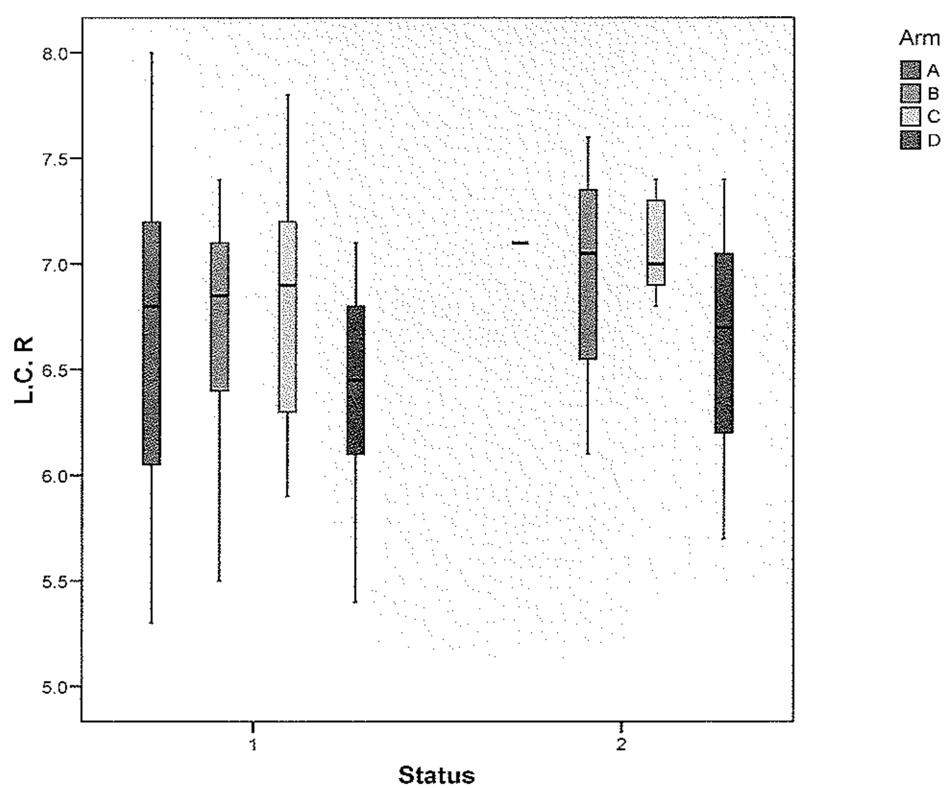


Figure 4.11 Right Epicondylar Breadth Status by Arm

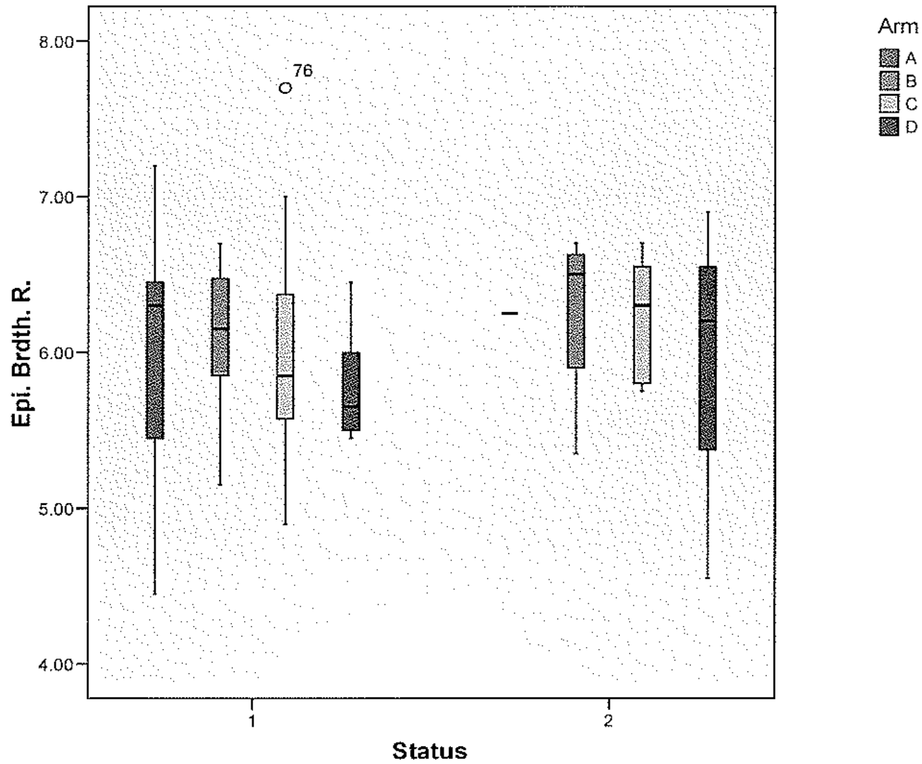


Figure 4.12 Left Epicondylar Breadth Status by Arm

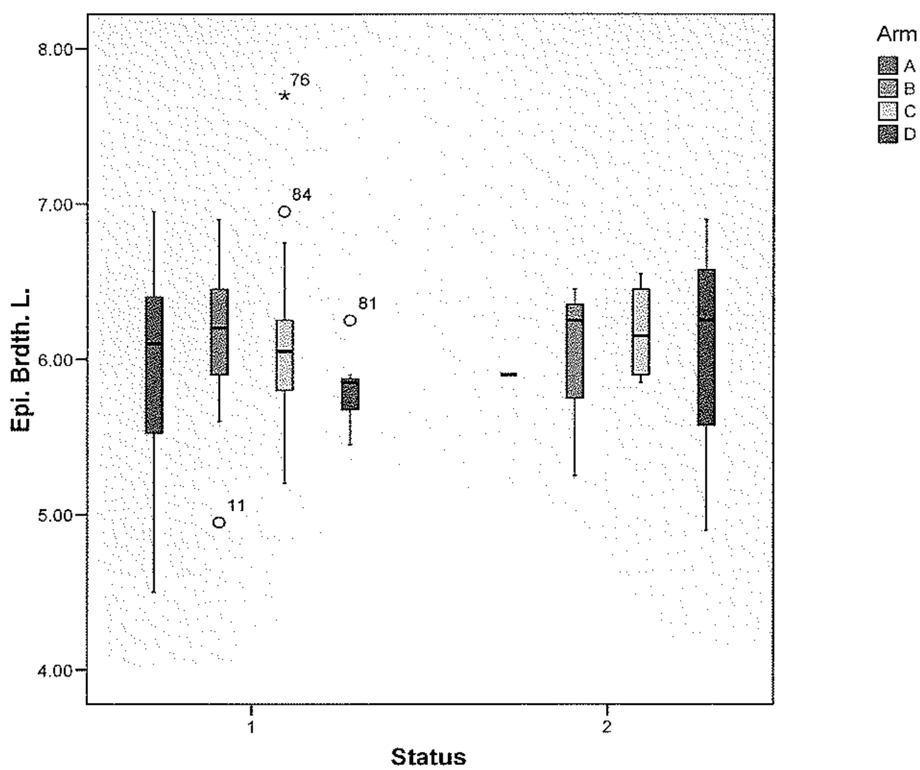


Figure 4.13 Right Shaft Measurement Status by Arm

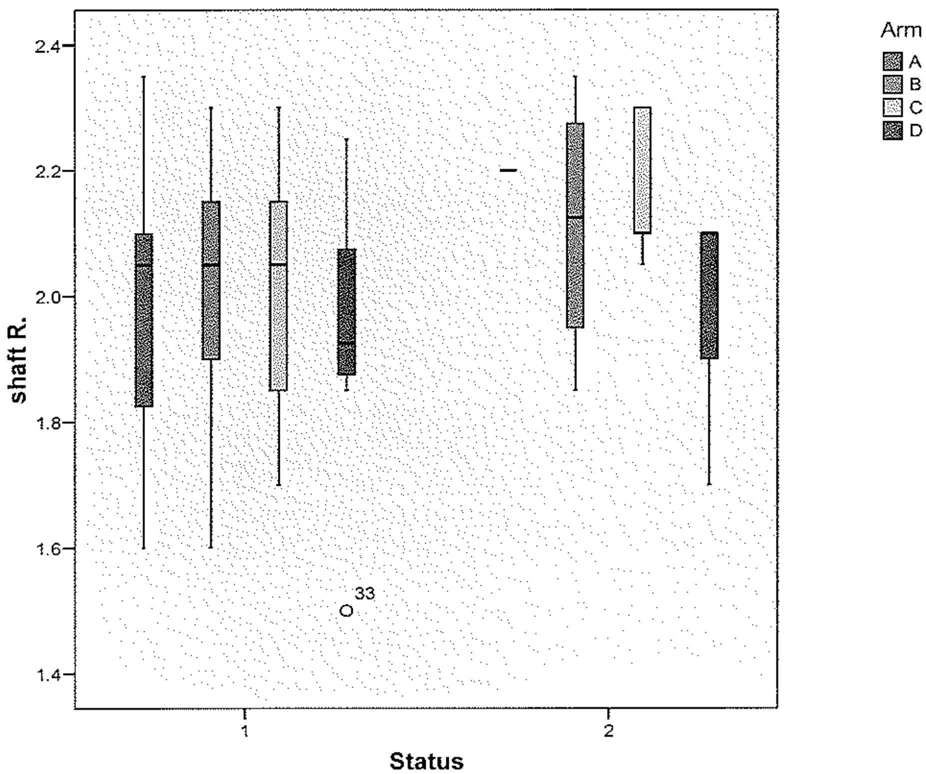
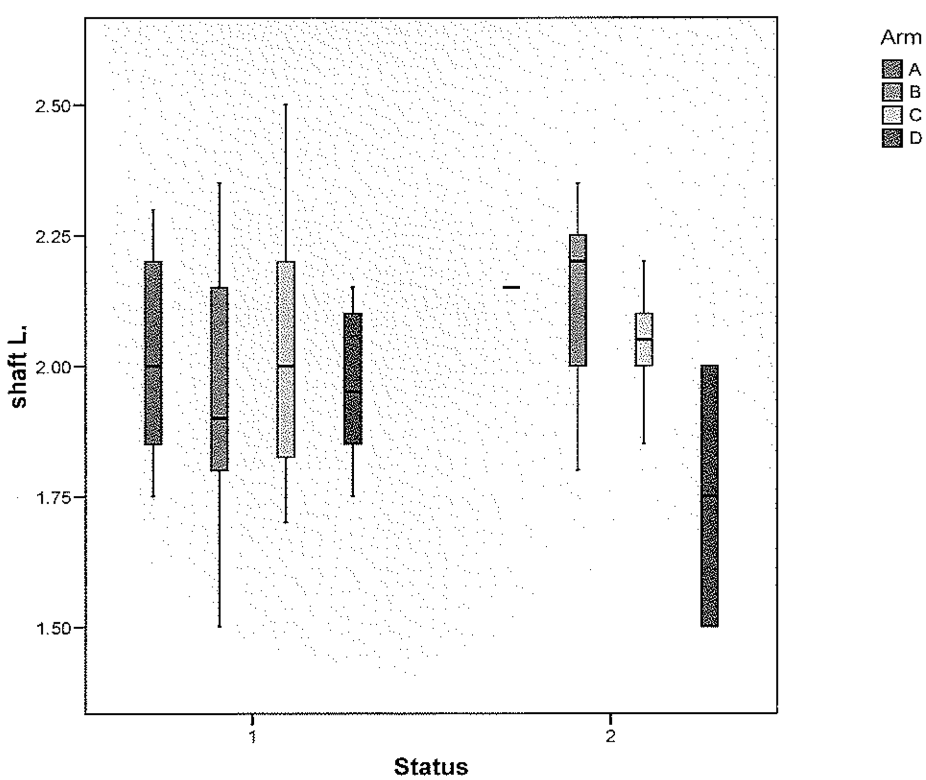


Figure 4.14 Left Shaft Measurement Status by Arm



Measurements

When controlled for sex males were always significantly larger than females ($p < 0.001$) and when compared between status groups males were still larger overall although the higher status groups saw some minor variations in significance in the shaft diameter and epicondylar breadth

