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## Morphological Features of the Proximal Femur: Investigations of Habitual Activities, Sex and Health in a Bronze Age Population from the Arabian Peninsula

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MORPHOLOGICAL FEATURES OF THE PROXIMAL FEMUR:  
INVESTIGATIONS OF HABITUAL ACTIVITIES, SEX AND HEALTH  
IN A BRONZE AGE POPULATION FROM THE ARABIAN PENINSULA

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A dissertation submitted in partial fulfillment  
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## ABSTRACT

### **Morphological Features of the Proximal Femur: Investigations of Habitual Activities, Sex and Health in a Bronze Age Population from the Arabia Peninsula**

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Bronze Age sites on the Arabian Peninsula are relatively rare. The undisturbed nature of Tell Abraaq, located in the United Arab Emirates, is significant since it represents one of the longest known occupied settlement sites dating from the 3<sup>rd</sup> millennium BC to the 1<sup>st</sup> century AD. This site has revealed an undisturbed communal tomb that was used for approximately 200 years (2200-2000 BC), housing commingled and disarticulated human remains of at least 286 adults and 127 subadults. The strategic coastal position of Tell Abraaq, at the intersection of several major cultural centers, allowed its people to actively participate in world trade and politics. The current project attempted to better understand human behavior and adaptation in harsh environment during a sparsely known period through the systematic study of musculo-skeletal markers (MSMs) on proximal femora.

Analyses using new forensic techniques combined with macroscopic and microscopic examination of adult proximal femora (n=102) presented a distribution across age categories and a skewed ratio of males to females. The population was relatively healthy with high incidences of MSMs including pilasterism (95%), articular

border convexity (79.12%) and anterior cervical imprint (67.05%). None of the MSMs, apart from the posterior cervical imprint, showed side biases. There were various degrees of biases between sexes, with males overall showing more frequencies of MSMs.

Interpreting the results within its archaeological and cultural context, the bones of the Bronze Age Tell Abraq revealed a very hard working population existing in a complex economic and social community, with at least a partial sexual division of labor.

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## CHAPTER 1: INTRODUCTION

### *1.1. OVERVIEW AND STATEMENT OF RESEARCH OBJECTIVES*

Reconstructing the lives of ancient people in order to understand human behavior is important for the kinds of questions that interest anthropologists. For example, how did human groups adapt and survive in challenging environments? What kinds of everyday occupations and labor patterns were carried out between males and females? What groups within the larger community were most at risk for poor health and early death, and what were the reasons? Answering these kinds of questions involves utilizing a wide range of methodologies within the area of bioarchaeology, including the reconstruction of biological identity (age, sex, and stature) and biological health (age-at-death, the presence of disease, differential use of the body, and the pattern of wear-and-tear of the body).

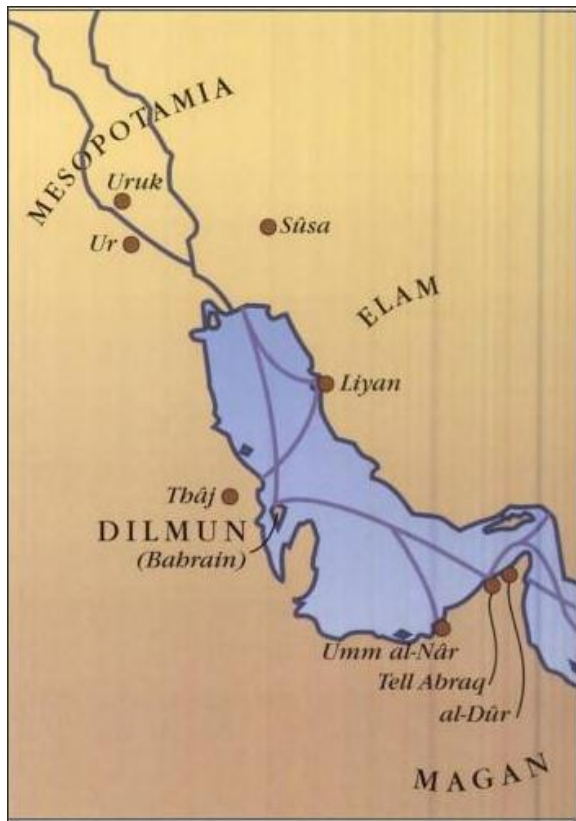
This project involves the analysis of adult individuals recovered from a large Bronze Age (c. 2200-2000 BC) tomb at the archaeological site of Tell Abraq, located on the coast of the Persian Gulf in the United Arab Emirates (U.A.E.; refer to Figure 1 and 2).

This collection is currently curated at the University of Nevada, Las Vegas. The current project is one of the first to conduct large-scale analyses on the remains since its excavation. Bronze Age sites on the Arabian Peninsula are relatively rare, and the undisturbed nature of the Tell Abraq site, including the tomb, (which is one of the few that was not looted in antiquity) makes this an important contribution towards understanding that period (Potts 2000).

Figure 1. U.A.E. (Google Satellite photo)



Figure 2. Location of Tell Abraq in U.A.E. (Potts 2000:10)



In order to obtain as much information as possible about the daily lives of the men and women who lived in Tell Abraq, several tested and a few innovative methods were used in the reconstruction of biological identity and health. These techniques include (1) using several new forensic techniques for the assignment of age, sex and possible stature to the femoral bone (Bass 2005; Albanese et al. 2008; Ruff 1987; Wescott 2005; Ubelaker 1989; Brothwell 1981; Byers 2008; Prasad *et al.* 1996), (2) assessing musculo-skeletal markers of stress (MSM) (Capasso *et al.* 1998; Hawkey and Street 1992; Jozsa et al. 1989; Oetkeking 1930; Molleson and Hodgson 1993; Hrdlicka 1934; Kosticks 1963; Odgers 1931; Mariotti *et al.* 2004) (3) using a macroscopic examination of the femoral bones for pathology and anomalies (Ortner & Putschar 1985; White and Folkens 2005, Byers 2008), and (4) using three-dimensional scanning of the upper portion of the femur bone to obtain information on microstructural features of the bone (Cassidy 1984; Ruff *et al.* 1984; Jones *et al.* 1977; Claussen 1982; Brickley 2002; Tsubota *et al.* 2002; Vander Sloten J. and Van der Perre G 1989). This multi-methodological approach to data collection on the femur, one of the more abundant and well-preserved bones in the collection, provides a wealth of data on biological identity and health. These data can then be used to answer questions about adaptation 4000 years ago in a coastal region of the Arabian desert. In addition to the biological data, archaeological reconstruction of the habitation area, artifacts, and faunal remains associated with the tomb can further contextualize the biological information, so that patterns in social and economic life may be explored.

