A PALEOPATHOLOGICAL ASSESSMENT OF OSTEOARTHRITIS IN THE LOWER APPENDICULAR JOINTS OF INDIVIDUALS FROM THE KELLIS 2 CEMETERY IN THE DAKHLEH OASIS, EGYPT

by

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ABSTRACT

Osteoarthritis (OA) is a degenerative pathological condition of the appendicular joints which affects the cartilage and underlying bone. OA is relatively common in both the archaeological and clinical context, and a significant amount of research has been conducted on this osteological condition. The purpose of this thesis is to assess the incidence, demographic prevalence, and general severity of hip and knee OA in a Roman-Christian period (50 A.D – 450 A.D) population sample from the Dakhleh Oasis, Egypt. The bioarchaeological sample originates from the Kellis 2 cemetery which is associated with the ancient town of Kellis. The town of Kellis is believed to have been a prosperous economic hub in Egypt, located in the Western Sahara Desert approximately 250 kilometers west of the Nile. The skeletal samples (n=135, 83 females and 51 males) was visually assessed for the osteological characteristics of OA in the hips and the knees. Joint surfaces of the hip include the acetabulum and femoral head. Joint surfaces of the knee include lateral/medial tibio-femoral compartments and the patellofemoral compartment. The ages of the individuals assessed in this study range from 19-72 years, and have been divided into five age categories which were then cross-tabulated with sex and OA incidence in order to determine demographic prevalence of OA.

Findings indicate that age is a significant etiological factor of OA prevalence for both males and females. Males are afflicted by the disease significantly more than females in the hips (F: [L] 3.6%, [R] 5.9% and M: [L] 13.7%,[R] 13.7%) and also slightly more affected in the knees(F: [L] 17.5%,[R] 18.3% and M: [L] 22.9%,[R]21.3%). The acetabulum tends to be more arthritic than the femoral head for both males and females. Femoral condyles tend to be more arthritic than tibial condyles for both males and females. The patello-femoral compartment tends

to be the most arthritic part of the knee while the medial condyles of both tibiae exhibit virtually no OA (with the exception of one individual). The joint surface observed with the highest OA prevalence is the femoral surface of the patella (F: [L] 17.5%,[R] 15.9% and M: [L] 21.3%,[R] 21.3%). The highest prevalence of OA by joint complex is observed on the left knee in males (22.9%), and the lowest prevalence of OA is observed on the left hip of females (3.6%). Both hip and knee joints have higher prevalence of unilateral OA manifestation than bilateral.

Isotopic and archaeological evidence indicates that the individuals at Kellis maintained an agricultural subsistence regime, and that the males within the population may have been highly mobile migrating to and from the Dakhleh Oasis. Subsistence agriculture has its necessary physical demands which may have been a contributory factor to OA rates. Males show higher OA rates than females throughout the joints of the legs. Sexual dimorphism of OA for the hips is suggestive of sexual divisions of labor. OA of the knees lacks sexual dimorphism therefore the knee joint complex of males and females were likely subjected to similar levels of mechanical loading. It can be concluded based on the OA data that males and females exhibit similar activity, or biomechanical stress levels in the knee joint complexes. Males exhibit significantly higher pathological manifestation of OA in the hip joint complexes, indicative of higher levels of mechanical loading in the hip joint complex which can theoretically be attributed to sexual divisions of labor or perhaps terrestrial mobility.

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CHAPTER ONE: INTRODUCTION

Paleopathology is the study of traumatic and disease related lesions in skeletal remains of historic and prehistoric origin (Ortner, 2003; Rothschild and Martin, 2000). While a great deal paleopathological literature can be found in anthropological journals, the history of this research is not rooted in anthropology but rather in medicine, propelled by the curiosity of physicians and the proclivity for the exploration of human physiology (Mann and Hunt, 2005). General interests in topics related to paleopathology have shifted throughout the late 1800's and early 1900's (Mann and Hunt, 2005). Ubelaker (1982), comments that the early focus in paleopathology was on traumatic and pathological lesions, followed by descriptions of infectious diseases within populations. Physical anthropologists have long since adopted and built upon these methods of identifying skeletal indicators of disease in order to interpret the pathological trends within and between human populations (Larsen, 1997).

Paleopathological studies have focused on disease prevalence and distribution biogeographically, and have subsequently offered informative data on disease patterning and epidemiological trends observed in various human populations both spatially and temporally (Roberts and Manchester, 1997; Waldron, 2009). Paleopathological research can be exceedingly informative in many areas of physical anthropology particularly in the field of bioarchaeology (Cook and Powell, 2006). The article by Buikstra (1977), "*Biocultural dimensions of archaeological study: a regional perspective"* discussed the importance of a more holistic-based approach to bioarchaeological research utilizing multiple types of osteological and archaeological data collection and interpretation. Studies which reveal more information about migration, diet, general stress levels, activity, development, etc. in bioarchaeology have shown a stronger emphasis in "biocultural perspectives of disease in relation to social, cultural, and environmental circumstances" (Larsen, 1997; 64). Paleopathological descriptions of bioarchaeological samples are an important aspect of the biocultural perspective, and therefore should be frequently utilized along with additional osteological evidence which can offer more knowledge about past populations.

Osteoarthritis (OA) is a disease which has received much attention in recent decades from the paleopathological community. Historically, the disease was considered to be the most common ailment observed in past populations and therefore was not initially the primary focus of bioarchaeological research (Bridges, 1992). Individuals such as Hrdlicka, Stewart, and Angel were perhaps some the first to specifically investigate the prevalence and patterning of OA. Referred to by some as osteoarthrosis or degenerative joint disease (DJD), OA is the most commonly encountered pathological condition in the human skeletal record second only to dental disease (Ortner, 2003). Although OA is generally accepted as a pathological condition of multifactorial etiology (Weiss and Jurmain, 2007), most regard it specifically as an age-related phenomenon which is the result of continuous mechanical loading of the joints throughout the lifetime an individual (Rogers and Waldron, 1995; Larsen, 1997; Jurmain, 1999; Ortner, 2003,). That being stated, researchers acknowledge the fact that humans are inherently variable and clinically, cases of OA have been observed in individuals who led relatively stress-free lifestyles, and has also in some cases not been observed in individuals whose occupations promote significant use of site-specific joint (professional athletes, pneumatic tool users, dancers, etc.) (Larsen, 1997; Weiss and Jurmain, 2007).

Many researchers have used the prevalence and distribution of OA to interpret levels of biomechanical stress in individuals incurred through the hardships of work and life within their culture. Some researchers use OA data as a basis for behavioral reconstructive methodology which in some cases have been successful (Angel, 1966a; Merbs, 1980) while others have been quite anecdotal and subject to critical reviews (Bridges, 1992; Jurmain, 1999). Cultural consideration regarding the behavioral reconstruction of this sample based on OA manifestations, while not the central focus of this thesis, will be discussed when relevant.

Within the last decade the utilization of OA as a means of inferring behavior has become less popular amongst researchers, some even claiming that such studies are doomed for failure (Waldron, 2009). Recently, studies have focused more on the description of OA while considering biocultural factors that may have contributed to OA patterning and prevalence observed in samples from one or more human populations (Pearson and Buikstra, 2006).
The purpose of this study is to determine disease frequency based on the assessment of the demographic prevalence, patterning, and general severity of lower appendicular OA in a bioarchaeological sample group from a Roman-Christian period (50 AD- 450 AD) Egyptian population. This project is inherently unique because there has yet to be a large-scale study of OA on a Roman-Christian period Egyptian population.

The diagnosis of OA is based on the visual assessment of dry bone for certain osteological characteristics. The osteological characteristics commonly considered as diagnostic evidence of OA in joints on dry bone are: osteophytes- bony spicules that develop on both the articular surface and at the margins (lipping) of the joint; porosity- subchondral sclerosis; and eburnation (Buikstra and Ubelaker, 1994). These characteristics are utilized in this thesis for the assessment of the demographic prevalence, patterning, and severity of OA in this sample. While eburnation (distinct polishing of the joint surface) is the only characteristic that can be conclusively associated with a positive diagnosis of OA on dry bone, all former characteristics are found to be associated with early stages of OA pathogenesis (Jurmain, 1977a; Jurmain, 1980; Larsen, 1997; Roger and Waldron, 1995). Assessment of OA will be based on scores calculated from individual joint surfaces, quantified separately to determine which focal area of each joint complex is actually arthritic. This data will be cross-tabulated with age categories and sex categories in order to determine demographic prevalence of OA. The next step will be to take the joint surface scores and compute composite joint scores which will inform on the anatomical patterning and severity of OA in the sample.

Chapter two of this thesis utilizes frequency analysis, cross-tabulations, and correlational data procedures to examine the demographic prevalence (# of OA cases/# of individuals in the sample group), patterning, and severity of OA based on the presence of osteophytes, porosity, marginal lipping (degree and extent), and/or eburnation found in the hip joint complexes of a representative adult sample (n-135) from the Kellis 2 cemetery. The hip complex is a synovial joint composed of two joint surfaces; the acetabulum and femoral head. The hip joint is a spheroidal, or ball-and-socket joint classified as triaxial because of it wide range of motion (White and Folkens, 2005). All OA characteristics will be assessed for each joint surface of the hip and then analyzed for demographic prevalence regarding age and sex in addition to also being analyzed for anatomical distribution and laterality. The scores from both joint surfaces will then be combined to form a composite as a means of informing patterning and severity of OA in the hip joint complex. Questions to be addressed are how the distribution of these characteristics vary within and between the sexes, how they vary within and between previously determined age categories (to be discussed in Materials and Methods section of chapter two), and how they vary by side.

Chapter three of this thesis utilizes frequency analysis, cross-tabulations, and correlational data procedures to examine the demographic prevalence (# of OA cases/# of individuals in the sample group), patterning, and severity of OA based on the presence of osteophytes, porosity, marginal lipping (degree and extent), and/or eburnation found in the knee joint complexes of a representative adult sample from the Kellis 2 cemetery. The knee joint complex is perhaps the most intricate and compound joint in the human skeletal system. It is composed of six joint surfaces; medial and lateral condyles of the tibia and femur, as well as the patellar surface of the femur and the femoral surface of the patella. The knee joint is a hinge joint classified as uniaxial because of its singular range of motion (White and Folkens, 2005). All OA characteristics will be assessed for each joint surface of the knee and then analyzed for demographic prevalence regarding age and sex. Composite scores for the knee joint will be computed but in light of the work of Bridges (1993), the knee joint complex will be discussed firstly as three sub-complexes (lateral, medial, and patellofemoral compartments) therefore averaged scores will be comparable to other joint complexes. Arthritis of the knee will be reported site specifically (e.g. 27% of males in group 3 were found to have patellofemoral OA). Questions to be addressed are how the distribution of these characteristics vary within and between the sexes, how they vary within and between previously determined age categories (to be discussed in Materials and Methods section of chapter two), and how they vary by side.

The author had originally intended on including data from the ankle joint for this study. The data were collected in the same fashion as the hip and the knee, and during data collection it was apparent that this population was completely lacking the diagnostic characteristics of OA in the ankle joint complex, with the exception of a sole individual (B-280). The ankle, or tibio-talar joint, is composed of two surfaces; the distal articular surface of the tibia and the superior surface of the talus. The tibio-talar joint is not commonly addressed in OA studies because of its relatively low rate of occurrence both clinically and paleopathologically (Rogers and Waldron, 1995; Ortner, 2003). The likely cause of such low frequency of ankle OA is believed to be related to the structural integrity of the tibio-talar joint. Classified as a biaxial joint, specifically a saddle joint, the mobility and range of motion for the tibio-talar joint is quite limited which is considered the primary reason for the general lack of OA in for the joint complex. The single individual (B-280) found to have OA of the ankle was a female of advanced age. The individual had severe porosity and slight eburnation on the superior surface of both tali. This example of OA may very well have been secondary or traumatic in etiology. For the purpose of this thesis, the lack of data excludes the need for an additional chapter on the ankle joint complex.

Chapter four will be the conclusion section of this thesis discussing the results of the analysis concerning the demographic prevalence, patterning, and severity of OA for both the hips and knees. Frequency of OA in the lower appendages will be discussed in regards to sex categories, age categories, and laterality; and if possible general comparisons with previous studies may be offered. The author takes into consideration that research of this nature in most cases cannot be validly compared (Bridges, 1993).

Direct comparison of statistical data about OA prevalence may not be comparable due to reasons such as; inter-observer variation in scoring and variation in scoring methods (Bridges, 1993). General frequency percentages of the prevalence of OA for both joint surface and complex may be tentatively compared due to the fact that researchers tend to use the same osteological characteristics for the assessment (Bridges, 1991; Jurmain, 1999). Previous studies which offer percentage frequencies of OA prevalence and/or patterning of OA may be compared when both appropriate and relevant. Comparative based OA research can offer uniquely informative biocultural interpretations about different peoples throughout the world. Hypotheses regarding agriculture and social factors such as sexual divisions of labor have been developed based upon the demographic prevalence and anatomical patterning of appendicular OA. Chapter four will also include a discussion of possible future directions in OA research and behavioral reconstruction in bioarchaeology both at Kellis 2 and other sites as well.

When initiating paleopathological research one must consider the inherent limitations of using an osteoarchaeological assemblage. The methods employed by anthropologists are adapted from those in disciplines such as nutrition, pathology, demography, physiology, etc (utilizing data from living individuals). The issues with applying these methods to a skeletal sample is that much information is missing from this population and the selected sample may not accurately reflect the paleodemography and actual morbidity/mortality rates (Wheeler, 2009). This concept is referred to as the “osteological paradox,” considers external and internal biases inherent within a osteoarchaeological assemblage (Wood et al., 1992). The biases which can potentially confound interpretations of both past health, and demographic patterning to be considered for each population being studied are; selective mortality, individual frailty, and demographic non-stationarity (Wheeler, 2009). The general issue is that skeletal samples are mostly composed of individuals who did not survive to advanced age, making it impossible to get a completely accurate paleodemographic description of the sample in question. The osteological paradox is considered when making demographic interpretations of OA prevalence, patterning, and severity for the Kellis 2 cemetery population sample.

The overall goal of this thesis is to investigate the demographic prevalence, anatomical patterning, and severity of lower appendicular OA in an adult sample from the Kellis 2 Cemetery population. The data elucidated from this research will not only supplement the already vast amount of paleopathological research currently available on OA, but will also add to what is currently known about Egyptian bioarchaeological populations- specifically the individuals from the Dakhleh Oasis during the Roman-Christian period.

The Dakhleh Oasis Project (DOP) is a longstanding multinational and interdisciplinary research endeavor which was initiated by Dr. Anthony Mills in the 1970's. The DOP focuses on the factors related to desert ecology and human adaptability to such harsh environments (Dupras, 1999). Paleopathological research is imperative in gaining a more complete understanding of past human populations, and it is in the hopes of the author that this thesis will help to increase the knowledge about the Kellis 2 cemetery population and thus contribute to the already vast compendium of data for the DOP.

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CHAPTER TWO: PALEOPATHOLOGICAL ASSESSMENT OF OSTEOARTHRITIS FOR THE HIP JOINT COMPLEX

Introduction

The field of paleopathology focuses on the investigation and identification of diseases which are manifested on human skeletal remains (Larsen, 1997; Ortner, 2003). The analysis and assessment of pathological conditions observed in an osteoarchaeological assemblage can be quite informative, both bioculturally and paleoepidemiologically (Buikstra, 1977; Buikstra and Beck, 2006). Diseases observed on human skeletal remains can be utilized as evidence for both general and specific interpretations about stress, diet, and the presence of infectious diseases within a bioarchaeological sample, group, or perhaps even population (Buikstra, 1977; Buikstra and Beck, 2006; Larsen, 1997; Waldron, 2009). The former are reasons why paleopathological analysis is essential in bioarchaeology. Disease prevalence and severity coupled with cultural and demographic data can assist in isolating factors perpetuating the disease, thus broadening the current paleopathological understanding of the disease (Jurmain, 1999).

Paleopathological analysis is one of the various analytical tools frequently used by physical anthropologists in bioarchaeology. The variation of disease prevalence and patterning can be used to make hypothesis about the about past human lifeways. Diseases which are of special interest to osteologists are those which are activity-related pathological conditions such as osteoarthritis (OA) (Jurmain, 1999; Larsen, 1997). The expression of activity-related diseases demographically can be used to make biocultural interpretations about general levels of biomechanical stress endured by the population.

Osteoarthritis

The most commonly observed postcranial pathological condition found on the human skeleton in archaeological assemblages is osteoarthritis (OA), or degenerative joint disease (DJD) (Larsen, 1997; Rogers and Waldron, 1995; Weiss and Jurmain, 2007).OA is a degenerative disease of the appendicular joints which affects both the cartilage and underlying bone. OA can manifest one of two forms, primary and secondary. Primary OA is idiopathic or unknown in nature, and secondary OA is the result of a previous injury to the joint (Ortner, 2003; Rogers and Waldron, 1995). Secondary OA can be caused by injuries of varying severity and episodic trauma; anything than that can affect the congruity or the structural integrity of the joint complex can lead to secondary OA (Resnick and Niwayama, 1995). Primary OA will generally develop bilaterally whereas secondary will manifest unilaterally.

The commonality of OA in skeletal assemblages is also reflected in modern populations because OA affects roughly 50% of those over 60 years of age (Ortner, 2003). Although OA is common in ancient and modern populations, there is still much unknown about the degenerative disease. Some issues with both the paleopathological and clinical understanding of osteoarthritis come from discrepancies about the etiology and pathogenesis of the disease (Resnick and Niwayama, 1995; Waldron, 2009). The clinical and paleopathological research on OA throughout the world offers more data on the pathogenesis, etiology, and pathophysiology of OA.

Among the many definitions which exist for osteoarthritis, Mankin et al. (1986) offers perhaps the simplest yet most accurate version. "OA (osteoarthritis, degenerative joint disease) is a degenerative disease of the cartilage of joints. It is of diverse etiology and obscure pathogenesis" (p.1132). This general definition is representative of what is actually known about the disease today. The term "osteoarthritis" is indicative of inflammation based on the suffix "itis", although many researchers believe that inflammation is not a primary factor in pathogenesis and therefore DJD has been termed "osteoarthrosis" by those outside of North America (Rothschild and Martin, 1993; Weiss and Jurmain, 2007). From a clinical perspective the inflammation is actually a quite crucial factor in the pathogenesis of OA (Punzi et al., 2005) and therefore this terminology is preferred in more recent publications, both osteologically and clinically (although the term osteoarthrosis is still used by some). The last part of the definition is also generally correct that the etiology is quite multifactorial and that OA can manifest in many unique forms (Weiss and Jurmain, 2007; Ortner, 2003).

The etiology of OA is multifactorial, but perhaps the most significant factors can be identified as age and activity (Jurmain, 1999; Waldron, 2009; Weiss and Jurmain, 2007).Although OA has predominantly affected those both in antiquity and modernity, the complexities of the relationship between OA and various etiological factors remain quite a mystery (Jurmain, 1977a). Clinicians have determined two broad factors extrinsic – mechanical/functional factors and intrinsic- systemic/predisposing factors (Resnick and Niwayama, 1995).Systemic factors are those which are related to an entire organism as opposed to a single part. Age is perhaps the most significant systemic or intrinsic factor. With age comes many biochemical and histological changes to the bone and articular cartilage which can inevitably lead to joint degeneration (Jurmain, 1977a; Ortner, 2003; Waldron, 2009). The aging cartilage is less able to resist the forces of repetitive mechanical loading and therefore is more susceptible to microtrauma resulting in early stages of OA (Resnick and Niwayama, 1995).

Multiple lines of clinical data indicate age as a significant factor as well observed symptomatically (Kellegren et al., 1953) and radiologically (Roberts and Burch, 1966) in the living as well in macerated autopsy remains (Bauer, 1941; Goodfellow and Bullough, 1967).

Although age is a significant etiological factor, there still exist those with early onset OA and those advanced aged individuals with no sign of OA throughout their entire skeleton (Bridges, 1991; Jurmain, 1977a; Ortner, 2003). While OA is highly correlational with age, recent research indicates that the cumulative effects of physiological and biomechanical wear and tear over time is a significant etiological factor as well (Lieverse et al., 2007). Age should always be controlled for in OA studies, but the researcher must also consider general levels of activity based on additional lines of evidence during the interpretation of OA patterning. Depending on the individuals lifestyle demands OA manifestation can be quite variable in severity. Movement over time is perhaps the most integral factor when considering the production and progression of OA (Weiss and Jurmain, 2007). This is generally accepted in both the clinical and paleopathological community because non-synovial joints such as sutures which lack range of mobility simply do not develop OA (Roberts and Manchester, 2007).

Additional systemic factors which have shown to be contributory to the development of OA include but are not limited to sex, genetics, ancestry, anatomical variation, nutrition, and body weight (Resnick and Niwayama, 1995; Weiss and Jurmain, 2007). In addition to the former factors, climate and diet have also been suggested to play a role in the etiology of OA (Moskowitz, 1989; McAlindon et al., 1996a, b). Establishing a degree of significance to the etiology of OA to any of these factors is difficult because some are inter-related such as: ancestry and genetics nutrition and body weight, as well as sex and anatomical variation (Waldron, 2009). Clinical research is one way to identify various etiological factors OA while paleopathological comparative-based research can also be utilized as a means of isolating the various etiological factors related to OA. Such research has investigated OA in osteological assemblages in order to compare rates regarding agricultural development (Bridges, 1989; Larsen, 1990; 1995), mobility and subsistence regimes (Lieverse et al., 2007; Merbs, 1983), economic intensification (Klaus et al., 2009), temporal patterns of OA demography (Baetsen et al., 1997; Waldron, 1994; 1997), variable lifestyle stress (Jurmain, 1977a; 1980), ancestral variation, and the relationship between OA and other activity-related pathological conditions (Larsen, 1997; Molnar et al., 2009).

OA variation is described vividly in both the clinical and paleopathological literature. The general pathogenesis of OA is characterized by the loss of articular cartilage in large synovial joints eventually resulting in bone-on-bone contact (Resnick and Niwayama, 1995; Rogers and Waldron, 1995). Ortner (2003) describes three major components of skeletal involvement observed in the pathogenesis of osteoarthritis; breakdown of articular cartilage, reactive bone formation (sclerosis), and new bony/cartilaginous growth at the joint margins. Waldron (2009) describes the biological, physiological, and chemical aspects of each stage of OA on the Table 1.

Table 1: Stages of OA Pathogenesis (Waldron, 2009)

Stages	Pathogenic Description
1	*Enzymatic breakdown of the cartilage matrix; the metabolism of the chondrocytes is affected, followed by the release of enzymes, including metalloenzymes (metal ion enzymes required in 1/3 of all cells), that further breaks down the matrix. The chondrocytes release enzyme inhibitors to counteract the protelytic affect-usually insufficient amounts.*
2	*Cartilage begins to fibrillate both vertically and horizontally; surface of cartilage begins to erode, followed by the release of fragments of collagen and proteoglycan (one of the constituents of the matrix) into the joint cavity-these breakdown products initiate the third phase*
3	*Inflammatory response in the synovial membrane; produces inflammatory cytokines including IL (-1), TNF, and metalloproteinses which can either diffuse into matrix or directly destroy it with the release of yet further proteolytic enzymes. The inflammation in the synovial membrane is accompanied by the formation of new blood vessels due to the generation of vascular endothelial growth factor (VEGF) by the synovium. This stage is completed by the formation of new bone (w/reparative intentions).*

Osteoarthritis involves the entire synovial or diarthroidal joint including the cartilage, synovium, and underlying bone. The cellular response to injury varies between the different tissues within the joint complex (Sandell and Aigner, 2001). When joint stability becomes structurally compromised and results in subsequent injury of the underlying cartilage (whether primary or secondary OA) the cells or chondrocytes begin to repair the cartilage- this is referred to as the biosynthetic phase (Sandell and Aigner, 2001). What follows is the degrative phase in which the enzymes released by the chondrocytes digest the bone matrix which lead to further bony and cartilaginous erosion (Sandell and Aigner, 2001). The pathogenic process of OA is essentially perpetuated by cellular confusion where the chondrocytes are rebuilding cartilage but the byproduct being the erosion of the matrix which leads to osteophytic development. Rogers et al. (1997) describe osteophytes as "lateral outgrowths of bone at the margin of the articular surface of a synovial joint (p. 89)." Enthesophytes are simply osteophytes which are localized along the margins of the joints. The reparative process which follows attrition comprises the early stages of osteoarthritic pathogenesis.