Figure 4.15 Left Epicondylar Breadth Measurement Status by Sex

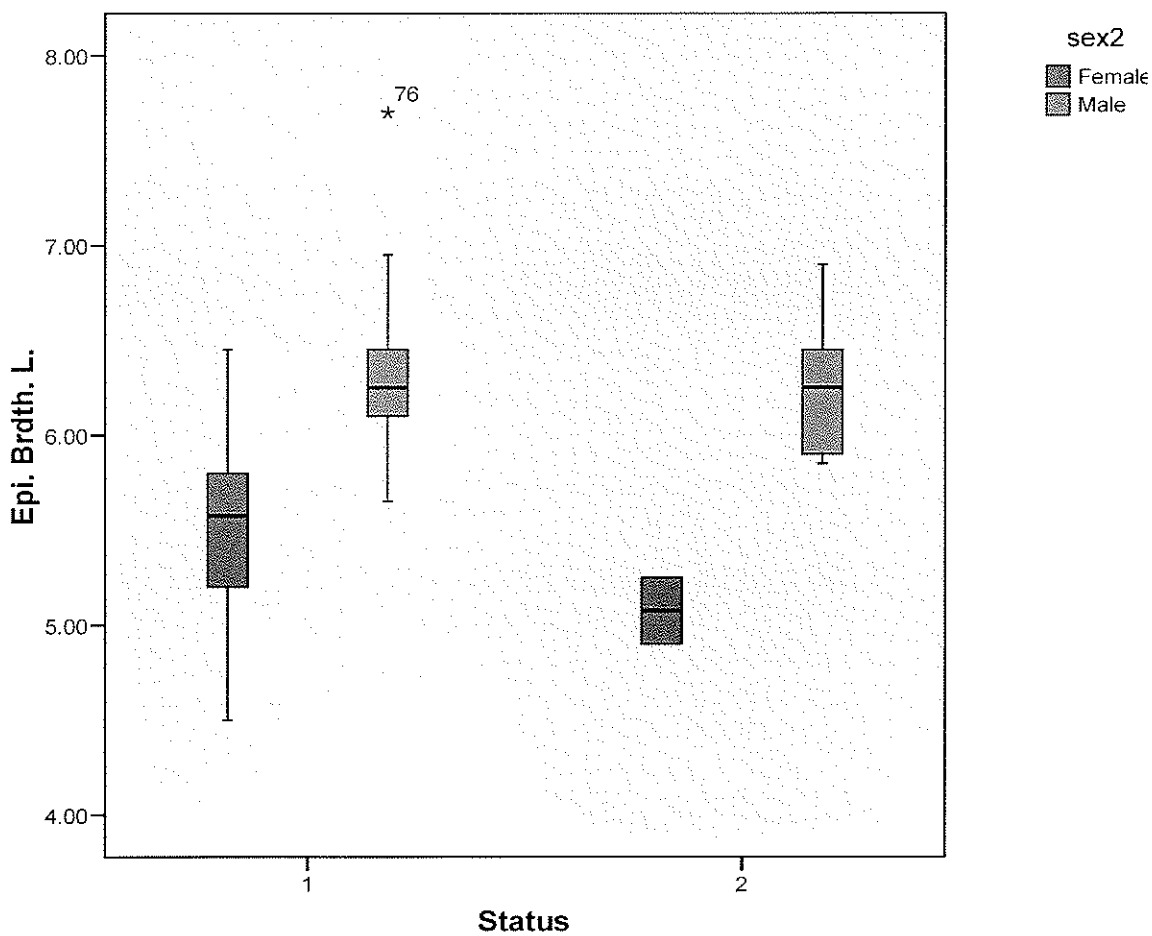


Figure 4.16 Right Epicondylar Breadth Measurement Status by Sex

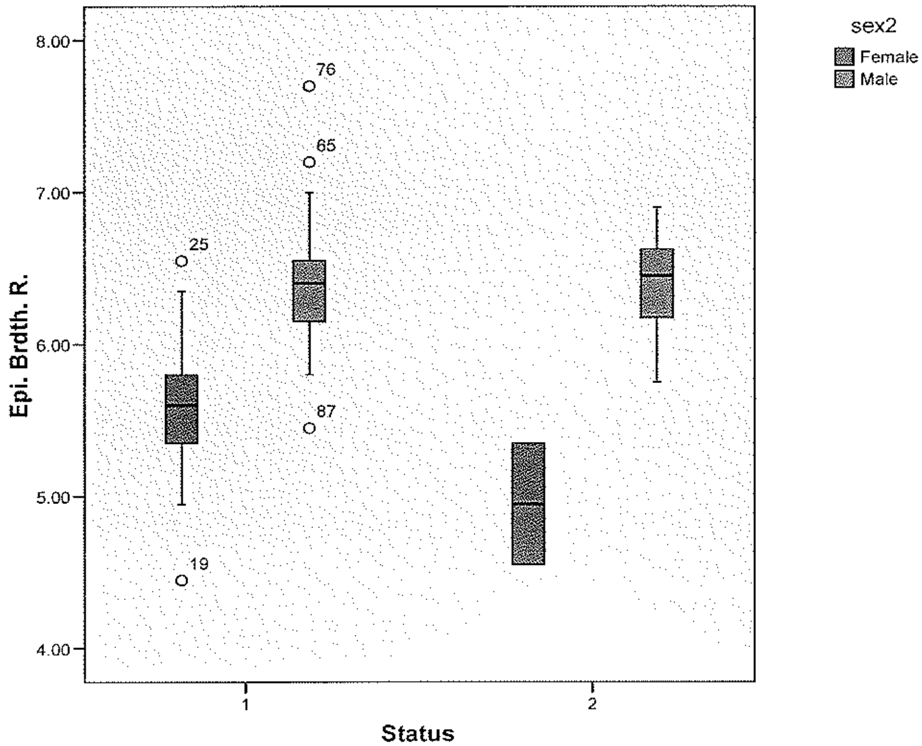


Figure 4.17 Right Least Circumference Measurement Distribution Status by Sex

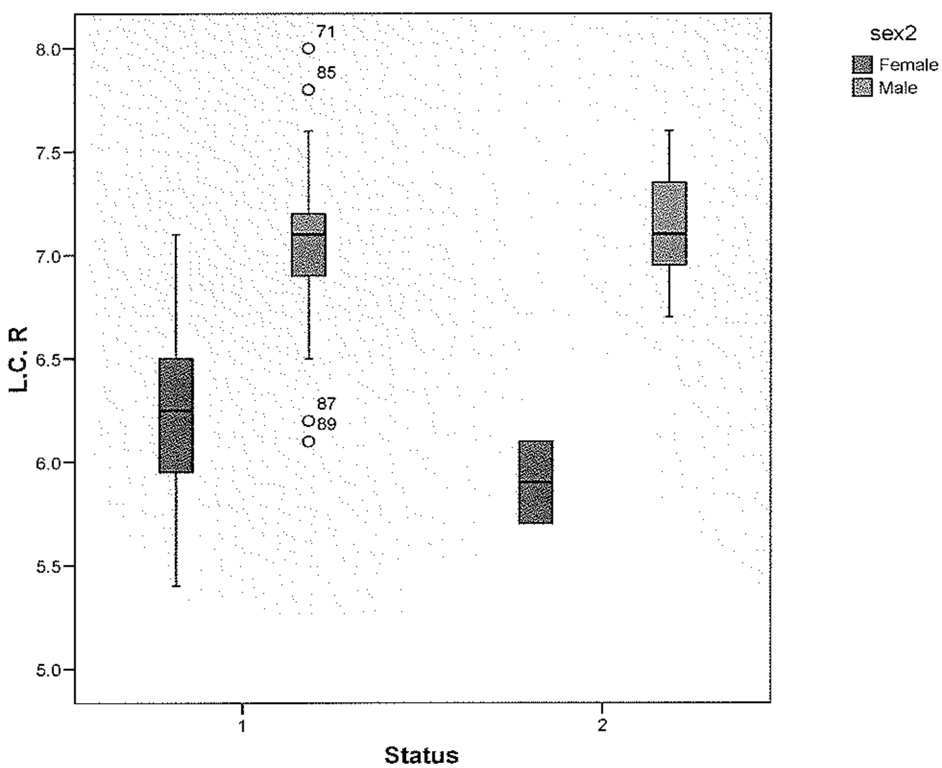


Figure 4.18 Left Least Circumference Measurement Distribution Status By Sex

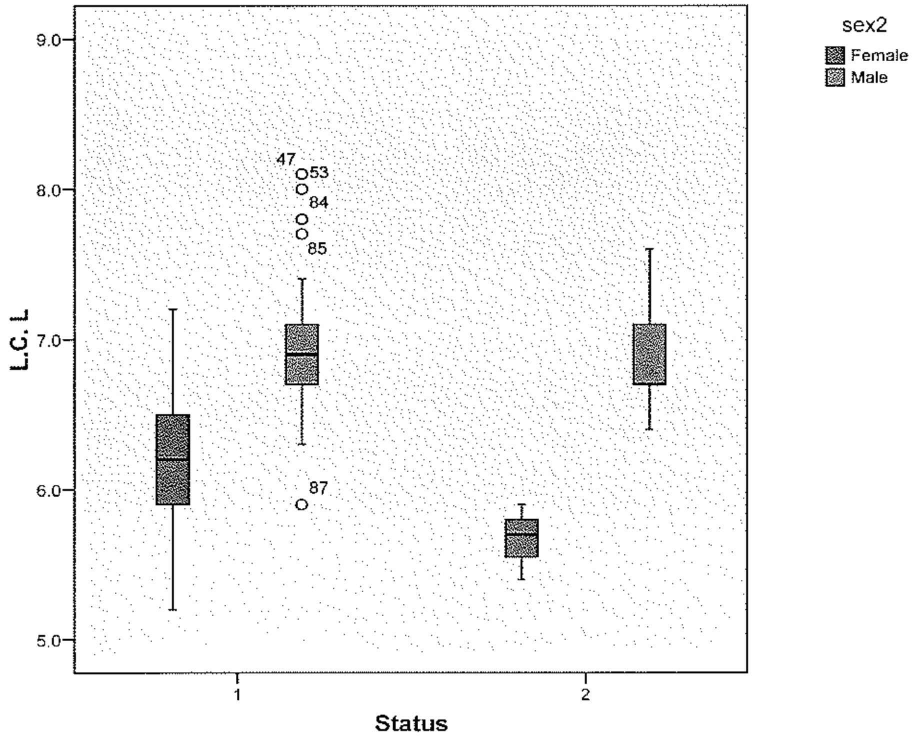


Figure 4.19 Left Diameter of Shaft Measurement Distribution Status by Sex

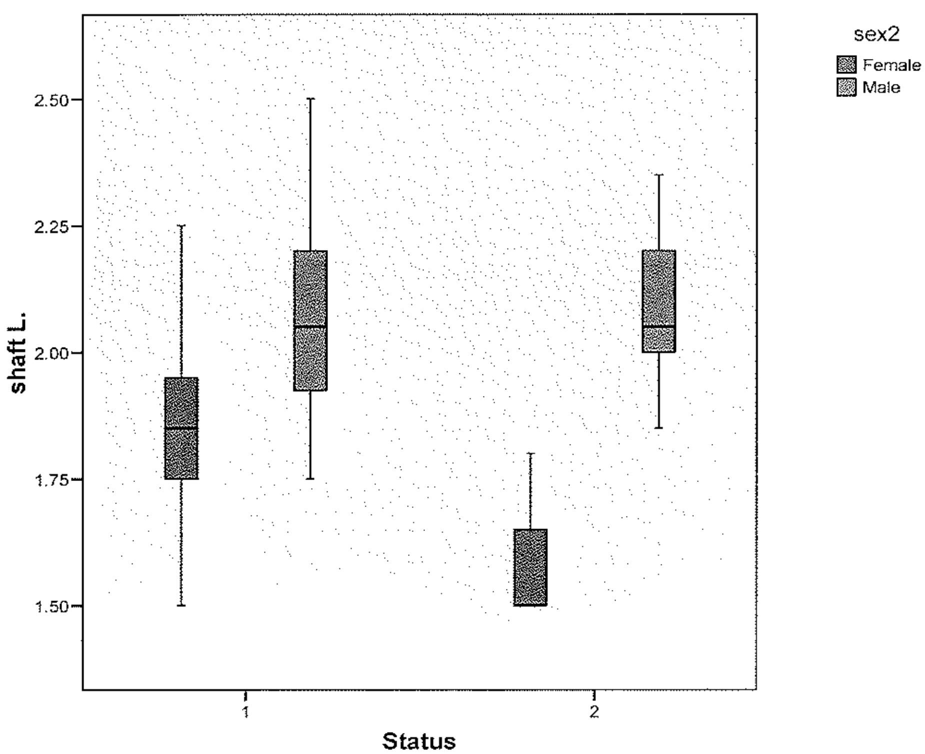


Figure 4.20 Right Diameter of Shaft Measurement Distribution Status by Sex

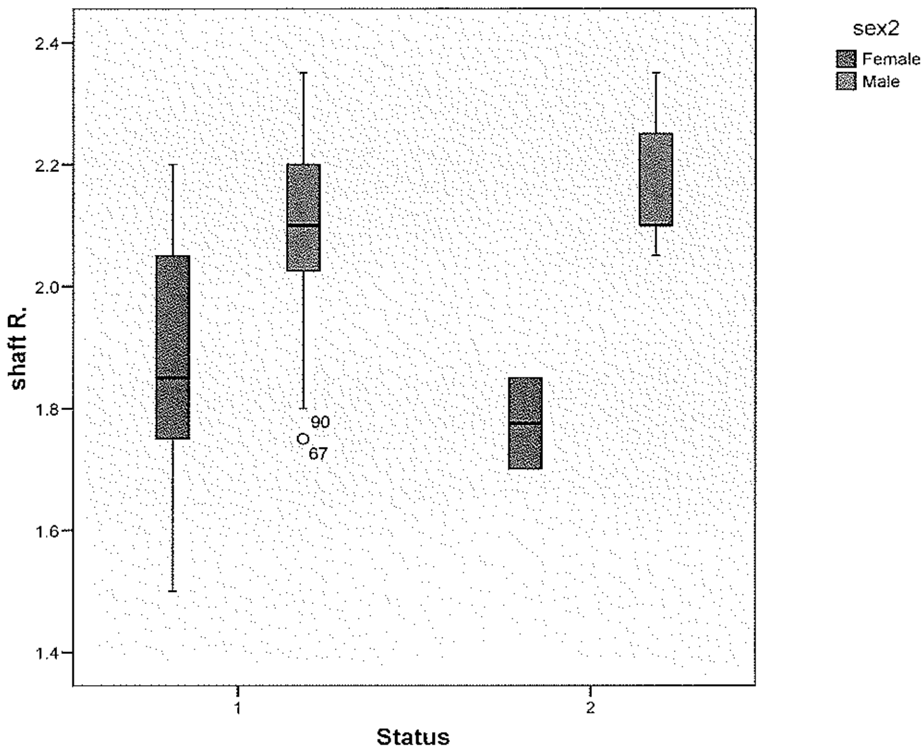


Figure 4.21 Right Humerus Maximum Length Status by Sex

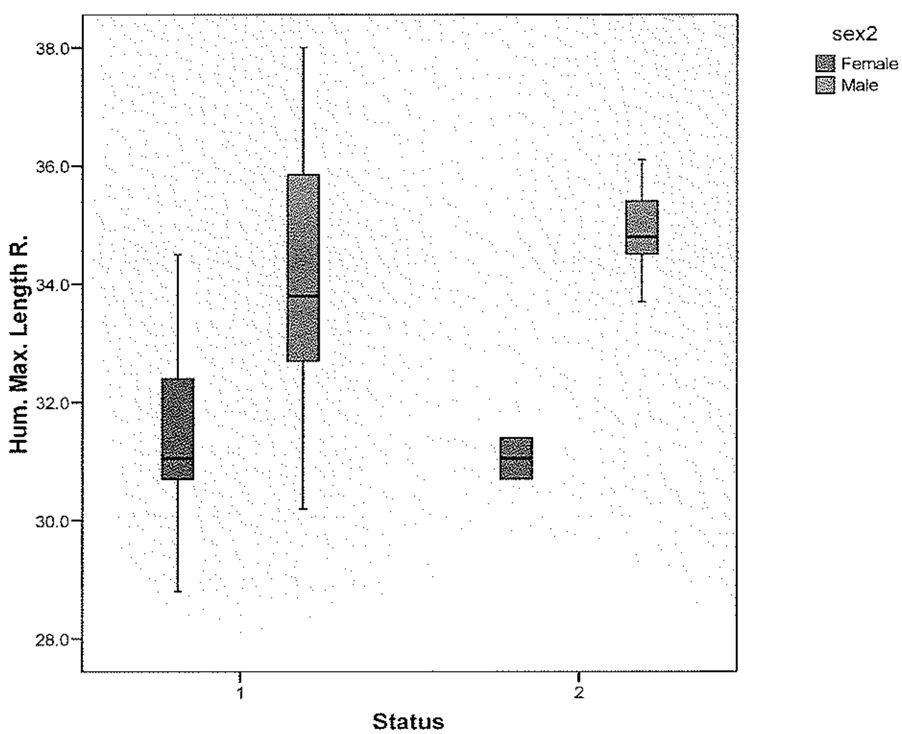
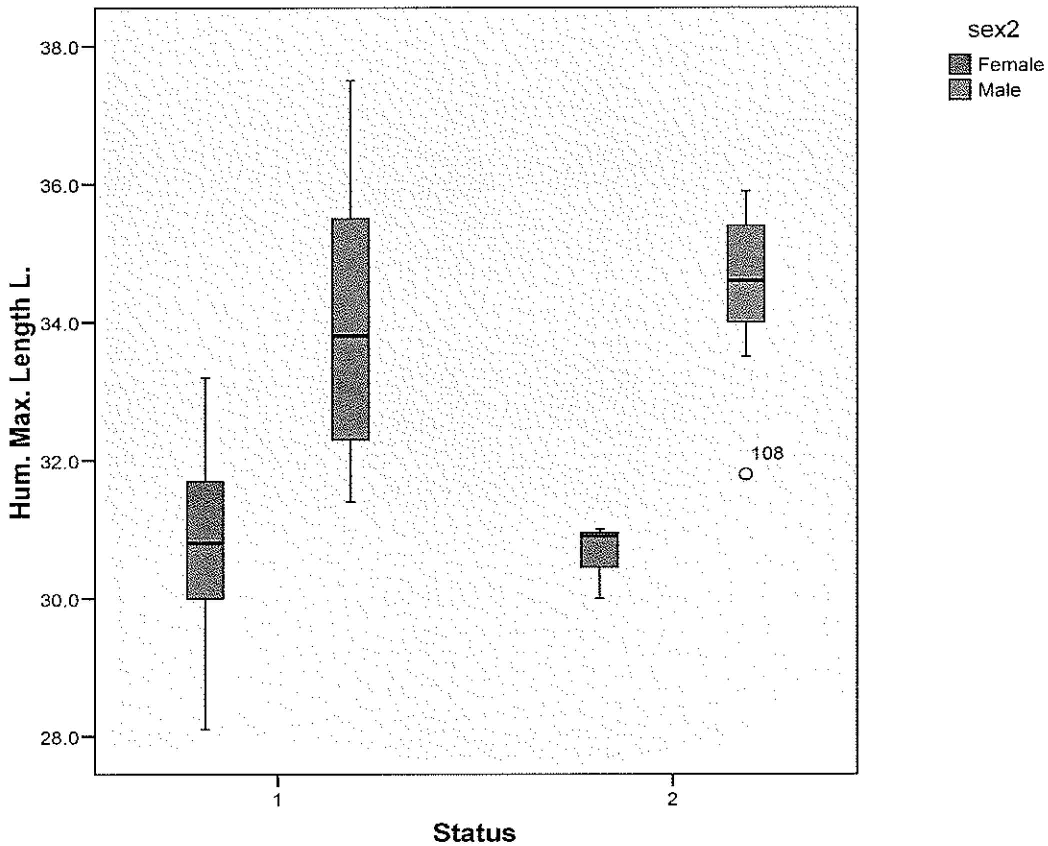


Figure 4.22 Left Maximum Humerus Length Status by Sex



Figures 4.15 through 4.22 illustrate distributions of measurements when the sample was compared between the status groups and controlled for sex. These illustrate that the males were substantially larger than the females of the same group, and in the case of the low status males, substantially larger than those of the high status females as well.

For females there was little significant variation between the two status groups; however there were two corresponding areas in which the low status females were significantly more robust than the high status female individuals. For the left side humerus shaft diameter (Figure 4.19) the low status females showed a significantly larger mean than the high ($t= 2.499$; $df= 27$; $p= 0.019$). The other area is the left side least circumference of the shaft (Figure 4.18) with the low status females exhibiting a significantly larger measurement ($t= 2.0162$; $df= 29$; $p= 0.039$). The males within the status groups had no statistically significant variation.

When compared between the Periods AB and CD for differences controlling for sex, no significant differences were found for males. Females did yield one significant result for the right humerus maximum length measurement, with the earlier Period AB females exhibiting longer bones ($t= 2.132$; $df= 26$; $p= 0.043$) suggesting that upper body size decreased between the two time periods. When the sample was split for arm positions and then further compared by status no significant results were generated within either temporal population for either status. No statistically significant results were yielded when the upper limb measurements were layered by status and compared between the two temporal populations. Neither status exhibited statistically larger measurements between the temporal populations. However when the two temporal populations were layered and compared within sex the males were always significantly larger than the females, this did not change across time.

Musculoskeletal Stress Markers

Figure 4.23 represents the visual data yielded through crosstabulations using the Pearson Chi square Fisher's Exact formula, which generated statistically significant results for the right deltoid attachment area when controlled for sex and compared between status groups. The other significant result for this site was found when controlled for arm positions and compared between status groups. No statistical significance was found for the right deltoid when controlled for sex and compared between arm positions, when controlled for status and compared between the sexes, when controlled for arm and compared between sex groups, or when controlled for status groups and compared between arm positions.

Figure 4.23 Right Deltoid Sex by Status

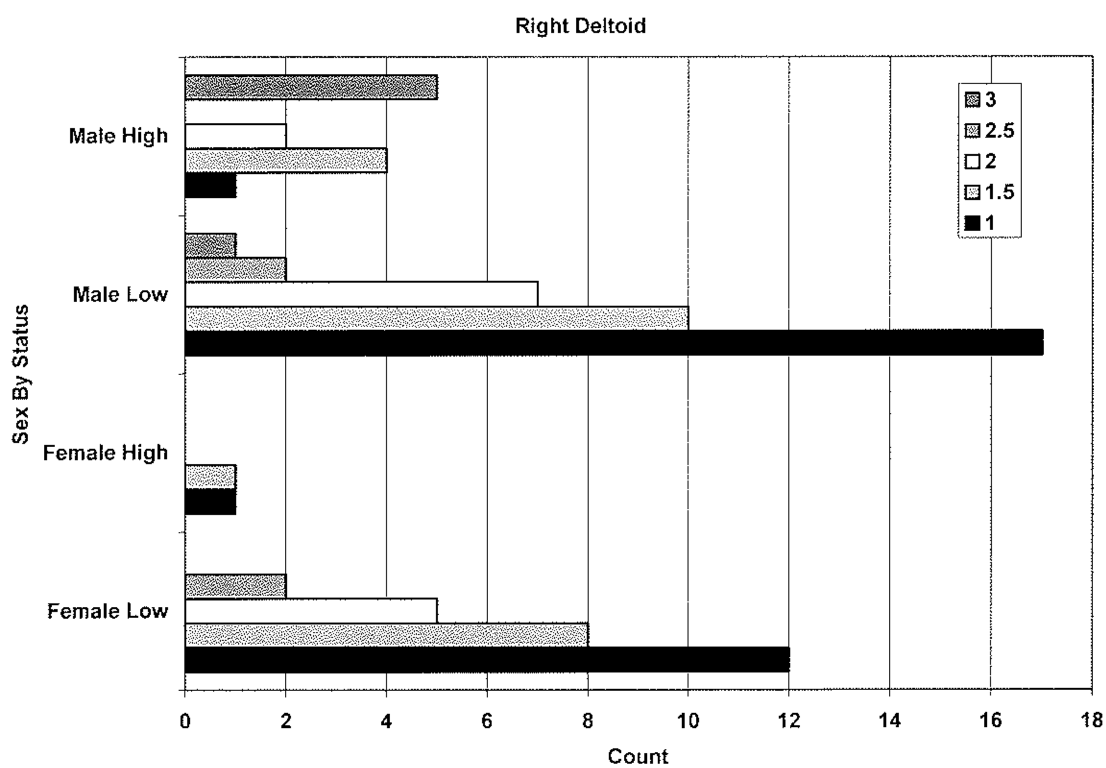
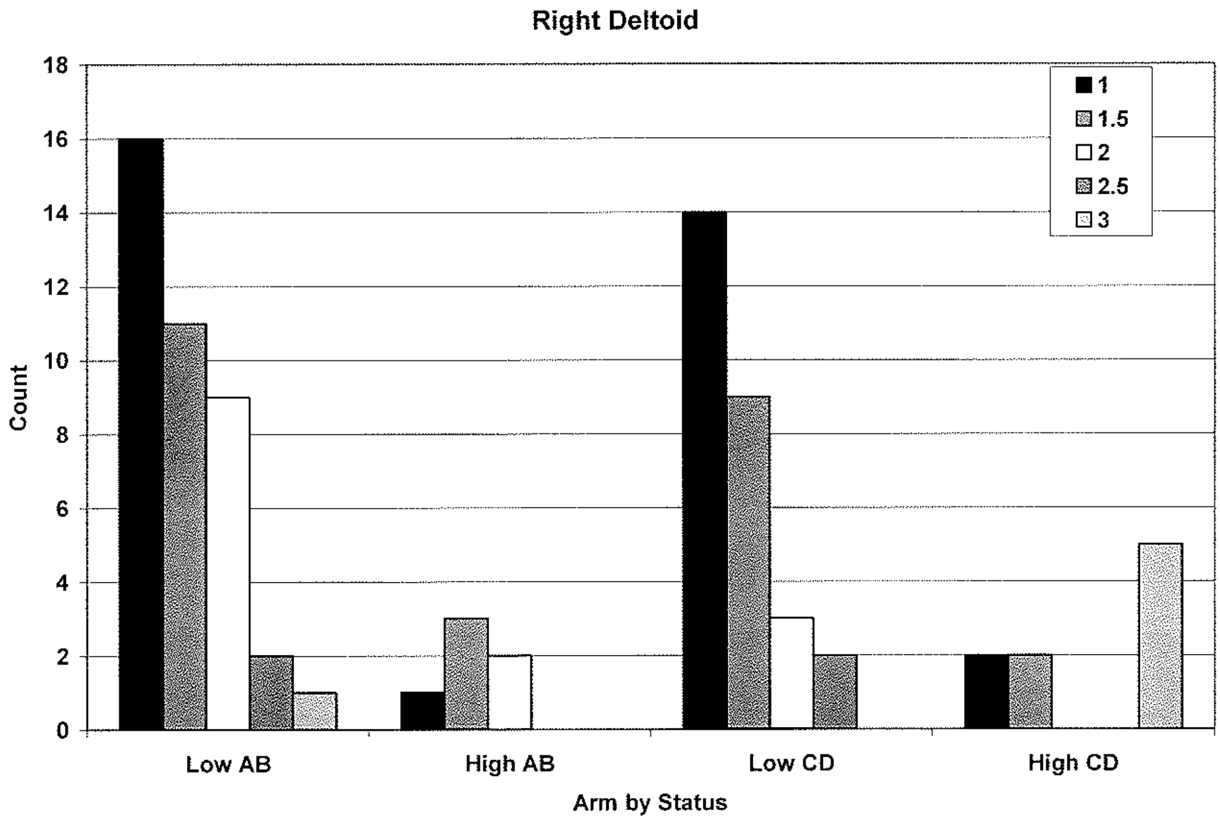


Figure 4.24 illustrates that the males, specifically those of the high status group are over represented in two grades. The first sees an over representation of high status

males in grade of 3, and the second in the grade of 1 (χ^2= 15.524; df= 4; p=0.003). This suggests that there is a division in the use of the right deltoid muscle not only between the status groups but also within the status group. This is perhaps due to the fact that this particular sub sample is comprised of high status clergymen and secular patrons of the monastery. The former are unlikely to be involved in menial labour, or any form of repetitive labour that might require the use of heavy force and loading.