The empirical data derived from the analyses of the adult femora was used to test several hypotheses. The specific hypotheses being tested include the following: (1) given



the arid desert environment combined with coastal ecologies, diet was diverse and plentiful. If this statement can be supported, there will be very little pathology relating to poor nutrition, such as bone thinning and osteoporosis (especially in females who can suffer from calcium deficiency during the childbearing years). Fluoride may also have played a negative role on health and this can be assessed on the femoral bone (Ortner & Putschar 1985). (2) Males and females were relatively healthy. Data used to test this hypothesis was drawn from frequencies of male versus female pathologies as derived from a macroscopic assessment of the bone surfaces. Diseases that can be observed (if present on the femur) include non-specific infections, osteoarthritis, trauma/fractures and localized anomalies (Ortner & Putschar 1985) (3) Males and females had different patterns of occupation and labor. Differential frequencies of musculo-skeletal stress markers (MSMs) on the male and female femora determined if there were statistically significant patterns in use of the lower body by males and females (Capasso *et al.* 1998; Kosticks 1963; Angel 1959; Hrdlicka 1934). (4) Individuals who worked hardest also suffered from other health problems. This hypothesis was tested using the combined data set to see when there is a co-occurrence of nutritional problems, disease, MSMs and microstructural abnormalities. (5) Musculo-skeletal markers of stress (MSMs) accumulated on the body over many years will have anomalous microstructural architecture. This is a relatively new area of study (three dimensional, microstructural architecture) (Wade, Holdsworth & Garvin 2011) and the data collected from the Micro 3D Scanner provided additional information that was used to test this hypothesis. Thus the relationship between observed MSMs on the anatomy may have diagnostic patterns of microstructure that underlie those changes at the gross level. This is important to

establish because MSMs, though studied for decades, are complex modifications to the bone that are not yet fully understood, and their more widespread effect may indicate skeletal adaptation to hard physical labor (Kennedy 1998).



## CHAPTER 2: A BIOARCHAEOLOGICAL AND ENGENDERED-APPROACH TO ANALYTICAL FRAMEWORK

### 2.1. BRIEF HISTORY OF BIOARCHAEOLOGY

Bioarchaeology is a specialty within the discipline of physical anthropology. Physical anthropology encompasses a larger field - the study of human evolution through analysis of skeletal remains of *Homo sapiens* and their archaic ancestors, study of non-human primates for behavioral and genetic comparisons, forensic anthropology within a legal framework, and genetics and palaeopathology. The goal of bioarchaeology is the reconstruction of past populations' lifestyles by analyzing human remains *within* their cultural-historical context. The name captures the interdisciplinary tone of the field and its emphasis on biological anthropology in an archaeology setting (Larsen 1997, 2002; Buikstra & Beck 2006, Knudson & Stojanowski 2008).

Skeletal remains were not always looked favorably upon as a source of biocultural behavior and human adaptation. Many early archaeologists found it inconvenient and time-consuming for the process of site excavation (Bush & Zuelebil 1991:5), and often preferred to cover and forget they ever saw the remains (Noël Hume, 1975).

Bioarchaeology has since advanced in leaps and bounds over the few decades. Early researchers' emphases were on typology oriented – measurements and descriptions of bones, which laid the foundation to solving bigger questions. There was a gradual transition in studying skeletal remains of past populations from typology to *process*. This transition focused less on ethno-centricity, as researchers realized the error of interpreting past cultures through their own values and principles. Lewis Binford was one of the first pioneers of this new paradigm, advocating emic and ethnographic approaches in arriving

at objective conclusions of past populations' lifestyles, as illustrated in his 1962 work, 'Archaeology as Anthropology'. The later Post-processual approach, promoted by Ian Hodder (1983), argued the inevitable subjectivity of any archaeological interpretations – that we always “see data through a cloud of theory” (Johnson 1999:102). It also argued that humans do not always behave rationally towards achieving optimal results – they are free agents and may not follow expected social rules and conventions (Johnson 1999:104). This schism in approaches still exists today. Bioarchaeology, a sub-discipline that bridges the biological and social sciences, strives to acknowledge and embrace this diversity in order to comprehend human life and its complexity by negotiating the layers of interpretative dimensions (Charles 2005:16).

Bioarchaeology has now taken a population perspective. Researchers study various aspects of skeletal remains – pathology, bone trauma, bone modification – and then extrapolate a holistic picture such as dietary patterns (Lieverse *et al.* 2011; Walker & Erlandson 1986), gender biases (Peterson 2002; Martin 1997), health status (Larsen 1997; Milner 1982, 1991), structural violence (Martin *et al.* 2010; Casserino 2009; Martin 1997), activity patterns (Cope *et al.* 2005; Molnar 2010), demographic profiles and adaptation (Larsen *et al.* 1995; Hanson & Butler 1997), and then substantiating the evidence with mortuary practices and archaeological, archaeobotanical, geoarchaeological and palaeoenvironmental information.. However, one must be careful in interpreting the lifestyles of past populations through their remains. For example, what they perform as a mortuary ritual of their dead might reflect their views and ideologies of the dead, and not of the living. This research deals with musculoskeletal markers, a type

of bone modification, on the femur bone of the Tell Abraq collection and attempts to address some of the scenarios stated above.

In addition to the difficulties in teasing apart the nuances of skeletal evidence for extrapolation, the basic methodologies for acquiring data, such as determining age and sex, are also wrought with contradictions and differences (Larsen 1997). One issue of contention is the platymeric index (PI), a ratio derived from the space below the lesser trochanter on the femur. While many researchers claim it is a good indicator for determining the sex of the individual (Bass 2005; Ruff 1987; Brown 2002), some researchers regard it an indicator for habitual activity; specifically differences between mobile and less mobile groups (Kiesewetter 2006; Larsen 1997; Cole 1994). Compiled books of human osteology such as Bass (2005), Buikstra & Ubelaker (1994) and White & Folken (2005) provide guidelines for collecting skeletal data, but also present all the degrees of complexity that comes with this endeavor. It is therefore, imperative to gather all cultural, archaeological, and historical information to test hypotheses, corroborate existing theories, and make the strongest deduction of the skeletal data at hand.

## **2.2. INCORPORATING GENDER STUDIES IN BIOARCHAEOLOGY**

*“Gender is a process, a set of behavioral expectations or an effect, but it is not a thing.”*  
(Sorensen 2000:70-71).

Like the study of bioarchaeology, the study of gender in archaeology gradually evolved over the decades. While initially ignored, this subject, especially the value of women’s contributions to society, was eventually investigated, found thought-provoking and important, and penned down on paper.