The damage done to the cartilage directly impacts the joint space by tightening or narrowing the joint complex (Ortner, 2003). This loss of space affects the structural integrity of the joint and subsequently causes further cartilage loss due to bony attrition. The focal loss of cartilage and the damage induced inflammation then attacks the remaining cartilage and underlying bone (Mann and Hunt, 2005). Upon exposure of the subchondral bone, a callus will form which is the early stages of osteogenic repair, which is then followed by the normal reparative processes. Regions of the joint which are most exposed will develop osteophytes (Ortner, 2003; Rogers and Waldron, 1995). Osteophytes can develop on either the surface of the joint which are referred to as surface osteophytes, or they can develop at the margins of the joint which is then referred to as osteophytic (marginal) lipping (Jurmain, 1999). The final and most severe change seen with osteoarthritis occurs when the cartilage within the joint capsule has completely worn away, and the bones begin to abrade leading to eburnation, or the polishing of the joint surface. There is much argument as to whether changes in cartilage initiate bony changes or the reverse, and pathophysiology is poorly understood. In archaeological remains the chronological pathogenic process of OA is of less importance being that the end result is in most case the presence of generally accepted osteological manifestations (Larsen, 1997).

The diagnostic characteristics of OA are different between clinicians and osteologists. This is due to the varying methods which OA is assessed between the disciplines. Clinicians rely on patients' description of symptoms and x-rays while the osteologist can observe the joint in its entirety in most cases without connective or soft tissue. The diagnostic criteria vary depending on what is being looked at. The commonly used diagnostic characteristics of OA for osteologists include marginal and surface osteophytes, porosity, and eburnation (Jurmain, 1977a; Rogers and Waldron, 1995; Waldron, 2009). The formation of new bone (osteophytes) can be observed around the margins of the acetabulum (Fig 1), which is also referred to as (slight) lipping. Marginal osteophytes on the acetabulum can be quite variable in severity. This characteristic is often described in regards to extent of joint surface covered, and the degree for which it is raised (Buikstra and Ubelaker, 1994).

Figure 1: Marginal Lipping on the Acetabulum

The next feature is the formation of osteophytes on the surface of the joint as the result of vascularization of the subchondral bone (Fig. 2). An osteophyte is a bony spur which can develop on the surface or at the margins of the joint. Osteophyte formation has been found to be highly correlated with OA but is also commonly observed with advancing age (Rogers et al., 1997; Rogers et al., 2004). Osteophyte development can be quite variable; they can develop within the joint space or periarticularly on the ligaments of the joint capsule (Jurmain, 1999). Early stimulation for osteophytic development may occur following the penetration of the capillaries into the subchondral plate deep within the calcified zone of the cartilage (Brown and Weiss, 1988).

Figure 2: Surface Osteophytes on Femoral Head

The next feature observed is porosity or pitting on the joint surface in the form of a series of holes on the articular surface (Fig. 3). During pathogenesis of OA as the subchondral bone is worn down holes develop in the areas which are thinnest. Histologically, these holes are tiny cysts which in life are filled with reparative cartilage cells (Milgram, 1983).The holes can vary in size and cluster pattern. While most paleopathologists consider porosity to be one of the diagnostic characteristics of OA, a study by Rothschild (1997) has found no relationship between OA and porosity although the author was using clinical diagnostic criteria and not osteological.

Figure 3: Porosity on the Femoral Head

The last and most severe OA manifestation would be the production of eburnation or a polished area on the surface of the joint (Fig. 4). This eburnation is generally agreed to be a conclusive diagnostic characteristic of OA (Ortner, 2003; Rogers and Waldron, 1995). As the cartilage wears away the underlying bone begins to rub together without the protective barriers of a healthy joint complex. Eventually the bone becomes polished and in extreme cases can be deeply scraped with multiple striations (Rogers and Waldron, 1995). Eburnation of the hip joint complex is not as common as other anatomical regions. Eburnation is an indication of severe arthritis those with the osteological characteristic can be easily diagnosed.

Figure 4: Hip Joint Complex Exhibiting Eburnation

Rogers and Waldron (1995) note that osteoarthritic diagnosis should be avoided if marginal osteophytes are the only existing abnormality, as only bony development without eburnation is diagnostically inconclusive. The characteristics commonly utilized in scoring osteoarthritis include porosity, osteophytes, lipping, and eburnation (Bridges, 1993; Buikstra and Ubelaker, 1994; Jurmain, 1977a). Although eburnation is the only feature of OA with conclusive diagnostic potential, the former characteristics have all been found in association with OA and therefore are considered to be features observed in earlier stages of the disease. Clinicians use a unique system which visually describes the hip OA based on the specific pattern. This method was designed to help diagnose hip OA radiologically. Based on the anatomical position of the femoral head within the acetabulum the type of OA can be determined. If the OA has progressed superiorly from femoral head to acetabulum it is referred to as superior pole OA which is the most common type of hip OA (O'Reilly and Doherty, 1998).

Roberts and Manchester (2007) state; "Diagnosis of osteoarthritis rests on the identification of the abnormalities already described, but osteoarthritis cannot be diagnosed purely on the basis of one of one of these features" (p. 105). One cannot simply attribute porosity, osteophytic lipping, or surface osteophytes to osteoarthritis because these are all non-pathological bony changes associated with advanced age while also being osteological characteristics associated with OA (Waldron and Rogers, 1991). Figures 5 and 6 are examples of an extreme case of hip OA observed in the acetabulum and femoral head of B-414. The acetabulum (Fig. 5) exhibits multiple characteristics of OA such as eburnation, osteophytic marginal lipping, and porosity. The femoral head (Fig. 6) also exhibits several osteological characteristics of OA, perhaps most diagnostically significant is the eburnation on the superior pole. Diagnosis without eburnation must include at least two of the formerly mentioned osteological characteristics (Jurmain, 1999; Rogers and Waldron, 1995; Roberts and Manchester, 2007).

Figure 5: Advanced OA of the acetabulum (B414).

Figure 6: Advanced OA of the femoral head (B414).

Activity-Related Pathological Condition

The commonality of this condition has led to research conducted on skeletal samples from populations throughout the world (e.g., Baetsen et al., 1997; Bridges, 1991; Jurmain, 1975; Jurmain, 1990; Rogers et al., 1981; Waldron, 1997). A generally accepted principle about OA is that changes observed in and/or around the joints may be representative of modifications due to biomechanical factors such as trauma or activity, and those patterns have certain implications in the interpretation of lifestyle patterns from earlier populations (Bridges, 1991; Rogers, 2000).This concept has been termed the “stress hypothesis” by some and has been a foundation for many OA studies linking activity to OA patterning. According to Jurmain (1999), the “stress hypothesis” is based on the concept that advanced wear and tear over the extent of one’s lifetime is the strongest etiological factor of OA. Various researchers have shown that behavioral models and general lifestyle demands are reflective of degenerative joint pathology in population samples (Ortner and Putschar, 1981, Angel, 1966).

The early establishment of the connection between OA and activity incited intrigue about what types of information could be gathered based on the patterning of OA. Angel (1966) found a high incidence of OA on the elbow joint in both males and females and attributed the pathological manifestation to specific activities. His deduction regarding this unique osteoarthritic manifestation was that it was caused by throwing of a spear with an atlatl for males and metate seed grinding for females. This manifestation was then referred to as “atlatl elbow” and “metate elbow” (Angel, 1966). Sexually dimorphic patterns of OA have been interpreted as sexual divisions of labor which can be quite culturally informative (Larsen, 1997).Merbs (1983) considers this method to be problematic being that when one considers the many activities modern humans do on a daily basis it may be difficult to attribute site-specific OA to a single or even a few activities.

Most other OA research has been comparison based; investigating OA frequency rates between two or more geographically and/or temporally separate populations while considering various ecological and functional factors (Bridges, 1993; Jurmain, 1977a). The activity related emphasis on OA has been followed by extensive cross-cultural bioarchaeological investigations into demography and variation of OA (Jurmain, 1999). Links between subsistence economy and prevalence/patterning of OA have been investigated (Larsen, 1997). OA prevalence for females and males, and how those rates are reflective of differing activity patterns both within and between cultural groups has been considered in OA studies (Jurmain, 1977a; 1980; Weiss and Jurmain, 2007).

A landmark study by Jurmain (1977a) assessed OA prevalence and severity from four separate population samples; 20th century white and black males/females from Terry Collection, a 12th century Native American Pecos Pueblo collection, and lastly an Alaskan Eskimo (Inuit) group collected from various sites (Jurmain, 1977a; 1980). Jurmain (1977a) identified various possible etiological factors for OA variation between these groups. Findings of higher levels of OA in blacks than whites and in Eskimo over Pecos Pueblo indicate these cultural groups were going through more lifestyle stress than the other groups. Sexual differences were linked to hormone variation and divisions of labor as well. Merbs (1983) had an important publication related to “activity-induced pathology” which emphasized on the OA patterning and known ethnohistorical data. High levels of OA for the female temporo-mandibular joint (TMJ) was attributed to hide softening for leather.

Bridges (1991) investigated the prevalence of OA in a sample of hunter-gatherers and a sample of agriculturists from the Southeastern United States in order to determine which lifestyle was more physically demanding. Bridges’ (1991; 1992) research have indicated that hunter-gatherers tend to have slightly higher rates of OA than agriculturists but they are not statistically significant for the interpretation of variation in workload demand. The application of comparative methods investigating OA demographic prevalence/severity is a paleopathological and paleoepidemiological approach incorporating OA analysis into a much broader framework of in bioarchaeology (Larsen, 1997; Weiss and Jurmain, 2007).

Factors which primarily influence OA are age and activity (Ortner, 2003; Rogers and Waldron, 1995). Therefore most, if not all OA studies consider age to be an important control variable (Bridges, 1993; Weiss and Jurmain, 2007). The study of activity-related changes in skeletons from the archaeological context has led some to the identification of lifestyle differences related to patterns of subsistence methods such as hunting and gathering or agriculture, relative levels of terrestrial mobility, consequences of cultural contact, etc. (Bridges, 1991; 1992; Cohen and Armelagos, 1984; Klaus et al., 2009; Lieverse et al., 2007; Roberts and Manchester, 2007 Rogers et al., 1997).

The concept of being able to establish specific activity patterns based on the osteological manifestation is a dream for many osteologists (Jurmain, 1999; Larsen, 1997). The truth is that there has not been enough clinical data to confirm validly that specific activities result in site-specific OA. Jurmain (1999) conducted an extensive overview of epidemiological studies which examine OA in living individuals, and found mixed results between various types of athletes and laborers. Studies observed with higher incidence of positive correlation for activity and OA include; pneumatic drill users, baseball players, soccer players, American football players, ballet dancers, and farmers (Jurmain, 1999). Still other studies found no correlation for OA in some of the aforementioned occupations and others. Bioarchaeological research at the Spitalfields site in London has shown a lack of OA in the hands of known weavers indicating that activity was not as significant of an etiological factor in that sample (Waldron, 1994). Paleopathological and clinical studies such as those formerly mentioned and others, have changed some perspectives about paleopathological analysis and interpretation of activity-related pathological conditions. The best method of doing paleopathological research is to first describe ones findings then proceed to make broad and general interpretations. General descriptions about OA such as which joint is most afflicted, the incidence of laterality and bilaterality, and how the disease varies between the sexes are good comparative features to be discussed (Bridges, 1993). Goodman et al., discusses interpretations of OA, "The pattern, distribution, severity, and onset by age class and sex in adults can be used to interpret the role of cultural activity in the etiology of degenerative joint disease (p. 36)."

Some posit that OA is a product of joint size, in addition to level of activity for that joint complex (Larsen, 1997). Large and complex synovial joints are subject to much osteoarthritic change (Jurmain, 1999; Rogers and Waldron, 1995; Waldron, 2009). The hip joint is a diarthroidal joint, more specifically referred to as a ball-and-socket or spheroidal joint (White and Folkens, 2005). The hip joint is composed of the acetabulum and the femoral head. The acetabulum is positioned laterally on the oscoxa; the feature is actually the point of fusion between the ilium, ischium, and pubis. The other component of this joint is the femoral head which fits into the acetabulum forming the ball-and-socket joint. This joint is referred to as a triaxial joint because it has range of motion in three axes. The extensive range of motion exhibited by the hip allows for a variety of movements. Paleopathological research on the hip joint complex considers the relationship between OA and activity, and how an individual would sustain variable amounts of wear on this joint depending on lifestyle hardships (Jurmain, 1999; Rogers and Waldron, 1995; Weiss and Jurmain, 2007).

Patterns of hip OA have been investigated in both the clinical and paleopathological contexts (Baetsen et al., 1997; Cameron and Macnab, 1975; Resnick, 1975; Waldron, 1997). Morphologically the most severe changes in osteoarthritis of the hip are found on the femoral head, which can be noted by the presence of erosion and eburnation on the superior surface (Ortner, 2003). Some studies have investigated the anatomical position of OA on the femoral head such as medial or superior (Waldron, 1997). Clinical research has identified multiple types of hip OA. The femoral head tends to sink deeper within the acetabulum during pathogenesis of OA and is usually oriented superiorly, medially, or axially (Cameron and Macnab, 1975; Resnick and Niwayama, 1995; Waldron, 1997). Additional clinical research has identified up to six patterns of hip OA based on radiographic data (Cameron and Macnab, 1975).

Eburnation of the superior pole is more common than medial and axial poles eburnation (Cameron and Macnab, 1975). Also, eburnation on the more common superior pole is usually unilateral and frequently bilateral when on the axial and medial poles (Waldron, 2009). Another morphological characteristic on the femoral head, although quite rare and only found in extreme cases of OA, is referred to as a mushroom deformity when marginal extoses overhang the femoral neck (Mann and Hunt, 2005; Ortner, 2003; Waldron, 1997). Also noted in most cases are large lytic cavities on the femoral head as well as osteophytes on the intracapsular portion of the femoral neck (Ortner, 2003). There are certain conditions which predispose the hip to osteoarthritis such as “congenital hip dislocation, slipped capital femoral epiphysis and Legg-

Calve-Perthes disease" (Waldron, 2009:38). These conditions lead to what is referred to as acetabular dysplasia, and can cause deformities on the acetabulum itself such as marginal lipping, deepening of the socket, and in rare cases protrusion into the pelvis. These characteristics in combination allow osteoarthritis of the hip to be easily diagnosed visually in the archaeological context while sometimes much harder to investigate in the living due to the limitations of x-rays in resolution of the joint surface (Waldron, 2009). The hip joint being the largest of all the synovial complexes receives much attention in both the bioarchaeological and clinical literature. Research pertaining to patterns, prevalence, and severity of hip OA within and between populations has offered much data on etiology and pathogenesis (Bridges, 1991; Jurmain, 1977a; Waldron, 1997; Weiss and Jurmain, 2007).

A study by Waldron (1997) investigated the historical trend of hip OA on skeletal material from three different time periods recovered from various sites in England. The findings were interesting in that OA of the hip goes from 12.8% prevalence in Pre-Medieval, to 5.7% in Medieval, and finally down to 2.9% Post-Medieval. This indicates that OA of the hip may be more common in the far past and less a disease of modernity. Other studies have found varying levels of hip OA but in most cases the incidence and prevalence are usually low (Bridges, 1991; Jurmain, 1990; Larsen, 1982; Merbs, 1983). A study by Jordan et al. (1995) found that when OA rates from a rural North Carolina population were compared to U.S. urban population rates, that hip OA was markedly higher in the rural population (25.1% vs. 2.7%) which was attributed to the hardships of rural life. Trinkaus (1983; 1985) found OA to be quite prominent in Neandertal skeletons and this was also attributed to lifestyle hardships. One individual had severe left acetabular OA and no evidence of the pathological condition on the other leg indicating unilateral manifestation (Trinkaus, 1985).

Jurmain's (1980) study investigated the rates of moderate and severe appendicular OA in four distinctly different skeletal population samples. The findings were that the modern white male population had the highest rate of moderate OA (51%) followed closely by the modern black male population (47.3%). The modern white male population also had the highest rate of severe OA (2.9%) followed closely by the male Eskimo population (2.8%). Females had lower rates of moderate hip OA than males but white and black females had higher rates of severe hip OA than white and black males (WF-13.1% vs. WM-2.9% and BF-7.8% vs. BM-1.8%). The populational differences in rates of OA reflect variable biomechanical demands which are attributed to differing subsistence strategies and lifestyles (Larsen, 1997).

Although it is best to avoid attributing OA patterning to specific activities of a population sample (Jurmain, 1999), the availability of ethnohistorical data describing the population being studied, correlations with site-specific OA have been observed in the skeletal record (Angel, 1966; Merbs, 1983; Ortner, 1968). Patterns of hip OA have been found in association with horseback riders from the American Great Plains (Bradtmiller, 1983). These patterns have been explained as the result of specific loading which occurs during horse-back riding (Reinhard et al., 1994).

Comparative-based studies investigate possible etiological factors within and between population samples. Assessment studies in which no comparison is being made investigate the demography of OA within the sample of interest (Weiss and Jurmain, 2007).

Materials

All skeletal material utilized in this study comes from a collection associated with the Dakhleh Oasis Project. The Dakhleh Oasis Project (DOP) is a multinational interdisciplinary research project which focuses on the advancement of knowledge about the patterns of human biocultural adaptation to the environmental stress of a desert ecosystem (Dupras, 1999). The Dakhleh Oasis is one of five great depressions which can be found in the harsh and arid Western Sahara Desert of Egypt, approximately 250 kilometers west of the Nile as shown in the bottom left of Figure 7 (Dupras, 1999; Wheeler, 2009; Williams, 2008). The site where the individuals from this study originate is called Kellis 2, which is a Roman-Christian period cemetery (A.D. 50 – A.D. 450). The Kellis 2 cemetery is associated with the ancient town of Kellis, which at its peak during the 4th century was considered an important political and economic hub and is believed to have housed several thousand people (Dupras, 1999).

The environment in this region is consistent with that of other desert ecosystems exhibiting generally high temperatures, little annual rainfall, and frequently violent wind/sand storms (Dupras, 1999). This unique confluence of various ecological factors such as the aridity of the desert, alkalinity of the soil, and low rates of precipitation has allowed for excellent hard tissue (skeletal) and some soft tissue (hair, skin, finger/toe nails) preservation (Williams, 2008). These former factors which characterize the mortuary environment at Kellis 2 make this geographical region exceptional for bioarchaeological studies such as; the incidence of pathological lesions, isotopic research regarding diet and migration, paleodemography, or methods of subsistence (Dupras, 1999; Wheeler, 2009; Williams, 2008).The individuals from the Kellis 2 cemetery have exceptional skeletal preservation which makes for excellent research opportunities.

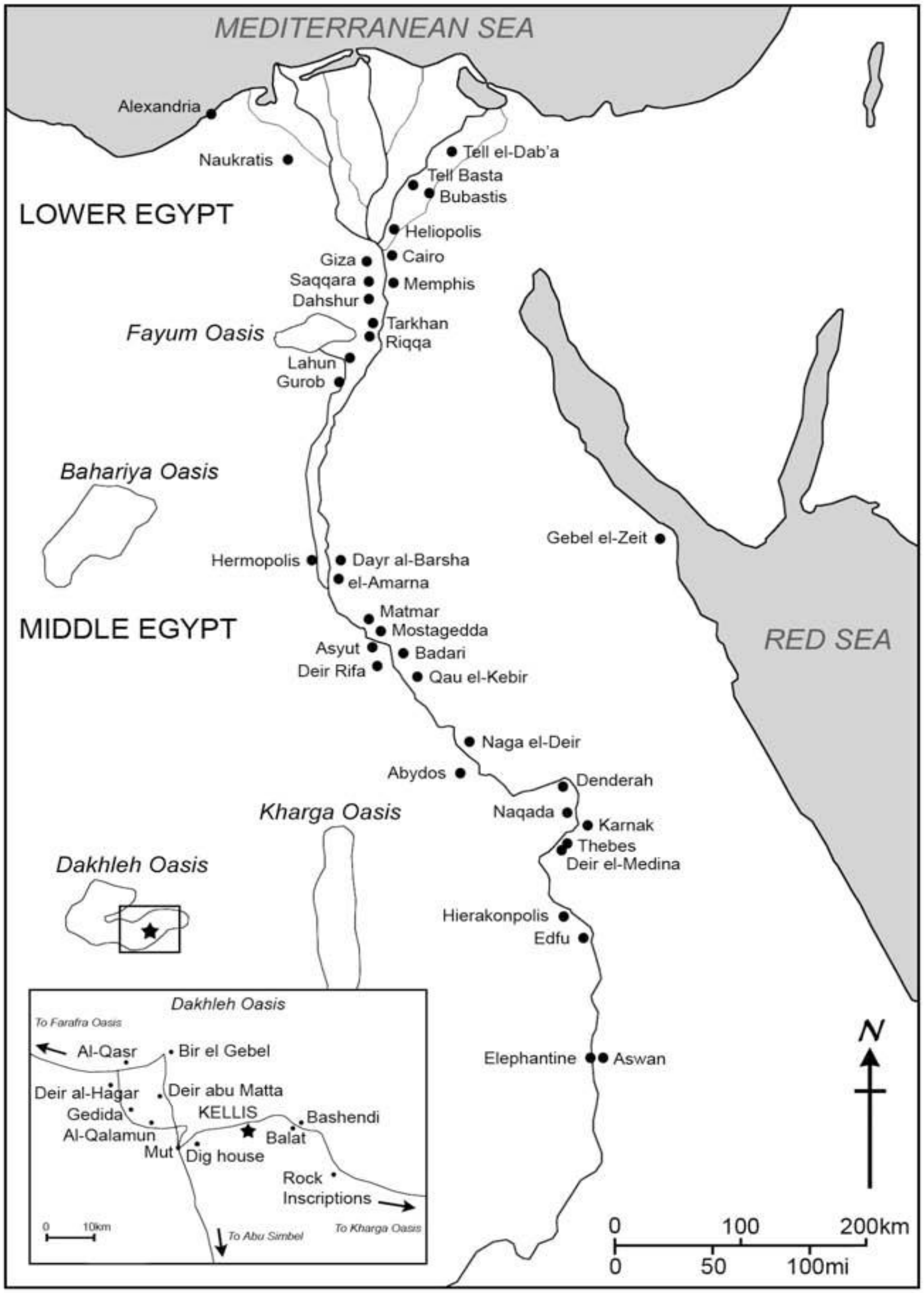

Figure 7: Map of Egypt Indicating the Location of the Dakhleh Oasis (Williams, 2008)

The burials at Kellis 2 are in most cases simple pit graves with mud brick either lining the entire grave, covering the top of the grave, as well as various other patterns. Figure 8 is a map of the Kellis 2 cemetery exhibiting the orientation of the graves and extent of the cemetery. The map on Figure 8 also indicates which graves have been identified, excavated, and the grave which have been found to be empty. Four tomb structures have been identified and are thought to possibly be family groups (Molto, 2001). Most graves are single interments with the exception of a few females with an infant, and multiple juveniles (Wheeler, 2009). The socioeconomic status of those buried at Kellis 2 is unknown based on the lack of grave goods or exuberant tomb structures (Dupras, 1999). Roughly 25% of all graves have had either some sort of jewelry (common with children) or some type of ceramics (Wheeler, 2009). Williams (2008) states that 46% of all graves have been anthropogenically disturbed which may account for the lack of grave goods.

Although occupation of the individuals buried at Kellis 2 cannot be derived, the town of Kellis is closely peripheral to many agricultural fields and the regions geological proximity from the water table would have adequately provided water for agricultural development as it does currently (Dupras, 1999). Research by Dupras (1999) investigated stable isotopic values of skeletal material from Kellis 2 and identified various foods which were consumed by the individuals buried there. In addition to isotopic values determined by Dupras (1999) which indicate the general dietary patterns of this sample, the isotopic data also indicated that the males were likely periodically migrating to and from the Nile River Valley (Dupras and Schwarcz, 2001). There has also been the exceptional acquisition of a written codex known as the Kellis Agricultural Account Book (Bagnall, 1997). This document describes the various crops and associated prices with inventory information as well (Bagnall, 1997). These two lines of evidence are direct links to the subsistence agricultural practices which occurred at Kellis. Agricultural practices require significant amounts of manual labor and as previously stated OA is primarily an age and activity related pathological condition therefore those who participate in agriculture would show signs of OA, possibly even site specific OA (Jurmain, 1977a; Jurmain, 1999; Larsen, 1997; Weiss and Jurmain, 2007).