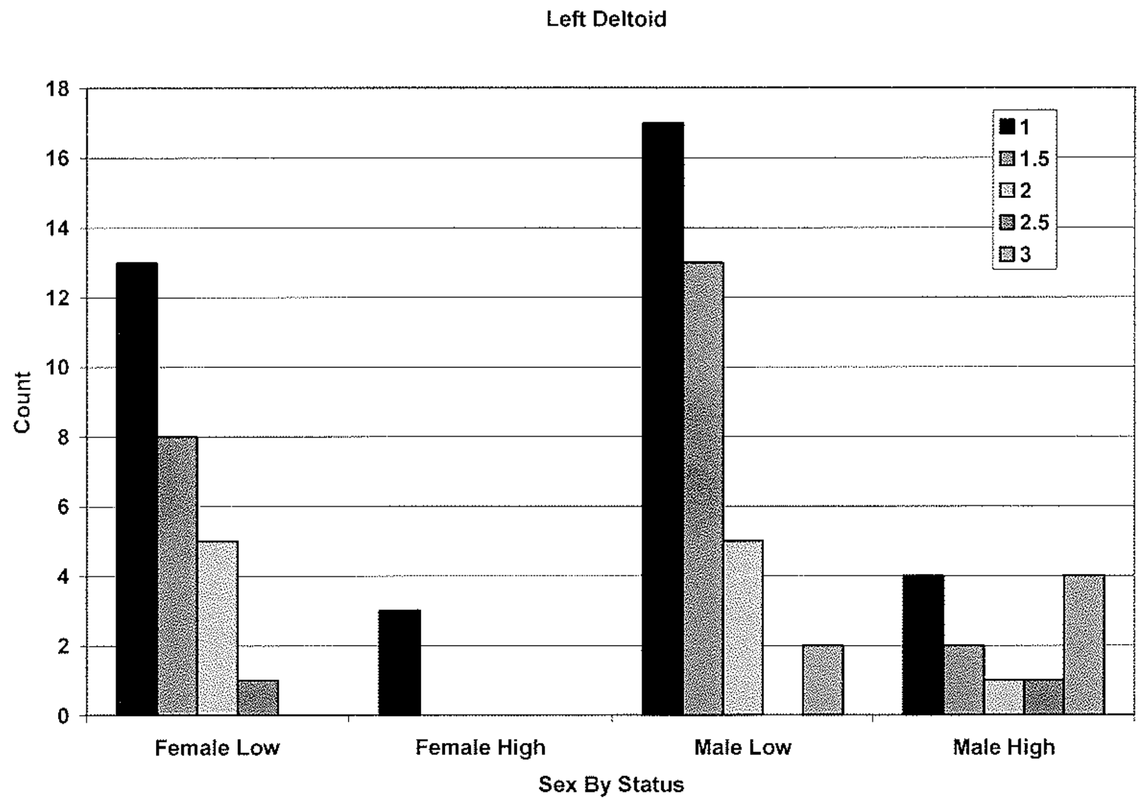
Table 4.24 Right Deltoid Arm by Status Distribution



When controlled for time period and compared by status (Figure 4.24) statistically significant differences in frequencies were observed by time period C (χ^2 = 12.230; df= 4; p= 0.016) and period D (χ^2= 6.679; df= 2; p= 0.035). In both these groups there is an over representation of high status individuals in grade 3, the highest grading often representing a traumatic or painful attachment site, given the overall distribution.

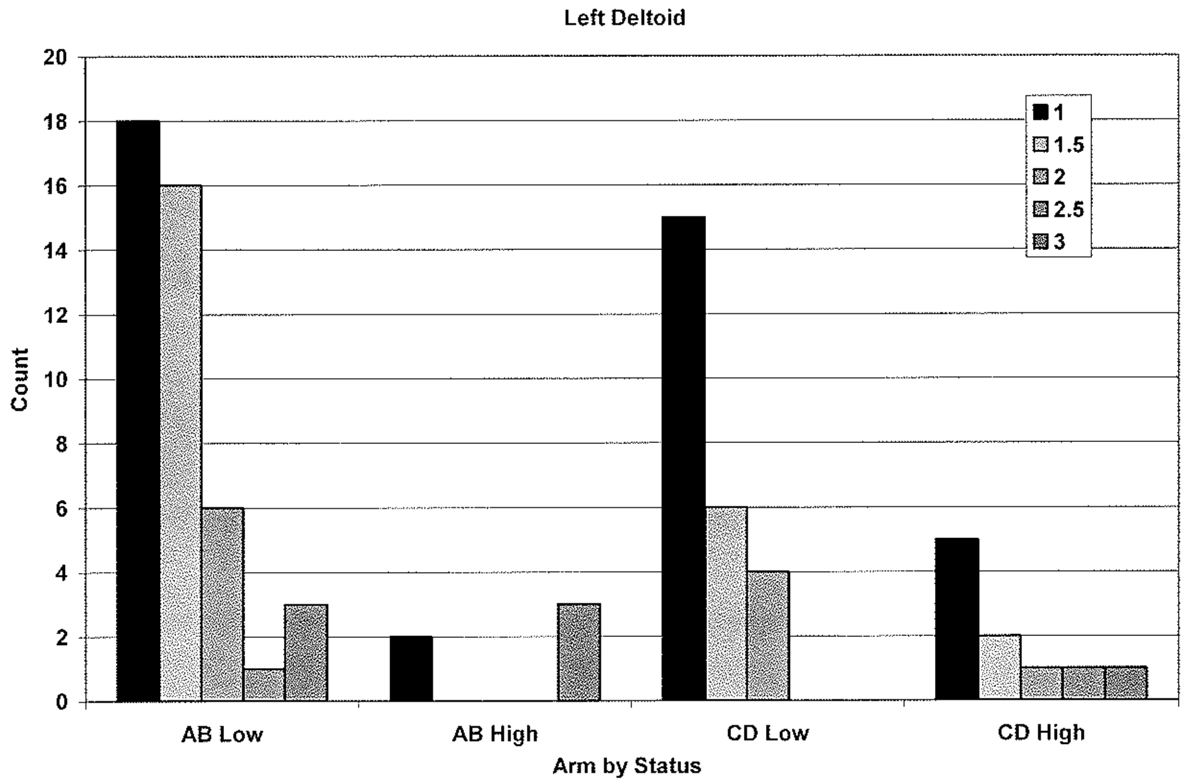
When further controlled by sex and compared by status (Figure 4.25) there is a significant over representation of high status males in grade 3 (χ^2= 15.524; df= 4; p=0.004). A similar result is yielded when the sample is split by period and compared by sex, showing significant differences in the distribution in period D with an over representation of males graded at 3 (χ^2= 11; df= 2; p= 0.004).

Figure 4.25 Left Deltoid Sex by Status Distribution of Scores



The left deltoid MSM generated two significant results. The first was split by sex and a comparison of status groups is made, there is an over representation of high status males in grade 3 (χ^2= 10.400; df= 4; p= 0.034). The distribution of gradings is illustrated in Figure 4.26.

Figure 4.26 Left Deltoid Arm by Status Score Distribution



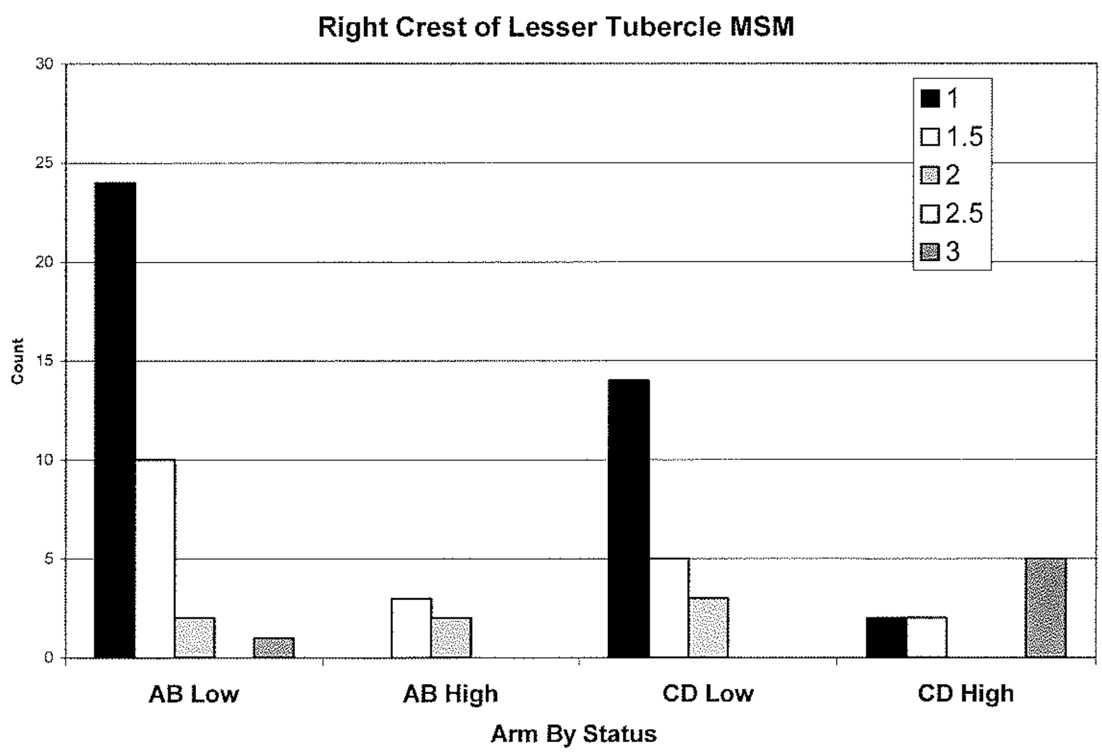
The second significant result was observed when the sample was split by temporal period and compared by status groups, with significant results seen for the first temporal category (arm positions A and B) yielding an over representation of highs status individuals in grade 3 given the overall distribution (χ^2= 12.985; df= 4; p= 0.028) illustrated in Figure 4.27.

The attachment site at the crest of the right greater tuberosity resulted in significance for two comparisons. When split by status and compared between temporal categories the low status individuals resulted in significant results because they are more heavily weighted in the scores of 3 and 1.5 than the high status individuals (χ^2= 5.747; df= 2; p= 0.035). When split by sex and compared by temporal group, males from the livestock raisers were over represented in the grades of 1.5 and 3 (χ^2= 5.779; df= 2; p= 0.042).

The left lesser tuberosity muscle attachment site yielded significant results when split by status and compared between temporal groups (χ^2= 10.979; df= 4; p= 0.014) manifesting in the low status groups with livestock raisers being over represented in both grade 2 and 2.5. As well as when split by temporal groups and compared between status groups (χ^2= 7.064; df= 3; p= 0.049) where the livestock raisers' low status group was over represented in grade 2 and the high status group in grade 1, again delineating the division of labour not only between groups but as well as within groups.

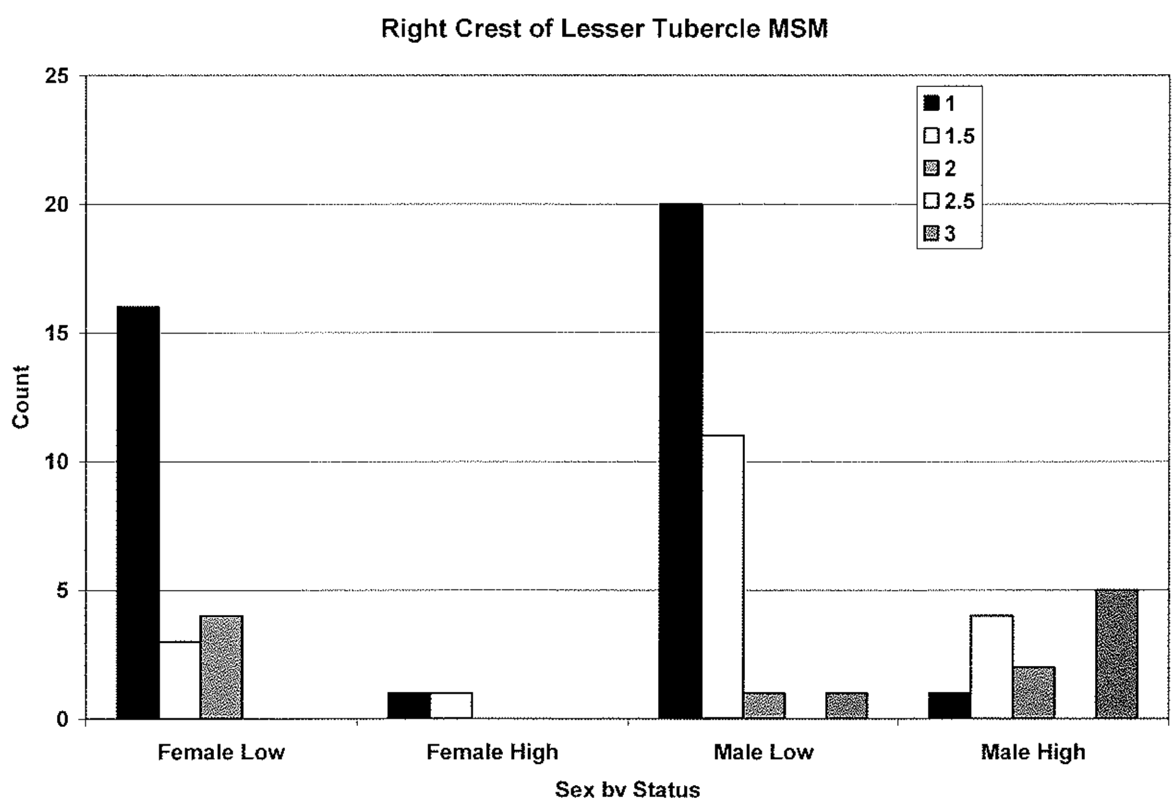
When crosstabs for the MSM of the crest of the lesser tuberosity of the right humerus were run significant results were found for: split by sex and compared by arm, split by status and compared by arm, split by arm and compared by sex and arm by status.

Figure 4.27 Right Crest of the Lesser Tuberosity MSM Score Distributions, Arm by Status



Split by arm and compared between status groups resulted in an over representation of high status individuals with a grade 3 in arm position C given the overall distribution, pictured above in Figure 4.27; and when split by sex and compared between status groups an over representation of high status males in grade 3 was yielded given overall distribution (χ^2- 17.459; df= 3; p= 0.001) pictured below in Figure 4.28. No significance was found in either status for the females.

Figure 4.28 Figure Right Crest of the Lesser Tuberosity MSM Score Distributions Sex by Status



The modification at the crest of the left lesser tuberosity yielded statistically significant result in two comparisons: first when split by sex and compared between status an over representation of high status males in grade 3 and a under representation of high status males in grade 1 given the overall distribution generated significant results (χ^2 = 17.459; df= 3; p= 0.001). Figure 4.29 demonstrates the overall distribution of scores for this comparison between the groups analyzed.