Despite the fact that many individuals use the words sex and gender interchangeably, they are different. “Gender” is a social expression that is culturally constructed and practiced, while “sex” is a biologically determined variable (Feree *et al.* 1998; Conkey and Spector 1984; McNay 2000). Sex is usually one of two categories (male or female), and osteologically best determined by the morphology of parts of the pelvis and the skull (Bass 2005). Gender is a more fluid concept that is on a continuum and can change within and cross-culturally. A good example of a dual gender concept is the Native American “two spirits,” which is a third gender category in certain tribes (Holliman 1997). Sex as a dichotomous concept is also slowly changing. Sharda Sharma (2008) discusses the growing population of eunuchs in India, estimated at 1.2 million, and their rights as legal entities within the constitution of the country.

During the initial phase of gender interest during the 1970s and 1980s in the field of archaeology, gender was studied via material culture, where objects were approached as reflections and symbols of gender. A wealth of information was acquired from mortuary sites where skeletal remains were often found with grave goods, – material culture – and researchers systematically searched for patterns and repetitions. The larger the amount of grave goods or the rarer/precious the objects, the higher the social status of the relevant female within her society (Sorensen 2006). Researchers similarly reassigned values on objects initially deemed undervalued, simply because they were women’s tools such as domestic utensils (Bevan 1997), and then argued that they significantly contributed to society. Conversely, opponents maintained that assigning such values was not objective, since researchers would inevitably use their own judgments to do so. The material culture was also passive objects in the construction of gender. Even though it

lacked complexity, the material culture approach nonetheless laid the foundation for future gender study.

The 1990s brought about another step when researchers questioned the intimacy and value of excavated objects towards the individuals they belonged to, rather than towards the researchers (Tringham 1991). For example, a grinder might not be of any worth to X but to Y, its owner, it might be of value, because this grinder might signify her control over the food distribution in her household, which is an aspect of domestic power. Margaret Conkey (1991) expanded on this notion by stating that all objects are interconnected and various occupations relied on the demands of the community. For example, a man fishing on a boat might need a cloth on his sail, invariably creating a demand for needle/awl and by extension the weaving business. Likewise, the wood from the boat would have to be cut down by an axe, supplied by a blacksmith, while the string and line would be provided by another vocation. In short, objects were much more than passive but rather shaped their owners and the larger society.

Even though the sexual division of labor was sought after to shape the females' roles in their community, Elizabeth Rega (1997) suggested that the allocations of resources may be more layered than just by gender differences – it could include social ranking in families or social units.

Material culture recently shed its passive role and took a more dynamic part, in that researchers posited that objects shaped and affected their owners by becoming mediums of social discourse, either creating or maintaining identities. Likewise, individuals chose to either keep performing the current gender roles or change as needed, transforming the dynamics of gender (Arnold 2001).

Mortuary rituals give us a glimpse of the social and gendered dynamic of societies since they are great visual reproductions of gendered systems. The effort, time, and expense dispensed following the burial of the dead might indicate a persistent ideology on many levels – the family or society’s current beliefs of the dead, the individual’s personal belongings buried with him/her, and what society deemed fit to inter with the dead. Apart from cultural materials, the use of space in the grave is important as well. Sorensen (2000:85) listed six factors pertinent in mortuary analysis – cemetery landscape, cemetery, form of disposal, position of remains, special distribution of grave goods, and the type and number of grave goods.

However, most of the time, preservation is poor and/or, as is the case with the Tell Abraq collection, the sites are not single burials and are fragmented and disarticulated, with no semblance of an orientation. These mass burials bring about added complexities.

Given the difficulty of extrapolating past dynamic ideology, an attempt at discerning gender roles of past cultures is very difficult to accomplish without bioarchaeology. Bioarchaeologists can examine occupational variation by studying human remains and then determine habitual activities from analyses of bone modifications at attachment sites (MSM) (Kennedy 1998; Capasso *et al.* 1999). Researchers acknowledge that human beings are active agents participating or directing culture change (Cowgill 1975) and the evidence of their development are ‘written’ on their bones.

Although there is much room for conceptual and methodological improvement in determining the gender roles of past culture, the best possible solution is to follow multiple lines of evidence (Nelson and Rosen-Ayalon 2002).