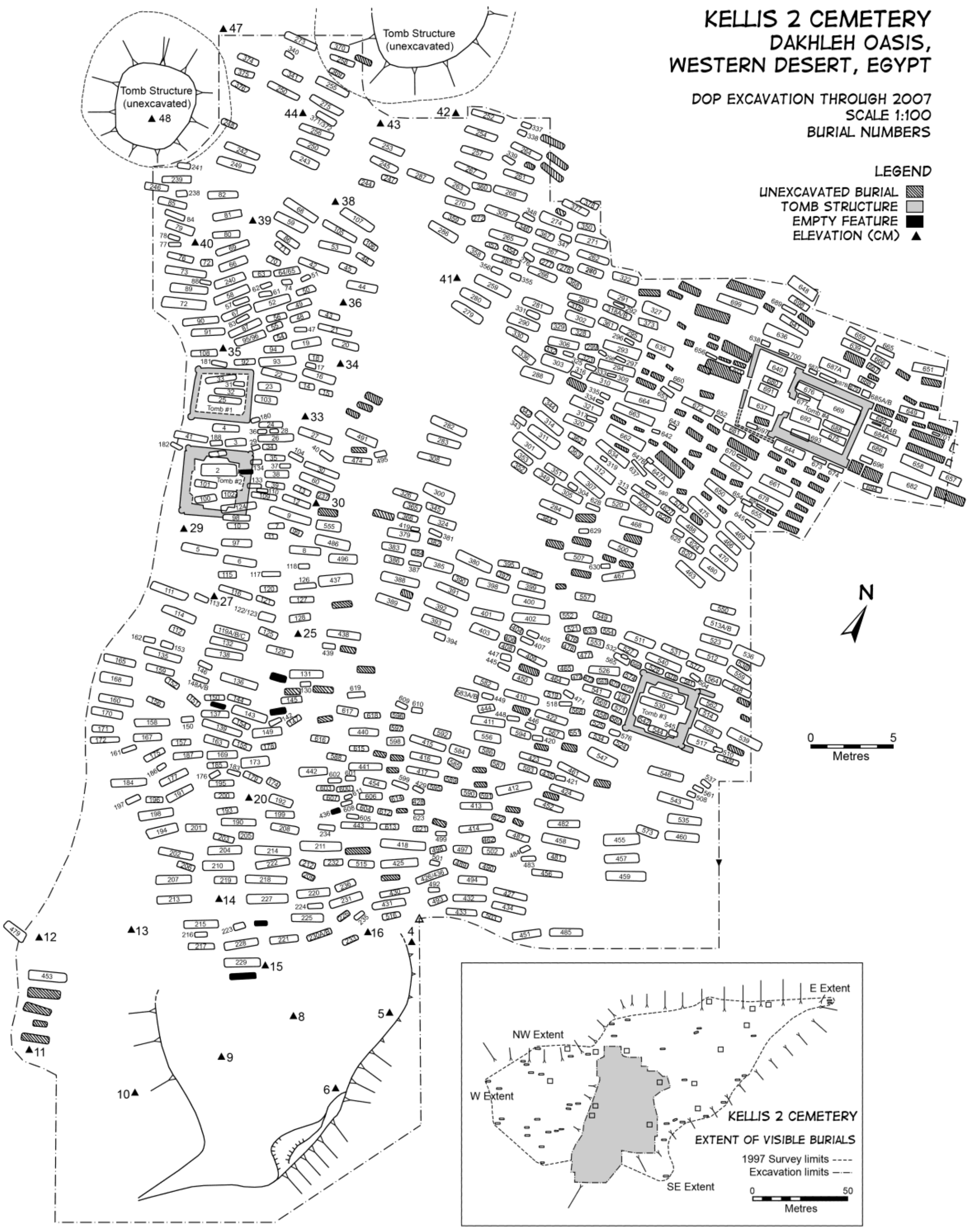

Figure 8: Map of Kellis 2 Cemetery (Williams, 2008)

Body preparation varies to some degree. Typically, the bodies were wrapped in linen shrouds in a lateral or crisscross motion and bound by thin linen rope (Wheeler, 2009). Interestingly the body preparation of some of the burials is reminiscent of ancient Egyptian mummification as described by Aufderheide (2003). Williams and Dupras (2004) find that some linens were found to contain a clay-like mixture which was composed, as determined by preliminary chemical analysis, of modern-day desiccants such as botanical oils (pine, castor, acacia), and manganese phosphate, sodium bicarbonate. These products and others were used during dynastic times in association with mummification as well (Aufderheide, 2003). Assortments of herbs including various types of myrrh have been found both on the body and within the wrappings. Fig. 9 is a great example of this type of mortuary preparation.

Figure 9: Burial from 2011 Season with Wrappings and Myrrh

As of 2010, 701 burials from the Kellis 2 cemetery had been excavated and analyzed, with approximately 255 of those individuals being adults (Wheeler, 2009). A list of all burials with a variety of information including but not limited to; age, sex, length, width, depth, etc. was provided for the author in the form of a Microsoft Excel © spreadsheet by Dr. Dupras. Being that osteoarthritis is highly dependent on age, the individuals chosen for this study were from the adult population (>15 years of age) of the Kellis 2 cemetery. This age was chosen as a general beginning of adulthood age but the determinant factor in this project was whether or not the individual had been sexed. Secondary sexual characteristics on the human skeleton are present at or around the time of adulthood and therefore this was an important factor in inclusion and exclusion of individuals from this study. The ages of the 255 adults are seventeen years of age being the youngest, and seventy-two years of age being the oldest, and the mean age of 38.53 shown on Table 2.

Table 2: Adult Population Descriptive Age Statistics

Descriptive Statistics	**Number of Individuals**	**Minimum Age**	**Maximum Age**	**Mean Age of Sample**
Age (years)	255	17	72	38.53

The author modified the original database by removing all individuals who did not meet the previously stated requirements. From those 255 individuals, 151 are female and 104 are male (Table 3) which is slightly disproportionate but reflective of mortality patterns during this period when considering factors such as childbirth without medical intervention (Wheeler, 2009). The proportion of males to females is roughly 1:1.5. Males make up 40.8% of the adult sample and females make up 59.2% of the adult sample (Table 3). Osteological prerequisites for this study were completeness of the individual (at least 50%) as well as both clean and intact joint margins and surfaces.

Table 3: Adult Demographic Representation at Kellis 2

SEX	NUMBER OF INDIVIDUALS	PERCENT OF SAMPLE
F	151	59.2%
M	104	40.8%
TOTAL	255	100.0%

An important factor in this study was the ability to control for age and sex, therefore those of unknown age and/or unknown sex were excluded. Final decision for individuals utilized in this study was based off the former prerequisites and accessibility at the storage facility in Dakhleh. The final sample which was assessed for osteoarthritic severity consisted of 135 individuals. Of the 135 adults including 84 females and 52 males (Table 3) which is a closely proportional demographic representation of the actual adult paleodemography of Kellis 2 when one compares the Valid Percents from Table 3 and Table 4. This is ideal from a statistical perspective because the amount in a sample should be demographically proportional to the actual population represented by the entire osteoarchaeological sample.

Table 4: Males and Females Analyzed in Study

SEX	NUMBER OF INDIVIDUALS	PERCENT OF SAMPLE
F	84	62.2%
M	51	37.8%
TOTAL	135	100.0%

All individuals utilized in this study were grouped into age categories as a means of controlling for age. In order to achieve precision during statistical analysis the author recoded the individuals into five age groups similar to Jurmain (1977a) for this study based on the age range of the sample assessed which was 19-72 with a mean of 37.41 years. Group one has an age range of 19-24 years, group two 25-35, group three 36-45, group four 46-55, and group five>55 as shown in Table 5. The age groups with frequency of individuals and percentage of sample is shown on Table 6. The age groups are cross-tabulated with the known sex of the individuals from this study and are shown on Table 7. A total of 540 joint surfaces (270 joint complexes) from the hip were analyzed and scored for paleopathological characteristics associated with osteoarthritis.

Table 5: Age Categories Defined in this Study

Age Category	Summary of Age Range (years)
1	19-24 years
2	25-35 years
3	36-45 years
4	46-55 years
5	>55 years

Table 6: Age Group Frequencies in Sample

AGE CATEGORY	NUMBER OF INDIVIDUALS	PERCENT OF SAMPLE
1	28	20.7%
2	50	37.0%
3	17	12.6%
4	26	19.3%
5	14	10.4%
TOTAL	135	100.0%

Table 7: Age Group Distribution Cross-tabulated with Sex Groups

Sex	Age Categories					Total
	1.00	**2.00**	**3.00**	**4.00**	**5.00**	
F	18	29	11	19	7	84
M	10	21	6	7	7	51
Total	28	50	17	26	14	135

Methods

The methods for scoring OA vary significantly depending on who is doing the reporting (Bridges, 1993; Waldron and Rogers, 1991). The difficulty of this matter is due to the conflicting ideas in regarding the diagnostic criteria for OA (clinical vs. archaeological), and which of the bony features associated with the disease can be best used to positively diagnose OA. While there have been attempts made at determining a universal diagnostic criteria for OA, clinical and archaeological studies use different means of identifying the disease (Bridges, 1993; Resnick, 1975; Rogers and Waldron, 1995). There is also significant variation in coding of OA within the discipline of physical anthropology and paleopathology. Ultimately, the means by which these traits are observed is a determining factor in diagnostic criteria.

Those who do research in paleopathology persistently advocate the need for a universal scoring and classification system of OA (Bridges, 1993; Rogers and Waldron, 1995; Weiss and Jurmain; 2007). The past few decades have brought upon new methods for determining age, sex, ancestry, stature, and most notably for this study; assessment and diagnosis of pathological conditions. Many of these methods can be found in Buikstra and Ubelaker's (1994) *Standards for Data Collection From Human Skeletal Remains*, and the methodology utilized in this study are derived and adapted from this text. While each researcher has their general proclivity towards what is best to determine osteoarthritic development, Buikstra and Ubelaker (1994) list all bony features associated with OA as a means of diagnosing the disease, and determining its severity.

The author assessed osteoarthritic severity based on the manifestation of bony characteristics associated with osteoarthritis. These characteristics are: the presence of surface osteophytes, degree of porosity, degree of marginal lipping, extent of marginal lipping, and eburnation. Although many researchers use the presence of two or three of the previously mentioned osteological characteristics, the author has chosen to use all the characteristics as consideration for the indication of OA. Associated scores for the formerly mentioned osteological characteristics are shown on Table 8. Each of the joint surfaces of the hip was scored based on the manifestation of the aforementioned osteological characteristics.

Table 8: Osteological Characteristics of OA with Associated Scores

Osteophytes		**Porosity**		**Degree of Marginal Lipping**		**Extent of Marginal Lipping**		**Eburnation**	
0	Absent	0	No porosity	0	Absence of lipping	0	No lipping	0	Absent
1	Present	1	Observable pinpoint porosity	1	Slight or moderate lipping	1	<1/3 of joint surface	1	Polished
		2	Extensive pitting	2	Well defined lipping (sharp ridge)	2	1/3-2/3 of joint surface	2	Streaked
		3	pitting on majority of joint surface	3	Distinguishably deep ridge	3	>2/3 of joint surface	3	Multiple striations

One-hundred and thirty-five skeletons were visually examined in this study for OA incidence (number of individuals found to have OA), demographic prevalence (number of OA cases divided by the number of individuals within each age category), anatomical distribution, and severity. The methodology is designed as a means of describing the demographic and anatomical patterns of OA observed in the Kellis 2 sample. Goals of analysis are descriptive based, identifying patterns such as the most and least OA afflicted joint complex/surface, sexual dimorphism (variations in prevalence), and laterality. Bridges (1993) discusses how these are good questions to be asked when assessing a single sample as a means of establishing the demography of OA. The first stage of the analysis was to score each locus of the joint complex, in this case the femoral head and the acetabulum.

The methods utilized in this thesis are based on the generally accepted opinion that the presence of one or two of these osteological characteristics is not indicative of OA with the exception of eburnation (Rogers and Waldron, 1995; Jurmain, 1999; Waldron, 2009). Most researchers use the presence of two or three of these characteristics as diagnostic criteria in the absence of eburnation (Jurmain, 1977b; Bridges, 1991). The author has chosen to diagnose osteoarthritis based on the scores of all osteological characteristics for distinguishable diagnostic precision and as a means of later determining which osteological characteristic correlates most strongly with eburnation. Those individuals with joint surfaces that had scores for each osteological characteristic that were higher than zero or showed the presence of eburnation were considered to be osteoarthritic.

This method differs from most OA studies in that instead of identifying moderate from severe OA (Bridges, 1991; Jurmain, 1977a), the author's methodology simply identifies the incidence of OA. In order to differentiate from moderate and severe, one simply needs to consider all who exhibit OA and separate those with eburnation from those without, and this would define a moderate and a severe group. This method allows for the determination of frequency or incidence of OA at each specific joint surface. Cross-tabulations of OA incidence with age and sex categories determined the demographic prevalence of OA at that joint locus and later for each joint complex. The next step was to determine the anatomical distribution of OA both within and between the left and right hip joint complexes based on the presence of OA anywhere in the complex.

Following visual inspection and assessment of 135 left and right acetabulae and proximal femora, the scores for each individual were typed into a Microsoft Excel Spreadsheet ©. The data from this study was then uploaded into IBM SPSS Statistics 19 © software program to make the necessary quantifications. The variables for the osteological characteristics of osteoarthritis were re-coded into variables which could inform on whether that individual joint surface was osteoarthritic. Using the COMPUTE VARIABLE function in SPSS, the author re-coded the OA characteristic variables from the acetabulum and femoral head to determine incidence and prevalence of L/R acetabular and femoral head OA, the prevalence of left and right hip OA, laterality prevalence, and the maximum joint complex scores for the left and right hip.

The incidence of OA was based on the number of females and males with hip OA, and the prevalence was the number of those with OA divided by the entire sample (within and between the sexes). Sex differences may indicate sexual dimorphism and/or sexual divisions of labor. Age group differences may reinforce the expectation that OA is mainly an age-related phenomenon as indicated by an increased percentage prevalence is associated with increased age group levels. The last step was to use joint surface scores to determine the levels of severity of OA for each joint complex. This information will inform on the anatomical distribution and severity rank of OA in the hip joint complex.

<u>Results</u>

Acetabulum

The incidence of OA is the amount of individuals within a sample diagnosed with OA, and the prevalence of OA is calculated by dividing the amount of individuals afflicted with OA by the total number of individuals within the sample. Table 9 shows the frequency and prevalence of OAon135 left acetabulae assessed. The frequency of left acetabular OA is 9 individuals, and the prevalence is 6.7%.The frequency of right acetabular OA is 10 individuals, and the prevalence of right acetabular OA is 7.4% (Table 10). Acetabular OA is slightly more common on the right side. This data represent the overall frequency and prevalence of osteoarthritis in the acetabulum in the 135 individual skeletal samples from the Kellis 2 cemetery population.

Table 9: OA Frequency of the Left Acetabulum

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	126	93.3
Present	9	6.7
Total	135	100.0

Table 10: OA Frequency of the Right Acetabulum

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	125	92.6
Present	10	7.4
Total	135	100.0

The next step is to look at the demographic prevalence of OA within the established age and sex groups. Table 11 exhibits a cross-tabulation of age groups and sex groups with the incidence of osteoarthritis of the left acetabulum. As expected both males and females within the first age category (19-25) show no indication of osteoarthritis of the left acetabulum. One single male and female in the second age category (25-35) were observed as being osteoarthritic in the left acetabulum. Similar to the first age category, the third (36-45) is lacking any sign of OA on the left acetabulum as well. Age categories four (46-55) and five (>55) is where OA is seen to be highly prevalent. One female exhibits left acetabular OA in both age categories four and five. Three males from age category four and two males from age category five, exhibit diagnostic evidence of OA. The female frequency of left acetabular OA is 3 individuals while the male frequency is 6 individuals (F-33.3% and M-66.6%).The results from these tests indicate that the female prevalence of left acetabular OA is 3.7% and the male prevalence is 11.8%.

Table 11: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Left Acetabulum

Sex	OA	Age Categories					Total Sample
		1.00	2.00	3.00	4.00	5.00	
F	N	0/18	1/29	0/11	1/19	1/7	3/84
	%	0	3.4	0	5.3	14.3	3.6
M	N	0/10	1/21	0/6	3/7	2/7	6/51
	%	0	4.8	0	42.9	28.6	11.8

To determine anatomical differences in the manifestation of acetabular OA it is necessary to examine both acetabulae. Table 12 exhibits a cross-tabulation of age groups and sex groups with the incidence of osteoarthritis of the left acetabulum. Once again as expected there is not a single individual with the first age category who exhibits the diagnostic characteristics of OA on the right acetabulum. One single female had OA of the right acetabulum in the second age category, and one single male had OA of the right acetabulum in the third age category. The majority of those individuals who exhibit the diagnostic characteristics of OA on the right acetabulum are in age category four and five. One female and four males in age category four are osteoarthritic within the right acetabulum. The prevalence goes up for females and down for males in the fifth age category. The female frequency of right acetabular OA is 4 individuals while the male incidence is 6 individuals. The results from these tests indicate that female right acetabular OA prevalence is 4.8%, and for males is 11.8%. The age-related data indicates that individuals within age category five make up 30% of those positively diagnosed with right acetabular OA.

Table 12: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Right Acetabulum

Sex	OA	Age Categories					Total Sample
		1.00	2.00	3.00	4.00	5.00	
F	N	0/18	1/29	0/11	1/19	2/7	4/84
	%	0	3.4	0	5.3	28.6	4.8
M	N	0/10	0/21	1/6	4/7	1/7	6/51
	%	0	0	16.7	57.1	14.3	11.8

The graphs shown on Figure 10 indicate some interesting patterns. Those in the top section denoted by “0” are not arthritic while those in the bottom section denoted with a “1” are positive for OA. Firstly, the graph indicates the relatively low rate of acetabular OA, secondly it also indicates that males are more afflicted than females, but females tend to be afflicted at an earlier age than males. The spike in right acetabular OA for males around the age of 55 may indicate extended years of physical labor or that age is a more significant etiological factor in the pathogenesis of OA for males than females.

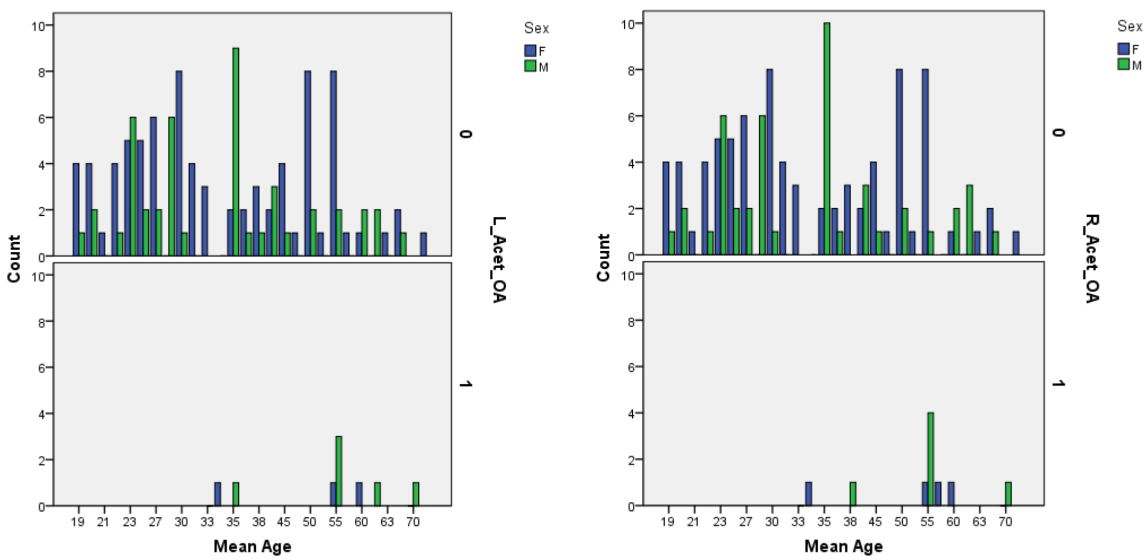

Figure 10: Graphs Illustrating the Age and Sex Distribution of OA in Left and Right Acetabulae

Femoral Head

When considering the hip joint one cannot simply regard one surface of the joint, as in most OA cases if one surface exhibits osteological characteristics its' opposing or articulating surface will as well (Resnick and Niwayama, 1995a; Rogers and Waldron, 1995). Table 13 shows the osteoarthritic frequency and prevalence on 135 left proximal femora. The frequency of OA on the left femoral head was 5 individuals and the prevalence was 3.7%.Table 14 illustrates the osteoarthritic frequency of 135 proximal right femora. The frequency of OA on the right femoral head was 3 individuals and the prevalence was 2.2%. OA was found to be slightly more common on left side.

Table 13: OA Frequency of the Left Femoral Head

OA	Number of Individuals (N)	Prevalence (%)
Not Present	130	96.3
Present	5	3.7
Total	135	100.0

Table 14: OA Frequency of the Right Femoral Head

OA	Number of Individuals (N)	Prevalence (%)
Not Present	132	97.8
Present	3	2.2
Total	135	100.0

To determine the demographic prevalence of the disease, the frequency of OA was cross-tabulated with age and sex categories from the sample (Table 15). As with both left and right acetabulae, the frequency of OA in age category one is non-existent. One single female from age category two exhibits left femoral head OA. Interestingly there is no sign of OA in age category three although there are only six males and eleven females in this category. There is one single male with OA in age category four. As expected, the majority of individuals with left femoral head OA can be found within age category five. One female and two males are found to osteoarthritic in this category. The female frequency of left femoral head OA is 2 individuals and the male incidence is 3 individuals (F- 40% and M-60%). The final demographic findings for left femoral head OA is female prevalence of 2.4%, and a male prevalence of 5.9%. This data reveals males are more afflicted by left femoral head OA than females.

Table 15: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Left Femoral Head

Sex	OA	Age Categories					Total Sample
		1.00	2.00	3.00	4.00	5.00	
F	N	0/18	1/29	0/11	1/19	1/7	3/84
	%	0	3.4	0	5.3	14.3	3.6
M	N	0/10	0/21	0/6	1/7	2/7	3/51
	%	0	0	0	14.3	28.6	5.9

The cross-tabulation of right femoral head OA prevalence (Table 16) with age and sex group exhibits arthritic changes similar to the left femoral head. As with the former joint surfaces assessed, there are no cases with OA on the right femoral head within the first age category. There also are no other cases with OA until age category four. There is one male in age category four and one female in age category four with OA of the right femoral head. The female frequency of right femoral head OA is 1 individual and the male incidence is 2 individuals (F-33.3% and M-66.6%). The final demographic findings for the right femoral head OA is a female prevalence of 1.2% and a male prevalence of 3.9%. Males tend to be more affected on the by OA on the right side similar to the left side. The graphs on Figure 11 indicate that femoral head OA is more common on the left side, but in general is not too common within the Kellis 2 cemetery population sample. Those in the top section denoted by "0" are not arthritic while those in the bottom section denoted with a "1" are positive for OA.

Table 16: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Right Femoral Head

Sex	OA		Age Categories					Total Sample
			1.00	2.00	3.00	4.00	5.00	
F		**N**	0/18	0/29	0/11	1/19	0/7	1/84
		%	0	0	0	5.3	0	1.2
M		**N**	0/10	0/21	0/6	1/7	1/7	2/51
		%	0	0	0	14.3	14.3	3.9

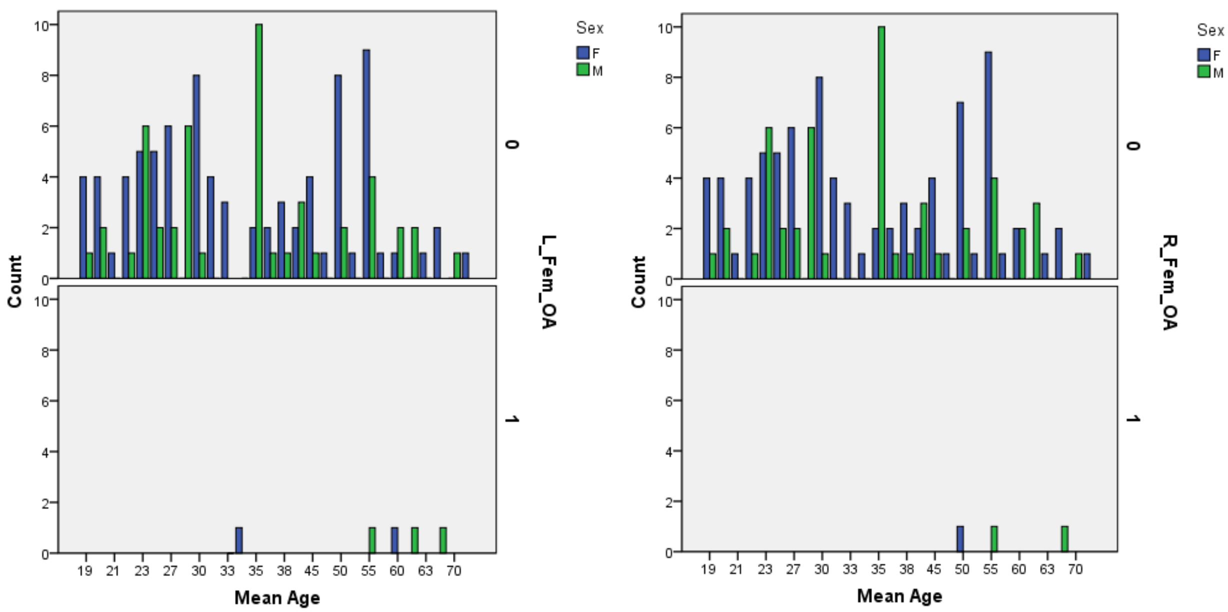

Figure 11: Graphs Illustrating the Age and Sex Distribution of OA in Left and Right Proximal Femora

The Hip Joint Complex

The frequency of left hip OA is 10 individuals with a prevalence of 7.4% of the 135 individuals assessed. The frequency of right hip OA is 12 individuals with a prevalence of 8.9% of the 135 individuals (Tables 17 and 18). These results indicate that OA is slightly more common on the right side than on the left.