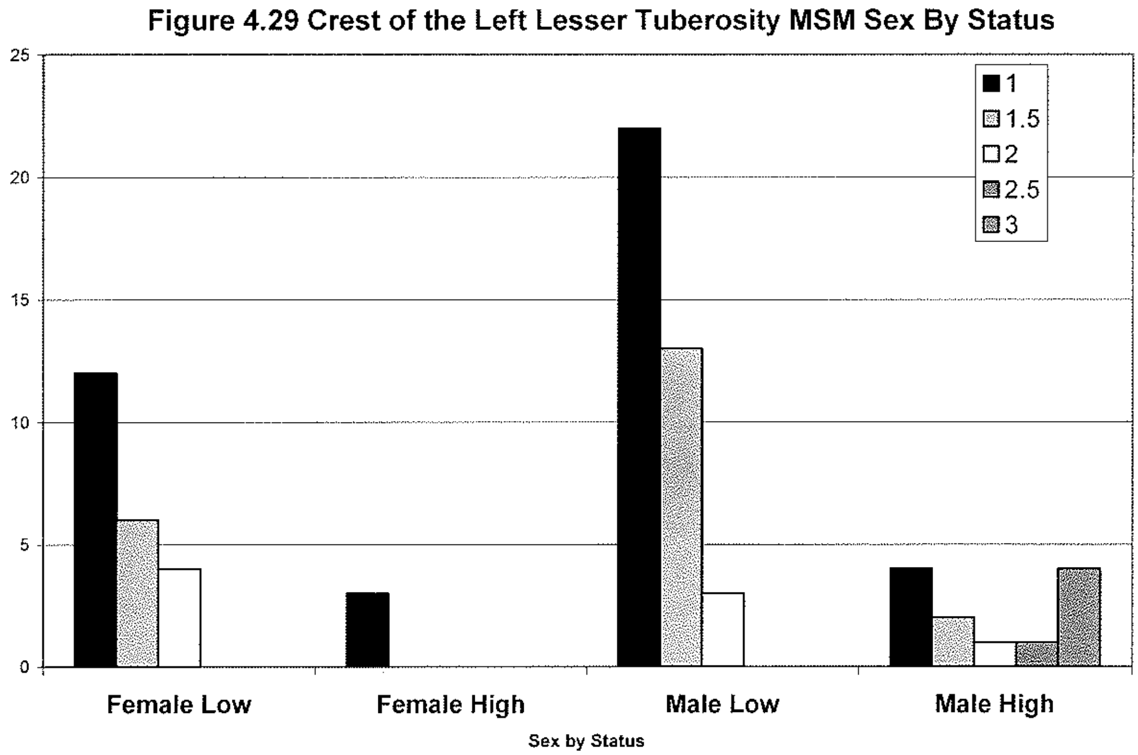
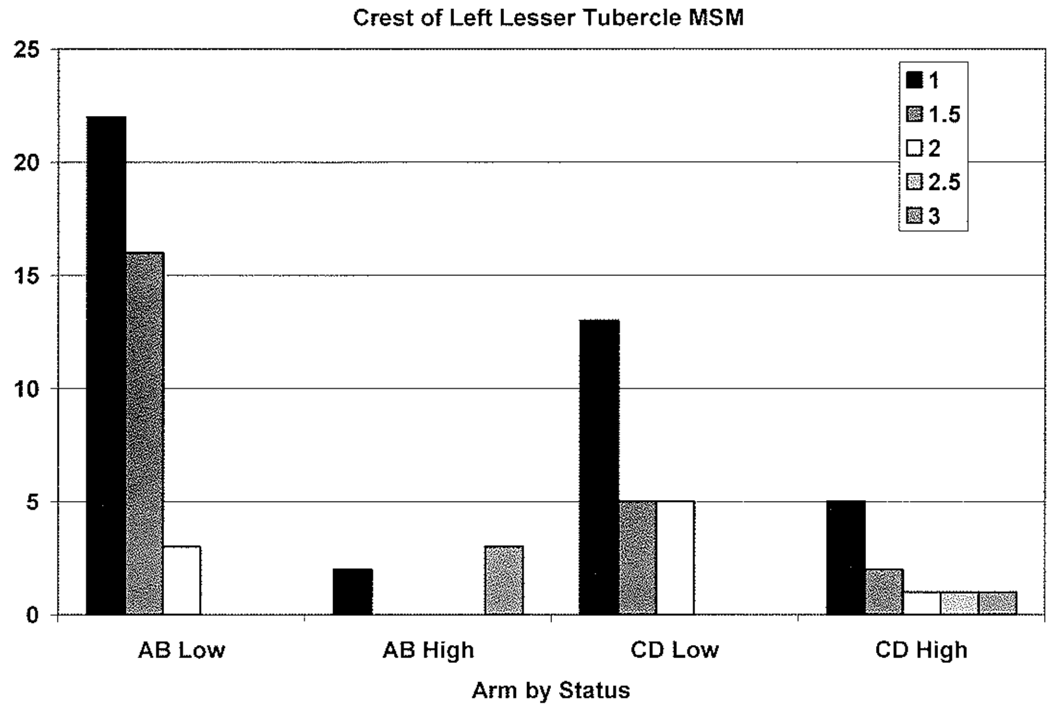


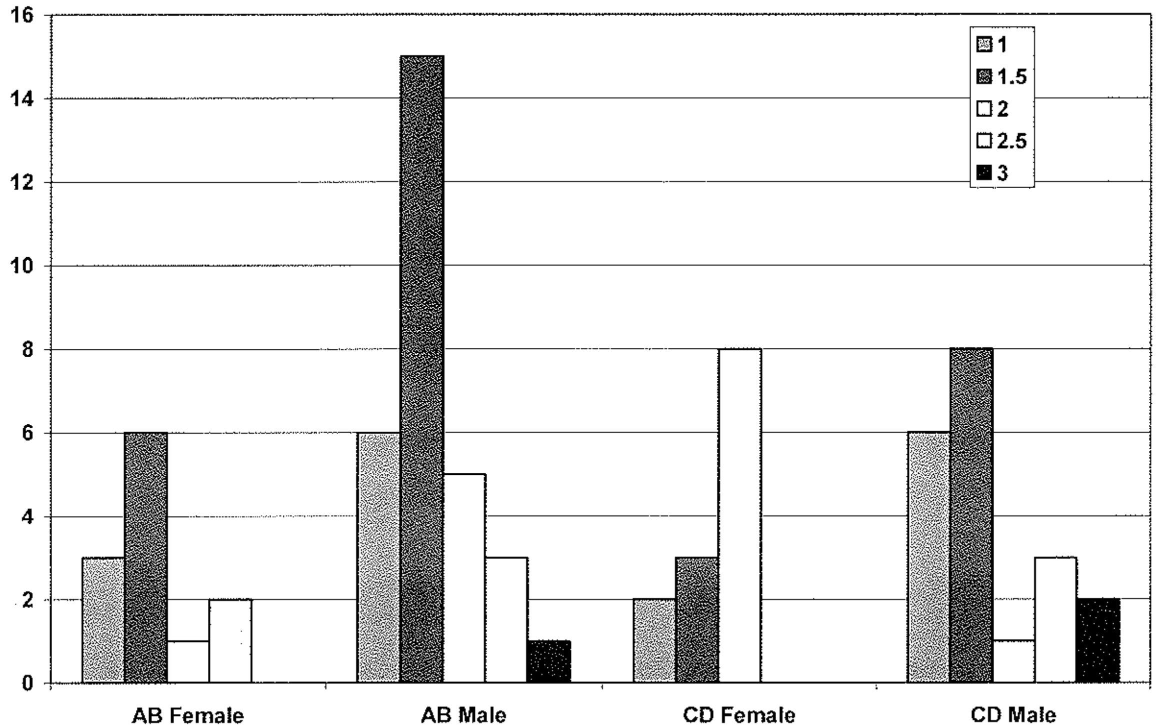
Figure 4.30 Crest of the Left Lesser Tubercle MSM Distribution, Arm by Status



Second when the sample was split for arm positions and compared between status groups, seen above in Figure 4.30, statistical significance was found within arm position B with an over representation of high status individuals in grade 3 given the overall distribution (χ^2= 14.423; df= 3; p= 0.002).

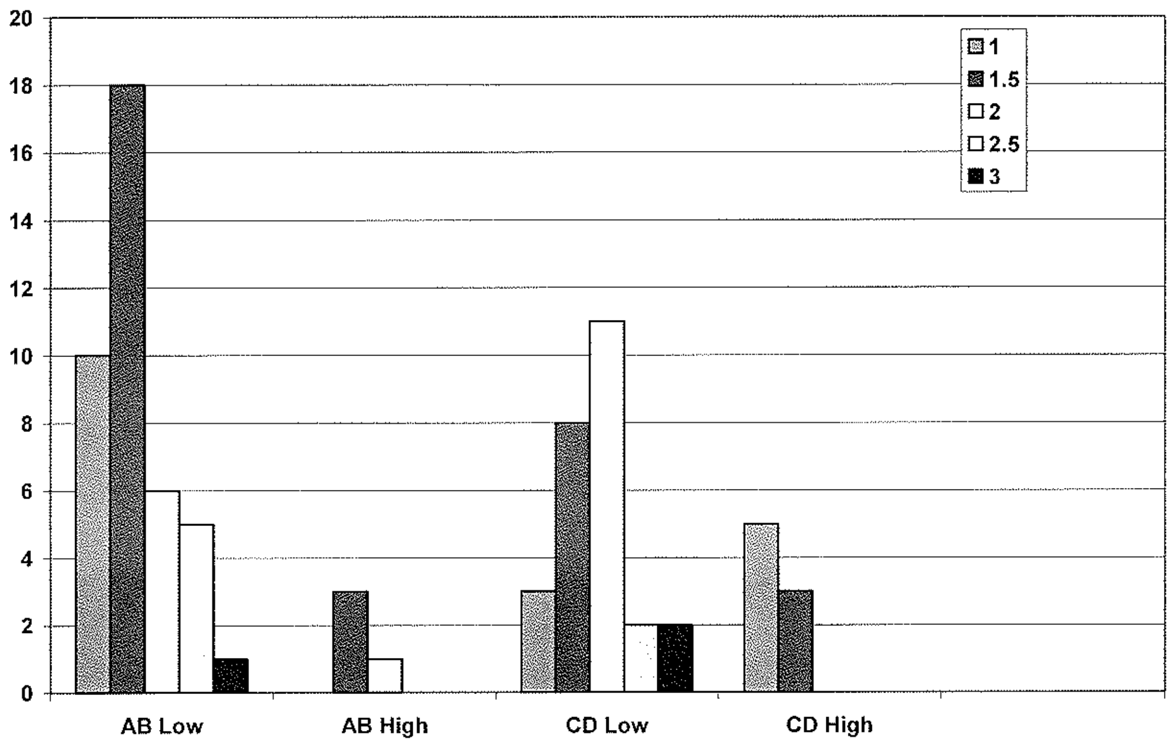
The right ulna yielded statistically significant results in three comparison categories. In split by temporal category compared by sex (Figure 4.31) there is an over representation of females in grade 2 and also an over representation of males in grade 2.5 for the second temporal period (χ^2= 12.471; df= 4; p=0.006)

Figure 4.31 Right Ulna Tuberosity, Arm by Sex



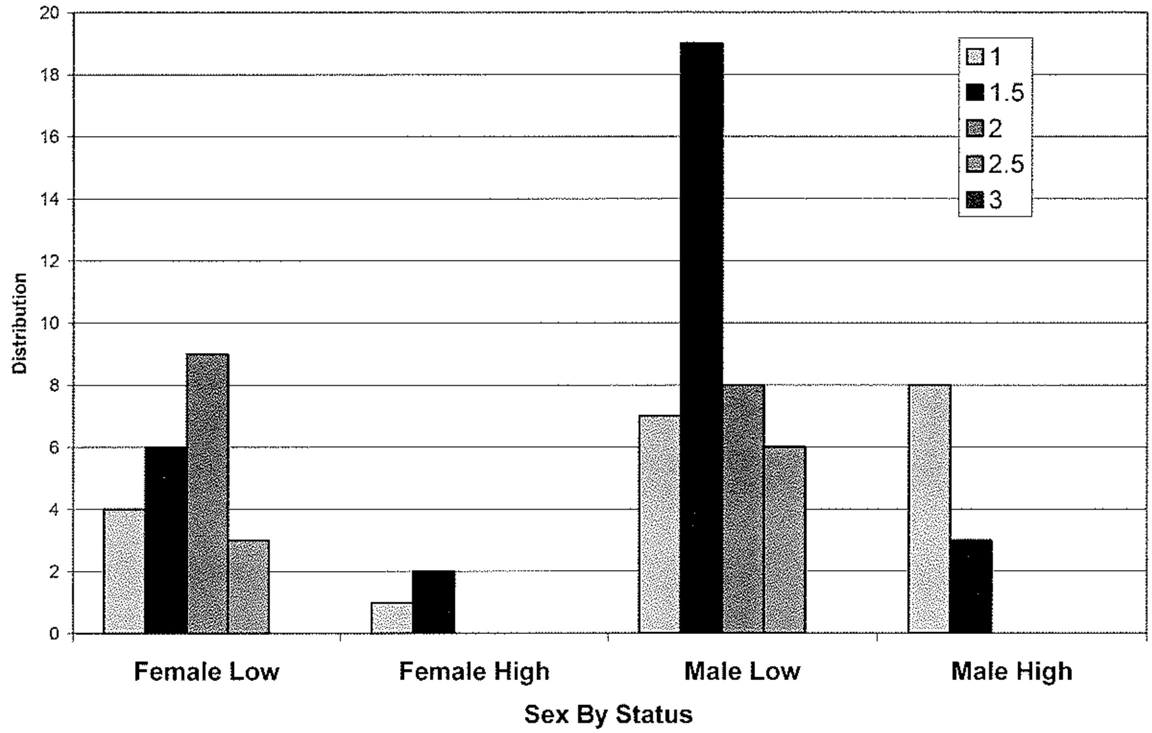
When split by temporal category and compared between status groups significance results from the high amount of high status individuals within the grade of 1 (χ^2= 10.164; df= 4; p= 0.016) which can be explained by the presence of the high status clergymen within the sample. Although not significant there is also a high amount of low status individuals within the grade of 2, suggesting that this is a muscle that is more highly utilized in a repetitive activity favoured by the lower class individuals.

Figure 4.32 Right Ulna Tuberosity Temporal Category by Status



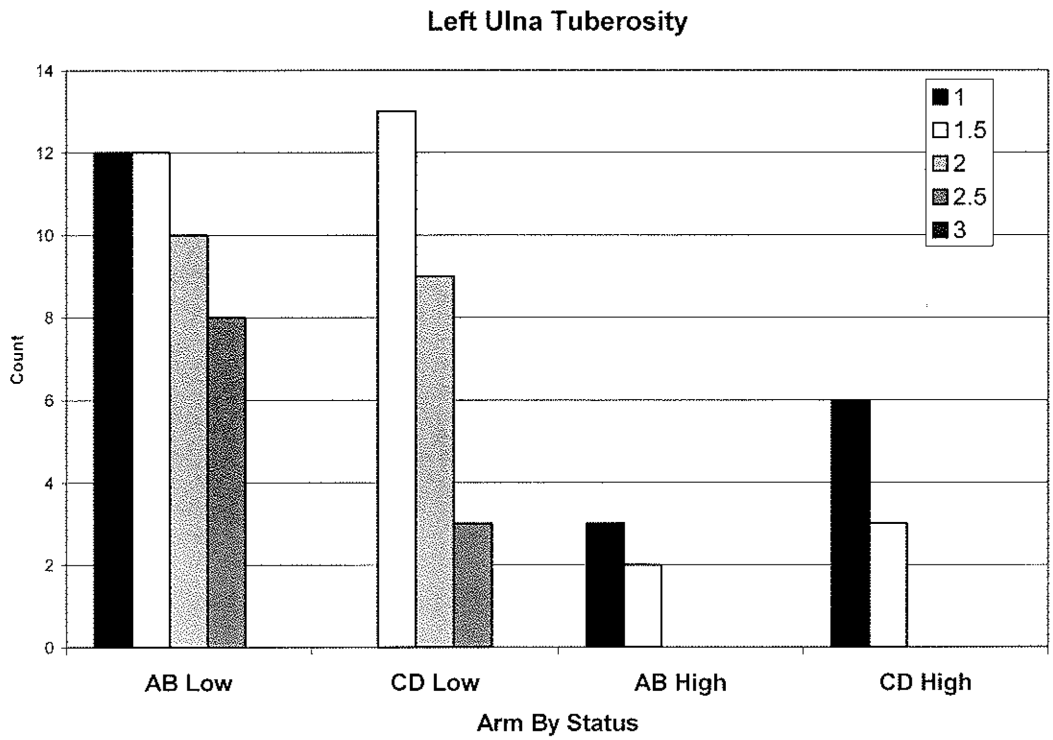
The final comparison was when the sample was split between sex groups and compared by temporal categories. The females of the second temporal period, livestock raisers, were seen to have a higher amount of individuals that scored a 2 (χ^2= 8.239; df= 3; p= 0.031).

Figure 4.33 Left Ulna Tuberosity Sex by Status



Significant results were generated for the left ulnar tuberosity when split by sex and compared between status groups. The over representation of high status males in grade 1 given the overall distributions of all other males was generated χ^2= 13.615; df= 3; p= 0.003 and can be observed in Figure 4.33, which illustrates the distribution of scores for each sex and status group.

Figure 4. 34 Left Ulna Tuberosity Arm by Status Score Distribution



Statistically significant results were also produced when split for arm and controlled for status in arm positions C and D. Both exhibited over representation of grade 1 in the high status group given the overall distributions: χ^2= 16.039; df= 3; p=0.001 and χ^2= 6.741; df= 2; p= 0.034 respectively (Figure 4.34).

No statistically significant results were yielded for either the left or the right radii, for either the tuberosities or the midshaft attachments. Nor were any statistically significant results generated in any of the six comparisons for either the right or left greater tuberosities. The lesser tuberosities for both arms also failed to produce statistically significant results fro any of the comparisons as well. For the forearm MSM sites the left and right olecranon processes, and the right and left radial mid-shaft tuberosities failed to yield significant results. Please see the table below for a complete listing of analyses yielding statistical significance and those that did not.

Lower Body

Asymmetry

Asymmetry was assessed in the lower limbs by comparing the right and left measurements for maximum femur length, the medial lateral shaft diameter, posterior anterior diameter, the maximum proximal shaft diameter, and the maximum diameter of the femoral head . Statistically significant differences were observed in the medial lateral diameter measurement ($t= -2.685$; $df= 77$; $p= 0.009$) and the maximum diameter of the femoral head ($t= 2.394$; $df= 72$; $p= 0.019$). When controlled for status group, statistically significant differences were observed for asymmetry in the medial lateral shaft diameter ($t= -2.767$; $df= 59$; $p=0.008$) and the maximum diameter of the femoral head ($t= 2.089$; $df= 55$; $p= 0.041$) for the low status group. There were no statistically significant differences between left and right lower limb measurements within the high status group. The same two measurements that were statistically significant for the low status groups were also significant for the female group when controlled for sex ($t= -2.812$; $df= 25$; $p=0.009$ and $t= 2.734$; $df=20$ $p= 0.013$ respectively). No significant differences were observed in any measurements for males. When the sample was controlled for time period, the aforementioned measurements yielded one statistically significant result for temporal period AB and one significant result for temporal period CD. In period AB, differences between the left and right medial lateral diameter were significant ($t= -2.379$; $df= 44$; $p=0.022$) and in period CD, the significant result was found in the maximum diameter of the femoral head ($t= 2.935$; $df= 23$; $p= 0.007$).

Measurements

The maximum length of the right and left femur when compared between periods AB ($t= -4.104$; $df= 51$; $p<0.001$) and CD ($t= -5.439$; $df= 35$; $p<0.001$) for sex generated statistically significant results for males over females for the left and the right femur (Fig. 4.35).