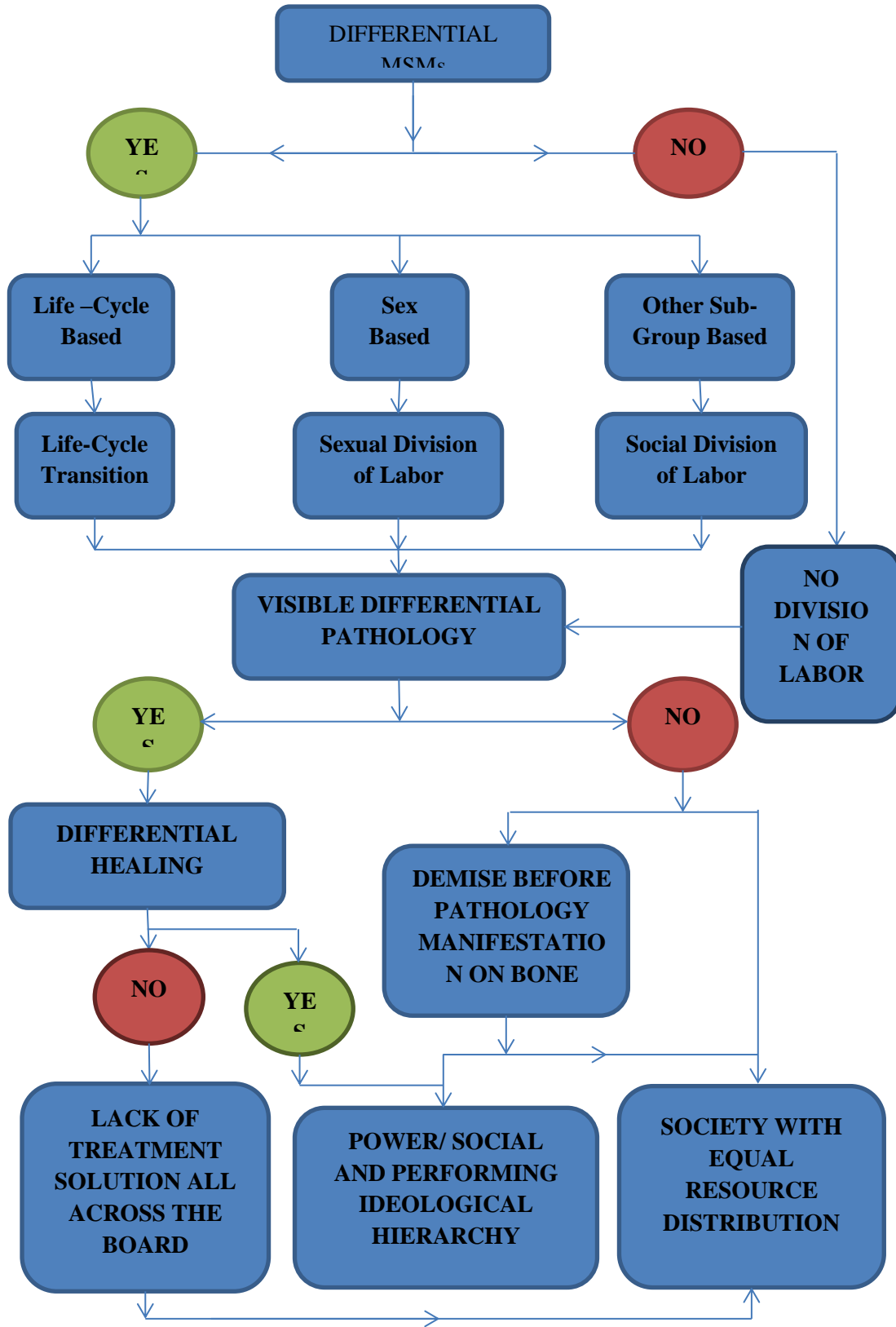
Peterson (2002) researched sexual labor patterns using bioarchaeological tools. She studied MSMs on the skeletal collections from Natufian sites (hunter-gatherer lifestyle) and Neolithic sites (agricultural lifestyle) to discern any changes of labor and differences between sexes after the transition from hunter-gatherer to an agricultural way of living. The author also examined the inventory, field notes, and published work on these sites, as well as the environmental and geographic regions of these sites. Five locations on the upper arms and shoulders were investigated and the MSM expressions were scored on robusticity (rough bony growth) and stress lesions (pitting). Results showed that Natufian males had higher MSMs on these areas, suggesting frequent use of overhand throwing motions, probably from throwing a spear during hunting. Natufian females showed higher MSMs concerning bilateral motions, perhaps indicating processing tasks. However, other MSMs point to similar amounts of robusticity. This gives us a picture of a partial division of labor during the hunter-gatherer period amongst the Natufians. In the Neolithic collections, male MSMs related to bilateral movement increased to resemble female patterns and on the whole, activity levels increased in both the sexes compared to the Natufian communities. This indicates a decrease in sexual division of labor in agricultural lifestyles, but the transition required more work from both sexes, resulting in more stress-markers compared to the hunter-gatherer ancestors.

By integrating a number of gender bioarchaeologists' works, Bettina Arnold (2006), Mark Nathan Cohen and Sharon Bennett (1993), Malcolm C. Lillie (1997) and Jane Peterson (2002), the researcher has compiled an analytical framework (refer to Figure 3) which fits with the current study. It can be divided into two huge sections: MSM and pathology. It also attempts to incorporate the social complexity and layers of

the population. For example, a society can have many levels of division of labor and not just one.



Figure 3. Analytical Framework



## **CHAPTER 3: ARCHAEOLOGICAL CONTEXT OF THE UNITED ARAB EMIRATES AND TELL ABRAQ ARCHAEOLOGICAL SITE DURING THE BRONZE AGE**

### ***3.1. INTRODUCTION***

The Tell Abra q site is located in the United Arab Emirates (U.A.E.). U.A.E. is one of seven countries that make for the Arabian Peninsula, the other six including Kuwait, Qatar, Bahrain, Yemen, Saudi Arabia and Oman. This peninsula played a pivotal role during prehistoric times and continues to do so now, as it is positioned among the landmasses of Africa, Asia, and Europe (Gregoricka 2011) and sits at a crucial junction with easy access to main water and land trade routes. While there have been numerous excavations and extensive research of archaeological sites and other cultural centers in Mesopotamia, Harappa, and Egypt, studies in the Arabian Peninsula has been sorely lacking until the late 1950s (Potts 2001). In the last few decades, archaeological information has grown by leaps and bounds and is establishing both chronology and cultural framework of this region. Excavations in the Arabian Peninsula, especially in southeast Arabia, have indicated that the settlement sites of this region partook in trade and commerce with these larger centers more than initially acknowledged, particularly during the Bronze Age (Martin 2007; Potts 1993b).

The Bronze Age (c. 3000-1300 BC) of the Arabian Peninsula encompassed part of the Hafit Period (3800-2900 BC), the Umm an-Nar period (2900-2000 BC) and the beginning of the Wadi Suq period (2000-1000 BC) (Potts 2001). In order to fully appreciate the successful adaptation of human groups at Tell Abra q, this chapter provides a detailed understanding of the geographical topography and palaeoecology during the

Pleistocene and Early Holocene era, and the cultural modifications consciously carried out by prehistoric populations living in the Arabian Peninsula during the Bronze Age.

### **3.2. GEOGRAPHY**

Geoarchaeologically, the Arabian Peninsula is bounded on the west by the Gulf of Aqaba and the Red Sea, on the east by the Gulf of Oman and the Persian Gulf, and on the south by the Gulf of Aden and the Arabian Sea. Synthesizing geoarchaeological, paleobotanical, zooarchaeological and molecular genetical evidences, including a total of 396 absolute dates, the Arabian Peninsula is indicated to have had climatic oscillations over the past 175,000 years (Parker and Rose 2008).

The tectonic plate of the Arabian Peninsula originally was a part of Africa until approximately 30 million years ago, when it broke off and moved towards the northeast. Major seismic modifications included the formation of the Red Sea, the creation of volcanic peaks along the western borders of Arabia, the formation of the eastern mountain range against the Indian plate, and the development of the Arabo-Persian Gulf basin, a shallow depression that resulted from the plate's compression against Eurasia. These compressions also created the world's largest oil reservoirs beneath the Arabian plate.

The subcontinent can be divided into four principal regions. The western highlands, called the Asir Highlands, run the length of the Red Sea and reaches as high as 3600 meters above sea level in the south as it extends to the Yemen. It is the highest point in the entire subcontinent (Hoyland 2001). The vast basin-shaped interiors are largely sandy and stony wastelands and include Rub' al-Khali ('Empty Quarters') (600,000 km<sup>2</sup>)

in the south, Nafud and Dahna deserts in the center (72,000 km<sup>2</sup>), and Wahiba Sands (12,500 km<sup>2</sup>) of Oman (Parker and Rose 2008). The third region is a range of mountains with plunging valleys in the southwest comprised of uplifted Tertiary limestone that slopes into the Rub' al-Khali. This region receives relief from the monsoon rains seasonally, giving the opportunity for many seasonal springs and lagoons to pool onto the coastal plains and allowing tropical plants to grow. Finally, there are the coastal plains, the eastern coastlands of the Persian Gulf, which are particularly hot and humid. However, abundant groundwater juxtaposes with the harsh climate (Hoyland 2001).