Table 17: OA Frequency of the Left Hip

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	125	92.6
Present	10	7.4
Total	135	100.0

Table 18: OA Frequency of the Right Hip

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	123	91.1
Present	12	8.9
Total	135	100.0

The demographic prevalence of left hip OA is shown cross-tabulated with age and sex groups on Table 19. One female and one male from age category two are found to have OA of the left hip. No individuals for age category three have OA while age categories four and five both have one female and three males. The frequency left hip OA for females is 3 individuals while the male frequency is 7 individuals (F-30% and M-70%).The female prevalence of left hip OA is 3.6% while the male prevalence is 13.7%.Females make up 30% of the incidence of left hip OA while males make up 70% of the frequency. 80% of the frequency of left hip OA is from age category four and five.

Table 19: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Left Hip

			Age Categories					Total
Sex	**OA**		**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	Sample
F		**N**	0/18	1/29	0/11	1/19	1/7	3/84
		%	0	3.4	0	5.3	14.3	3.6
M		**N**	0/10	1/21	0/6	3/7	3/7	7/51
		%	0	4.8	0	42.9	42.9	13.7

The demographic prevalence of right hip OA is shown cross-tabulated with age and sex groups on Table 20. One female is found to have OA of the right hip in age category two, and one male with OA in age category three. There are two females with OA in age category four and four males in age category four. In age category five there are two females and two males. The female frequency of right hip OA is 5 individuals while the male incidence is 7 individuals

(F-41.7% and M-58.3%). The female prevalence of right hip OA is 5.9%. The male prevalence of right hip OA is 13.7%. The highest frequency of right hip OA (83.3%) comes from age categories four and five. The frequency of bilateral hip OA is 8 individuals with a prevalence of 5.9% while the frequency of unilateral OA is 14 individuals with a prevalence of 10.4% (Tables 21 and 22). These results indicate that unilateral hip OA is more common than bilateral hip OA.

Table 20: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Right Hip

Sex	OA	Age Categories 1.00	2.00	3.00	4.00	5.00	Total Sample
F	N	0/18	1/29	0/11	2/19	2/7	5/84
	%	0	3.4	0	10.5	28.6	5.9
M	N	0/10	0/21	1/6	4/7	2/7	7/51
	%	0	0	16.7	57.1	28.6	13.7

Table 21: Bilateral OA Frequency of the Hip

OA	Number of Individuals (N)	Prevalence (%)
Not Present	127	94.1
Present	8	5.9
Total	135	100.0

Table 22: Unilateral OA Frequency of the Hip

OA	Number of Individuals (N)	Prevalence (%)
Not Present	121	89.6
Present	14	10.4
Total	135	100.0

The demographic prevalence of bilateral hip OA is shown on Table 23. In age category two there is one female with bilateral hip OA. In age category four there is one female and three males. There is one female and two males in age category five with bilateral hip OA. Bilateral hip OA has a female frequency of 3 individuals and a male frequency of 5 individuals (F-37.5% and M-62.5%).The female prevalence of bilateral hip OA is 3.6% and the male prevalence is 9.8%. Males appear to be slightly more susceptible to bilateral hip OA than females.

Table 23: Age Group and Sex Group Cross-Tabulation with Bilateral Hip OA Frequency

Sex	OA	Age Categories					Total Sample
		1.00	**2.00**	**3.00**	**4.00**	**5.00**	
F	**N**	0/18	1/29	0/11	1/19	1/7	3/84
	%	0	3.4	0	5.3	14.3	3.6
M	**N**	0/10	0/21	0/6	3/7	2/7	5/51
	%	0	0	0	42.9	28.6	9.8

The demographic prevalence of bilateral hip OA is shown on Table 24. There one male and one female with unilateral hip OA in age category two. One male is found with unilateral hip OA in age category three. Two females and four males are observed with unilateral hip OA in age category four. There are two females and three males with unilateral hip OA in age category five. Unilateral hip OA has a female frequency of 5 individuals and a male frequency of 9 individuals (F-35.7% and M-64.3%).The female prevalence of unilateral hip OA is ~6% (5.95%) and the male prevalence is 17.6%. Males are more afflicted by unilateral hip OA than females.

Table 24: Age Group and Sex Group Cross-Tabulation with Unilateral Hip OA Frequency

		Age Categories					Total
Sex	**OA**	**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	Sample
F	**N**	0/18	1/29	0/11	2/19	2/7	5/84
	%	0	3.4	0	10.5	28.6	5.9
M	**N**	0/10	1/21	1/6	4/7	3/7	9/51
	%	0	4.8	16.7	57.1	42.9	17.6

Discussion

The various scores quantified from each joint locus have offered unique insight into the patterns of osteoarthritis in the hip joint complex in the Kellis 2 cemetery population sample. The overall prevalence of OA can be used to infer which joints are most afflicted, the specific surface which is affected by OA, and whether the disease has a side proclivity on either joint surface or complex. The raw frequency percentages of hip joint surface/complex OA indicate the demography of OA in the Kellis 2 cemetery population sample. Due to the fact that OA is considered by most to be an activity-related pathological condition (Bridges, 1992; Jurmain, 1999; Larsen, 1997; Waldron, 1997), the disease presence and patterning can be utilized in concordance with other lines of evidence such as archaeological or ethnohistorical data in the interpretation of general lifestyle patterns of past societies. Unfortunately for this sample there is no ethnohistorical data available, and the strongest archaeological evidence of lifestyle or subsistence is the Kellis Agricultural Accounting book (Bagnall, 1997) which clearly designates this sample as maintaining an agricultural subsistence regime. Isotopic evidence also supports this concept (Dupras, 1999).

This study offers unique data on not only the joint complex but each individual joint surface. The demographic prevalence of OA at specific loci can be informative about age or sex related pathogenic trends in this sample. Males from the Kellis 2 skeletal population have been found to make up 2/3 of the incidence of left acetabular OA. Male prevalence is higher in the advanced age groups whereas female prevalence tends to be similar in each of their representative age categories. The age related findings indicate that individuals from age categories four (46-55 years) and five (>55 years) make up 77.8% of individuals with left acetabular OA. Male prevalence is 11.8% and female prevalence is 3.7% for OA of the left acetabulum. Males from the Kellis 2 skeletal population are slightly more prone to OA of the left acetabulum than females.

The right acetabulum exhibits similar OA tendency. The males make up 60% of the incidence and the prevalence generally increases in by age group with each sex. Males are more afflicted by right acetabular OA than females, although both sexes show correlations with age. Eighty percent of the incidence for right acetabular OA can found in age categories four and five. The prevalence of right acetabular OA for males is 11.8% and for females is 4.8%. Males from the Kellis 2 skeletal population are slightly more prone to OA of the left acetabulum than females. Interestingly, on both the left and right acetabulae the youngest individual with OA is female and the oldest individual is male. Developmental differences may account for the age disparity in the onset of acetabular OA. Females develop acetabular OA earlier but males seem to be more affected with advanced age indicating that age is a more significant etiological factor for males than females. This same trend has been observed by Cook (1984) from the Lower Illinois Valley during an investigation into the health of a Woodland and Mississippian population sample.

The data from the proximal femora showed lower percentages of OA prevalence than the acetabulae. Males are more afflicted by left femoral head OA than females(3:2). Although there are so few males and females with left femoral head OA there still seems to be a trend that shows age to be a more significant factor for males and less for females. The age related findings indicate that 60% of the individuals from the Kellis 2 sample affected by left femoral head OA are older than 55 years of age. The youngest individuals with left femoral head OA is a female and the oldest is a male. The general pattern for left femoral head OA is that females differentially develop the disease at varying ages in their lives while males tend to develop the disease more with advanced age. Right femoral head OA is of low prevalence in this sample. Only three individuals are observed with this pathological condition. While the general prevalence is low, once again age seems to be a stronger etiological factor of OA on the right femoral head and males are also slightly more prone to right femoral head OA than females. More individuals were found with OA on the left femoral head than the right.

Comparing the scores and percentage OA prevalence from each joint can also inform on possible patterns related to pathogenesis and pathophysiology. For example the data from the left and right acetabulae and proximal femora (Table 25) when discussed in raw percentages indicates that acetabular OA (L- 6.7% and R-7.4%) is more common than femoral head OA (L-3.7 % and R-2.2%). It therefore may be suggested that perhaps hip OA pathogenically begins in the acetabulum and ends in the femoral head, resulting in eburnation or a mushroom head deformity (Waldron, 1997). Clinical and paleopathological research indicates that this tends to be the general pattern with hip OA in that cartilage from the acetabulum begins to erode negatively impacting the structural integrity of the joint capsule and causing the superior aspect of the femoral head to also become arthritic (Cameron and Macnab, 1975; Waldron, 1997). Males having higher rates of hip OA may be interpreted etiologically as being related to activity and perhaps body size. Disparities of OA manifestation between males and females can be interpreted as possible sexual divisions of labor, not attributable to a specific activity but instead relative activity level or biomechanical stress demands (Jurmain, 1999; Larsen, 1997).

Table 25: Percentage of Acetabular and Femoral Head OA Prevalence by Group in Sample

Group	Acetabulum		Femoral Head	
	Left	Right	Left	Right
Males	11.8%	11.8%	5.9%	3.9%
Females	3.7%	4.8%	2.4%	1.2%
Total Sample	6.7%	7.4%	3.7%	2.2%

More generally speaking it can be simply observed through the raw frequency percentages of OA within and between joint surfaces/complexes that Kellis 2 males are more afflicted by OA than females. Merbs (1983) found similar levels of sexual dimorphism for OA of the hip and attributed it the male Inuit performing more strenuous tasks than females, indicative of sexual divisions of labor. Bridges (1991) suggests, based on comparative OA findings from a pre-agricultural (Archaic) sample and a post-agricultural sample from the Southeastern United States, that sexual dimorphism of OA is found more in agriculturists than hunter-gatherers, also indicating sexual divisions of labor. Taking into consideration that this sample is mostly female (1:1.5), there is quite a high disparity in OA prevalence both on the left hip and the right hip for males and females as seen in Table 26. Interestingly in males the prevalence of hip OA is equal on left and right sides whereas in females OA is observed more on the right hip. The total sample hip OA prevalence is observed slightly more on the right hip than the left (Table 26).

Table 26: Prevalence of Hip OA

Group	Left Hip	Right Hip
Males	13.7%	13.7%
Females	3.6%	5.9%
Total Sample	7.4%	8.9%

Hip OA in the Kellis 2 sample also tends to be unilateral in both males and females as opposed to bilateral as indicated on Table 27.Laterality is a very important aspect of OA because in many cases one can assume that unilateral OA is secondary and bilateral is primary. Both males and females exhibit higher levels of unilateral OA. The general anatomical pattern of OA in the Kellis 2 sample as indicated by the data suggests that unilateral OA of the right hip is perhaps the most common pattern. This data may also mean that the pathogenic pattern of OA in the Kellis 2 sample is that OA of the hip begins in the right and left acetabulae, and then the right hip complex becomes entirely more arthritic. Age related findings indicate that unilateral OA is more correlated with advancing age therefore it is unlikely that this pattern begins unilateral and then later becomes bilateral pathogenically.

Table 27: Laterality Prevalence of Hip OA

Group	Unilateral	Bilateral
Males	16.7%	9.8%
Females	5.9%	3.6%
Total Sample	10.4%	5.9%

Based on rates of prevalence it seems that hip OA tends to develop in females earlier within this population but advances more severely in males later in life (Figure 12).Females' bodies develop slightly faster than males and it may be suggested that degenerative osteological processes may occur slightly earlier in the female similar to maturation patterns.For example, osteoporosis is another pathological condition known to occur earlier in females (Ortner, 2003). Although each age category does not have an equal amount of individuals, the percentage of prevalence appears to be rising with advanced age; this is more evidence of the fact that age may play the most significant etiological factor of OA.

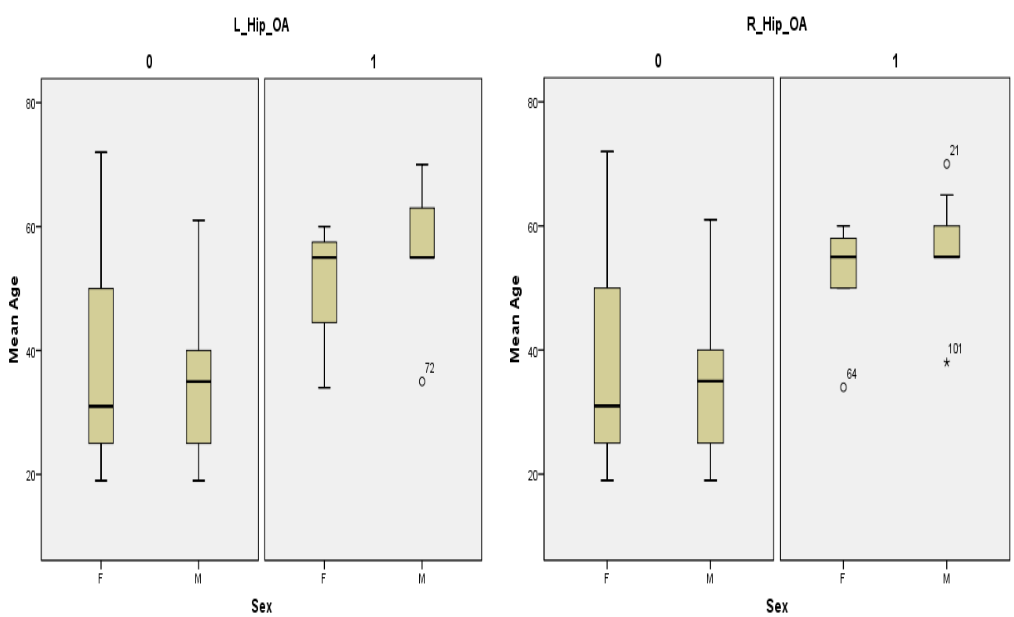

Figure 12: Box-Plot graphs of Age and Sex Distribution of Hip OA

The data indicates that age was perhaps a more significant etiological factor for males than females in the Kellis 2 skeletal sample. Males have higher rates of OA incidence and prevalence which is observed in virtually every population sample which been studied for OA (Bridges, 1991; 1992; Jurmain, 1977a,b; Larsen and Ruff, 2011). While rates are expected to be less for females than males, the disparity is significant enough to make interpretations regarding sexual divisions of labor. Most researchers will agree the pattern of OA cannot be conclusively attributed to a specific activity, but rather levels of mechanical loading underwent by the joint complex (Jurmain, 1999; Larsen, 1997). Being that OA is both an activity and age-related pathological condition, demographic variation of the manifestation of this disease can be culturally informative. The rates of hip OA between males and females while not indicative of variation in activity can be inferred as variation is workload demand or mechanical stress (Larsen and Ruff, 2011).

Conclusions

The purpose of conducting paleopathological research is to better understand the epidemiology of a bioarchaeological sample. Although there is not always a clinical equivalent for what osteologists observe in the field, the more research conducted the better these pathological conditions can be understood. There is a strong debate in the field of paleopathology that is focused on the concept of behavioral reconstruction. Some researchers believe that certain osteological characteristics such as OA are indicative of specific activities which can be utilized as a means of interpreting cultural patterns and behavior (Larsen, 1997). Other researchers, while accepting of the fact that OA is an activity-related pathological condition,also accept that based on modern clinical data OA cannot be conclusively attributed to specific activities based on patterning (Jurmain, 1999; Waldron, 2009).

The more contemporary and valid method for investigating OA is to describe the pathological condition vividly and determine the demographic patterning of OA within a sample (Weiss and Jurmain, 2007).Because this study utilizes different protocols for data collection and quantification, it is not possible to the compare it with previous studies conclusively. While specific rates for OA may not be comparable, the age and sex related patterns may be compared on a general basis (Bridges, 1993). Previous findings on OA in osteoarchaeological assemblages indicate that males have a higher OA prevalence than females regardless of subsistence strategy or socioeconomic status (Bridges, 1992). The sexual dimorphism of hip OA in the Kellis 2 sample do not "specifically define behaviors associated with either sex, but they are suggestive of contrasting patterns of physical activity" (Larsen, 1997; 177).The sexual dimorphism of hip OA in the Kellis 2 sample may be indicative of sexual divisions of labor; males were apparently doing more strenuous labor involving perhaps excessive heavy lifting (Jurmain, 1999; Merbs, 1983). This is concurrent with the findings of Pierce (1987) that males having significantly higher hip OA suggests change in activity and workload with the adoption of agriculture.

In regard to OA and its relationship with terrestrial mobility, the sexual dimorphism of hip OA is quite interesting. Previous work by Dupras and Schwarcz (2001) found that the isotopic values differed for some of the males from the sample. These variations in isotopic value were indicative of these individuals originating from outside of the Dakhleh Oasis. Males were believed to be the primary sex which traveled the desert along trade routes while females stayed within their homeland. This concept is discussed by Larsen (1997) in regard to adaptive strategies. When discussing OA of adult males and females in the Great Basin, those found to have lower levels of OA were assumed to be limnosedentary; tethered to a wetland area which provided food and water. Those with higher levels of OA were believed to be limnomobile; a lifestyle which was quite physically demanding. Using multiple lines of evidence including archaeological, textual, isotopic, and paleopathological data, it can be assumed based on OA of the hip that males may have led more physically demanding lifestyle.

The data also suggests that males were in fact coming to and leaving from the Dakhleh Oasis perhaps for economical or trading purposes (Dupras, 1999; Dupras and Schwarcz, 2001). Another consideration is the concept of terrain. A substrate such as sand is quite different from other substrates throughout the world. The biomechanical demand for walking on sand is likely higher than other forms of substrate such as dirt or rock, therefore one might expect higher levels of hip OA in a desert population. Studies investigating the relationship between terrain type and

OA prevalence have yet to be conducted to the authors knowledge therefore any associations should be avoided.

Bridges' (1992) comprehensive research on various OA studies found some important patterns relating to OA. One of those findings significant to this study is that there is no consistent relationship between the pattern of involvement of OA and subsistence economy. It may not be valid for comparative purposes to identify subsistence-related patterns from OA, although the uniqueness of the Kellis 2 sample is that extensive isotopic and archaeological research has been conducted on the dietary aspects of the population sample. The isotopic data coupled with the Kellis Agricultural Account Book (Bagnall, 1997) and extensive archaeological excavations have established this sample as coming from an agricultural community, and therefore the rates of OA may be used for interpretation of levels of physical activity.

The incidence and prevalence of hip OA indicates that males were likely subjected to higher levels of physical stress than females (Jurmain, 1999; Larsen, 1997). The sexually dimorphic pattern of hip OA in this sample cannot be validly attributed to specific activities related to agricultural subsistence, but instead is indicative of males encountering higher levels of mechanical loading and physical stress throughout their lifetime. The disease is highly correlated with age in both males and females, although more so in males. The acetabulum tends to be the most arthritic part of the hip joint complex. Females develop hip OA earlier but it is more severe in advanced age males indicating that age may be a more significant etiological factor in males than females.

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CHAPTER THREE: PALEOPATHOLOGICAL ASSESSMENT OF OSTEOARTHRITIS FOR THE KNEE JOINT COMPLEX

Introduction

The field of paleopathology, or the study of disease as represented on human skeletal remains (Ortner, 2003) lies within and between disciplines such as medicine, paleontology, dentistry, and anthropology (Cook and Powell, 2006). Physical anthropologists who study past humans and/or ancient human ancestors find the presence of pathological conditions on skeletal remains to be infinitely informative. Chronic ailments which manifest osteologically can be used to infer epidemiological trends, and can also be insightful about general levels of stress (Jurmain, 1991; 1999; Larsen, 1997). Many osteologists believe certain pathological conditions can be used to make interpretations about behavior (Jurmain, 1999). Rogers (2000) states, "changes in and around the joints may represent modifications due to biomechanical factors such as activity or trauma, which may have important implications in the interpretation of the lifestyle of earlier population" (p. 163). Osteoarthritis is considered by most as an activity-related pathological condition (Bridges, 1992; Jurmain, 1999; Larsen, 1997; Rogers and Waldron, 1995; Waldron, 2009).

Osteoarthritis

The most commonly observed postcranial pathological condition in human skeletal assemblages is osteoarthritis (Ortner, 2003; Rogers and Waldron, 1995; Weiss and Jurmain, 2007). Osteoarthritis (OA), or degenerative joint disease (DJD), is a multifactorial disorder which affects the cartilage and underlying bone of the appendicular joints (Jurmain, 1999; Larsen, 1997; Ortner, 2003; Rogers and Waldron, 1995). The presence and severity of the disease is highly correlated with both age and activity (Jurmain, 1991; Roberts and Manchester, 2007; Rogers and Waldron, 1995).Larger and more complex joint structures such as those of the lower limbs are highly susceptible to OA (Jurmain, 1999; Roberts and Manchester, 2007).

The commonality of OA in human skeletal remains from archaeological sites is proportionally matched by the representation of OA in the clinical context (Brandt et al., 1998; Ortner, 2003). Although the disease is commonly encountered in both the clinical and archaeological context, there is much debate as to the patterns of pathogenesis, etiology, pathophysiology, and diagnostic criteria both within and between disciplines (Bridges, 1993; Jurmain, 1999). Descriptions and definitions of OA differ between (and sometimes within) the archaeological and clinical context. Diagnostic characteristics on dry bone are not equated necessarily radiologically (Bridges, 1993; Rogers, 2000). The primary etiological factors for OA generally accepted in both disciplines are age and activity (Resnick and Niwayama, 1995; Rogers and Waldron, 1995; Weiss and Jurmain, 2007). Secondary factors which have shown to be contributory to the development of OA include but are not limited to sex, genetics, ancestry, anatomical variation, nutrition, and body weight (Resnick and Niwayama, 1995; Weiss and Jurmain, 2007).

The term “osteoarthritis” is clinically indicative of inflammation based on the suffix “itis”. Some European researchers believe that inflammation is not actually a primary factor in OA pathogenesis, and therefore DJD has been termed “osteoarthrosis” by those outside of North America (Rothschild and Martin, 1993; Weiss and Jurmain, 2007). The inflammation of the joint complex is actually a significant factor in the reparative and degenerative processes of OA (Punzi et al., 2005) and therefore this terminology is preferred in more recent archaeological and clinical publications(although the term osteoarthrosis is still used by some). Currently there are three generally accepted facts about OA; the disease is multifactorial in etiology, variable in manifestation, and obscure in pathogenesis (Jurmain, 1999; Ortner, 2003; Weiss and Jurmain, 2007). These concepts have been the driving force behind many OA studies in both the clinical and archaeological context (Bridges, 1992; Jurmain, 1991;Sandell and Aigner, 2001; Waldron, 1997).

Although OA has predominantly affected those both in antiquity and modernity, the complexities of the relationship between its various etiological factors remains quite a mystery (Jurmain, 1977a). Clinicians have determined two broad factors related to the development of OA; extrinsic (mechanical/functional), and intrinsic (systemic/predisposing) factors (Resnick and Niwayama, 1995).Systemic factors are those related to an entire organism as opposed to a single part. Age is perhaps the most significant systemic or intrinsic factor. With age comes many biochemical and histological changes to the bone and articular cartilage which can inevitably lead to joint degeneration (Jurmain, 1977a; Ortner, 2003; Waldron, 2009). The aging cartilage is less able to resist the forces of repetitive mechanical loading and therefore is more susceptible to microtrauma resulting in early stages of OA (Resnick and Niwayama, 1995). Multiple lines of clinical data indicate age as a significant factor as well observed symptomatically (Kellegren et al., 1953) and radiologically (Roberts and Burch, 1966) in the living as well in macerated autopsy remains (Bauer, 1941).