Figure 4.35 Left Femur Maximum Length Measurement Arm by Sex

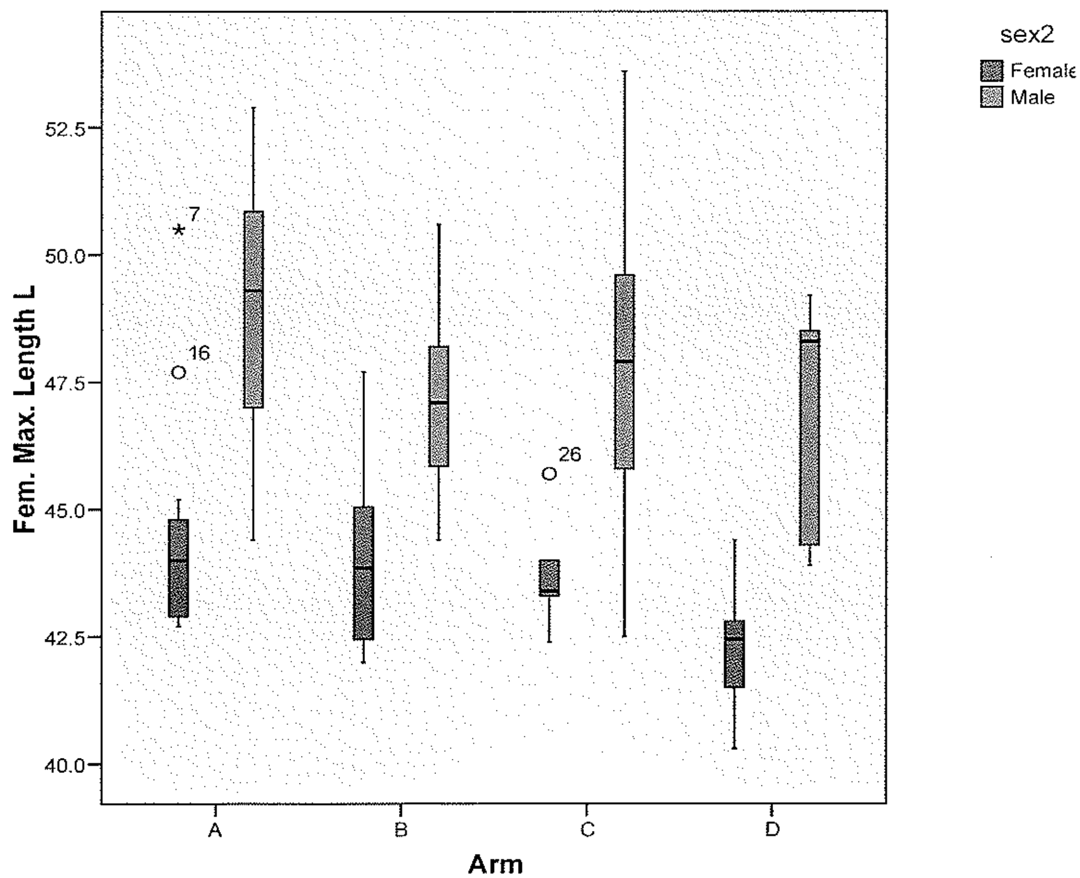


Figure 4.36 Right Femur Maximum Length Measurement Status by Arm

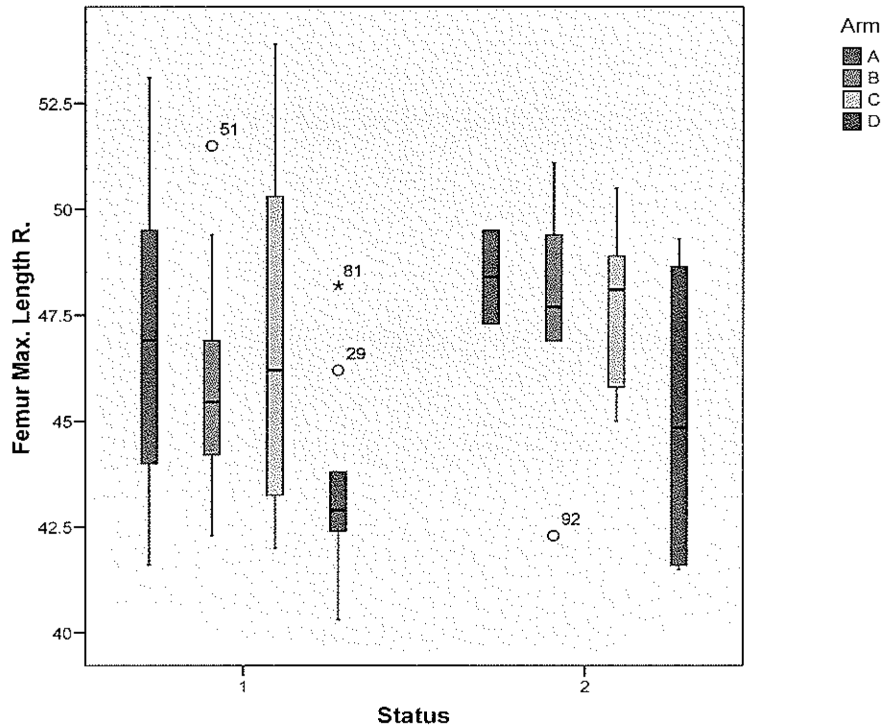
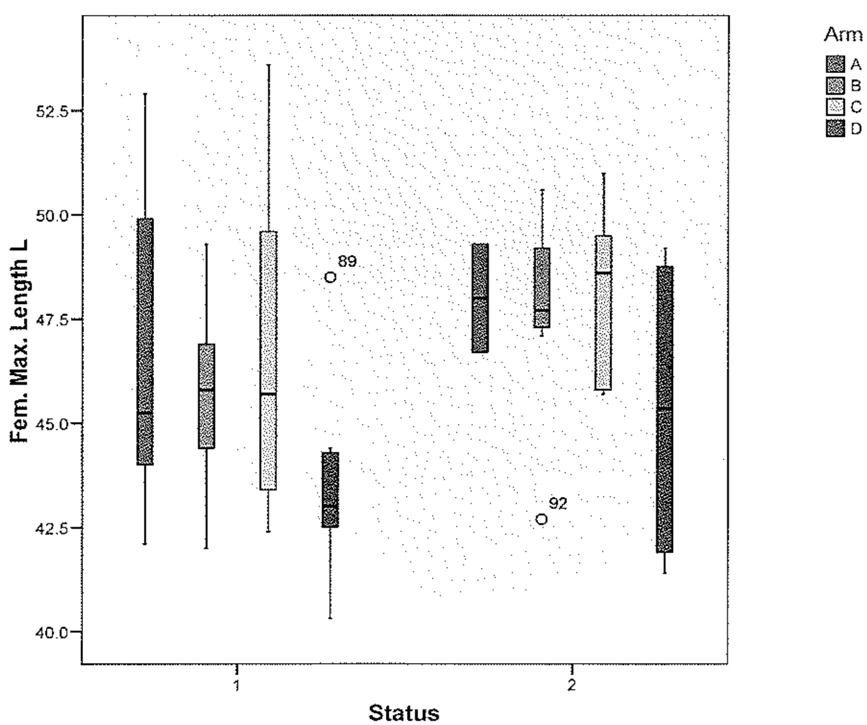


Figure 4.37 Left Femur Maximum Length Measurement Status by Arm



When further controlled for status no statistical significance was found within the periods, but the comparison of distributions of lengths between the two sides yields interesting results as seen in Figures 4.36 and 4.37.

Figure 4.38 Left Femur Maximum Length Measurement Status by Sex Distribution

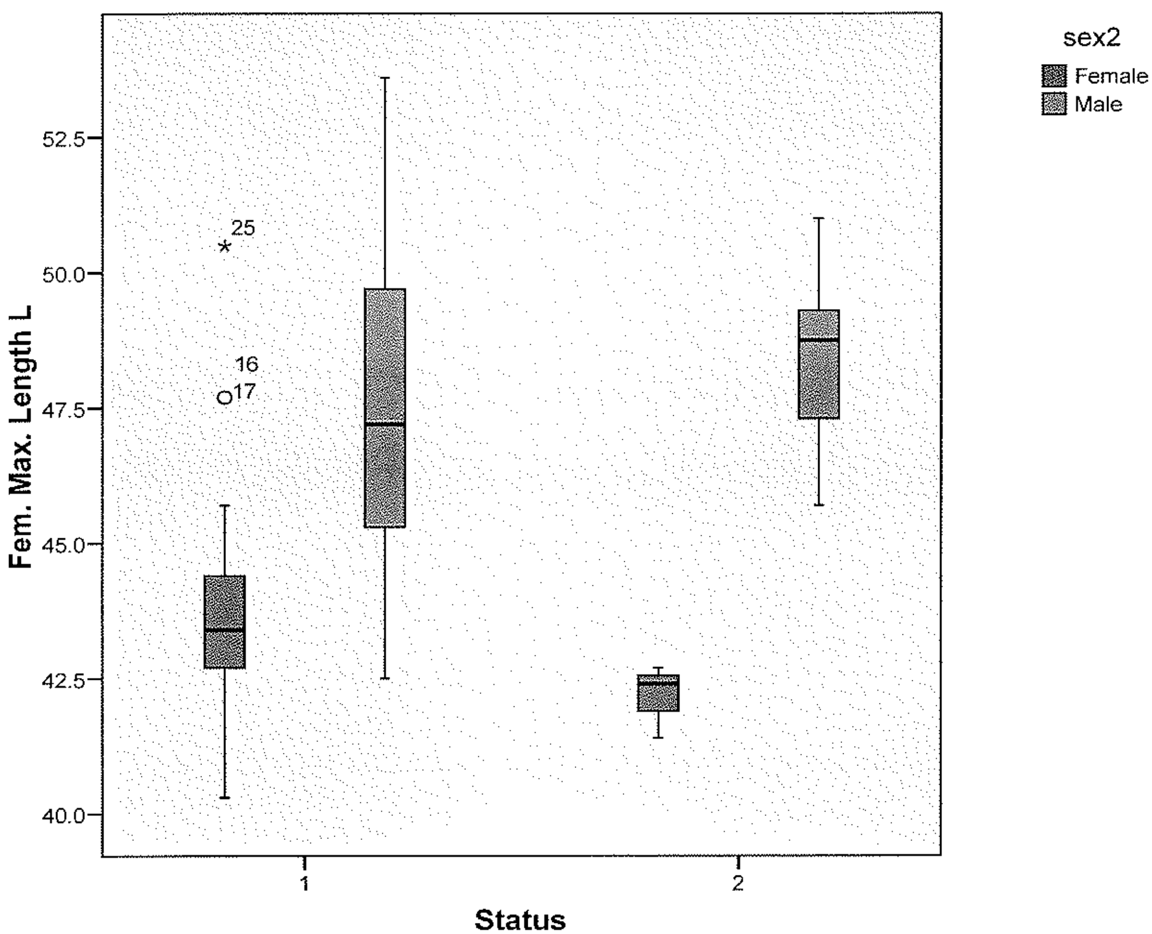
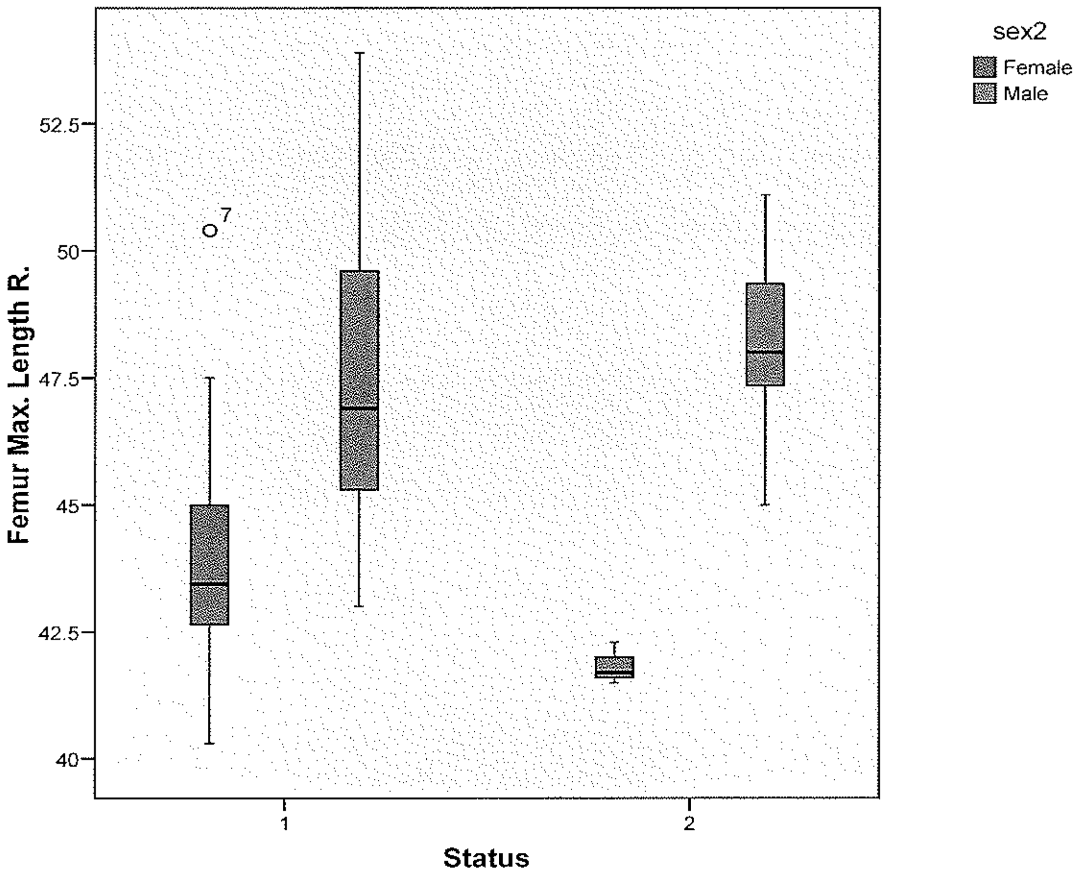


Figure 4.39 Right Femur Maximum Length Status by Sex Distribution



When status groups were compared within the sex categories for the femur maximum length, significant differences were observed only in the female group. Graphs illustrating these distributions can be found in Figures 4.38 and 4.39. The left femur was significantly larger for the low status females than for the high status females (t= 3.205; df= 7.124; p= 0.015) and the right femur produced similar results (t= 4.753; df; 18.682; p< 0.001). When the sexes are further compared by time periods AB and CD, statistically significant differences are seen in females for both the left (t= 2.234; df= 30; p= 0.033) and right (t= 2.552; df= 29 p= 0.016) femora with period AB exhibiting a longer maximum length than period CD. When time periods are compared within the status groups no statistically significant results were yielded for either status.

When the rest of the lower limb measurements were analyzed by period and compared between the sexes, statistically significant results were found for males over females in period AB for all measurements except the left maximum proximal shaft diameter. For period CD, only 5 out of the 8 showed males significantly larger than females: the anterior posterior diameter for both left and right, the right maximum diameter of the shaft, and the maximum diameter of both the left and right femur head. When the time periods were then compared between the status groups no statistically significant results were observed.

Figure 4.40 Right Posterior Anterior Diameter of Shaft Sex by Status Distribution

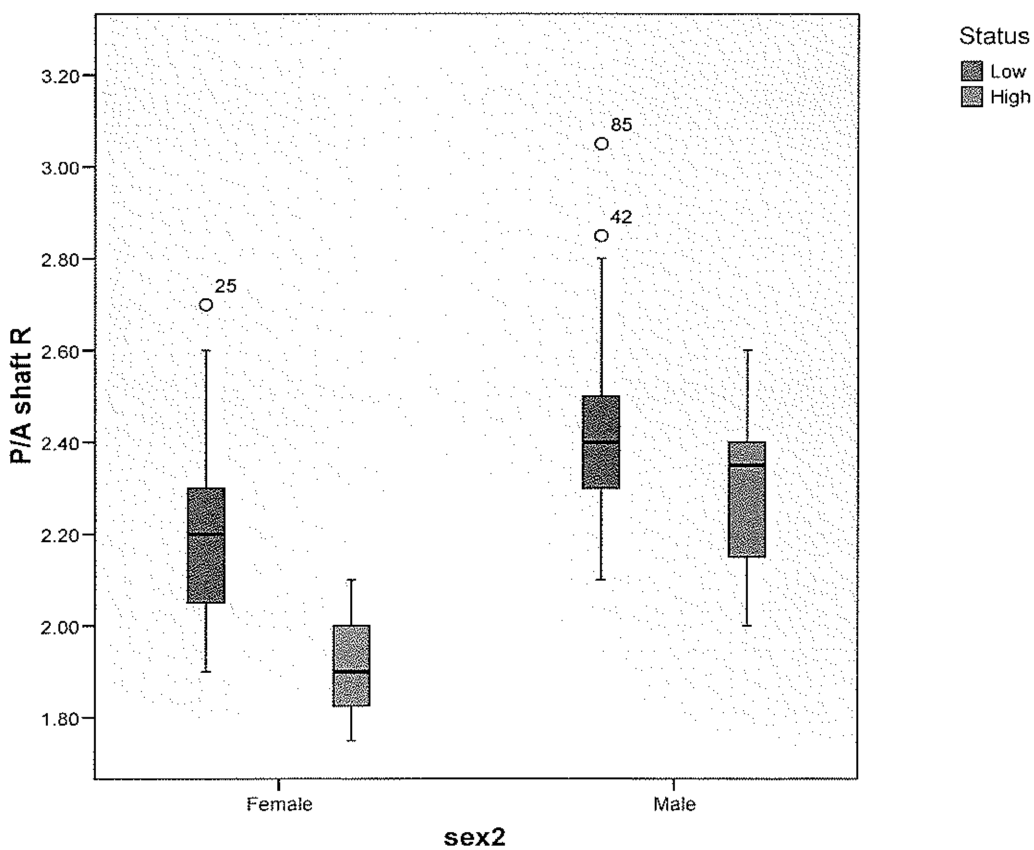
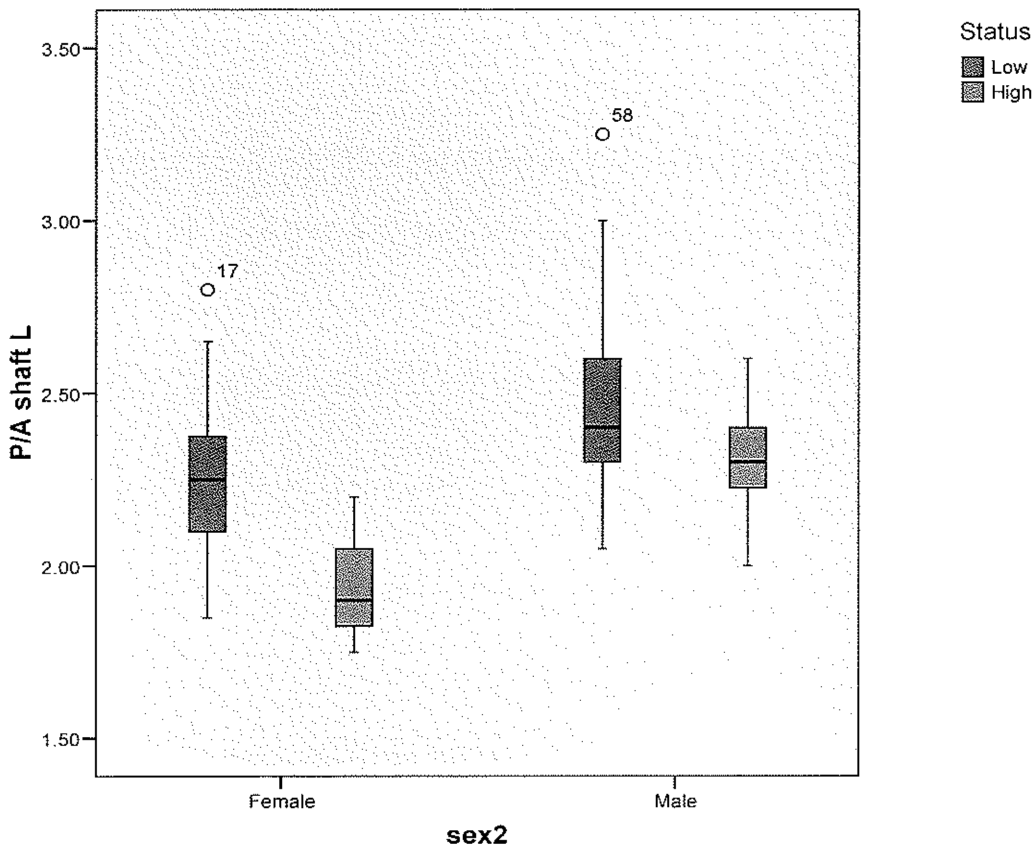


Figure 4.41 Left Posterior Anterior Diameter of Shaft Sex by Status Distribution



When the lower limb measurements were split by sex and compared between the status groups within the sex groups statistically significant results for the females were found in the medial lateral diameter measurement for the left femur ($t= 2.479$; $df= 28$; $p=0.019$), for the anterior posterior shaft diameter for the left ($t=2.126$; $df=28$; $p= 0.030$) and the right ($t=2.291$; $df=28$; $p= 0.042$), and the maximum head diameter for the right ($t=2.232$; $df=23$; $p= 0.036$), with the low status females always being more robust than the high status females. For the males, only one statistically significant result was observed: the anterior posterior shaft diameter for the left ($t=2.143$; $df=51$; $p=0.037$) was larger for low status males than for the high status male group. Examples of the distributions for the anterior posterior diameters of the shaft are shown in Figures 4.40

and 4.41. No statistically significant results were yielded when the lower limb measurements were split by sex and compared between arm positions

When the measurements were split by status and compared between time periods the right maximum proximal shaft diameter for low status period AB yielded statistically significant results (t= 2.120; df= 76; p= 0.037), with the low status individuals of this period having a more robust maximum proximal shaft diameter measurement than the high status individuals with the mean difference between the two groups being 0.243cm. No significant results were found within status 2 between arm positions.