### **3.3. CLIMATE**

The climate in the peninsula is largely manipulated by two different weather systems (Bart & Steinkohl 2001). The Atlantic north-westerlies move in from the north, then eastwards down the Arabian Gulf, and dissipate over the Rub al-Khali desert and Musandamn Peninsula, carrying cool winds and light precipitation during the winters (Parker et. al 2004). Most of the precipitation, however, comes from the other weather system. The southwest Indian Ocean monsoon system ushers in summer storms, bringing with it heavy rainfall that is trapped by the highlands of Oman and Yemen, with the vast plain interiors obtaining very little moisture (Glennie & Singhvi 2002). Thus the highlands receive approximately 200-1000 mm of rainfall annually while the lowlands receive only about 100-200 mm per year. As a result, most of the ecologies depend on the strength and consistency of this monsoon. Their dependence on moisture makes the region precarious to annual and periodical fluctuations, which was the case during the Quaternary period. Biogeochemical and lithogenic data obtained from Arabian Sea cores

over the last 350,000 years also support the notion that monsoon winds are sensitive to changing glacial climates and consequently affect south Arabia's ecozones.

Moving onto specific archaeogeological evidence, marine cores from Indian Ocean, Gulf of Oman, and the Arabian Sea indicate a sharp change in fluctuations 12,500 B.P., where ice-sheets retreated and sea levels rose (Zonneveld et al. 1997). Computer simulations suggest an increased precipitation level (5 mm/day to 7.5 mm/day, and 50% more than present day), and the monsoons stretched further into the interior region than before. While this change was rapid, the change back to aridity after 5000 BP was more gradual. The stable oxygen isotope record of various planktonic foraminiferal attests to temporal variations in marine palaeostudies. These variations are corroborated by a series of dated speleothems in the Hajar and Dhofar mountains (Sarnthein 1972; Kutzbach 1981).

Adrian G. Parker and Jeffrey I. Rose (2008) have assimilated all the known records pertaining to climate changes and environmental fluctuations in the Arabian Peninsula, including a total of 396 absolute dates, and built a comprehensive database referred to as HOPE ENV, designed to acquire and illustrate the composite sum probability curve and climatic oscillations over the past 175,000 years in the sub-continent. Chronological categories have been defined according to the marine isotope stages (MIS). As mentioned earlier, this is a highly oscillating period in terms of climate. High aridity was generally present 300,000 years ago, followed by an abrupt and drastic increase in rainfall over South Arabia that occurred 120,000 years ago, and another peak appearing approximately 74,000-82,000 years ago. Increased aridity followed until 50,000 years ago. Desert Rub' al-Khali attests to this hyperaridity indirectly through the

aeolian accumulation sometime before 37,000 years ago. The period that followed amounted to over one-thousand short-lived lakes in the desert region. The Mundafan depression was the exception, which lasted for 800 years and yielded fossilized faunal (including large vertebrates) remains, and phytoliths and dikaka evidence of grasses, shrubs, and herbs in its sediments. A major phase of aeolian accumulation between 17,000 and 9,000 years ago puts this category in the hyperaridity box again, followed by a high pluvial period which gradually started decreasing around 5,000 years ago to give way to the current climate in southern Arabia.

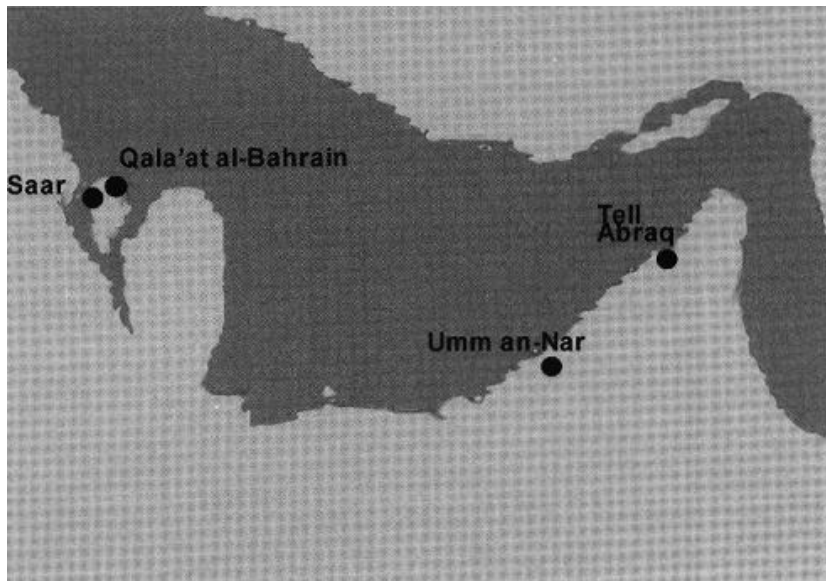
The coastal region of southeastern Arabia was exploited by sedentary settlement sites only after the Gulf of Oman pushed past the straits of Hormuz, during higher sea levels and a pluvial period, into the shallow and wide depression now called the Persian Gulf around 14,000 kya. However, from 6,000 cal. BP, the monsoons retreated and the northwestern winds from the Atlantic ushered in a period of gradual increase in aridity (Parker and Goudie 2008). While on a macro level, the Arabian Peninsula received unrelenting harshness and monotony in landscape, at a micro level, the sub-ecologies were much more varied and diverse.

Until c.3,000 BC, a more humid climate prevailed in which the wind systems were generally weaker than present day (Glennie et al. 1994). Thereafter, the climate of the Arabian Gulf became more arid.

Although the Tell Abra q site today is located several kilometers inland from the coast of the Arabian Sea, study of the local geomorphology shows that the site was only a few hundred meters away from the ancient shorelines from the third millennia BC, thereby making Tell Abra q a coastal settlement during the Bronze Age (Potts 1989;

Uerpmann and Uerpmann 2005) (refer to Figure 4). The warm and dry climate during the occupation of Tell Abraq and other coastal settlement sites in this region played a role in determining the house architectures – large fortified towers build protectively around a water well and smaller barsati-like huts constructed of palm fronds dispersed closely around the fortification (Magee 1996; Potts 2000).