Although age is a significant etiological factor, there still exist those with early onset OA and those advanced aged individuals with no sign of OA throughout their entire skeleton (Bridges, 1991; Jurmain, 1977a; Ortner, 2003). While OA is highly correlational with age, recent research indicates that the cumulative effects of physiological and biomechanical wear and tear over time is a significant etiological factor as well (Lieverse et al., 2007). The former is indicated by the incidence of individuals with early onset OA, and by the incidence of advanced age individuals who have no signs of the disease whatsoever. Age should always be controlled for in OA studies, but the researcher must also consider general levels of activity based on additional lines of evidence during the interpretation of OA patterning. Depending on the individuals lifestyle demands OA manifestation can be quite variable in severity. Movement or mechanical loading on the joints over time is perhaps the most integral factor when considering the etiology and pathogenesis of OA (Weiss and Jurmain, 2007). This is generally accepted in both the clinical and paleopathological community because non-synovial joints such as sutures which lack range of mobility simply do not develop OA (Roberts and Manchester, 2007).

Additional systemic factors which have shown to be contributory to the development of OA include but are not limited to sex, genetics, ancestry, anatomical variation, nutrition, and body weight (Resnick and Niwayama, 1995; Weiss and Jurmain, 2007). In addition to the former factors, climate and diet have also been suggested to play a role in the etiology of OA

(Moskowitz, 1993; McAlindon et al., 1996a, b). Establishing a degree of significance to the etiology of OA to any of these factors is difficult because some are inter-related such as: ancestry and genetics (Schultz, 1998), nutrition and body weight, as well as sex and anatomical variation. Clinical research is one way to identify various etiological factors OA while paleopathological comparative-based research can also be utilized as a means of isolating the various etiological factors related to OA. Such research has investigated OA in osteological assemblages in order to compare rates regarding agricultural development (Bridges, 1989; Larsen, 1990; 1995), mobility and subsistence regimes (Lieverse et al., 2007; Merbs, 1983), economic intensification (Klaus et al., 2009), temporal patterns of OA demography (Baetsen et al., 1997; Waldron, 1994; 1997), variable lifestyle stress (Jurmain, 1977a; 1980), ancestral variation (Inoue et al., 2001), and the relationship between OA and other activity-related pathological conditions (Molnar et al., 2009).

OA variation is described vividly in both the clinical and paleopathological literature. The general pathogenesis of OA is characterized by the loss of articular cartilage in large synovial joints eventually resulting in bone-on-bone contact (Resnick and Niwayama, 1995; Rogers and Waldron, 1995). Ortner (2003) describes three major components of skeletal involvement observed in the pathogenesis of osteoarthritis; breakdown of articular cartilage, reactive bone formation (sclerosis), and new bony/cartilaginous growth at the joint margins. Waldron (2009) describes the biological, physiological, and chemical aspects of each stage of OA on the Table 28.

Table 28: Stages of OA Pathogenesis (Waldron, 2009)

Stages	Pathogenic Description
1	*Enzymatic breakdown of the cartilage matrix; the metabolism of the chondrocytes is affected, followed by the release of enzymes, including metalloenzymes (metal ion enzymes required in 1/3 of all cells), that further breaks down the matrix. The chondrocytes release enzyme inhibitors to counteract the protelytic affect-usually insufficient amounts.*
2	*Cartilage begins to fibrillate both vertically and horizontally; surface of cartilage begins to erode, followed by the release of fragments of collagen and proteoglycan (one of the constituents of the matrix) into the joint cavity-these breakdown products initiate the third phase*
3	*Inflammatory response in the synovial membrane; produces inflammatory cytokines including IL (-1), TNF, and metalloproteinses which can either diffuse into matrix or directly destroy it with the release of yet further proteolytic enzymes. The inflammation in the synovial membrane is accompanied by the formation of new blood vessels due to the generation of vascular endothelial growth factor (VEGF) by the synovium. This stage is completed by the formation of new bone (w/reparative intentions).*

The pathogenesis of OA involves the entire synovial or diarthroidal joint including the cartilage, synovium, and underlying bone. The cellular response to injury is variable between the different tissues within the joint complex (Sandell and Aigner, 2001). When the stability of a joint becomes structurally compromised, excessive loading forces within the joint can result in subsequent injury of the underlying cartilage (whether primary or secondary OA).The cartilage cells or chondrocytes begin to repair the cartilage initially following injury to the joint capsule-this is referred to as the biosynthetic phase (Sandell and Aigner, 2001). What follows is the degradative phase in which the enzymes released by the chondrocytes digest the bone matrix which lead to further bony and cartilaginous erosion (Sandell and Aigner, 2001). The pathogenic process of OA is essentially perpetuated by a cellular race to repair where the chondrocytes are rebuilding cartilage while the byproduct of such repair causes erosion of the matrix resulting in osteophytic (atrophic or hypertrophic) development (Ortner, 2003). The reparative process which follows articular attrition comprises the early stages of osteoarthritic pathogenesis. Perspectives on OA pathogenesis have changed frequently over the years (Weiss and Jurmain, 2007). OA was originally thought to be a disease of degenerative nature, a simple result of progressive wear and tear related to mechanical loading and age. The disease is now viewed as a highly metabolically driven dynamic process which includes the continuous destruction and repair of joints facilitated by an assortment of both mechanical and biochemical factors (Brandt et al., 1998; Sandell and Aigner, 2001).

The damage done to the cartilage directly impacts the joint space by tightening or narrowing the joint complex (Ortner, 2003; Resnick and Niwayama, 1995). This loss of space within the joint complex further affects the already compromised structural integrity of the joint, and subsequently causes further cartilage loss due to articular attrition. The focal loss of cartilage and the damage induced inflammation erodes the remaining cartilage and underlying bone (Mann and Hunt, 2005). Upon exposure of the subchondral bone, a callus will form which is the early stages of osteogenic repair, which is then followed by the normal reparative processes of resorption and apposition (Ortner, 2003; Rogers and Waldron, 1995; White and Folkens, 2005). There is much argument as to whether changes in cartilage initiate bony changes or the reverse, and pathophysiology is poorly understood (Roberts and Manchester, 2007). In archaeological remains the chronological pathogenic process of OA is of less importance being that the end result is in most cases the presence of specific osteological manifestations (Larsen, 1997).

The skeletal evaluation of OA is based on osteological characteristics which are resultant of various osteogenic processes related to OA pathogenesis. OA involves the entire synovial joint including cartilage, synovium, and underlying or subchondral bone therefore these characteristics can be observed anywhere within the joint especially on the articular surfaces. Osteological characteristics of OA include osteophytes both surface and marginal, porosity, and eburnation. Osteophytes are bony spicules or protuberances which can develop on either the surface of the joint and within the margins of the joint (Jurmain, 1999; Rogers and Waldron, 1995). Marginal osteophytes, also described as osteophytic lipping, can be observed on the distal femora in Figure 13. This characteristic is often described in regards to extent of joint surface covered, and the degree for which it is raised (Buikstra and Ubelaker, 1994).

Figure 13: Distal Femora with Severe Marginal Osteophytic Lipping (B-646)

Surface osteophytes develop as a result of a reparative osteogenic reaction. When the structural integrity of a joint is breached and results in microfractures within the hyaline cartilage, the bone cells act as though they are repairing bone by applying new bone to the impacted area- this is called hypertrophic bony development (Ortner, 2003; Jurmain, 1999). Early stimulation for osteophytic development may occur following the penetration of the capillaries into the subchondral plate deep within the calcified zone of the cartilage (Brown and Weiss, 1988). Figure 14 is a good example of localized periarticular osteophytes on the patellar surfaces of the femora from B-87. Osteophyte formation has been found to be highly correlated with OA but is also commonly observed in individuals of advanced age (Rogers et al., 1997; Rogers et al., 2004).

Figure 14: Localized Osteophytes on Patellar Surface of Femora (B-87)

As OA progresses continued articular attrition causes subchondral sclerosis or a thickening of the bone (Mann and Hunt, 2005) as well as subchondral cysts which manifest osteologically as porosity (Rothschild, 1997). Porosity is manifested on the articular surface of the joint by the discontinuity of subchondral bone (Rothschild, 1997). Moderate porosity can be observed on the patellar surface the femur shown in Figure 15. This osteological manifestation is unable to be observed radiologically by x-ray (Rothschild, 1997). As suggested by Merbs (1983), porosity is reflective of sclerotic osteogenic reaction which occurs during OA pathogenesis. Vascularity is lost in the bone causin the marrow to become fibrous which subsequently penetrates the subchondral bone. Histologically these holes are tiny cysts which in life are filled with reparative cartilage cells (Milgram, 1983).

Figure 15: Porosity on the Patellar Surface of Femur (B-251)

In cases of severe OA where there is significant focal loss of cartilage, the underlying bone will begin to abrade causing eburnation or polishing of the joint surface (Rogers and Waldron, 1995). This polished surface is quite distinguishable from other natural (non-pathological) features. The eburnated joint surface can range in severity from slightly polished to deeply striated. Figure 16 (B-488) is a good example of a manifestation somewhere between slight and severe. The eburnation is more dramatically represented on the articulating surface of the patella (FSP).

Figure 16: Eburnation of the Patello-Femoral Compartment (B-488)

The knee, similar to the hip, is a diarthroidal joint, and is referred to as a hinge joint based on the relative range of motion (White and Folkens, 2005). As opposed the hip, the knee is very unique because while the range of motion may be less, there exists instead of one joint compartment three (Rogers and Waldron, 1995; Ortner, 2003; Waldron, 2009). The three compartments are the patellofemoral, and medial/lateral tibiofemoral compartments. Of the three compartments the most commonly affected during osteoarthritis is the patellofemoral compartment (Waldron, 2009). Interestingly, some researchers support the idea that patellofemoral OA is the result of bipedal evolution (Jurmain, 1999). Their findings indicate while modern and ancient humans all have high rates of PF OA, that quadrapedal non-human primates actually exhibit quite low levels of PF OA (Jurmain, 1999). These evolutionary perspectives are interesting and biomechanically make some sense. The patella is a giant sesamoid bone, and it has a wide range of movement which is the most probable cause for such high prevalence of OA in bipedal humans.

The next most common compartment affected by osteoarthritic changes is the medial tibiofemoral compartment (Ortner, 2003), which may be the result of site-specific mechanical loading produced by the morphology of the valgus angle observed in the human leg. Findings of higher rates of medial versus lateral tibiofemoral osteoarthritis may be indicative of such conclusions but at this point is pure speculation. In congruence with the high frequency of osteoarthritic changes seen in the medial tibiofemoral compartment, there seems to be a very low frequency of this development in the lateral tibiofemoral compartment (Jurmain, 1999). Based on the biomechanics of the valgus angle, the sites with the highest frequency of osteoarthritis do correspond to locations of maximum biomechanical stress in the knee, supporting the role of this type of stress as a factor in osteoarthritis" (Ortner, 2003:548).

Waldron (2009) finds that patellofemoral osteoarthritis (Figure 17) is three times as common as tibiofemoral osteoarthritis. Because of this variation in prevalence of osteoarthritis in the knee, it has become generally accepted amongst clinicians (gross anatomy) and paleopathologists to analyze and record osteoarthritic development of each compartment separately (Rogers and Waldron, 1995). While the knee represents one inherent joint complex, it is actually made up of three joint sub-complexes and for statistical purposes when determining the prevalence of osteoarthritis based on composite scores each compartment is discussed separately.

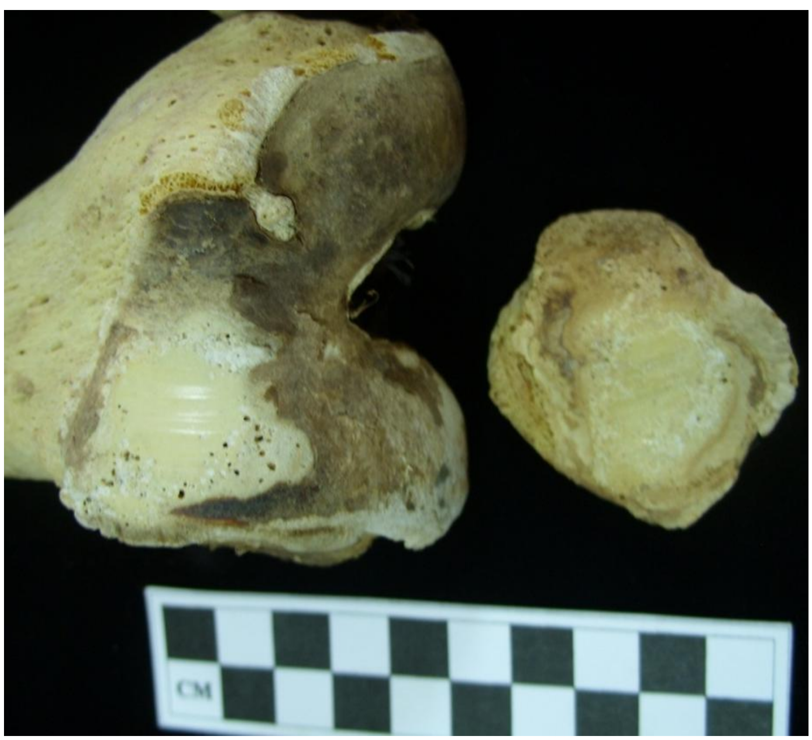

Figure 17: Advanced OA of Patello-Femoral Compartment (B-280)

Activity-Related Pathological Condition

Landmark studies on OA have been conducted by J. Lawrence Angel (1966), T. Dale Stewart (1947; 1966), and Jurmain (1977 a, b, 1980, 1990, 1991). These studies were all comparative; population based descriptive works (Buikstra and Beck, 2006). Questions related to chronological trends of OA, methods of subsistence (agriculture or hunter-gatherer), sexual dimorphism in OA manifestation, and perhaps even sexual divisions of labor based on the high levels of disparity. Research prior the 1970's focused on linking patterns of OA to specific activities (behavioral interpretations) commonly encountered within the given society being studied.

Angel (1966) found a high incidence of OA on the elbow joint in both males and females and attributed the pathological manifestation to throwing of a spear with an atlatl for males and metate seed grinding for females. This manifestation was then referred to as "atlatl elbow" and "metate elbow" (Angel, 1966). This type of interpretation can elicit information on sexual divisions of labor which can be quite culturally informative (Larsen, 1997).Merbs (1983) discusses how the attribution of OA patterning to specific activities can be a problematic method being that when one considers the many activities modern humans do on a daily basis, it may be difficult to associate site-specific OA to a single or even a few activities. The concept of site-specific OA being attributed to one single activity is not so much generally accepted in modern research. The growing knowledge about the various aspects of OA has led researchers to avoid attributing OA directly to specific activities, but to discuss possible activities common to the culture and how those activities may have contributed to OA (Jurmain, 1999). Using multiple lines of evidence can be infinitely informative when trying to understand the patterns of OA.

Clinical research has shown questionable results in whether specific activities can be conclusively linked to site-specific OA which much be expressed as cautionary when making interpretations about OA (Jurmain, 1999).

Comparative-based research later became more descriptive and less behaviorally oriented. Studies by Jurmain (1977a,b; 1980) compared four geographically and temporally different samples (Alaskan Inuit, Pecos Pueblo, Caucasian and African skeletons from the Terry Collection) and observed differences and related them to general hardships of life. A sensible deduction was made for disparity of OA prevalence between the Inuit and the Pueblo (Inuit significantly more arthritic) which Jurmain (1980) attributed to seasonality hardships. The Pecos Pueblo were harvesting crops during only part of the year while methods of subsistence for the Alaskan Inuit generally involve more hunting activities and would have gone on throughout the year. Bridges (1992) investigated the relationship of OA prevalence with subsistence methods and found that there were no statistically significant differences between hunter-gatherers and agriculturists. Larsen (1982) encountered similar findings in his Georgia Coast study of OA in a preagricultural and agricultural group especially in the patellofemoral compartment. Jurmain (1990) also found high levels of knee OA in a sample from a California coastal population.

The issue with OA in the clinical versus archaeological context is that material available in the analysis of each is quite different (Rogers and Waldron, 1995; Waldron, 2009). Living patients can describe symptoms which are consistent with OA such as joint stiffness or swelling of the joint (Brandt etal., 1998).Clinicians also mainly view joint through radiological or arthroscopic analysis (Altman et al., 1986; Cameron and Macnab, 1975; Weiss and Jurmain, 2007). In the analysis of dry bone in the archaeological context the osteologists consider the entire joint with or without cartilage. This issue makes it difficult for osteologists to use clinical epidemiological research comparatively with archaeological populations (Bridges, 1993; Jurmain, 1999). The diagnostic characteristic for OA which is generally agreed upon by both osteologists and clinicians is eburnation as a result of cartilage degeneration leading to bone on bone contact (Resnick and Niwayama, 1995). Figure 18 is an example of bilateral patellofemoral eburnation.

Figure 18: Severe Bilateral Patellofemoral OA with Eburnation

Materials

The skeletal materials used in this study were selected from a collection associated with the Dakhleh Oasis Project. The Dakhleh Oasis Project (DOP) is a longstanding multinational interdisciplinary research endeavor whose primary focus is better understanding human adaptability to the harsh conditions of the Western Sahara Desert of Egypt (Dupras, 1999). Since its inception in 1978, the DOP has been under the direction of Anthony Mills and under the auspices of the Society for the Study of Egyptian Antiquities and the Royal Ontario Museum (Dupras, 1999). The DOP research design utilizes a holistic perspective when investigating the complex relationships between humans and the harsh physical environment of a desert ecozone (Williams, 2008). The DOP focuses on the archaeological study of human behavior as well as the environmental history of the Dakhleh Oasis from the Neolithic to the present (Mills, 1984).

Located in the harsh and arid Western Sahara Desert of Egypt approximately 250 kilometers west of the Nile, the Dakhleh Oasis (Fig. 19) is one of five great depressions found in the Sahara Desert (Williams, 2008; Wheeler, 2009). Within the Dakhleh Oasis is the ancient town of Kellis which is believed to have housed thousands at its peak during the 4th century A.D. (Dupras, 1999). The town being located along an ancient desert trading route, it was considered an important political and economic hub (Wheeler, 2009). Archaeological evidence from the town of Kellis suggests both Egyptian and Roman influence based on the presence of both types of temples, although Roman influence is more significant as seen by the presence of Roman vaulted brick tombs, a Roman bathhouse, and two churches (Hope, 2001; 2002; 2003).

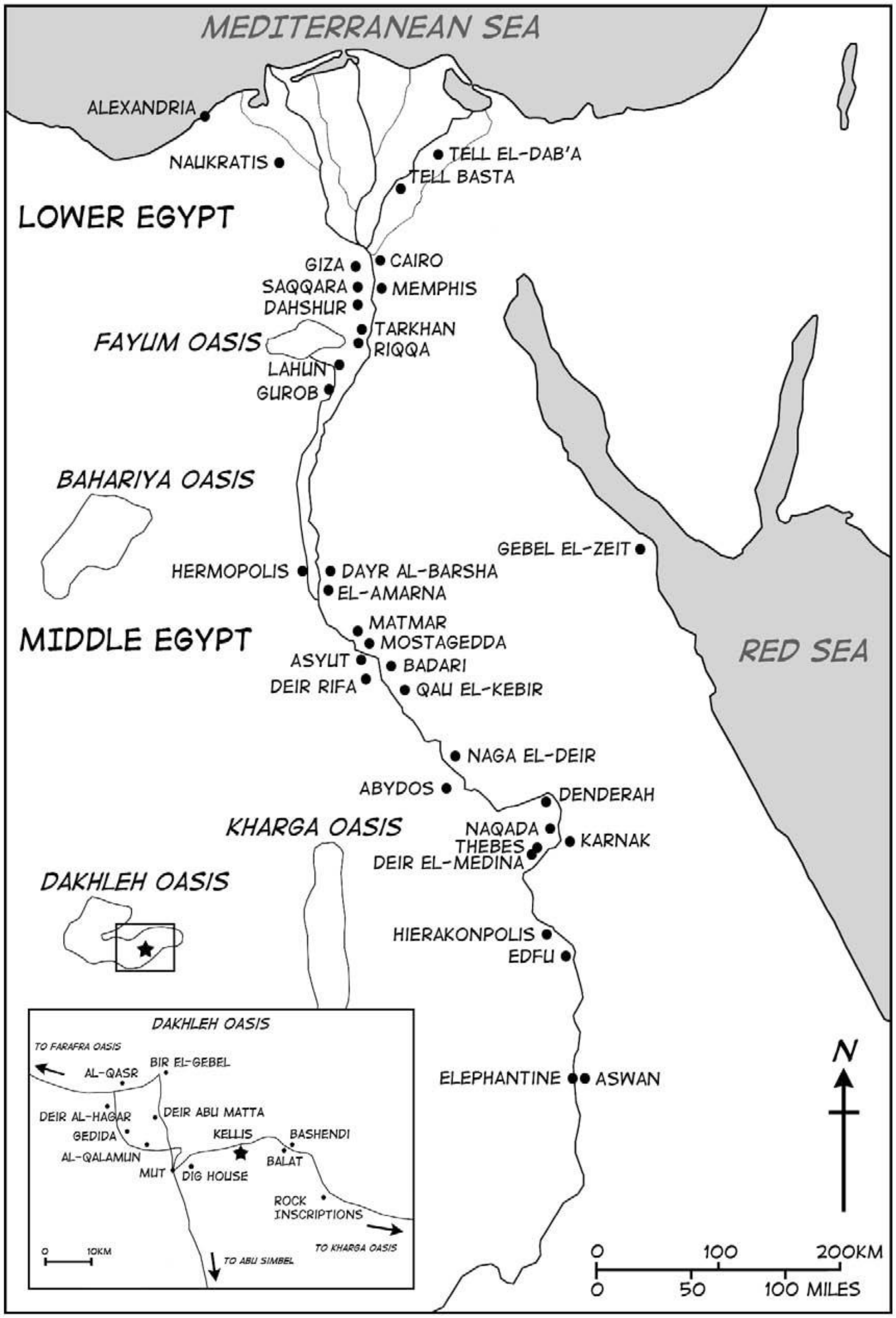

Figure 19: Map of Egypt with the Dakhleh Oasis (Williams, 2008)

The individuals from this study were excavated from what is now referred to as the Kellis 2 cemetery (Fig. 20). The cemetery is located just east of the town of Kellis and was discovered in 1977 during a routine visual walking survey and excavation commenced in 1991 (Dupras, 1999). Various skeletal elements were observed on the surface, and in the western section of the cemetery wind erosion has exposed many of the graves. The environmental characteristics of the Dakhleh Oasis are consistent with other harsh desert ecosystem exhibiting little annual rainfall, generally high temperatures, and often violent wind and sand storms. Conditions such as aforementioned, in addition to the aridity of the desert and the alkalinity of the soil, have allowed for a unique mortuary environment at Kellis 2. Aufderheide (2003) describes the importance of the mortuary environment in determining the relative state of preservation of skeletal material, and consequently the environmental conditions which are found at Dakhleh make for excellent skeletal preservation.