When the measurements were split by status and compared between sexes statistically significant results were yielded for all measurements in the high status group with males being significantly more robust and larger than females. In the low status group, statistically significant differences were observed in 6 out of the 8 measurements with males being larger than females: medial lateral shaft diameter right (t=-2.997; df=68; p=0.004) and left (t=-2.996; df=60; p=0.004); anterior posterior shaft diameter right (t= -4.407; df=68; p<0.001) and left (t= -3.436; df=62; p=0.001); right maximum proximal shaft diameter (t= -2.804; df= 73; p= 0.006); maximum head diameter right (t=-8.383; df=58; p<0.001) and left (t= -4.931; df= 59; p<0.001).

Figure 4.42 Right Medial Lateral Shaft Diameter Sex by Status Distribution

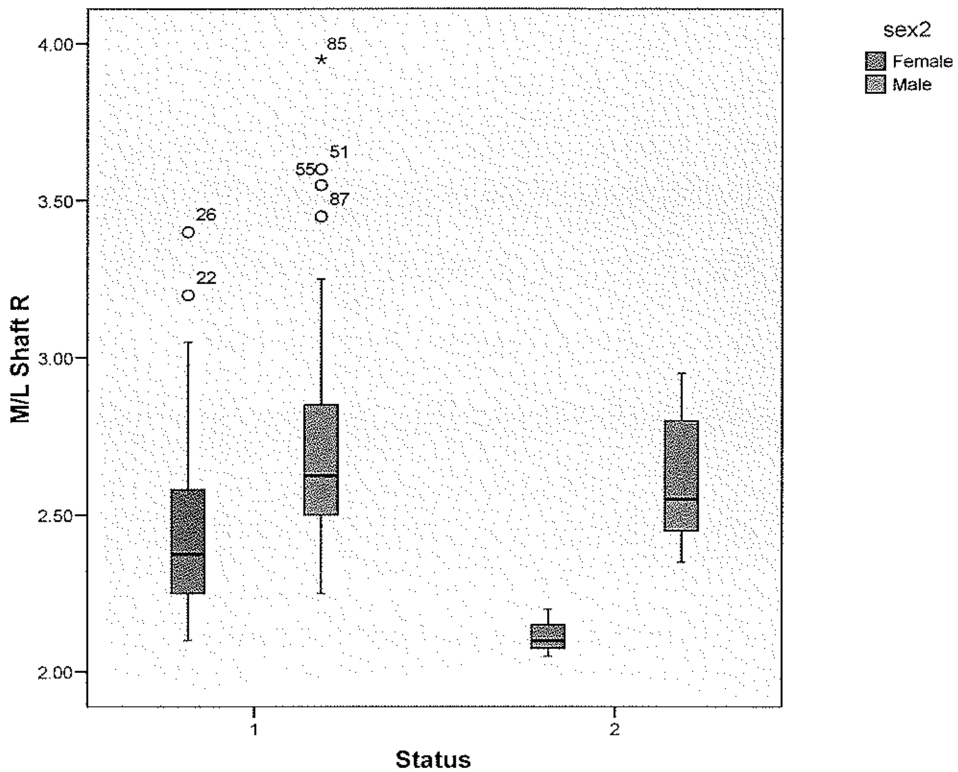


Figure 4.43 Left Medial Lateral Shaft Diameter Sex by Status Distribution

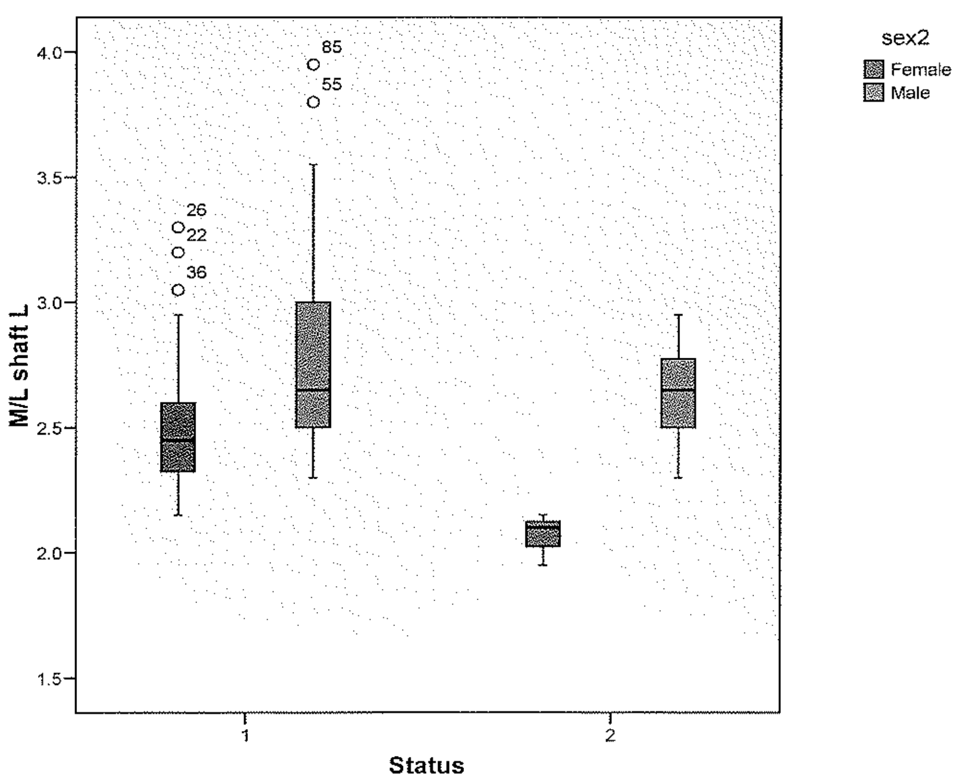
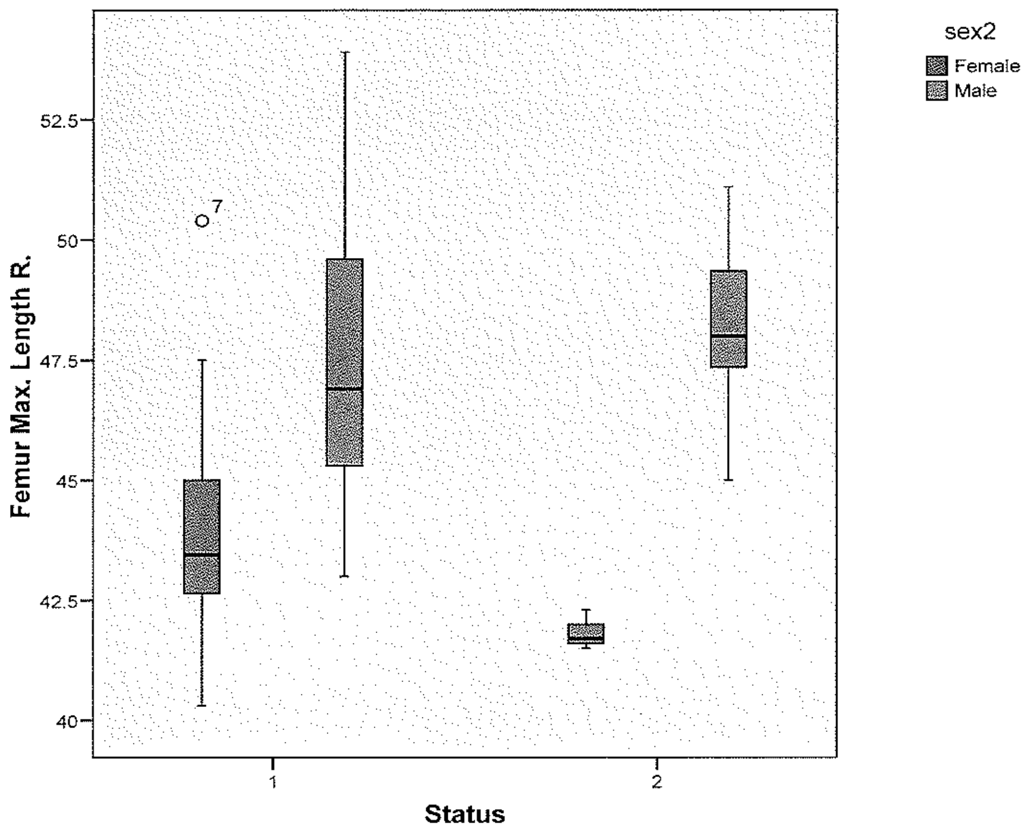


Figure 4.44 Right Maximum Length of Femur Status by Sex Distribution



Musculoskeletal Stress Markers

Crosstabulations were run for all of the MSM sites recorded in the analysis for the lower limb attachment sites. Each site was compared and controlled for time period, sex, and status. For a complete listing of which comparisons resulted in statistically significant results see Table 4.1.

The lower body exhibited a smaller portion of MSM's that yielded statistically significant results when compared to the upper body. Nonetheless, both the left and right sides yielded results.

Figure 4.45 Right Greater Trochanter Score Distribution Arm by Status

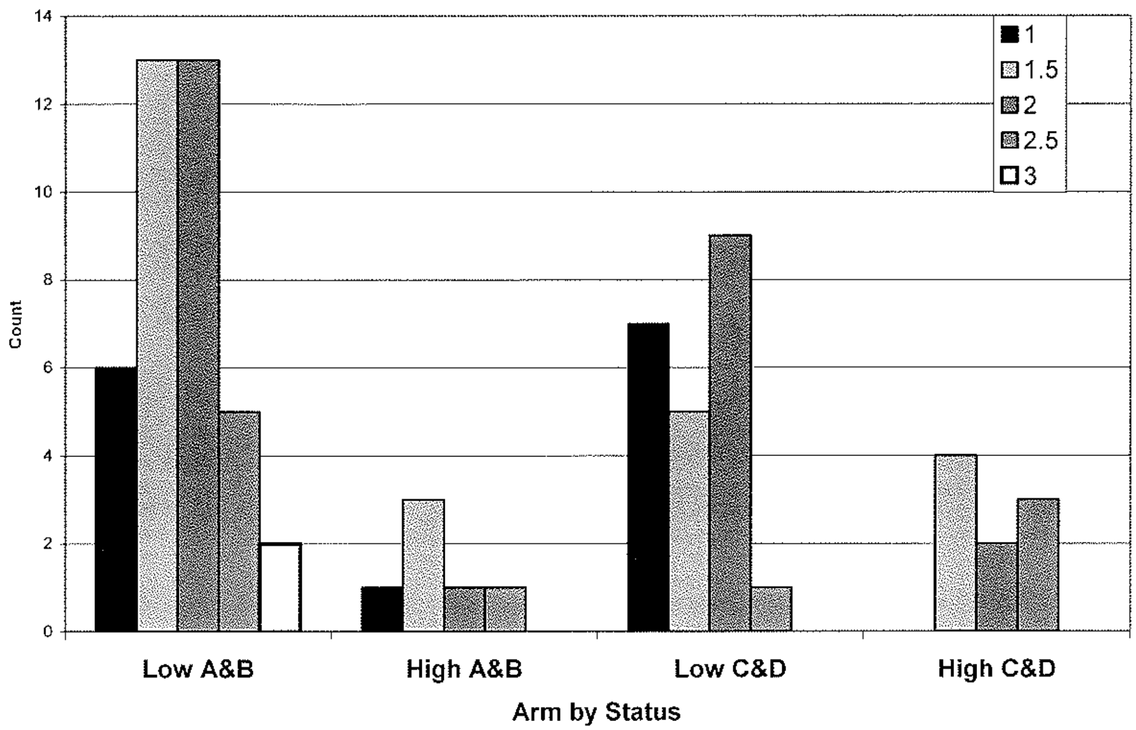
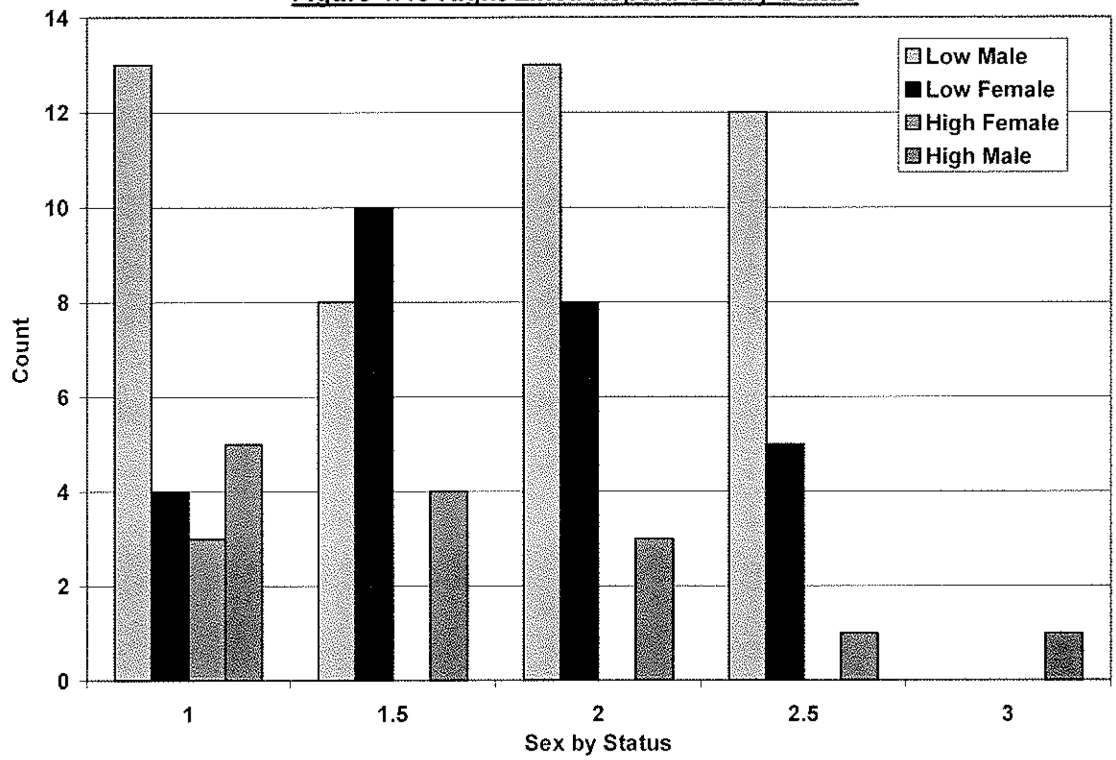


Figure 4.45 shows the distributions of the right greater trochanter which demonstrated statistically significant differences for second temporal category when controlled for status and substantially significant results in C when likewise controlled. Period A exhibits an over representation of individuals with grade 1.5 for the high status group (χ^2= 10.977; df= 4; p= 0.027). Period C, although not statistically significant is substantially different enough to warrant mention, with an over representation of high status individuals in grade 1.5. No significant results were yielded for the left greater trochanter in any of the comparisons.

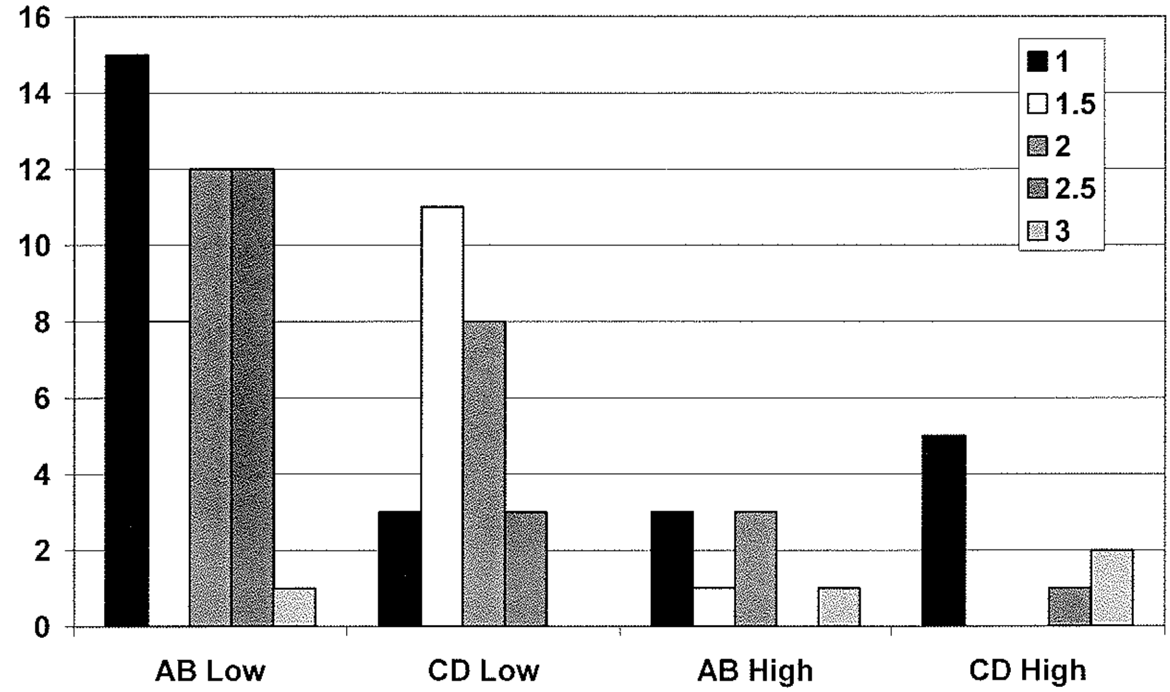
The only significant result for the right linea aspera of the femur was yielded when controlled for sex and compared between status groups. Significance was seen in high status females having an over representation given overall distribution within grade 1 (χ^2= 10.952; df= 3; p= 0.011). Distribution for grades can be observed in the below graph, Figure 4.46 which delineates scoring for split by sex and compared between status groups.