Figure 4. Geographical position of Tell Abraq (Uerpmann & Uerpmann 2005:fig.1)



There have been minor climatic changes between 3,000 BC to present day, which are indicated by the receding coastal lines, but no drastic changes have been recorded (Lambeck 1996). Therefore, Bronze Age Tell Abraq and present Tell Abraq more or less shared the same climatic conditions, aside from the closer access to open and sheltered waters.

### **3.4. FLORA AND FAUNA**

Palaeobotanical evidence reveals that marine shores and salt flats in the subcontinent grew cressa, salt tree, and sea rush, while coastal banks grew date palms, wild rue, mangrove, and mistletoe. More specifically, plant types in southeast Arabian have strong ties to the flora of Iran and southwest Pakistan (Baluchistan). This includes succulent spurge, almonds, figs, henna, and true indigo (Parker and Rose 2008).

Wheat and barley were also grown in Tell Abraq. Evidence of ground stones further strengthens the notion of a partial agricultural subsistence (Potts 2000). Theya Molleson (1994) studied the effects of daily grinding in an early Near Eastern agricultural community, Abu Hureyra, and due to the constant pivoting alternately around the knee and hip, the femur formed buttresses on either ends of the femur and the diaphysis (shaft) was more curved. Theya Molleson also found that girls and women had this feature more often than men. This was tested for the Tell Abraq bones as well. Cultivation of date palms was most certainly carried out in Tell Abraq since numerous date seeds have been recovered (Blau 1996). Date palms do not need irrigated water for their growth. These palms possibly provided shade for other crops to grow. This method was used by traditional agriculturalists in U.A.E. during pre-oil times and it still is used often in Oman and U.A.E. today (Wilcox and Tengberg 1995). Burnt date-palm wood and two species of mangrove were also recovered from charcoal. Sugar intake from these dates may have contributed to the high degree of caries found in the commingled and disarticulated skeletal collection from the tomb ten meters west of the settlement site (Potts 2000).

Tell Abraq also yielded the largest number of faunal and marine remains in the Arabian Peninsula (over 40,000 identifiable animal bones), including both wild and



domesticated animals and fresh water and open water fish (Uerpmann and Uerpmann 2005, Potts 2000). This included sheep, goat, gazelle, oryx, turtle, dolphin, dugong and cormorant. By the evidence of domestication, it is safe to assume that these animals were raised and used for various functional purposes, including as draft animals and for providing milk, wool, and meat. Consequently, herding played an important role in their economy to upkeep these important supplies. The bones from Tell Abraç should show a high degree of posterior cervical imprint (described in the Methods section) which usually appears due to prolonged periods of walking and standing. Butcher patterns and selective butchering are yet to be analyzed (Potts 2000, Uerpmann and Uerpmann 1996).

The large lagoonal system of Umm al-Qaywayn extends to the edge of the site, making it easy for the Tell Abraç population to have access to sheltered water. The extensive tidal shallows would have served as an ideal location to fish, an important source of nutrition in the ancient diet. Sieved samples from the site have recovered more than 11,000 bones from a 30 cm thick deposit of fishbones (Potts 2000; Uerpmann and Uerpmann 2005). Some of the identified species include jack, pompanos, snapper, spadefish, shark and sea catfish (Potts 2000). Fishing in the lagoon would not have required sophisticated techniques or tools. Today, baited fish traps and handlines are used in the lagoon. In Tell Abraç, large copper and bronze fish hooks were found, which could have been used for catching larger fish. Along with that, sinker stones were also found, indicating the use of fishing nets during that period (Uerpmann and Uerpmann 2005). There was an absence of tuna bones in Tell Abraç. In contrast, Shimal, a contemporary site located about 40 miles to the northeast of Tell Abraç and closer to the deeper waters of the Strait of Hormuz, had a considerable amount of tuna bones (Von Den Driesch

1994). It is therefore possible that fishery in the Bronze Age period was more opportunistic and systematic. However, the fishing range of Bronze Age fishermen also included the open waters, since many open water fish bones were also recovered. Thus, there should be a decent proportion of pilasterism in the current collection, (described in the Method section) which is associated with sea fishing (Oetteking 1930). Due to differential taphonomic processes, the contribution of marine food sources cannot be quantified, but it is safe to assume that it was an indispensable part of human subsistence in Tell Abraq (Uerpmann and Uerpmann 2005).

A few bioarchaeological investigations from the commingled skeletal remains have been conducted, and show strenuous walking and squatting habitual activity (Blau 1996). Male remains exhibit high levels of osteoarthritis and robusticity on their wrists (Cope et al. 2005) and high rates of fluorosis evident in teeth analysis (Greene et al. 2003). This may indicate extensive herding and fishing during that period.

### **3.5. TRADE NETWORK**

The Middle East during the Bronze Age was dominated by two great centers - Mesopotamia and Egypt, with their surrounding areas comprised of various kingdoms, city-states, and tribal confederations. Other powerful centers, including Elam in southwest Iran and Meluhha in the Indus Valley, were positioned further east (Hoyland 2001). East Arabia's critical coastal location was at the intersection of several major centers and fuelled the people of Arabia to open up from their isolation and play an active role in world trade and politics. It also witnessed some of the world's earliest seafaring

and maritime exchanges and reaped their economic benefits, changing the cultural trajectory of Arabia forever (Boivin & Fuller 2009).

By the 4th millennium, trading posts in the Arabian Peninsula were well developed and helped propel the development of cultivation systems in southern Arabia (Boivin & Fuller 2009). Ancient cuneiforms from the 3rd and 2nd millennia BC reveal that the region from Kuwait to Qatar, including Bahrain, was referred to as Dilmun, while the Oman Peninsula (Oman and UAE) was called Magan. Both of these names feature prominently in trade and commerce information (Bhacker & Bhacker 1997; Potts 1993c; Blau 1996).

The production and exportation of copper and bronze was one of the essential commodities of Magan (Weeks 1997; Hoyland 2001). Magan's strategic position and its resources deemed it valuable enough to conquer, which the Akkadian empire succeeded in temporarily during the 3rd millennium (Hoyland 2001). But, for the most part, these increasingly complex and maritime-competent local Arabian communities showed no signs of colonial control in their activities. They were active and independent agents engaged in producing and trading commodities inland and with foreign regions, gaining some control over the flow of products (Boivin & Fuller 2009).