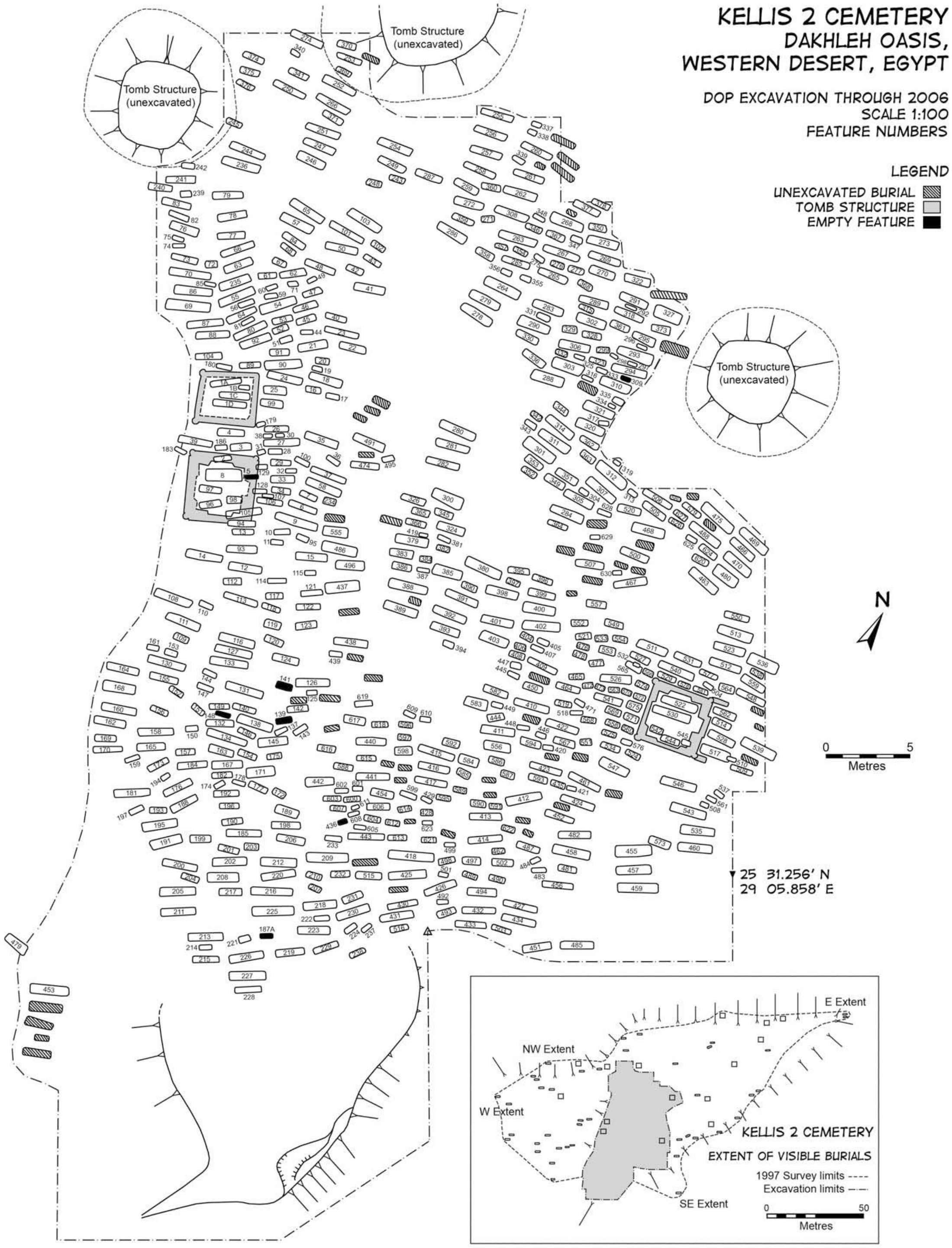

Figure 20: Map of the Kellis 2 (Williams, 2008)

Of the approximate 3000 to 4000 estimated burials, 701 have been excavated and analyzed as of 2010, and of those approximately 255 were classified as adults (Wheeler, 2009). A list of all burials with a variety of information including but not limited to; age, sex, length, width, depth, etc. was provided for the author in the form of a Microsoft Excel © spreadsheet by Dr. Dupras. Being that osteoarthritis is highly dependent on age, the individuals chosen for this study were from the adult population (>15 years of age) of the Kellis 2 cemetery. This age was chosen as a general beginning of adulthood age but the determinant factor in this project was whether or not the individual had been sexed. Secondary sexual characteristics on the human skeleton are present at or around the time of adulthood and therefore this was an important factor in inclusion and exclusion of individuals from this study. The ages of the 255 adults are seventeen years of age being the youngest, and seventy-two years of age being the oldest, and the mean age of 38.53 shown on Table 29.

Table 29: Adult Population Descriptive Age Statistics

Descriptive Statistics	Number of Individuals	Minimum Age	Maximum Age	Mean Age of Sample
Age (years)	255	17	72	38.53

The author modified the original database by removing all individuals who did not fulfill the previously stated requirements. From those 255 individuals, 151 are female and 104 are male (Table 29) which is slightly disproportionate but reflective of mortality patterns during this period when considering factors such as childbirth without medical intervention. The proportion of males to females is roughly 1:1.5. Males make up 40.8% of the adult sample and females make up 59.2% of the adult sample (Table 30). Osteological prerequisites for this study were completeness of the individual (at least 50%) as well as both clean and intact joint margins and surfaces.

Table 30: Adult Demographic Representation at Kellis 2

SEX	NUMBER OF INDIVIDUALS	PERCENT OF SAMPLE
F	151	59.2%
M	104	40.8%
TOTAL	255	100.0%

An important factor in this study was the ability to control for age and sex, therefore those of unknown age and/or unknown sex were excluded. Final decision for individuals utilized in this study was based off the former prerequisites and accessibility at the storage facility in Dakhleh. The final sample which was assessed for osteoarthritic severity consisted of 135 individuals. Of the 135 adults including 84 females and 52 males (Table 31) which is a closely demographic representation of this study similar to the actual adult paleodemography of Kellis 2 when one compares the Valid Percents from Tables30 and 31. This is ideal from a statistical perspective because the amount in one's sample should be demographically proportional to the actual population represented by the entire osteoarchaeological sample.

Table 31: Males and Females Analyzed in Study

SEX	NUMBER OF INDIVIDUALS	PERCENT OF SAMPLE
F	84	62.2%
M	51	37.8%
TOTAL	135	100.0%

All individuals utilized in this study were grouped into age categories as a means of controlling for age. In order to achieve precision during statistical analysis the author recoded the individuals into five age groups similar to Jurmain (1977a)for this study; group one (19-24 years of age), group two (25-35), group three (36-45), group four (46-55), and group five (>55) as shown in Table 32. The age groups frequency of individuals and percentage of sample is shown on Table 33.The age groups are cross-tabulated with the known sex of the individuals from this study and are shown on Table 34.

Table 32: Age Categories Defined in this Study

Age Category	Summary of Age Range (years)
1	**19-24 years**
2	**25-35 years**
3	**36-45 years**
4	**46-55 years**
5	**>55 years**

Table 33: Age Category Frequencies in Sample

AGE CATEGORY	NUMBER OF INDIVIDUALS	PERCENT OF SAMPLE
1	28	20.7%
2	50	37.0%
3	17	12.6%
4	26	19.3%
5	14	10.4%
TOTAL	135	100.0%

Table 34: Age Category Distribution Cross-tabulated with Sex Groups

		AgeCategories					
		1.00	**2.00**	**3.00**	**4.00**	**5.00**	Total
Sex	**F**	18	29	11	19	7	84
	M	10	21	6	7	7	51
Total		28	50	17	26	14	135

Methods

Many researchers advocate the need for a universal scoring and diagnosis system for OA (Bridges, 1993; Rogers and Waldron, 1995; Weiss and Jurmain; 2007). The assessment of osteoarthritis for this sample from the Kellis 2 cemetery population is based on the presence or absence of osteological characteristics generally accepted as being pathologically concurrent with an OA diagnosis. These characteristics as observed on dry bone consist of osteophytes, porosity, and eburnation (Rogers and Waldron, 1995; Waldron, 2009).Osteophytes are bony spicules that can form on either the articular surface of the joint or at the margins (lipping) of the joint surface. Porosity is pitting on the joint surface which is possibly caused by subchondral cysts of variable size and cluster. Degeneration of the cartilage leads to bone articulating directly against bone leading to eburnation (Rogers, 1998). Eburnation is a polishing of the joint surface as a result of the cartilage being completely worn away initiating bone on bone contact (Waldron, 2009). Clinically the main diagnostic characteristic would be alterations to the contours of the joint surface and eburnation.

Methods used by different researchers vary depending on their perception of each osteological characteristic and its relationship with OA. For this reason it is quite difficult to validly compare this data with previous studies (Bridges, 1993). The author chose to adapt methods from Buikstra and Ubelaker's (1994) OA scoring method from *Standards for Data Collection From the Human Skeletal Remains.* While each researcher has their general proclivity towards what is best to determine osteoarthritic development, Buikstra and Ubelaker (1994) gauge all bony features associated with OA as a means of diagnosing the disease, and determining its severity. These osteological characteristics have been used in many past OA studies and therefore the author has chosen to use each of them as diagnostic criteria for OA in this thesis. Associated scores for the formerly mentioned osteological characteristics are shown on Table 35. One-hundred and thirty-five skeletons were visually examined in this study for OA prevalence, incidence, severity, and anatomical distribution in the knee complex.

Table 35: Osteological Characteristics of OA with Associated Scores

Osteophytes		**Porosity**		**Degree of Marginal lipping**		**Extent of Marginal lipping**		**Eburnation**	
0	Absent	0	No porosity	0	Absence of lipping	0	No lipping	0	Absent
1	Present	1	Observable pinpoint porosity	1	Slight or moderate lipping	1	<1/3	1	Polished
		2	Extensive pitting	2	Well defined lipping (sharp ridge)	2	1/3-2/3	2	Streaked
		3	pitting on majority of joint surface	3	Distinguishably deep ridge	3	>2/3	3	Multiple striations

The methodology is designed as a means of describing the demographic and anatomical patterns and prevalence of OA in the Kellis 2 sample. Goals of analysis are descriptive based, identifying patterns such as the most and least OA afflicted joint complex/surface, sexual dimorphism (variations in prevalence), and laterality. Bridges (1993) discusses how these are good questions to be asked when assessing a single sample. The first stage of the analysis was to score each locus of the joint complex, in this case the left/right lateral and medial femoral and tibial condyles as well as the femoral surface of both patellae and patellar surfaces of both femora.

The initial osteological criterion for this study was good skeletal preservation (clean and intact joint surfaces), anatomical completeness, known age (adult) and known sex of each individual skeleton. Although OA was assessed in the knees for 135 individuals, there are not 135 of each joint surface available for analysis. Prevalence for OA of each joint locus will be determined based off of the amount of joint surfaces available at the time of analysis (e.g. incidence of OA/# of joint surfaces available).The methods utilized in this thesis are based on the generally accepted opinion that the presence of one or two of these osteological characteristics is not indicative of OA with the exception of eburnation (Rogers, 1998; Rogers and Waldron, 1995; Jurmain, 1999; Waldron, 2009).

The scores for each joint locus of the knees were uploaded into IBM SPSS Statistics 19 © in order to do the necessary quantifications. Those individuals who had scores for each characteristic that were higher than zero or showed the presence of eburnation were considered to be osteoarthritic. This method allows for the author to determine frequency or incidence of OA at each joint surface and when cross-tabulated with age and sex groups the demographic prevalence of OA for each surface and complex can be determined.

Following the determination of OA prevalence within sex group, those percentages are compared to determine what percent of females are affected, what percent of males are affected, and how many males and females in each age group are affected. Additionally the incidence percentages will be determined based on the number of females and males with knee OA. Sex differences may indicate sexual dimorphism and/or sexual divisions of labor. Age group differences may reinforce the expectation that OA is mainly an age-related phenomenon as indicated by an increased percentage prevalence is associated with increased age group levels.

The next step is the assessment of the severity of osteoarthritis on each joint complex separately based on the maximum score of each joints apposing articular surface (0-26). This is done to determine OA prevalence for that specific joint and the anatomical distribution of OA on left and right knee joint complexes. This information will also inform on the anatomical distribution of rank with OA in the knee joint complex, and be informative on the laterality of knee OA. Research such as Bridges (1993) indicates that the knee must be considered one joint complex consisting of three subcomplexes if it is to be compared statistically with other joint complexes. Most joints consist of two articulating surfaces such as the hip and the shoulder (when clavicle is not considered). Therefore composite joint scores are reflective of the average joint surface score (e.g. joint surface score + joint surface score/ maximum joint complex score- in this case 26). The knee is composed of a lateral, medial, and patellar compartment which will each be scored and averaged separately in order to be comparable to other joint score in this study.

Results

Lateral Condyle of Femur

The frequency of OA is the number of individuals with OA, and the prevalence is the incidence of OA divided by the number of individuals in the sample utilized. Out of 135 individuals assessed for OA of the knee, the final sample consisted of 134 left and right lateral femoral condyles (Tables 36 and 37). The frequency of left lateral femoral condyle OA is 3 individuals and the prevalence is 2.2%. The frequency of right lateral femoral condyle OA is 5 individuals and the prevalence is 3.7%. The data informs that that more individuals are affected by right lateral femoral condyle OA in the Kellis 2 sample. The lateral femoral condyles are not significantly afflicted within the Kellis 2 skeletal sample.

Table 36: Raw Frequency Data on OA of the Left Lateral Femoral Condyle

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	131	97.8
Present	3	2.2
Total	134	100.0

Table 37: Raw Frequency Data on OA of the Right Lateral Femoral Condyle

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	129	96.3
Present	5	3.7
Total	134	100.0

Using cross-tabulations of OA incidence with age and sex group data, the author is able to determine the demographic prevalence of left (Table 38) lateral femoral condylar OA. There is one male with left lateral femoral condyle OA in age category three. There is one female with left lateral femoral condyle OA in age category four. And lastly there is one male in age category five with left femoral condyle OA. The female frequency of left femoral condylar OA is 1 individual, and the male incidence is 2 individuals. The female prevalence of left lateral femoral condylar OA is 1.2% and the male prevalence is 4%. Although OA of the left lateral femoral condyle is relatively uncommon in this sample, males are slightly more prone to this condition based on the data.

Table 38: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Left Lateral Femoral Condyle

Sex	OA		Age Categories					Total Sample
			1.00	2.00	3.00	4.00	5.00	
F		N	0/18	0/29	0/11	1/19	0/7	1/84
		%	0	0	0	5.3	0	1.2
M		N	0/10	0/20	1/6	0/7	1/7	2/50
		%	0	0	16.7	0	28.6	4

Using cross-tabulations of OA incidence with age and sex group data, the author is able to determine the demographic prevalence of right (Table 39) lateral femoral condylar OA. There is no sign of right lateral femoral condyle OA until age category four in which three females exhibit OA on this joint locus. There is a single female and a single male from age category five who exhibit OA on the right lateral femoral condyle in. The female frequency of right lateral femoral condylar OA is 4 individuals and the male frequency is 1 individual. The female prevalence for right lateral femoral condylar OA is 4.8% and male prevalence is ~2% (1.96). This is one of the few joint loci which has higher female incidence and prevalence of OA in the entire study. Females appear to be significantly more prone than males to OA on the right lateral femoral condyle in the Kellis 2 skeleton sample.

Table 39: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Right Lateral Femoral Condyle

		Age Categories					Total
Sex	**OA**	**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	Sample
F	**N**	0/18	0/29	0/11	3/19	1/7	4/84
	%	0	0	0	15.8	14.3	4.8
M	**N**	0/10	0/20	0/6	0/7	1/7	1/50
	%	0	0	0	0	28.6	2

The graphs in Figure 21 indicate a relatively low frequency of OA on both the left and right lateral condyles of the femora. It appears that males are affected earlier with left lateral condylar OA but later with right lateral condylar OA. It does also appear that females are more significantly affected on their right lateral femoral condyle than their left. These graphs also indicate the general lacking or rarity of OA on the lateral femoral condyles in the Kellis 2 population sample.

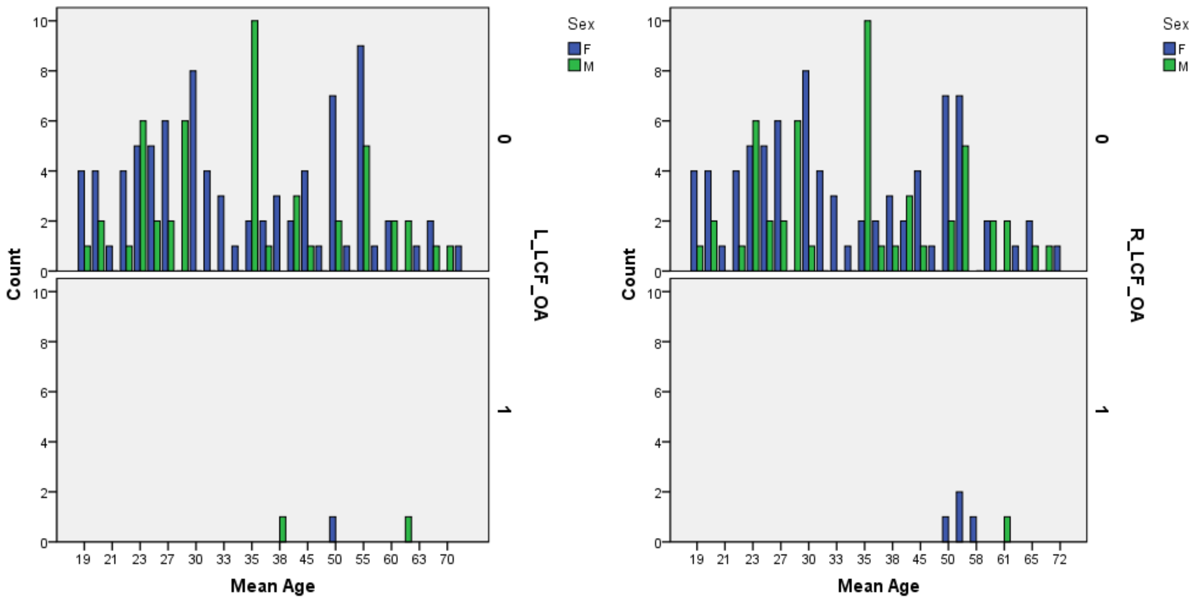

Figure 21:Graph Illustrating the Age and Sex Distribution of OA on the Left and Right Lateral Condyle of Femur

Medial Condyle of Femur

The frequency of OA is the number of individuals with OA, and the prevalence is the frequency of OA cases divided by the number of individuals in the sample utilized. Of the 135 individual skeletons assessed, 134 were able to be analyzed for left medial condylar OA in this study. As with the left lateral femoral condyle there were 134 individuals who qualified for statistical analysis and assessment of OA. The frequency of left medial condylar OA is 6 individuals and the prevalence 4.4% (Table 40). The right medial femoral condyle has slightly higher rates of OA with an incidence of 8 individuals and a prevalence of 5.9% (Table 41). These raw frequencies indicate that right medial condylar OA is more frequent than left.

Table 40: Frequency Data on OA of the Left Medial Femoral Condyle

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	128	95.5
Present	6	4.5
Total	134	100.0

Table 41: Frequency Data on OA of the Right Medial Femoral Condyle

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	126	94
Present	8	6
Total	134	100.0

Age and sex group cross-tabulation data informed on the demographic prevalence of left and right medial femoral condyles (Table 42). There are no cases of left medial condylar OA for males or females in the age categories one or two. There is one single male with OA on the left medial femoral condyle in age category three. Age category four and five show expected boosts in OA prevalence for females with two in age category four and two in age category five. There is one male individual with OA on this joint surface in age category five. Out of 134 left medial femoral condyles, 6 individuals (4.5% of sample) are found to have OA. Female frequency of left medial femoral condylar OA is 4 individuals and male frequency of left medial femoral condylar OA is 2 individuals. Female prevalence for left medial femoral condylar OA is 4.8%, and the male prevalence is 4%. Females exhibit both higher frequency and prevalence than males for OA of the left medial femoral condyle.

Table 42:Age Group and Sex Group Cross-Tabulation with OA Frequency of the Left Medial Femoral Condyle

		Age Categories					Total
Sex	**OA**	**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	Sample
F	**N**	0/18	0/29	0/11	2/19	2/7	4/84
	%	0	0	0	10.5	28.6	4.8
M	**N**	0/10	0/20	1/6	0/7	1/7	2/50
	%	0	0	16.7	0	28.6	4

Age and sex group cross-tabulation data on the right medial femoral condyle exhibits similar results as those from the left medial femoral condyle (Table 43). There are no cases of OA in age categories one, two, or three for males or females. Interestingly there is a spike in the frequency for females in age category four with 5 individuals. There is one male with OA of this joint surface in age category four. Age category five has two females with OA. Female frequency of right medial femoral condylar OA is 7 individuals and male frequency of right medial condylar OA is 1 individual. Female prevalence for left medial femoral condylar OA is 8.4%and male prevalence is ~2% (1.96). Females are much more severely affected by OA on the right medial femoral condyle.

Table 43: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Right Medial Femoral Condyle

Sex	OA		Age Categories					Total Sample
			1.00	2.00	3.00	4.00	5.00	
F		N	0/18	0/29	0/11	5/18	2/7	7/83
		%	0	0	0	27.8	28.6	8.4
M		N	0/10	0/21	0/6	1/7	0/7	1/51
		%	0	0	0	14.3	0	1.9

The graphs on Figure22 exhibits the data in a different way but still yields sexually dimorphic information based on the distribution. Those in the top section denoted by “0” are not arthritic while those in the bottom section denoted with a “1” are positive for OA. Females are affected significantly more than males are by OA on the left and right medial femoral condyles. Interestingly as can be seen on Figure 22 the youngest and the oldest individual with OA on this joint surface are male ages 38 and 70. Looking at Figure 19, one can see that the OA section is dominated by female incidence.

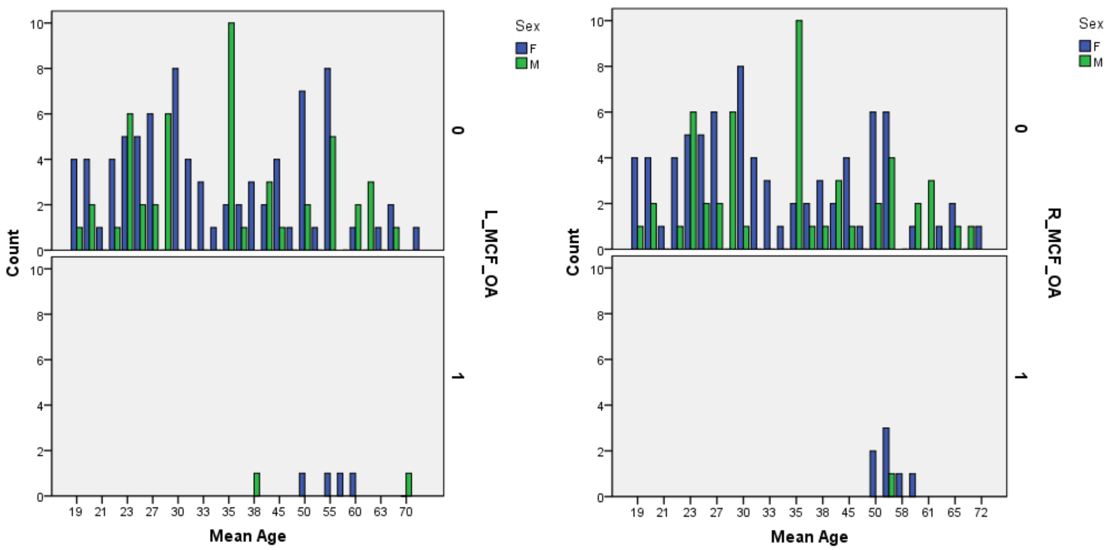

Figure 22:Graphs Illustrating the Age and Sex Distribution of OA on the Left and Right Medial Condyle of Femur

Lateral Condyle of Tibia

The frequency of OA is the number of individuals with OA, and the prevalence is the amount of cases with OA divided by the number of individuals in the sample utilized. Following the assessment of 135 individual skeletons the author found that 133 of those individuals could be utilized in the OA assessment of the left lateral condyle of the tibia and 134 were able to be investigated for OA on the right lateral tibial condyle. The frequency of OA on the left lateral condyle of the tibia is 4 individuals with a prevalence of 3% (Table 44). The frequency of OA on the right lateral condyle of the tibia is 2 individuals with a prevalence of 1.5% (Table 45). These statistics indicate that OA is twice more prevalent in this sample on the left lateral condyle of the tibia than the right.

Table 44: Raw Frequency Data on OA of the Left Lateral Condyle of the Tibia

OA	Number of Individuals (N)	Prevalence (%)
Not Present	129	97
Present	4	3
Total	133	100.0

Table 45: Raw Frequency Data on OA of the Right Lateral Condyle of the Tibia

OA	Number of Individuals (N)	Prevalence (%)
Not Present	132	98.5
Present	2	1.5
Total	134	100.0

Demographic prevalence is calculated by utilizing cross-tabulations of age and sex categories with left/right lateral condyles of tibia OA (Table 46). There are no individuals from either sex with OA in the first age category as expected. Interestingly there is one single male with OA in the age category two. There is one more male with OA in age category four, and two females with OA in age category five. The female frequency of OA on the left lateral condyle of the tibia is 2 individuals while the male frequency is also 2 individuals. The female prevalence of left lateral tibial condylar OA is 2.4% and the male prevalence of 4%. Although males and females exhibit the same OA frequency, proportionally males are more afflicted.

Table 46: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Left Lateral Condyle of the Tibia

Sex	OA		Age Categories 1.00	2.00	3.00	4.00	5.00	Total Sample
F		N	0/18	0/29	0/11	0/18	2/7	2/83
		%	0	0	0	0	28.6	2.4
M		N	0/10	1/21	0/6	1/7	0/6	2/50
		%	0	4.8	0	14.3	0	4

Being that this study is controlling for age, sex, and side; the right condyle of the tibia was assessed for OA as well and frequencies are shown in the cross-tabulation in Table 47. There are no individual from either sex with OA of the right lateral condyle of the tibia in age categories one, two, or three. The only osteoarthritic representatives can be found in age category four with one female and one male. The female frequency of right medial tibial condylar OA is 1 individual and the male frequency is 1 individual as well. The female prevalence of right medial tibial condylar OA is1.2% for females, and ~2% (1.96) for males. Similar as its left counterpart, females and males both make up 50% of the incidence of OA on this joint surface (F-1, M-1).

Table 47: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Right Lateral Condyle of the Tibia

Sex	OA		Age Categories					Total Sample
			1.00	2.00	3.00	4.00	5.00	
F		N	0/18	0/29	0/11	1/18	0/7	1/82
		%	0	0	0	5.6	0	1.2
M		N	0/10	0/21	0/6	1/7	0/7	1/51
		%	0	0	0	14.3	0	1.9

The graphs shown on Figure 23 illustrate the frequency of individuals with OA of the left and right lateral condyles of the tibia by mean age. Those in the top section denoted by "0" are not arthritic while those in the bottom section denoted with a "1" are positive for OA. The data indicates that OA of the left lateral tibial condyle is both more frequent and occurs earlier in life. These graphs depict perhaps best the low levels of OA on the lateral condyles of the tibia.