Figure 4.46 Right Linea Aspera Sex by Status



The left linea aspera was one of the most modified muscle insertion sites in the lower body; it yielded statistically significant results for three of the six layers of comparison: arm by status, sex by status, and status by arm.

Figure 4.47 Left Linea Aspera Arm by Status Distribution



The left linea aspera yielded statistically significant results for the livestock rearers of the second temporal category (arm positions C and D) when controlled for status. The distribution of scores is illustrated in Figure 4.47. This analysis revealed a number of over representations in a number of grades. The low status yielded an over representation in grade 1.5 and the high status yielded over representation in both the grades of 1 and 3. This in particular is interesting because its extrapolated data suggests the division of labour between the high class clergymen and the secular wealthy villagers, as the former are unlikely to have performed any labour that might result in a score of 3, or overdeveloped musculature (χ^2=18.707; df= 4; p<0.001).

The second significant result is found in both the male and female groups when compared within the status groups. Within the females there is an over representation of high status females in the score of 1, in fact the whole high status female population is represented within this grading (χ^2= 9.643; df =3; p=0.020). Within the males there is an over representation of high status males within the grading category of 3 (χ^2= 14.254; df= 4; p= 0.014).

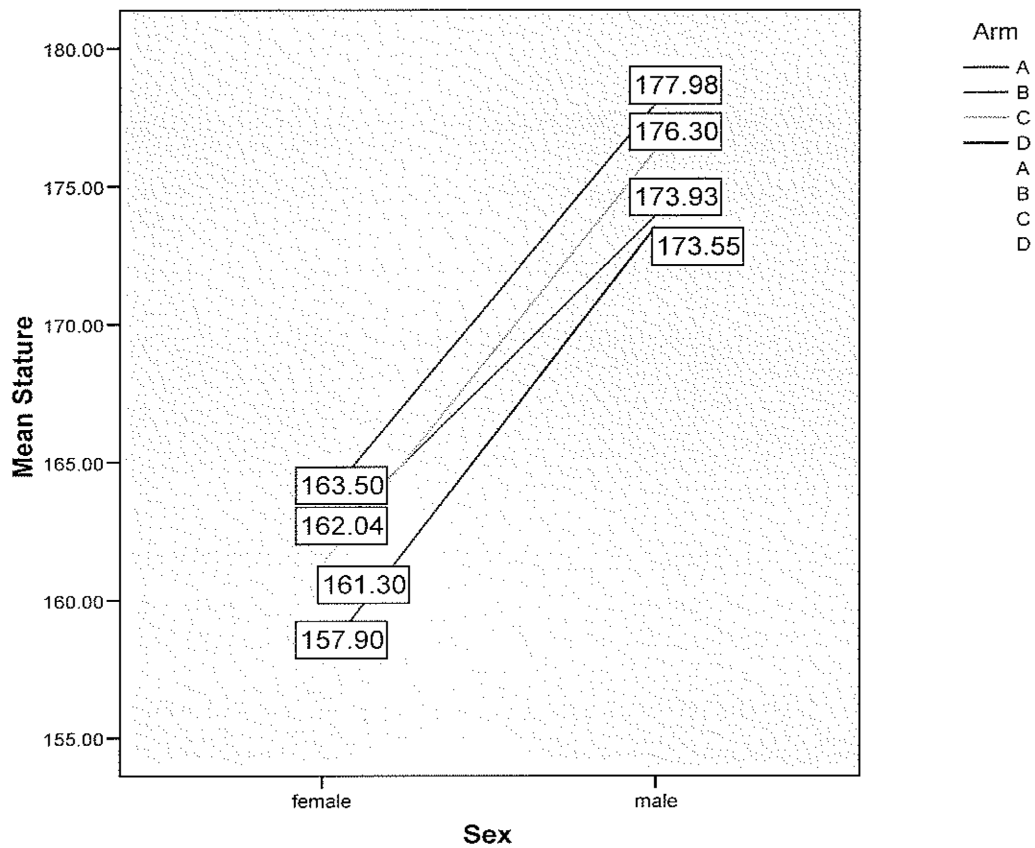
The final significant result is found in the low status individuals regardless of sex, where there is an over representation of livestock rearers in the score category of 1.5. The second temporal category is therefore more heavily weighted at the lower end of the scoring given overall distribution of the other scores (χ^2= 8.943; df= 4; p=0.046).

The right and left fovea capitis generated no statistically significant results in any of the comparison categories. Neither the left nor the right tibial tuberosities resulted in any significant results when analyzed by ay of the comparison methods, likewise neither the left or right soleal lines of the tibia yielded any significant results.

For a complete listing of the comparisons run on all of the musculoskeletal stress marker sites please se the below table

Stature Estimation

Figure 4.48 Mean Stature Range Sex by Arm



Mean height was estimated from a stature estimation extrapolated from anatomical length of the left femur. Mean height for the high status females was calculated at 157.26 ± 3.72cm, with a range of 155.12cm to 158.58cm. Low status females mean height was calculated as 160.67± 3.72cm with a range of 152.9cm to 178.09cm. Low status males' mean height was calculated as 175.31± 3.94cm with a range of 162.04cm to 189.42cm. High status males' mean height was calculated as 176.89± 3.94cm with a range of 170.63cm to 182.92cm. The distribution of height and mean height range for each arm position by sex is presented in Figure 4.57.

Estimated stature for individuals from period CD demonstrated a wider range (152.90cm – 189.42cm) but a smaller mean height of 168.69cm, than Period AB which had a narrower range of estimated stature (157.9cm – 187.79cm) and a larger mean height of 171.12cm. Mean stature for each period, as seen in Figure 4.58, reveals that in the case of both males and females the greatest mean stature is found in period A, and the smallest in period D. This suggests a decrease in average stature of each sex throughout the time periods. It is interesting to note that while this trend holds true for females, in the males from period B mean stature is less than that of those in period C but still greater than those of period D. The trend holds true for the two temporal categories, with a higher mean stature for females in temporal category than Period CD, and a higher mean stature for males in period AB than CD.

Figure 4.49 Mean Stature Sex by Arm

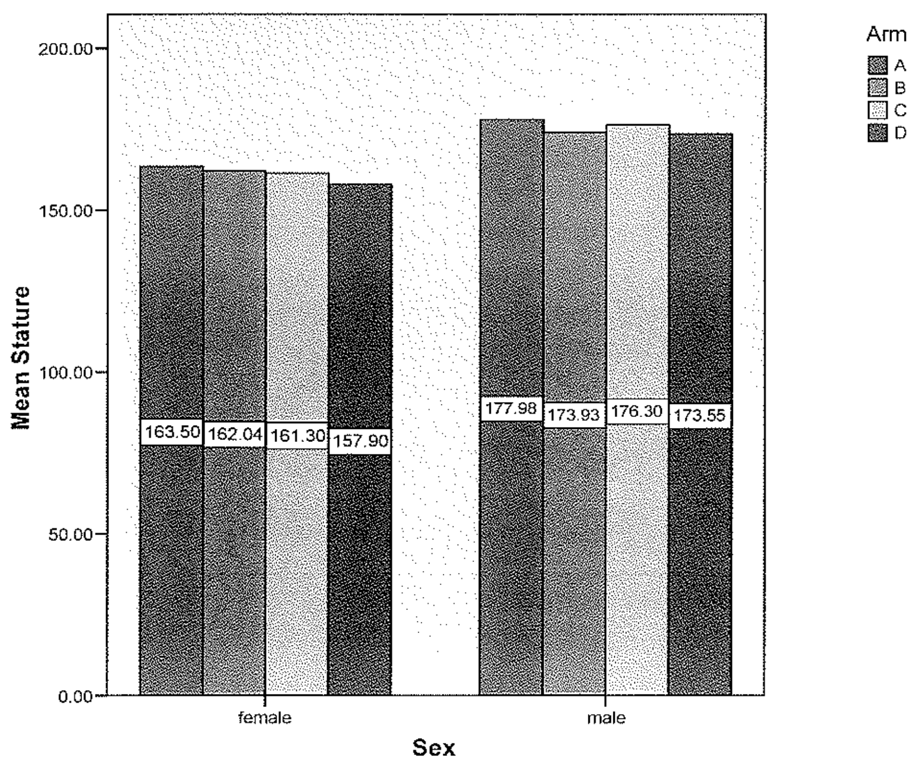


Figure 4.50 Stature Sex by Temporal Category

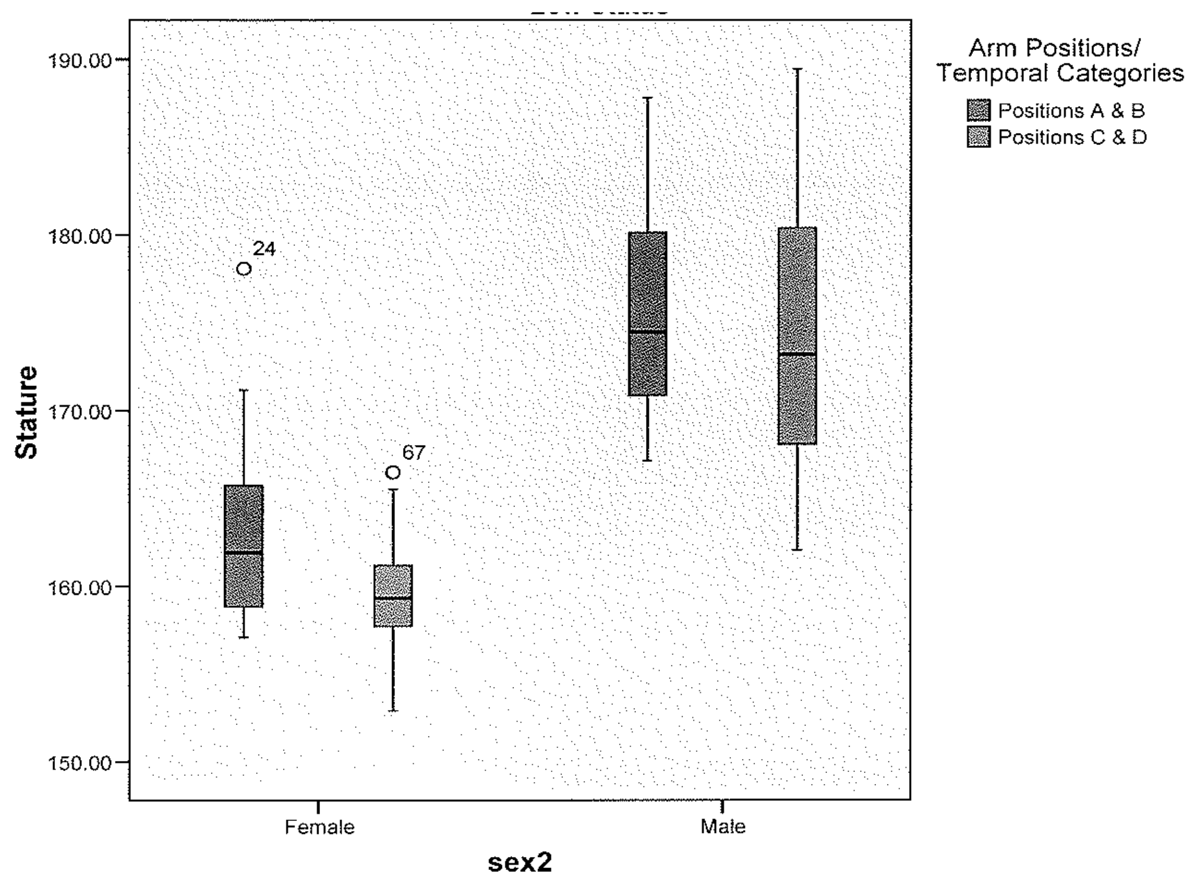


Table 4.1 Statistical Analysis Results for Each Comparison Category

N= no significant results Y = significant results

*Please note that Arm refers to Temporal Periods 1 and 2 referring to the grouped category of arm positions A and B, and C and D respectively.

Element	Sex by Status	Status by Arm*	Arm* by Sex	Arm* by Status	Status by Sex	Sex by Arm*
Deltoid Left	**Y**	N	N	**Y**	N	N
Deltoid Right	**Y**	**Y**	N	**Y**	N	N
Olecranon Process Left	N	N	N	N	N	N
Olecranon Process Right	N	N	N	N	N	N
Ulnar Tuberosity Left	**Y**	**Y**	N	**Y**	N	N
Ulnar Tuberosity Right	N	N	**Y**	**Y**	N	**Y**
Radial Tuberosity Left	N	N	N	N	N	N
Radial Tuberosity Right	N	N	N	N	N	N
Radial Midshaft Tuberosity Left	N	N	N	N	N	N

Radial Midshaft Tuberosity Right	N	N	N	N	N	N
Greater Tuberosity Crest Right	N	**Y**	N	N	N	**Y**
Greater Tuberosity Crest Left	N	N	N	N	N	N
Lesser Tuberosity Crest Right	**Y**	**Y**	**Y**	**Y**	N	N
Lesser Tuberosity Crest Left	**Y**	N	N	**Y**	N	N
Greater Tuberosity Right	N	N	N	N	N	N
Greater Tuberosity Left	N	N	N	N	N	N
Lesser Tuberosity Right	N	N	N	N	N	N
Lesser Tuberosity Left	N	N	N	N	N	N
Greater Trochanter Right	N	N	N	**Y**	N	N
Greater Trochanter Left	N	N	N	N	N	N
Lesser Trochanter Right	N	N	N	N	N	N
Lesser Trochanter Left	N	N	N	N	N	N
Fovea Capitis Right	N	N	N	N	N	N
Fovea Capitis Left	N	N	N	N	N	N
Tibial Tuberosity Right	N	N	N	N	N	N
Tibial Tuberosity Left	N	N	N	N	N	N
Soleal Popiteal Line Right	N	N	N	N	N	N
Soleal Popiteal Line Left	N	N	N	N	N	N
Linea Aspera Right	**Y**	N	N	N	N	N
Linea Aspera Left	**Y**	**Y**	N	**Y**	N	N

Chapter 5 Discussion and Conclusions

Overall

Overall, before comparison by status, sex or time period, general trends can be observed in the results. It would appear that males are larger than females for the majority of comparisons between the sexes regardless of status our time period. Males appear to be generally taller given the stature estimations and, although overlaps in estimated statures occur, the males have a pattern of being taller and larger in body size than females. In general the males' MSM scores suggests they are more heavily structured, with the majority of the grade 3 scores occurring in males rather than females. This is likely attributable to a differentiation in work patterns and the division of labour between the sexes. Upper limb scores, particularly those of the humerus and specifically the deltoid MSM, are the most heavily marked in the males and no occurrence of a grade 3 deltoid MSM for either right or left occurs in any females. Differentiation between the sexes in the lower limb is less observable than those found in the upper limbs and this is highly influenced by locomotor patterns which are not easily discernible.

Upper Limb

Measurements

Asymmetry

The overall population showed marked asymmetry in bone dimensions in both upper and lower limbs, although the upper limbs and the humerus in particular showed more marked and significant differences. Overall the right humerus exhibited marked asymmetry compared to the left. This could suggest a preference for the use of the right limb over the left, a dominance of right over left, which is consistent with the majority of populations where only 9-10% of the overall population is left hand dominant. Overall analysis illustrated that the right upper limb was more robust than the left, with an average length for the right humerus being longer than the left and larger measurements for the shaft, least circumference and epicondylar breadth.

Males were always larger than females, with high status males being significantly larger than females, and low status females being substantially larger than high status females. Significant differences between the two female status groups were problematic as the number of high status females in the sample is small and not proportional to the low status female sample size. Therefore although analysis reveals within this sample a great degree of difference, overall population conclusions cannot be drawn because results would be skewed due to sample sizes. It is possible to say that this general trend in larger overall body size of low status females as compared to high status females is in accordance with the amount of physical labour performed by each group within the population. Despite the small sample size it is appropriate to suggest that this difference is within the normal variation between two status groups with vastly different activity patterns.

Asymmetry is also present as a significant result across all four of the time periods. This suggests only minute changes in arm preference when performing repetitive activities throughout time. Although MSM scores did not indicate a significant difference in side preference, overall size and robusticity in terms of measurements indicates a continuation of right limb dominance for size. This would encompass cortical thickness as shaft diameter and least circumference are both larger for right limbs than left and these measurements can be affected by long term mechanical loading through development and growth.

Following Steele and Mays (1995) bilateral asymmetry was calculated using their percentage of directional asymmetry (%DA) defined as follows: (right – left) / (mean right and left) x 100. This illustrated what portion of the sample population had bilateral asymmetry and for which side. Within the population as a whole 11% (8 individuals) were left side dominant based on paired humerus maximum length, 4% (3 individuals) had no preference and 85% (64 individuals) were right side dominant. This is on par with normal variation within most populations, who generally manifest a 9-10% portion of the population being bilaterally asymmetric for the left side, of exhibit left hand dominant tendencies.

Musculoskeletal Stress Markers

The humerus is the major long bone analysed in the upper limb, and both measurements and MSM scores were taken for examination. Of particular interest for the humerus MSM scores is the deltoid muscle attachment. The only other pair of MSM's that resulted in as many significant results as the deltoid was the ulnar tuberosity. However the deltoid is more evenly distributed between the left and the right for its results with a total of three significant results for the right attachment site and 2 for left attachment site.