The site of Tell Abraq unearthed copper and copper alloy in all four excavations since 1989, not only in completed forms but as amorphous droplets or ingots. This suggests that copper and bronze mining and smelting operations were carried out at the site itself. Arsenic and nickel, secondary refining slag of copper metallurgy, were also found in concentrations at the site. Raw material cannot be procured locally, however, implicating a supra-regional level trade. Though copper and bronze were mainly cast

during the Wadi Suq period and Iron Age, small scale operations were undertaken in Tell Abraq from the earliest phases of its occupation, indicating an incipient metallurgy industry (Weeks 1997).

Evidence of contact with Babylonia, Elam, Dilmun, southern Iran, and Harappa are implicated through cuneiform sources and through imports of ceramics, seals, and stone vessels, such as exquisite Bactrian combs found at the settlement site and within the tomb (Potts 1993b). Archaeological evidence of Harappan cubical stone weights and pottery similar in make and style to Mesopotamia also gives credence to Tell Abraq's role in the flourishing trade network (Blau 1996).

### **3.6. MORTUARY PRACTICES**

Within the southeast Arabian Peninsula, the Umm an-Nar period (2500-2000 BC) received its name from a small island opposite the U.A.E. and Bronze Age Tell Abraq that broadly represents everything typical of the Umm an-Nar period. Settlement sites prior to the Umm an-Nar period, during 3400-2900 BC, usually consisted of roughly square, mudbrick fortifications. The dead were usually buried in single-chambered stone graves composed of a double ringwall. These were called the 'Hafit' graves (Potts 1993c; Frifelt 1980).

The square fortifications gradually changed to square fortifications with rounded edges and finally to round fortifications as seen in the Umm an-Nar period (E.g. Hili 8 (Cleuziou 1996; Phillips 2007) Bidiyah (Al Tikriti 1989), with the new types of circular, communal graves. Umm an-Nar communal graves normally consisted of a floor of masoned plinth surrounded by unworked limestone walls. 'Hili Gardens' itself uncovered

14 circular communal graves spanning over 500-600 generations in an almost linear manner (McSweeney *et al.* 2008). However, sizes differed and ranged between 5-13 m in diameters, as did interior chambers and orientations. Some, like one in Umm an-Nar and one in the Hili oasis, had decorations of human and animal figures on the outside of the wall (Potts 1993c; Frifelt 1991). In other cases, there was evidence of a second story, as seen in a few Umm an-Nar graves (I, II, IX and X) and in Hili North Tomb A. These were most likely used for accommodating additional individuals above capacity (Potts 1993c).

The skeletal material from the tomb at Tell Abraq is highly disarticulated and broken. However, much information can be gleaned by studying each type of bone separately and treating each bone or fragment of bone within that category as belonging to a separate individual. From previous analyses, there are approximately 286 adults based on the left talus and 127 subadults based on the left proximal femur (Baustian 2010, Blau 1996). Almost all of the burials were interred in such a way that there are very few skeletons that remain articulated.

The tomb is located 10 meters to the west of the Tell Abraq fortification tower (refer to Figure 5). It is a circular structure, with a diameter of 6m, built from locally available beach rock (Arabic *farush*), while the external surface has a layer of finely masoned limestone ashlar blocks (refer to Figure 6). The entire tomb is constructed on a flat beach rock pavement (Potts 2000). This pavement extends beyond the south of the actual enclosed tomb and features a retaining wall with what was likely an entrance step. Internally, the tomb is divided into two chambers with a wall running north to south. A 50cm wide opening is left between the internal wall and southern wall of the tomb, which

acts as a passageway between the two chambers (Potts 1993a). A comparison with several other Umm an-Nar tombs shows that one chamber, the western chamber for Tell Abraq, might have been a receptacle for ‘overflowing’ bones that were pushed out of the eastern chamber to make room for additional interments. For example, Hili N and Tomb B acted as receptacles for predominantly secondary burials for Hili E and Tomb A respectively at Mowaihat in Ajman (Phillips 2007).

Figure 5. Illustration of Tell Abraq site during the Bronze Age (personal communication - Potts)

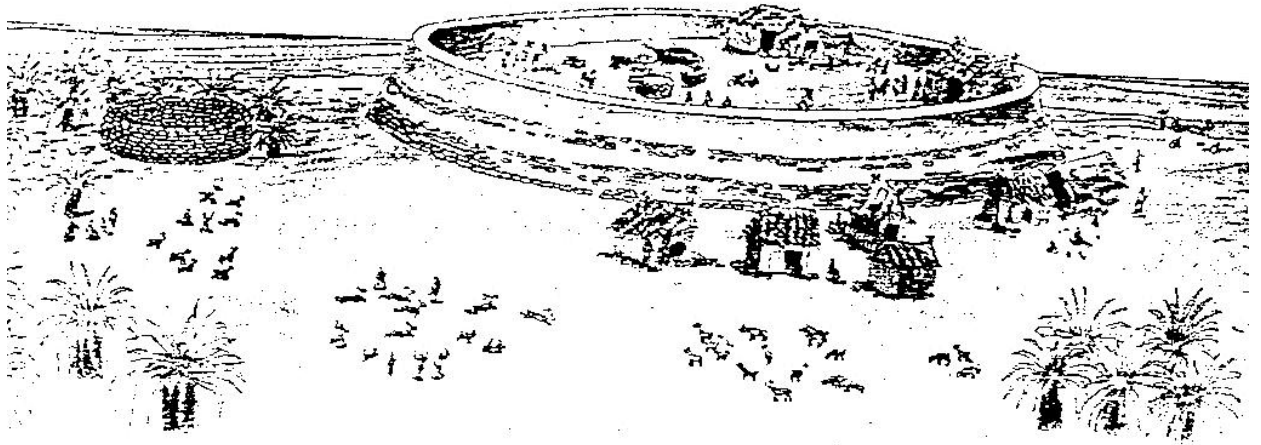


Figure 6. Excavated tomb of Tell Abraq (personal communication – Potts)



The tomb was discovered hidden beneath 2m of stratified deposit. Potts (2000) stated that the deposit belonged to the expanding settlement site of Tell Abraq that dates back to 1900-1800 B.C. The ceramics found in the tomb represent a transitional phase between the late Umm an-Nar period (c. 2500-2000 BC) and the Wadi Suq period (c. 2000-1300/1200 BC), in which the general shape of the jars (short, squat, with smooth, everted rim) are associated with the former period while the string-cut bases of the jar and cups are common traits of the latter period. The black-on-orange jars also have a coarser temper with more a simplified and geometric design than the late Umm an-Nar pottery from Tomb A at Hili North. As a result, the Tell Abraq tomb might date to the Terminal Umm an-Nar period around 2200-2000 BC (Potts 1993a). This date has been confirmed with two radiocarbon dates from a burnt deposit located just beneath the surface on which the tomb pavement was built. The two radiocarbon dates obtained in



1989 were from K-5574 and K-5575. This puts a *terminus post quem* of c. 2190-2130 cal. BC for the initial construction of the tomb (Potts 1993a).