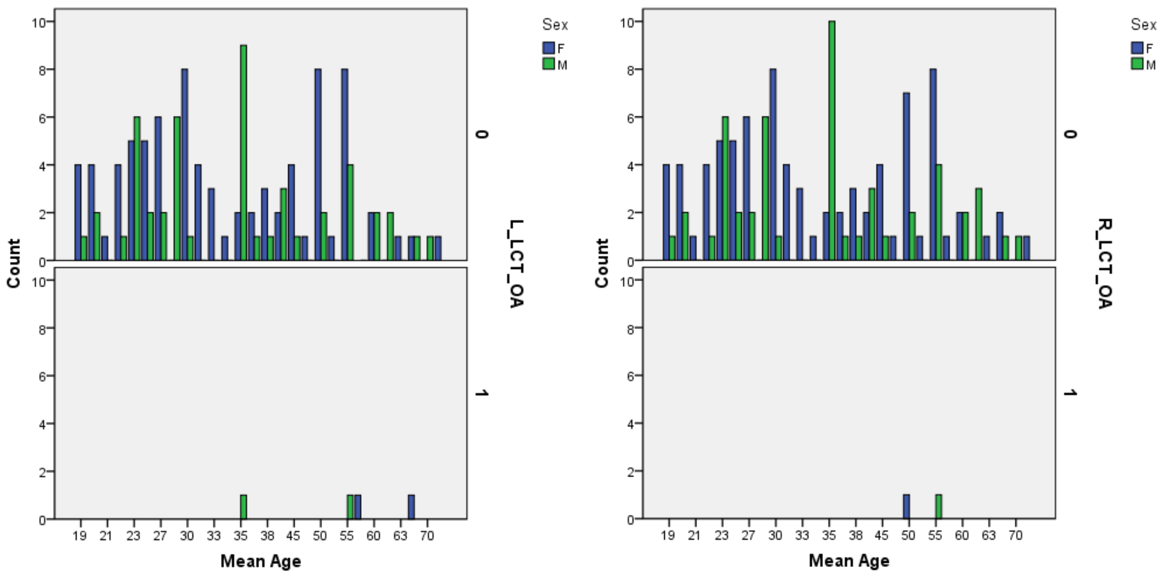

Figure 23: Graph Illustrating the Age and Sex Distribution of OA on the Left and Right Lateral Condyles of the Tibiae

Medial Condyle of Tibia

The frequency of OA is the number of individuals with OA, and the prevalence is the frequency of OA divided by the number of individuals in the sample utilized. The frequency of individuals with left and right medial condyle of tibia OA is almost nonexistent (Tables 48 and 49). One single individual out of 134 usable left medial condyles of tibiae were found to have OA (.7%). The frequency of OA on the left medial condyle of the tibia is 1 individual and the prevalence is .7%. There are no cases of OA on the right medial condyle of the tibia. The right medial condyle of the tibia is the only joint surface in this study completely lacking any incidence of OA.

Table 48: Frequency Data on OA of the Left Medial Condyle of the Tibia

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	133	99.3
Present	1	.7
Total	134	100.0

Table 49: Frequency Data on OA of the Right Medial Condyle of the Tibia

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	134	100.0
Present	0	0
Total	134	100.0

Although there is only one single individual with OA of this joint surface (LMCT), it is still important to know what age and sex group that individual was part of (Table 50). The only individual with OA on the left medial condyle of the tibia was a female in age category four. The female frequency of OA for the left medial condyle of the tibia is 1 individual with a female prevalence of 1.2%. Being that there are no individuals with OA on the right medial condyle of the tibia it is unnecessary to provide an age and sex group cross-tabulation with OA frequency with graphs to show distribution patterns.

Table 50: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Left Medial Condyle of the Tibia

Sex	OA		Age Categories					Total Sample
			1.00	2.00	3.00	4.00	5.00	
F		N	0/18	0/29	0/11	1/19	0/7	1/83
		%	0	0	0	5.3	0	1.2
M		N	0/10	0/21	0/6	0/7	0/6	0/50
		%	0	0	0	0	0	0

Patellar Surface of Femur

The frequency of OA is the number of individuals with OA, and the prevalence is the number of cases with OA divided by the number of individuals in the sample utilized. The patellar surface of the femur appears to have one of the higher rates of OA than any other joint surface in the knee complex. The frequency of OA on the patellar surface of the left femora is 8 individuals with a prevalence of 6%. The frequency of OA on the patellar surface of the right femora is 13 individuals with a prevalence of 9.7%. The data from Tables 51 and 52 indicate that OA on the patellar surface of the femur is relatively common and that it occurs more frequently on the right side.

Table 51: Frequency Data on OA of the Patellar Surface of Left Femur

OA	Number of Individuals (N)	Prevalence (%)
Not Present	126	94
Present	8	6
Total	134	100.0

Table 52: Frequency Data on OA of the Patellar Surface of Right Femur

OA	Number of Individuals (N)	Prevalence (%)
Not Present	121	90.3
Present	13	9.7
Total	134	100.0

The frequency of OA on the patellar surface of the left femur is shown cross-tabulated with sex and age categories on Table 53. Neither sex has any cases of OA in age category one. There is one female and one male in age category two with patellar surface of femora OA. There are three females with OA in age category four, and three males with OA in age category five. The female frequency of OA on the patellar surface of left femora is 4 individuals and the male frequency of 4 individuals. The female prevalence of OA is 4.8% and the male prevalence is 8% for left patellar surface of the femur. Both sex show age-related patterns but males are found more in age category five and females in age category four.

Table 53: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Left Patellar Surface of Femur

Sex	OA		Age Categories					Total Sample
			1.00	2.00	3.00	4.00	5.00	
F		N	0/18	1/29	0/11	3/19	0/7	4/84
		%	0	3.4	0	15.8	0	4.8
M		N	0/10	1/20	0/6	0/7	3/7	4/50
		%	0	5	0	0	42.8	8

Controlling for age and sex, the prevalence of OA on the patellar surface of the right femur is shown on the cross-tabulation on Table 54. Similar as the previous joint surfaces assessed, there are no cases of OA for either sex in the first age category. There is one female with OA on the patellar surface of the right femur. There are four females and two males from age category four. And in the last age category there are two females and four males. The frequency of OA for this joint surface is still close to even distribution for females and males (F-7 M-6). Female prevalence of right patellar surface of the femora OA is at 8.4% and male prevalence is 11.8%.

Table 54: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Right Patellar Surface of Femur

Sex	OA		Age Categories					Total Sample
			1.00	2.00	3.00	4.00	5.00	
F		N	0/18	1/29	0/11	4/18	2/7	7/83
		%	0	4.8	0	22.2	28.6	8.4
M		N	0/10	0/21	0/6	2/7	4/7	6/51
		%	0	0	0	28.6	57.1	11.8

The graphs in Figure 24 indicate a variable distribution between OA on the left and right patellar surfaces of femora. Those in the top section denoted by "0" are not arthritic while those in the bottom section denoted with a "1" are positive for OA.OA on the left patellar surface of the femora tend to be evenly distributed over the mean age range while on the right there seems to be a stronger correlation with OA frequency and mean age. This is also one of the few joint surfaces where males are developing the disease earlier and females are more afflicted with advanced age.

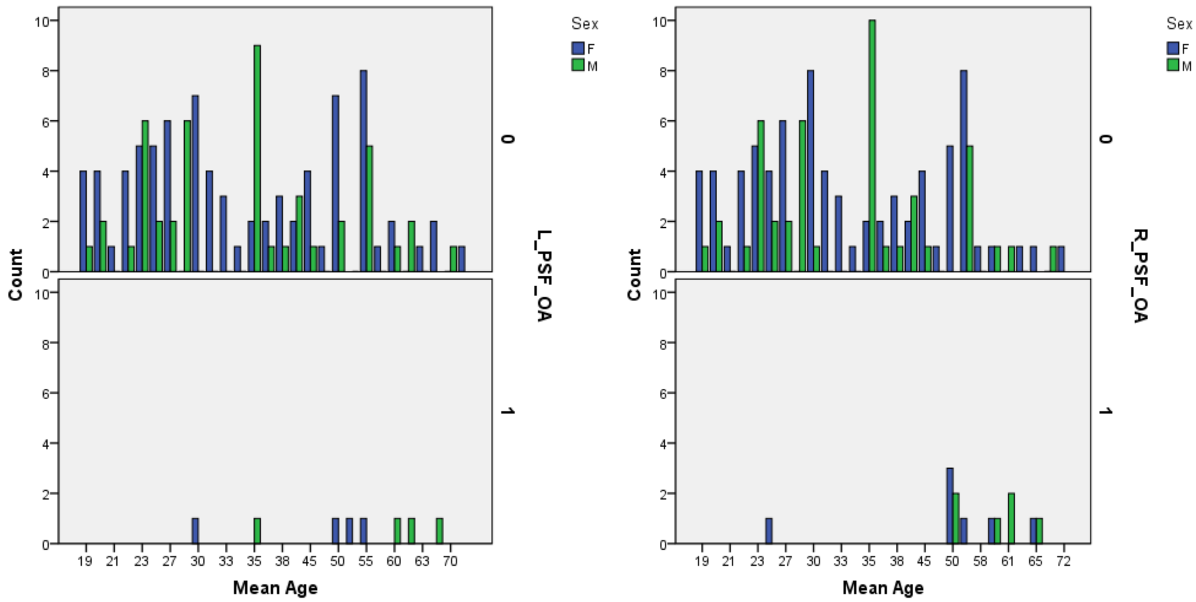

Figure 24: Graph Illustrating the Age and Sex Distribution of OA on the Left and Right Patellar Surface of Femora

Femoral Surface of Patella

The frequency of OA is the number of individuals with OA, and the prevalence is the amount of cases of OA divided by the number of individuals in the sample utilized. One-hundred and twenty-seven left patellae and 129 right patellae were utilized in this study. Both left and right femoral surfaces of patellae show high levels of OA prevalence as seen in Tables 55 and 56. The frequency of OA on the femoral surface of the left patellae is 24 individuals and the prevalence is 18.9%. The frequency of OA on the femoral surface of the right patellae is also 24 individuals with a prevalence of 17.8%. The disparity in prevalence by side is because there are more right patellae than left patella. A similar prevalence rate on each side is indicative of bilaterality. This femoral surface of the patellae (left and right) exhibit the most significantly affected joint surface observed in this study.

Table 55: Frequency Data on OA of the Femoral Surface of Left Patellae

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	103	81.1
Present	24	18.9
Total	127	100.0

Table 56: Frequency Data on OA of the Femoral Surface of Right Patellae

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	106	82.2
Present	24	117.8
Total	129	100.0

The frequency of OA on the femoral surface of the left patellae is shown cross-tabulated with age and sex category data on Table 57. Similar as every other joint surface assessed for OA prevalence there is not a single individual with OA in age group one as expected. There are 3 females with OA on this joint surface in the age group three. There are 2 males in from age group three with OA on the femoral surface of their left patella. There is a spike in prevalence for OA on this joint surface with 8 females in age group four positive for OA as well as 3 males in age group four. Lastly in age group five there are 3 females and 5 males with OA on the femoral surface of their left patella. The female frequency for OA on the femoral surface of the left patella is 14 individuals and the male frequency is 10 individuals. The prevalence of OA on this joint surface for females is 17.5%, and the male prevalence of OA on this joint surface is 21.3%.

Table 57: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Femoral Surface of Left Patellae

		Age Categories					Total
Sex	**OA**	**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	Sample
F	**N**	0/18	3/29	0/10	8/16	3/7	14/80
	%	0	10.3	0	50	42.8	17.5
M	**N**	0/10	0/19	2/5	3/7	5/6	10/47
	%	0	0	40	42.8	83.3	21.3

In order to control for side in addition to age and sex groups, both left and right patellae were assessed for frequency and prevalence. The frequency of OA on the femoral surface of the right patellae is shown in cross-tabulated data on Table 58. There are no individuals with OA on this joint surface within age group one or two. One single male has OA on this locus from age group three. Similar as the left patella there seems to be a spike in OA frequency in females from age group four. There are also 4 males from age group four with OA on this joint surface. Lastly in age group five there are 3 females and 5 males with OA on the femoral surface of the right patella. The female incidence for OA of the femoral surface of the right patella is 13 individuals while for males the incidence is 10 individuals. The prevalence of OA on the femoral surface of the right patella in females is 15.9% and the prevalence for OA on this joint surface for males is 21.3%.

Table 58: Age Group and Sex Group Cross-Tabulation with OA Frequency of the Femoral Surface of Right Patellae

Sex	OA	Age Categories 1.00	2.00	3.00	4.00	5.00	Total Sample
F	N	0/18	0/29	0/10	10/18	3/7	13/82
	%	0	0	0	55.6	42.8	15.8
M	N	0/10	0/20	1/5	4/6	5/6	10/47
	%	0	0	20	66.7	83.3	21.3

Age and sex distribution is shown on the graphs in Figure 25. Those in the top section denoted by "0" are not arthritic while those in the bottom section denoted with a "1" are positive for OA. Firstly, it can be noted that younger females are more prone to OA of the femoral surface of the left patella than the right patella. The second observation one can observe from the graphs on Figure 22 is that OA on the femoral surface of the patella is relatively common amongst the Kellis 2 skeleton population.

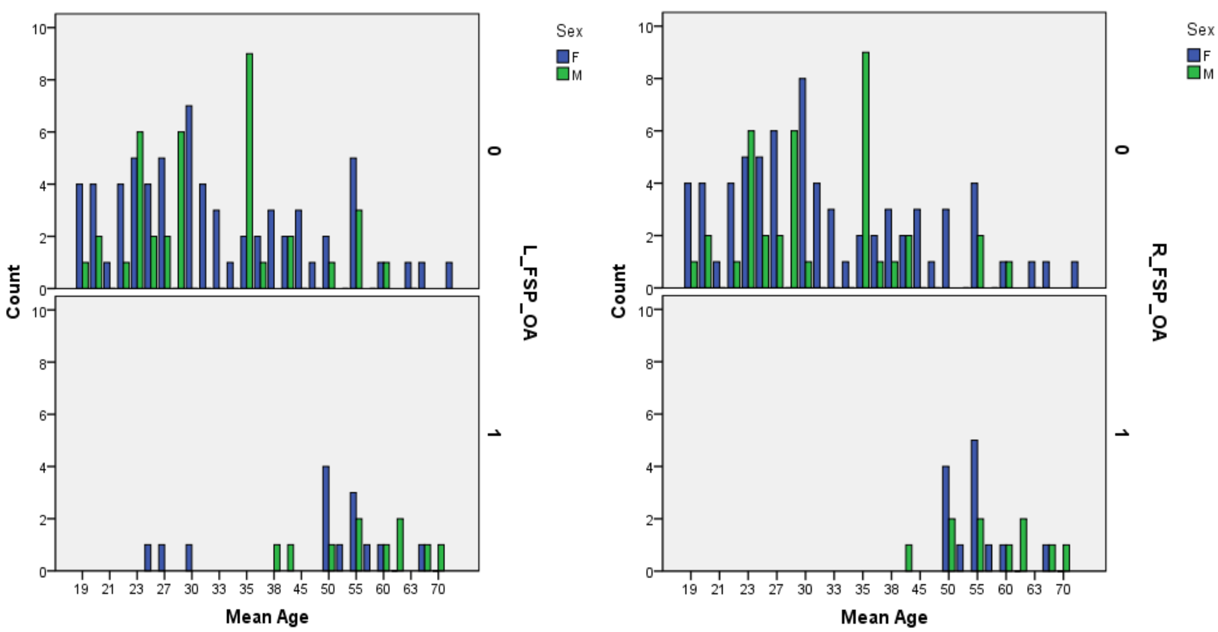

Figure 25: Graph Illustrating the Age and Sex Distribution of OA on the Left and Right Femoral Surface of Patellae

The Knee Joint Complex

The frequency of OA is the number of individuals with OA, and the prevalence is the frequency of OA divided by the number of individuals in the sample utilized. The incidence of left knee OA is 25 individuals and the prevalence of left knee OA is 19.5% (Table 59). The frequency of right knee OA is also 25 individuals with a prevalence of 19.4% (this is due to there being one less in the total sample of left knees) (Table 60). OA of both the left and right knees is found to be quite common in the Kellis 2 sample.

Table 59: OA Frequency of the Left Knee

OA	Number of Individuals (N)	Prevalence (%)
Not Present	103	80.5
Present	25	19.5
Total	128	100.0

Table 60: OA Frequency of the Right Knee

OA	Number of Individuals (N)	Prevalence (%)
Not Present	104	80.6
Present	25	19.4
Total	129	100.0

The incidence of left knee OA is shown cross-tabulated with age and sex category data on Table 61. Three females and one male can be found with left knee OA in age category two. Two males were found to have OA of the left knee in age category three. Eight females and three males are found to have OA of the left knee in age category four. Three females and five males are found to have left knee OA in age category five. The female frequency for left knee OA is 14 individuals while the male frequency is 11 individuals. The female prevalence for left knee OA is 17.5% and the male prevalence is 22.9%. Male frequency is lower but proportionally males are more afflicted by OA of the left knee.

Table 61: Age Group and Sex Group Cross-Tabulation with OA Frequency of Left Knee OA

		Age Categories					Total
Sex	**OA**	**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	Sample
F	**N**	0/18	3/29	0/10	8/16	3/7	14/80
	%	0	10.3	0	50	42.8	17.5
M	**N**	0/10	1/19	2/5	3/7	5/6	11/48
	%	0	5.3	40	42.8	83.3	22.9

Controlling for age, sex, and side the right knee is investigated for OA as well.The incidence of right knee OA is shown cross-tabulated with age and sex category data on Table 62. There is on female with right knee OA in age category two and one male in age category three. There are 11 females and 4 males with right knee OA in age category four. Lastly there are 3 females and 5 males with right knee OA in age category five. The female frequency for right knee OA is 15 individuals, and for males is 10 individuals. The female prevalence for right knee OA is 18.3% and the male prevalence is 21.3%. Once again females have generally a higher frequency of right knee OA but males proportionally are still more afflicted.

Table 62: Age Group and Sex Group Cross-Tabulation with OA Frequency of Right Knee OA

		Age Categories					Total
Sex	**OA**	**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	Sample
F	**N**	0/18	1/29	0/10	11/18	3/7	15/82
	%	0	3.4	0	61.1	42.8	18.3
M	**N**	0/10	0/20	1/5	4/6	5/6	10/47
	%	0	0	20	66.7	83.3	21.3

The frequency of OA is the number of individuals with OA, and the prevalence is the frequency of OA divided by the number of individuals in the sample utilized. The frequency of bilateral knee OA is 20 individuals and the prevalence is 15.7%. The frequency of unilateral knee OA is 30 individuals with a prevalence of 23.1%. Unilateral knee OA is significantly more common than bilateral knee OA (Tables 63 and 64).

Table 63 : Bilateral OA Frequency of the Knee

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	107	84.3
Present	20	15.7
Total	127	100.0

Table 64: Unilateral OA Frequency of the Knee

OA	**Number of Individuals (N)**	**Prevalence (%)**
Not Present	100	76.9
Present	30	23.1
Total	130	100.0

The frequency of left knee OA is shown cross-tabulated with age and sex category data on Table 65. There is 1 female in age category two with bilateral knee OA and 1 male in age category three with bilateral knee OA. There is a sudden spike in bilateral OA frequency seen with 8 females in age category four. There are 3 males with bilateral knee OA in age category four. There are 3 females and 4 males with bilateral knee OA in the Kellis 2 population sample. The female frequency of bilateral knee OA is 12 individuals and the male frequenc is 8 individuals. The female prevalence of bilateral knee OA is 15% and the male prevalence is 17%.

Table 65: Age Group and Sex Group Cross-Tabulation with Bilateral Knee OA Frequency

		Age Categories					Total
Sex	**OA**	**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	Sample
F	**N**	0/18	1/29	0/10	8/16	3/7	12/80
	%	0	3.4	0	50	42.8	15
M	**N**	0/10	0/20	1/5	3/7	4/5	8/47
	%	0	0	20	42.8	80	17

The OA frequency data was cross-tabulated with age and sex data and is shown on Table 66. There are 3 females and 1 male in age category two with unilateral knee OA. There are 2 males with unilateral knee OA in age category three. There is another spike in female frequency in age category four with 11 females and 4 males. Lastly there are 3 females and 6 males with unilateral knee OA in age category five. The female frequency for unilateral knee OA is 17 individuals while the male incidence is 13 individuals. The female prevalence for unilateral knee OA is 20.7% and the male prevalence is 27.1%. The female frequency is higher while the male prevalence is still higher than the female prevalence.

Table 66: Age Group and Sex Group Cross-Tabulation with Unilateral Knee OA Frequency

		Age Categories					Total
Sex	**OA**	**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	Sample
F	**N**	0/18	3/29	0/10	11/18	3/7	17/82
	%	0	3.4	0	50	42.8	15
M	**N**	0/10	1/20	2/5	4/6	6/7	13/48
	%	0	5	40	66.7	85.7	27.1

Discussion

The data derived from this study is very descriptive and offers information on prevalence of OA not only within the knee joint complex but also on each surface within the knee joint complex. The knee joint shows relatively high incidence and prevalence of OA. This is to be expected because the knee is one of the most complex joints in the human body consisting of not one single compartment but three compartments. The knee joint consists of the medial/lateral compartments and the patellofemoral compartment (Ortner, 2003; Rogers and Waldron, 1995).The complexity of the knee joint has made it difficult to assess, and compare OA data from other studies (Bridges, 1993). The biomechanics of the knee joint complex makes certain regions of the joint more susceptible to OA (Resnick and Niwayama, 1995). The patellofemoral compartment involves the largest range of motion which with advanced age leads to excessive wear and tear on the surface of the joint.

The frequency and demographic prevalence of OA on the various parts of the knee for the Kellis 2 sample can inform on various etiological factors of OA for the representative population sample. The lateral condyle of the femora is not as severely affected by OA although it does exhibit side disparities. OA of the right lateral femoral condyle is more common than OA of the left lateral femoral condyle. With such a small sample of those with OA of the left lateral femoral condyle it is difficult to identify a true trend. OA on this joint locus is more common in males and is only observed in age categories three, four, and five- indicating age as strong etiological factor for both males and females. OA of the right lateral femoral condyle is differentially distributed. Female incidence is significantly more than male incidence (5:1) and occurs most frequently in age category four. The incidence of OA and the disparities in the data are not significant enough to make sound biocultural interpretations about sexual divisions of labor. There is some degree of sexual dimorphism of the right lateral femoral condyle which may meant that females are simply more susceptible to this pattern of OA.

With the medial condyle of the femur, OA seems more prone to the right side in females and the entire sample (Table 67) although the disparity is so slight that it may be insignificant. While the sample may be small, of those with OA of the medial femoral condyle OA, there still seems to be a pattern in the knee that indicates the right side in general tends to be more arthritic. The demographic prevalence data of left and right medial condylar femoral OA indicates one single individual with left medial condylar OA can be found in age category three and is male, the remaining cases with left/right medial condylar OA is found in age categories four and five.

There are more females than males with OA on both left and right medial femoral condyles. There appears to be somewhat of a correlation with age and OA prevalence for both males and females on each joint locus. Females are severely afflicted in age category four for the right medial femoral condyle. Females also make up significantly more of the frequency for both left and right sides. The youngest individual with medial femoral condylar OA is a male (left) from the third age category. Females outweigh the frequency of OA by 11:3; this data indicates that females from the Kellis 2 sample are highly susceptible to OA of the medial femoral condyle especially on the right side. Male OA prevalence is the same for both left and right medial/lateral femoral condyles while females have quite high levels of medial femoral condylar OA. This disparity indicates varying amounts of activity at this joint site (Jurmain, 1999).