In high status males a high MSM score for the left and right deltoid are manifested when compared to the lower status for grade 3, suggesting that a higher proportion of the males in the high status were performing a labour intensive activity involving the deltoideus muscle. When the division of labour is considered for the time period of medieval era, it is unlikely that high status males were involved in menial labour to the extent, if at all, that low status males would have been involved in. Considering that the sample is largely drawn from a monastery and the surrounding areas, it is unlikely that these high status males with heavily marked deltoid muscles are of the monastic order, as high ranking clergymen would also be unlikely to be involved in such labour intensive repetitive activity. However, because wealthy landowners and patrons of the monastery from the surrounding areas were included in the cemeteries of the monastery it is a possibility that the repetitive activity that resulted in heavily marked deltoid muscle attachments is some form of swordplay or warfare exercise. Each muscle is responsible for its own suite of motions, the deltoid being responsible for flexion, medial rotation, extension and lateral rotation of the arm and shoulder. These movements would correspond to the thrusting and retreating of a sword or other weapon, the hefting of a shield or even the exchange of physical blows between opponents. Of the five high status male individuals who exhibit a right deltoid MSM score of 3 only one of the four reciprocal left deltoid grade 3 scores is from the same individual. Therefore a total of 8 individuals of known sex and status exhibit a grade of 3 for the deltoid attachment site. While this suggests a higher degree of left arm dominance than would be expected in a population, it relies on the concept that the repetitive activity required to manifest a grade 3 in the deltoid would be caused by a arm dominant activity. It is possible that the right and left grade 3's result from two separate repetitive activities or possibly to related activities, however there is not enough specificity to further interpret hand dominance.

The low status males would possibly use the same suite of muscles for a hoeing motion, an outward thrusting or movement away from the midline of the body (abduction) and a movement back towards the midline of the body (adduction). The deltoid controls these two movements as well as flexion and extension both of which would also be utilized in a hoeing movement. Chapman (1997) corroborates the possibility that these movements could be utilized for a hoeing activity in her Pecos Pueblos population. Although the populations are disparate in both culture and time, it is likely that the muscles utilized for similar activities would be common between the samples.

Males in general are usually larger and more robust than females, especially within this time period and geographical and cultural area. It is unsurprising than that females have a much lower degree of robusticity for the deltoid attachments than the males. Less surprising is the fact that although a score 3 is represented in low status females, who likely had a much more labour intensive lifestyle, the highest deltoid score for high status females is a 1.5 which is barely more robust than normal variation of the population. This suggests that low status females performed a heavy repetitive activity involving the upper arm muscles and given that distribution is similar for the left and the right it was a bilateral activity for the low status. Chapman (1997) discusses the influence of corn agriculture on female upper arm MSM expression, specifically the processing of maize through manos and metates, a form of grain grinding similar to a mortar and pestle that involves a downward and outward movement. Although grain processing was most likely performed by grist mills, the grinding and processing of small amounts of grain could have been performed within the household, although this would have been isolated cases and not likely to reflect these results,. The grain that was processed would not have been corn until well into the 16th century and would more probably have been rye or wheat. A more likely alternative is the washing of clothing, specifically the scrubbing motion. This movement involves the same movements utilized by the sword arms of males but in a different direction, rather than an outward thrusting motion it would be a downward scrubbing motion. Although there would be no loading stress, there would be a force stress which accounts for the lower scores overall for the deltoid muscles of the low status women.

In terms of comparative analysis when the left deltoid is compared between status group and by temporal category it becomes apparent that for the first temporal period, which consists of arm positions A and B, a more substantial amount of individuals from both the high status and the low status groups with a score of 3, are from the this period rather than the second, comprised of C and D arm positions. This suggests that heavier repetitive activity affecting the deltoid muscle and its attachment occurred in the grain producers who existed within the first temporal population. Therefore the more labour intensive form of agricultural economy for the upper limb would be grain production, which involves a more diverse and repetitive suite of activities. Actions such as hoeing and harvesting, tasks more likely to performed by the males of the population and by those in a lower status group, require the use of the deltoid muscle in a flexion, adduction, abduction and extension manner while applying a degree of force and while maintaining a moderate level of loading, all of which would place stress upon the attachment site of the deltoid tuberosity on the humerus, creating a more robust deltoid marker within the first two arm positions than in the second two.

MSM's that may also be involved in these motions for both the left and the right sides are the crests of the lesser tuberosities which represent the supraspinatus which initiates and assists the deltoid with adduction of the arm; the teres major which adducts and medially rotates; and the latissimus dorsi which extends, adducts and medially rotates the humerus; teres minor which laterally rotates the arm. Significant differences in the distribution of this MSM was obsevered in the high status groups of period CD, which corresponds with the increased representation of the deltoid muscles in this same group. This collection of muscles would work in concert with the deltoid muscle to create the motions needed to swordfight, lift a shield, swing a staff or a mace, or any other form of warfare exercise or weaponry. Although there is a possibility that these muscles may have been involved in everyday activities, continued repetitive stress of an activity that is performed over extended periods of time is needed in order to create muscles markings such as these. This does not exclude activities not suggested within the text, but from the known data presented the hypothesis put forth is more than likely.

Similarly although there are no significant results for the females of the same group, a decrease is seen in the overall scores of the females in temporal population 2, the livestock producers. Given the distribution there is a more synthetic distribution of scores in the first temporal population with more females scored in grade 2 and 1.5 in the first temporal population than in the second. This suggests a decrease of upper limb repetitive activity over time within the lower status female population. The high status female population is more or less static throughout time, with very little change in MSM scores throughout the arm positions.

The only significant result for the attachment of the triceps brachii on the olecranon process is somewhat contradictory to the results found within the MSM's of the humerus and the rest of the ulna MSM's, because it illustrates a deceases in MSM expression to grade 1 within the first temporal population and within the high status. Since this group has otherwise exhibited a maintenance or increase of high scores for the rest of the upper limb muscles it is odd that this MSM would not follow suit, especially as it is a stabilizer of the abducted humerus and a chief extensor of the forearm. While the majority of the discussion has focused on the impact of force and loading on the MSM of the upper arm, the hypothesis of warfare activities being the most likely repetitive activity would involve this muscle and be reflected in its MSM. One possible answer for this anomaly is that although the forearm is involved in the repetitive activity force is belayed from it to another muscle group or skeletal element thus reducing the stress placed on it. Stabilization of the humerus may be performed from the muscles that attach along the scapula and crests of the tuberosities.

The left ulnar tuberosity is very interesting because it is the one element that manifested the most statistically significant results of all the other MSM's. The overall interpretation of what these results mean is slightly more difficult to interpret then many of the other results because the movements controlled by the muscle associated with this MSM are very generalized. The brachialis muscle which inserts on the ulnar tuberosity controls flexion of the forearm in all directions. So while interpretation of the results may suggest a decrease or increase in flexion stress between groups, more specific interpretation is nigh impossible. However, it should be noted that a decrease in distribution of scores in high status males is seen for the left ulnar tuberosity, with an over representation of scores falling into the grade 1 category. Low status distribution is still even with scores falling into every category, but given the results for upper limb MSM scores it is odd that such a high amount of high status males failed to score higher given the overall distribution of males.

For the left ulnar tuberosity for females there is an interesting dichotomy between those who have within normal variation and those who represent the higher manifestations of robusticity. Within the temporal population of 1 there is an over representation of scores 1 within arm position A and also an over representation of score 2.5 within arm position B. This suggests that given the overall distribution the females fall into more or less two categories of activity, those who perform a heavy loading repetitive activity and those who do not, with very little middle ground. This can perhaps be explained by the status distribution, given that high status females are generally more delicately built than the low status females, with less robust markers.

When this site is further compared between arm positions for differences in status distribution, there is a high amount of high status individuals in the second temporal period representing arm positions C and D.

Lower Limb

Asymmetry

There is less asymmetry in the lower limbs than what is found in the upper limbs, a understandable result given that the lower limbs are involved in more daily activities of living than the upper limb. Locomotion in particular would balance the differences observed in preferential use of a lower limb side over the other, because equal weight and stress is placed on each limb in order to perform running and walking. It is also understandable that there would be a significance in asymmetry found in the lower status individuals rather than in the upper status, as the lower status are more likely given the historical and cultural context to be those who perform labour while on foot. Due to the nature of the agricultural activities it was not expected that a plethora of significant results would be found between the temporal populations, as both would use a high degree of locomotion to perform their given tasks. For the first temporal population, because they are predominantly grain producers, walking would be used in order to plough a field, sow the grain, and for harvesting a scythe or other form of cutting blade would be operated while walking down a rough windrow. For the second temporal population who were predominantly livestock raisers, walking would be involved in the production of crops used to feed the animals, fodder and hay, but also in the herding of the animals. Depending upon the type of livestock some would be more labour intensive for herding than others.

Measurements

Lower limb measurements mirror those of the upper limbs for overall length. The femur maximum length when controlled for sex yields a larger average femur length for males than females. This result is likely due to normal variation between the sexes and to the amount of physical activity performed during growth and development of young males, and the less physically demanding labours expected of a female during their growth and development.

Certain patterns are held true in the lower limb comparisons, that were seen in the upper limbs, males are still larger than females given maximum length; low status females are still, in general, more robust than high status females. This comparison however is given further dimension when it is shown that the low status females show a larger shaft dimension for both anterior- posterior and lateral-medial dimensions. This means that the femur itself in low status females is larger, and more robust, and indicates evidence of more strenuous activities (Bridges, 1989). Similar findings were seen in Mississippian agriculturalists whom had thicker and stronger long bone diaphyses. Although it is impossible to say whether it is agricultural activity alone that has influenced the Danish low status females to have thicker shaft dimensions than the high status females. It is interesting to note similarities to other populations however. Little difference is seen between the males in the lower limb, except a single dimension in low status males was significantly larger than in high status males. As a result low status male shaft shape is perhaps rounder, as a wider anterior posterior measurement would shorten the difference between medial-lateral dimension and anterior-posterior dimension. This cannot be further interpreted as it is a single difference in size and could have been caused by numerable actions, and patterns of activity.

Musculoskeletal Stress Markers

As already stated the lower limb yielded a smaller amount of significant results, an expected result given that much of the muscle in the lower limb are equally used throughout time in locomotion and other daily activities which would influence outcomes. Many of the muscle attachment sites analyzed are associated with muscles, tendons or ligaments which are largely used in running, walking, jumping, and squatting. All of these motions would be integral to the agricultural practices associated with both temporal populations, with the exception of jumping. Running and walking are necessary functions for ploughing, planting and harvesting for one temporal population, and the same activities to a lesser degree in the livestock agriculturalists who would utilize these motions predominantly for herding and maintenance of their animals.

The greater trochanter is the insertion and originating site for a vast amount of muscles associated with the abdomen and the legs. Part of or all of the following muscles exert influence on this area; gluteus medius, gluteus minimus, all three vastus muscles, quadriceps, and femoris muscles. Thus it is no wonder the greater trochanter has yielded significance in comparison. However the results it did yield conform to the pattern of expected results: an over representation in arm position A for the low status in 1.5, and an over representation of the high status in arm position C for grade 1.5, suggesting a decrease in robusticity of this MSM. Although one would assume that this MSM would increase for those in the second temporal population, the decrease in robusticity is found in the high status portion of the population, suggesting a decrease in bipedal locomotion to perhaps a vehicular or pack animal. It may also indicate a decrease in the use of riding horses, a luxury of the wealthy that after the Black Death many may not have been able to afford. The lack of representation in higher scores for the first temporal population correlates with the fact that their expression of activity is more focused in the upper limbs, which are more heavily loaded during repetitive activity than the lower limbs during this time. The same results hold true for the left side lesser trochanter associated muscles which also performs or aids the same tasks , with an over representation seen in low status arm position A/B being highly represented within grade 1 and a large amount of the high status being represented in score 1 for arm position C/D.

Stature Estimation

For males there appears to be very little difference in overall height distribution, and because of the limited size of the higher status sample it is impossible to say that one status is significantly larger than the other. On the whole, in terms of height males appear to be generally the same mean height based on femur length measurements, with ranges that have similar distributions. The females however have a more disparate distribution, again because the samples are not equal in size and because the high status females are underrepresented it is impossible to say either is significantly taller. However, it is possible to state that the Low status females are substantially taller than the high status females whose tallest member is well within the range of both the high and low status males' mean height range. The distribution of heights for low status females had a much wider variation and extends well into the distribution of male height. Whereas the high status females tallest female is barely taller than the smallest male of either status and given the error margin this could be proven untrue.

This disparate distribution in height reinforces the overall trend of males from both statuses being more robust and larger than females, with a wider distribution between the sexes found in the high status population. Low status females appear to be generally taller and more robust than their high status counterparts, but still remain on a whole shorter than their male counterparts. High status females are much more delicate when compared to their male counterparts.

There were a number of MSM's and skeletal elements that upon data organization it was discovered were too incomplete or incompatible for statistical analysis. The clavicle was not represented in the sample to a high enough degree to represent any significant results. However it can be said that a substantial portion of the sample which had a clavicle studied exhibited a highly overdeveloped sternal end MSM, what is commonly known as a rower's mark. The gluteal line information taken for this study, specifically where the three gluteal muscles passed over the ilium of the innominate were not recorded in a manner that allowed for statistical analysis, the same predicament was found for the Schmorl's nodes. These two characteristics were recorded as present or absent, but the absent did not indicate if the bone was absent or if the element did not manifest the required characteristic. The data was incomplete and therefore no interpretable data could be taken from the records.

Individual 7H

Within the sample population a single individual has emerged that requires further note. Although perhaps not the most heavily muscled individual overall 7H manifests several interesting characteristics that allows for further insight into the recreation of this particular individual's behavioural reconstruction and daily repetitive activities.

7H manifests a score of 2.5 for his right deltoid attachment and a 3 for the crest of the lesser tubercle which is the landmark for the attachment site for the pectoralis major muscle. The entire humerus of 7H was CT scanned in order to more clearly reveal the extent of the pectoralis major MSM. When digital reconstructed it was possible to measure the depth of cortical furrowing/pitting that occurred within the attachment site. A measurement of 2.2 millimetres at the deepest intrusion into the cortical bone was recorded, and the length of the furrow was measured at 4.3 centimetres long. This is an uncommonly severe attachment site for the upper arm; many of the grade 3's for this site do not have such extensive cortical damage and this particular MSM could be termed enthesopathic or traumatic in nature. As well as the abnormally large pectoral attachment a small oblong and dime sized eburnation on the ventral portion of the humeral head was also recorded in an area where in normal anatomical position and movement an eburnation would not occur. Upon reconstruction of the shoulder joint and articulation of the humerus and the scapula in movement, it was discovered that a portion of the scapula may have caused the eburnation when the right upper limb was fully extended and raised above the head in a swinging motion while under heavy loading stress. It can only be hypothesized as to what this stress may have been, however since 7H is a low status individual it is unlikely that the motion involved a sword, and given the limited amount of activities within the monastery that can be attributed with these criteria, it is suggested that 7H is a low status parishioner or villager from the surrounding area. His occupation is likely to have been that of a blacksmith, specifically the type of smithy that did ironworks, perhaps those for the monastery. This conclusion is drawn from the repetitive motion of drawing a heavy blacksmith hammer upwards in order to strike a heated piece of metal upon an anvil, which fulfills the requirements for creating an eburnation on the humeral head and also would contribute to the heavily marked upper limb muscles as well. It is these conclusions which make 7H of interest, with the specificity of the combined stress markers it was possible to recreate a plausible lifestyle pattern for the individual who had been merely one within a sample, and now was a low status male with an occupation.

Conclusions

The analysis and study of musculoskeletal stress markers as indicators of repetitive activity and as tools for reconstructing behavioural patterns in past populations has both its limitations and its benefits. The skeletal system and its associated ligaments, tendons and muscles are very malleable and plastic, open to external as well as internal forces. This allows for a sort of blueprinting of changes in activity patterns within a population and between population, however it is very general. It allows the observer to study trends in loading, force, and in many cases health, it does not, or very rarely allows for the supposition of specific behaviour to the exclusion of all others. While Stirland's (1998) conclusion attempts to evaluate areas of muscle insertion either by measurement or subjective evaluation are doomed failure is somewhat pessimistic in its tone, it holds some valid truth. Despite the loosely structured guidelines for grading, measuring, locating and interpreting MSM's, conclusions about their interpretation and meaning are subjective. Interpretation depends upon the population and the researcher studying said population. The specific MSM's are also integral to understanding outcome, as very few muscle attachment sites and the associated muscles operate independent of surrounding muscles when performing a task. Therefore a single MSM site cannot be used to correctly interpret or reconstruct activity; it is more appropriate to use a suite of muscles that can be used in a complementary fashion by the individual in order to assess the possibility of which movements may have influenced the scoring of each site.

Understanding that as researchers, most anthropologists are limited in interpretation by a number of issues, correct interpretation of skeletal signs of activity requires three basic concepts:

(1) biological interpretations, i.e. understanding the element's overall morphology in terms of how mechanical forces and biological processes such as growth and development and bone re-growth and remodelling effect it
(2) cultural interpretation, i.e. understanding which activities would have caused these modifications or influenced the biological processes: such as nutrition, division of labour, actual practices.
(3) social interpretation, i.e. understanding the distribution of the trait within and among groups in terms of social and economic organization of the activity (Robb, 1994)

Limitations are caused by the ability of the researcher to recreate the lives of the population being interpreted. Lack of historical documentation about daily life of all portions of the population limits the knowledge about external influences, such as specific activities and division of labour. If an activity cannot be imagined by the researcher then it is excluded from the possibilities despite its validity and the possibility it may have existed. Therefore no interpretation can be wholly disqualified, however when interpreting this form of data it is better to examine the results for generalizations that yield trends, movements or changes, rather than look for specificity. Broader changes in economic activities, subsistence patterns, reflections on habitual daily activity, habitation and demography can yield interesting and intriguing insights into a past population.

Based on this research, the following conclusions can be stated:

- there is a general trend of sexual dimorphism between the sexes, with males being significantly larger than females, across status and time, despite economic changes;

- although not statistically significant, likely due small sample size, low status females are in general substantially larger than high status females, and low and high status males are similar in size when compared by measurements.
- while not exclusively supported , it appears in general that individuals from the first temporal period (AB) were larger and more robust than those from the second temporal period (CD).

The final point speaks to the primary question of the research: broad economic changes in agricultural practices do appear to affect the skeletal system within this population. Grain producers, those found within the first temporal population representing periods A and B, have higher general scoring of MSM's where results were significant. There is a general trend of decreasing MSM's in the livestock raisers, especially observable in the upper limb. The lower limb is less likely to exhibit interpretable conclusions because its results are marred by a plethora of activities and a high degree of population variation. This overall robusticity of the lower limb is incongruent for the population as it would seem to represent a population who spends a large amount of time traversing rugged and steep terrain, which is absent from this geographical region.

In closing upper limb MSM's appear to be more readily able to exhibit modifications in activity patterns exclusive of daily life activity. Although there are changes in the lower limb MSM distributions, they are harder to interpret due to their involvement in a wider range of activities. There is an observable difference in the skeletal modifications between the pre-Black Death grain producers and the post-Black Death livestock raisers. The grain producers exhibit hardier and more robust upper arm muscle MSM's which correspond to their heavy repetitive activity involved in maintaining field crops. High status males and low status males exhibit less of difference in MSM manifestation, with the exception of the deltoid MSM and the muscles associated with the lesser tubercle. Low status and high status females are very dissimilar, due to the vastly different daily lives and the division of labour between the social hierarchies. Where most high status women would take on a supervisory role in daily life, low status women are much more likely to be involved in menial labour that would modify muscle insertion sites.

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