Table 67: Percentage of LCF and MCF OA Prevalence by Group in Sample

Group	Lateral Condyle of Femur		Medial Condyle of Femur	
	Left	Right	Left	Right
Males	(2) 4%	(1)2%	(2) 4%	(1) 2%
Females	(1) 1.2%	(4) 4.8%	(4) 4.8%	(7) 8.4%
Total Sample	(3) 2.2%	(5)3.7%	(6) 4.5%	(8) 6%

The lateral condyles of both tibiae exhibit low levels of OA prevalence, and the left side has a slightly higher frequency of OA (4:2) and prevalence (Table 68). Males and females make up equal frequency of OA on the lateral tibial condyles. Although the same amount of males and females can be found with both left and right lateral tibial condylar OA, the demographic pattern differs slightly. The data indicates that OA of the left lateral tibial condyle is both more frequent and occurs earlier in life. In general the trend indicates males as developing OA on either joint locus earlier than females who are only found with OA in age categories four and five. The medial condyle of the tibia exhibits the lowest prevalence of OA in the entire sample (Table 68). One individual is found to have OA on the left medial condyle of the tibia and no individual is found to have OA on the right medial condyle of the tibia. The sole individual (B-655) with OA on the left medial condyle of the tibia is a 55 year old female. The individual declared arthritic (B-655) exhibits eburnation (Figure 26), which are both the clinical and paleopathological diagnostic criteria for OA (Rogers and Waldron, 1995; Mann and Hunt, 2005; Brandt et al., 1998). The author experimented with different exposures during photography and found negative exposure brings out the eburnation as can be observed by comparison of the photographs on Figure 23.

Table 68: Percentage of LCT and MCT OA Prevalence by Group in Sample

Group	Lateral Condyle of Tibia		Medial Condyle of Tibia	
	Left	**Right**	**Left**	**Right**
Males	(2) 4%	(1) 2%	(0) 0%	(0) 0%
Females	(2) 2.4%	(1) 1.2%	(1) 1.2%	(0) 0%
Total Sample	(4) .3%	(2) 1.5%	(1) .7%	(0) 0%

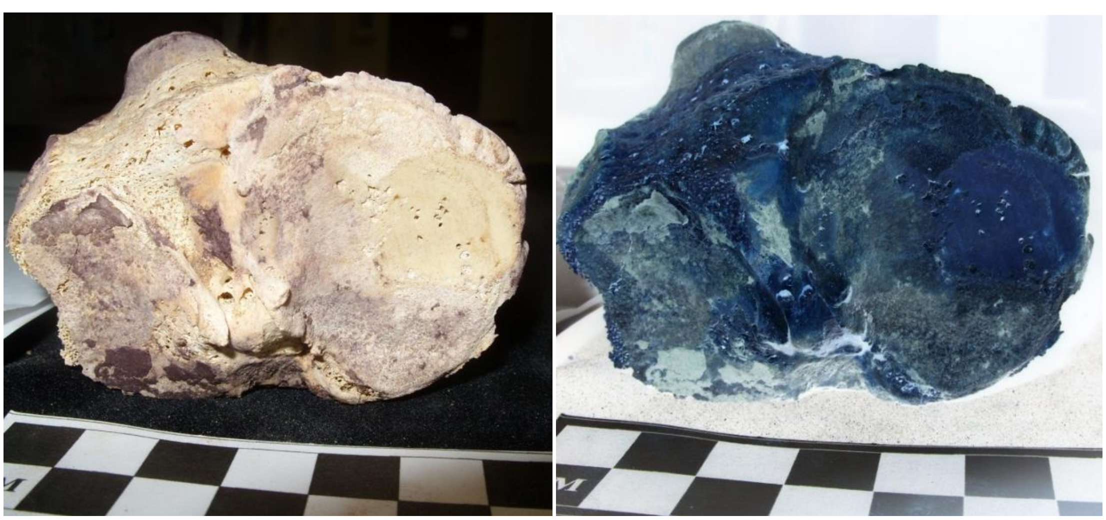

Figure 26: Severe OA (eburnation) on medial condyle of the left tibia (B-655)

The patellofemoral compartment exhibits the highest prevalence of OA in the knee joint complex both in males and females (Table 69). OA on the patellar surface of the femur is more common on the right side than on the left (13:8). PSF OA is not highly sexually dimorphic in the Kellis 2 sample. OA Prevalence rates are similar for males and females, the disease is highly correlated with age and males are found to be in higher frequency in age category five (n=3) and females in highest incidence in age category four (n=3). Males and females are equally afflicted with OA of the patellar surface of the femora throughout the sample.

Table 69: Percentage of PSF and FSP OA Prevalence by Group in Sample

Group	**Patellar Surface of Femur**		**Femoral Surface of Patella**	
	Left	**Right**	**Left**	**Right**
Males	(4) 8%	(6) 11.8%	(10) 21.3%	(10) 21.3%
Females	(4) 4.8%	(7) 8.4%	(14) 17.5%	(13) 15.9%
Total Sample	(8) 6%	(13) 9.7%	(24) 18.9%	(23) 17.8%

The femoral surface of the patella exhibits the highest frequency and prevalence of OA out of each joint surfaced assessed in this study. In fact the FSP has the highest incidence of eburnation of any joint surface in this study, followed closely by the PSF. Figure 27 is an example of severe OA of the patellofemoral compartment (B-280) of a 60 year old female. Left and right share similar OA prevalence (24:23). Females have a higher frequency and prevalence of OA on the femoral surface of left patellae in the Kellis 2 sample. The pathogenic patterns of OA are sexually dimorphic. Male prevalence is positively associated with age with growing frequency from age category three through five. Females develop the disease much earlier than males having 3 individuals with OA in age category two. The majority of the females with OA on either right or left FSP are grouped in age category four (L-8 and R-10). The patellofemoral compartment exhibits the highest rate of eburnation within the entire knee joint complex.

Figure 27: Severe OA (eburnation) of the Patellofemoral compartment (B-280)

The prevalence findings for the entire knee joint are shown on Table 60. Males show higher prevalence for both left and right knee OA, although female prevalence is not extremely lower there still is a bit of a disparity. The total sample seems to be evenly affected by both left and right knee OA (Table 70). Males are more affected by left knee OA within their group while females are more affected on their right knee within their group. Knee OA tends to be more unilateral in manifestation for both males and females (Table 71). These unilateral cases may be more related to secondary OA based on their anatomical distribution.

Table 70: Prevalence of Knee OA

Group	Left Knee	Right Knee
Males	22.9%	21.3%
Females	17.5%	18.3%
Total Sample	19.5%	19.4%

Table 71: Laterality Prevalence of Knee OA

Group	Unilateral	Bilateral
Males	27.1%	17%
Females	20.7%	15%
Total Sample	23.1%	15.7%

The box-plot graphs on Figure 28 indicate a few things about OA patterning in the Kellis 2 sample. Firstly, males are more afflicted by knee OA between the sexes and slightly more prone to OA of the left knee. Males tend to develop knee OA before the age of 60. Females develop right knee OA earlier than left knee OA. Prevalence disparities are more apparent on the left knee. These patterns and rates of OA in the knee are not variable enough to definitively suggest sexual divisions of labor but the rates are indicative of age being perhaps the most significant etiological factor for OA in the Kellis 2 sample.

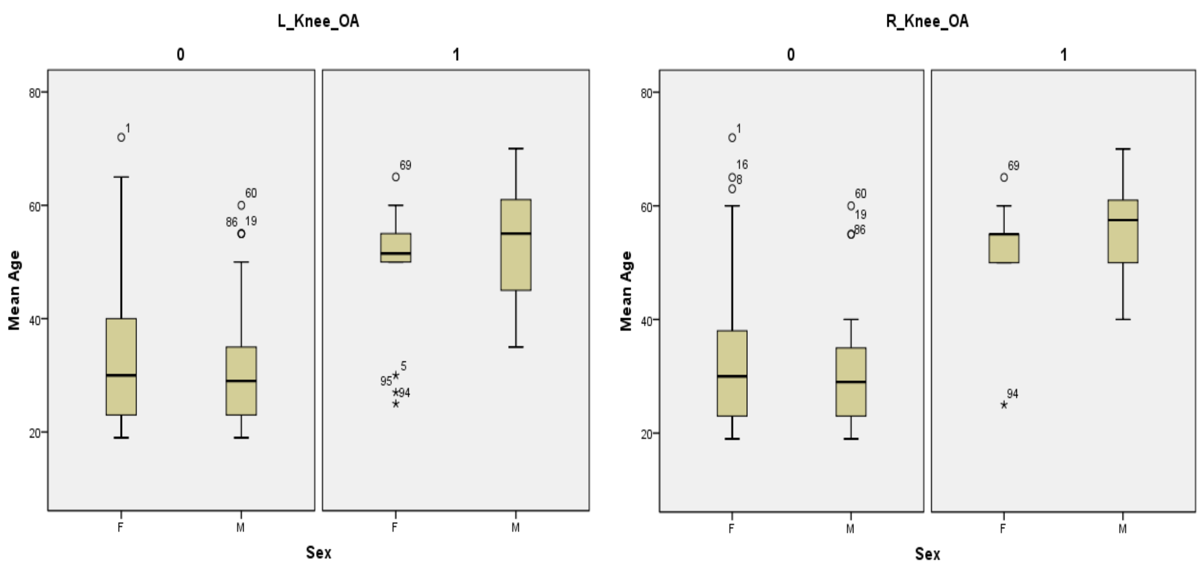

Figure 28: Box-Plot graphs of Age and Sex Distribution of Knee OA

Conclusions

As previously stated it is inherently difficult to compare clinical and archaeological data and therefore OA patterns from x-rays or symptomatic descriptions cannot be compared validly (Jurmain, 1999). One must consider biomechanics as being highly related to the patterning of OA being that the disease is so highly correlated with activity. One consideration for the knee is the lack of OA on the medial condyles of the tibiae. The patterning of OA (or lack thereof) may be due to biomechanical factors related to the valgus angle of humans. The valgus angle on the medial part of the knee may relieve pressure of the medial femoral condyle from the articulating tibial condyle. This may lead to enthesopathic manifestations while not affecting the structural integrity of the joint complex.

There seems to be little to no sexual dimorphism of knee OA. Males have higher OA prevalence for both left and right knees but the disparity is not at a high enough level to be significant. The joint surface which is most affected is the femoral surface of the patella, and the surface leas affected is the medial condyle of tibia. The findings from this study indicate that OA starts in the femora and proceeds to the tibia based on the mildness of OA observed on the tibia. The higher rate of patellofemoral compartment OA is indicative of less axial loading pressure and more overuse of the patellae going over the femora during extension. The lack of medial tibial condylar OA is interesting; anatomically this region simply must not be very susceptible.

Bridges' (1992) work found that there are no statistically significant differences in OA levels of pre-agriculturists and agriculturists therefore it is hard to validly say that the rates at

Kellis 2 are concordant with agriculturists. Other research (Jurmain, 1999; Larsen, 1997) has found high levels of knee OA in individuals who participated in farming activities, and based on isotopic, textual, and archaeological data suggests that Kellis was an agricultural community. The lack of sexual dimorphism in knee OA indicates males and females shared similar levels of biomechanical stress on a daily basis. The disease is observed earlier in females and more severe in males. Data from the knee shows that age is a significant etiological factor for males and females, and that either sex is about equally susceptible to knee OA. The rates of knee OA are not indicative of sexual divisions of labor. Earlier female development may be attributed to the endocrine system (Weiss and Jurmain, 2007). The most conclusive findings about the knee from this study is that age is perhaps the most significant etiological factor with OA, and the demographic findings indicate that males and females were participating in similar amounts of mechanical loading of the knee joint complex.

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CHAPTER FOUR: CONCLUSIONS

Discussion

This study represents a unique opportunity to assess the osteoarthritic prevalence and severity of a unique bioarchaeological sample from Egypt. The Dakhleh Oasis Project is an interdisciplinary multinational research endeavor which has studied the material and biological remains of populations which lived in the Dakhleh Oasis, one of five great depressions in Egypt. The geological proximity of the Dakhleh Oasis surface from the water table is quite close which makes the region very fertile in many areas allowing for agricultural development. The skeletons used in this study are from the Kellis 2 cemetery which is located near the town of Kellis. The ecology of the desert provides a unique mortuary environment. Several factors such as the heat, aridity, and alkalinity of the soil combine in the desert resulting in excellent osteological preservation at Kellis 2. The skeletons from this site have been analyzed for disease, diet, and paleodemography among other things (Dupras, 1999; Wheeler, 2009; Williams, 2008). This is the first study which has assessed a substantial number of skeletons from this group for the incidence, demographic prevalence, severity, and anatomical distribution of OA.

The joints throughout the body differ in OA prevalence and severity for various reasons. Certain joints may become arthritic due to activities occurring early or perhaps later in life. “Some joints (elbow and hip particularly, as compared to other joints) appear to be under differential risk, given the age of the onset of mechanical loading; early injury and/or modification of joint mechanics can produce OA changes later in life” (Jurmain, 1999: 105).

The biomechanical aspects of joints can also be quite informative as to OA patterning. Jurmain (1999) states, "the knee appears to be most prone to activities involving repetitive bending, while the hip and spine appear to be more at risk as the result of heavy lifting" (p.105).

The data in this thesis indicates that knee OA is more common than hip OA in the Kellis 2 population. Sexual differences indicate that males are more afflicted by both hip and knee OA. This may have to do with the fact that males tend to have generally larger bodies than females therefore the anatomical influences may increase mechanical loading (Weiss and Jurmain, 2007). Most if not all previous OA studies find males to have a generally higher incidence of OA than females (Bridges, 1991; 1992; Jurmain, 1977a; Waldron, 1997). Although OA in all joint complexes is found higher in prevalence with males, there is a significant disparity of hip OA prevalence between males and females in the Kellis 2 skeletal population sample (Table 72). Differential rates of OA manifestation between males and females, or sexual dimorphism, is interpreted as varying levels of physical activity. OA being an activity-related pathological condition (Larsen, 1997) those joint surfaces with little to no signs of OA would likely have been subjected to less biomechanical stress. Cultural patterns such as sexual divisions of labor can be assumed in cases of population samples which exhibit high levels of sexual dimorphic OA (Jurmain, 1999; Larsen, 1997; Larsen and Ruff, 2011).

Table 72: Prevalence of Hip OA

Group	Left Hip	Right Hip
Males	13.7%	13.7%
Females	3.6%	5.9%
Total Sample	7.4%	8.9%

When the general patterns of OA from the Kellis 2 sample are compared with previous studies, the variable aspects of the disease become apparent. Rogers and Dieppe (1994) have found from a British (pre-Medieval and post-Medieval) skeletal sample that hip OA was more frequent than knee OA in early history, and that knee OA is actually a relatively new pathological development. This is not the case for skeletons from Kellis 2 because the opposite is the case in that knee OA was more common than hip OA. Rogers and Dieppe (1994) believe that obesity may have been the cause of the high hip OA prevalence. Merbs' (1983) research on a Canadian Inuit population sample found that patellofemoral OA is not as prevalent as OA of the later tibiofemoral compartment. The Kellis 2 sample exhibits the highest levels of OA in the patellofemoral compartment.

Table 72 shows the prevalence rates of knee OA by side and sex. Males are equally afflicted by left and right hip OA while females are slightly more afflicted on the right. The total sample appears to be more afflicted on the right as well. Males show significantly higher prevalence of hip OA than females; these differences indicate sexual dimorphism which is usually interpreted as sexual divisions of labor (Jurmain, 1999; Larsen, 1997). When considering multiple lines of evidence, the higher rates of hip OA may also be attributed to higher levels of terrestrial mobility which is supported by isotopic data (Dupras and Schwarcz, 2001). The most conclusive interpretation of the disparity in prevalence rates is that males were doing more physically demanding labor as shown by the higher levels of OA. The prevalence rates for the knee are different (Table 73). The only similar pattern is that males have higher prevalence rates than females. Although it has already been established that in the archeological context OA is slightly more common in males than females therefore these rates should be expected. Males are more affected on the left while females more so on the right. The total sample is equally affected on both sides. These rates are not variable enough to confidently and validly claim possible sexual divisions of labor.

Table 73: Prevalence of Knee OA

Group	Left Knee	Right Knee
Males	22.9%	21.3%
Females	17.5%	18.3%
Total Sample	19.5%	19.4%

The prevalence of bilaterality and unilaterality for both the hips and knee is informative on both the etiology and perhaps pathogenesis of OA (Tables 74 and 75). Unilateral OA is usually secondary in nature, the result of injury or episodic micro/macro trauma to the affected joint. High levels of unilateral hip OA in males may be related to behavioral patterns such as riding horses or camels (Molleson, 2007), or could be the result of increased mobility (Larsen, 1997) as also indicated by isotopic evidence (Dupras and Schwarcz, 2001). The laterality disparities are significantly less for the knee which indicates that males and females were subjected to similar amounts of mechanical loading in this joint complex.

Table 74: Laterality Prevalence of Hip OA

Group	Unilateral	Bilateral
Males	16.7%	9.8%
Females	5.9%	3.6%
Total Sample	10.4%	5.9%

Table 75: Laterality Prevalence of Knee OA

Group	Unilateral	Bilateral
Males	27.1%	17%
Females	20.7%	15%
Total Sample	23.1%	15.7%

Although clinical and archaeological OA findings in most cases cannot be conclusively compared due to differing diagnostic criteria between disciplines (Jurmain, 1999; Weiss and Jurmain, 2007), the general pattern of OA in the Kellis 2 sample is reflective of modern clinical rates when comparing the hips and the knees- the knee is more arthritic both within and between age and sex groups. The disparity between male and female OA in both the hips and the knees is indicative of males living a more strenuous lifestyle due to likely sexual divisions of labor (Jurmain, 1980). The case of OA in the hips is more convincing because the disparity for OA prevalence of this joint is significantly greater than for the knee (although males are still more afflicted than females in the knees as well.

General findings of severity from this thesis may be used as a method of ranking OA prevalence by joint complex (Table 76). This type of data can be interpreted in various ways; the right medial knee does not exhibit excessive levels of osteological characteristics associated with OA, and that the left/right patellar knees share the highest OA scores. The higher score seen in the joint complex of the left medial knee may be reflective of Molleson and Blondiaux's (1994) findings that OA on the medial condylar aspects of the left knee have been observed in associated with horse riding in previous Near East studies and on the skeletons from the Spitalfields, London. This is believed to be the result of the rider mounting on the left side of the horse. The findings are similar to those of past paleopathological OA studies in that patellofemoral OA is the most severe in the lower appendicular joints.

Table 76: Maximum OA Scores by Joint Complex

Joint Complex	Maximum OA Score Received
Right Medial Knee	12
Left Lateral Knee	14
Right Hip/Right Lateral Knee	16
Left Medial Knee	19
Left Hip	21
Left Patellar Knee/Right Patellar Knee	23

There are some aspects of this project that the author would have done differently after looking back at all the data. Firstly, the variable "degree of lipping" and "extent of lipping" would have been more substantial as simple "lipping" which would have been scored 0-3 (although this variable change is not found to effect the rates of OA incidence and prevalence). The other variable that would have been good to change was "osteophytes," this variable is useful although scoring present/absent (0/1) was not as statistically sound as if the variable had been graded 0-3 just as the remaining variables. It would have also been interesting to examine OA within the age groups that it was observed. There were many instances where there tended to be more individuals with OA in age category four instead of five, and in the curiosity of the author it might be informative to examine where within age categories four and five OA was observed by mean ages. Another methodological aspect of this research which may have needed some alterations was coding for OA. Most researchers differentiate between moderate and severe OA (Bridges, 1991; 1993; Jurmain, 1977a; 1980) which the author for this project decided to code OA as simply present or absent depending on the presence of osteological characteristics.

It was the authors' decision to examine the rate of intra-observer variation during this study by simply looking at complete composite scores for the individuals assessed in the beginning of this study (Table 77). On average (when all individuals scores are totaled) composite joint scores dropped from the first to second assessment; hip scores dropped 23.3% and knee scores dropped ~32%. It must be stated that the intra-observer comparisons are made from the first skeletons assessed in the beginning of the study. It is the assumption of the author that these scores lowered due to the initial sensitivity toward any osteological characteristic which was considered to be related to the variables which were being assessed. The other fact to be addressed is that the more skeletons one observes throughout the a study, the more one can develop a sense of the range of variation and severity of pathological manifestations (e.g. how can one determine what moderate lipping is until they have seen both the complete absence of lipping as well as extreme examples). The intra-observer variation observed in this study indicates to the author that in future paleopathological research the author will allow themselves a day or two to pre-assess individuals from the collection of interest in order to avoid such intra-observer variation.

Future Research

The demographic data collected on OA from this study can be compared on a relatively superficial basis (Bridges, 1993; Jurmain and Kilgore, 1995). Rates of demographic incidence and prevalence can be compared (generally) based on the author's diagnostic criteria of OA. The characteristics generally agreed upon as being associated with OA manifestation are used in the scoring methodologies of other researchers and are subsequently used for scoring purposes in this study.(Jurmain, 1999; Ortner, 2003; Rogers and Waldron, 1995; Waldron, 2009; Weiss and Jurmain, 2007). One of the biggest issues in paleopathology is the use of clinical data to make interpretations of their own finding (Ortner, 2003; Rogers and Waldron, 1995).

The barrier which exists between the diagnostic criteria in the clinical context and within the paleopathological context needs to be broken by determining a general consensus on the osteological characteristics of OA as seen in both contexts. In order to better understand OA there needs to be more interdisciplinary research done between anthropologists and clinicians. The more integrated research the easier it will be to establish and generally accepted definition of OA. Perhaps the best way to accomplish this is more research on mascerated remains and radiographs (Rogers, 1998). Macerated remains allow for both the clinician and osteologist to view the joint surfaces and margins without being obstructed by connective tissue, and the use of comparative radiology may allow for certain aspects of OA manifestation to be identifiable via x-ray. This research method would also supplement the already vast clinical data on occupation and OA (Jurmain, 1999). While this method may have ideal implications for osteologists, there are many ethical and logistical issues which may make funding such research difficult.

The other aspect of OA studies which needs to be rethought is how OA related to activity. Various studies have shown both positive and negative correlations with OA and activity as well as OA and site-specific activity (Jurmain, 1999). For this purpose osteological research related to behavioral reconstruction needs to be more holistic such as Buikstra's (1977) "biocultural perspectives" in bioarchaeology which utilized multiple lines of evidence in the interpretation of bioarchaeological findings. Instead of simply assessing OA prevalence and severity for a sample, future research should include other aspects of skeletal morphology related to activity such as enthesopathic patterning and cross-sectional geometry (Bridges, 1989; Buikstra and Beck, 2006). Musculoskeletal stress markers (MSMs) or enthesopathies are regions on the skeleton where muscle, ligament, and tendon attachments become ossified due to mechanical stress (Larsen, 1997). These osteological manifestations have proven to be quite informative about site-specific activities both within and between populations (Hawkey and Merbs, 1995; Molnar et al., 2009; Stirland, 1998).

Larsen and Ruff (2011) combine the use of OA assessment and cross-sectional geometry (CSG) to determine levels of activity between pre-agricultural foragers and agricultural farmers. CSG dimensions of bone diphyses are different than OA in that mechanical influences are chronic as opposed to OA and enthesopathies which are more related acute mechanical influences such as episodic trauma (Bridges, 1989; Jurmain, 1999; Larsen, 1997).Using multiple lines of activity related evidence would logically be more informative on activity levels of skeletal samples from a given population. Although this prospect would be ideal, it may not be possible in every case study to bring specialists in these osteological fields together for a skeletal study. While this may be quite an elaborate method it should be considered in future activity-related research. If one were to investigate the relationship between diaphyseal dimensions, enthesopathic patterning, and OA incidence/prevalence and severity within and between population samples, the data obtained would be quite substantial in regard to activity-related osteological manifestations.

Research related to OA can be informative on many levels if one uses multiple lines of evidence in association with OA prevalence and severity. A useful and important method to be used in OA research is the assessment of the entire appendicular skeleton as opposed to one section of the body. OA patterning, incidence, and prevalence between all the joints is more informative than simply investigating OA in region of the body. Age and sex disparities may inform on etiology, pathogenesis, and pathophysiology of OA more substantially with samples assessed for OA on the entire body. In order to better understand the patterns of OA in the Kellis 2 sample this should be accomplished in the future and perhaps the method should be similar to the one employed in this thesis in order to maintain continuity.

The most important aspect of OA research is the methodology used in the paleopathological assessment of OA. The next most important aspect of OA research is adequate and at times excessive description throughout the entire research and writing process. OA research has lost some popularity in the paleopathological literature but there is still much to be learned about this disease. Populations throughout the world should be assessed and then compared. Extrinsic and intrinsic factors should be considered etiologically. The patterning and prevalence of OA while not able to conclusively inform on which activities were occurring, can be used to interpret levels of activity. The demography of OA in a skeleton population sample can be culturally informative about lifestyle and work patterns. This concept is what was observed in the Kellis 2 sample with regards to OA of the hip, while OA of the knee prevalence was close to even. Females had a higher incidence of knee OA in many parts of the joint complex but proportionally males were more afflicted than females. The purpose of this study was to describe the patterning and prevalence of OA from the lower appendicular joints. The prevalence rates and the demography of OA in the Kellis 2 skeleton population sample indicate that males are more arthritic, and that the largest prevalence disparity can be found in the hip joint complexes. This disparity or sexual dimorphism can be interpreted as sexual divisions of labor, although the knee joint complexes indicate that males and females were participating in similar amounts of physical labor.

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