Daniel T. Potts carried out extensive excavations from 1993 to 1998, starting with the west chamber, under the supervision of J.N. Benton (University of Sydney) and with the help of three bioarchaeologists – Debra L. Martin (University of Nevada, Las Vegas), Alan Goodman (Hampshire College), and Richard Wright (University of Sydney). Within the tomb, there was a 1.40m thick deposit of fragmented, disarticulated, and commingled bones, as well as artifacts and soil. The western chamber was first excavated in 1993, and as many bones as possible were recovered, recorded, and labeled before excavating the eastern chamber in the next season during 1997-1998 (Potts 2000; Potts 1993b).

Generally, burial goods have long been associated with social roles, wealth, and status of the inhabitants (Beck 1995; Binford 1972). However, treatment of the dead is very complex and nuanced beyond the status of the individual while alive. These complex factors include circumstances of death, the prevailing political, social, and economic context of the deceased's community, and their specific ideologies and cultural construction of death and the living (Robb et al. 2001). Consequently, studying grave goods within a cultural context is essential for a more robust reading and explanation of the contents. The Tell Abraq grave goods cannot be assigned to select individuals buried within the tomb, since the method of disposing the dead leaves the human remains commingled and fragmented. However, grave goods taken as a whole can indicate whether the individuals buried with it were wealthy or poor, or both if the variety of grave goods found are of a wide spectrum – from plain stone tools to exotic, rare artifacts. Grave goods could also indicate whether they were locally procured or obtained



from sites within close proximity to distant lands. The type of grave goods could also be occupation based artifacts like grinding stones, implying different economy prevalent.

In the western chamber alone over 200 artifacts were recovered. Grave goods found within the tomb included bronze rings, carnelian and agate stone beads, gold pendants, two spearheads, seventeen fig shells, soft-stone and ceramic vessels, abundant ostrich eggshells, a small piece of ivory adorned with double-dotted circle and a decorated comb. Ethnographic studies show the Bedouin in the recent past using fig shells to feed liquids to babies (Potts 2000). The incised bone comb (11.2 x 8.3 cm) can be contextually dated to c. 2100-2000 BC. Both sides of the comb are decorated identically with a set of three double-dotted circles arranged in a triangular pattern. This most likely was an imported piece all the way from 'Bactria' (northern Afghanistan and southern Uzbekistan) (Potts 2000; Potts 1993b). Also found is an ivory stamp seal that indicate broad-ranged contacts with Mesopotamia, Iran, Bahrain, Bactria, Baluchistan and the Indus Valley (Potts 2000).

While the tomb has been dated from 2200-2000 BC, the Tell Abraq settlement site was occupied till the Iron Age (c. 2300-400 BC) (Potts 1993a). It was chiefly dominated by a single massive circular stone and mudbrick fortification tower, 40 meters in diameter, with a central well leading out (Potts 2000). While fortification towers were seen more commonly during the Umm an-Nar period (2500-2000 BC), Tell Abraq had one of the largest Bronze Age building in the Arabian Peninsula (Potts 2001). The fortification sites may have functioned as the residence of community leaders and their families, as well as a place of retreat for the rest of the population in times of crises. Post-holes were found all around the fortress, implying that the majority of the population

lived in palm-frond houses, locally called *arish* or *barasti* (Potts 2000) (refer to Figure 7). Aerial photos taken of the main cities of U.A.E. in the 1930s still implicate palm fronds as very common structures, intermittent with a few mudbrick buildings and forts. Historical sources indicate that these societies maintained complex social and economic structures (Magee et al. 2009), so it is very likely that Tell AbraQ had social and economic complexity as well.

Figure 7. Barista architecture (from <http://catbirdinoman.wordpress.com/2011/11/>)



### ***3.7. PREVIOUS BIOARCHAEOLOGICAL STUDIES ON THE TELL ABRAQ COLLECTION***

Dynamic changes occur in human and non-human bones. Various factors play into the remodeling of a bone - nutritional deficiencies, specific and non-specific infections, and habitual activities. They affect growth rates, stature, tooth size, and cranial base. Many of the changes, produced by one factor or a combination of factors, manifest themselves on the surface of the bone and at a more subtle level, within the bone. In 1892, orthopaedic surgeon J. Wolff (1836-1902) developed a concept (famously known as ‘Wolff’s Law of Transformation’) which examined the response of bone to mechanical

forces. In other words, this concept states that bone is laid down where bone is needed and resorbed where not needed (White and Folkens 2000).

Researchers have conducted research on certain parts of the Tell Abraq skeletal collection dealing with bone remodeling due to repetitive activities or pathology. For instance, Soren Blau found alterations on the *talus* (ankle) and *calcaneus* (heel) of the western chamber Tell Abraq remains and suggested that these were caused by “habitually high joint reaction forces” (Blau 1996:168). These markers typically indicate squatting or strenuous walking. She also noted changes to the metatarsals on a smaller proportion of the skeletal collection indicating repetitive kneeling. She proposed that this could be due to grinding or repairing nets or sails while sitting on the heels. However, the bones were too fragmentary to understand them in the context of age and sex (Blau 1996: 168).

One completely articulated skeletal remain was found near the presumed entrance. This individual has been identified as an 18 to 20 year old female and due to certain features like the upward curvature of her sacrum, arthritic effects on the right knee and ankle, and abnormal curvature of the left foot, this might represent one of the earliest cases of polio (Potts 2000, Westbrook 2002). Jamie Vilos (2011) studied Tell Abraq bones displaying extreme pathological trauma that most likely left the individuals severely handicapped but their continued survival showed that they were cared for by the community.

Studies have also been conducted on the trapeziometacarpal joint facet from the Tell Abraq tomb on 650 well-preserved adult carpals and metacarpals (Cope et al. 2005). Mild to severe osteoarthritis (OA) was indicated in 53% of the joints. There was also a

strong correlation between OA, sex, and robusticity indicating men were habitually involved in hard physical labor with the application of their hands.

Through gross preliminary analysis of the adult teeth, fluorosis was determined by dental mottling in a large portion of the Tell Abraq collection, along with heavy attrition (Potts 2001). Later, adult enamel analysis showed relatively high fluoride content in the Tell Abraq population using diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) (Greene et al. 2003). Caries and hypoplasia (severe enamel growth disruption due to infection) were found in the children (Potts 2001). Thus, previous studies revealed mild to severe OA in men, heavy attrition and fluorosis in many adult dentitions, and a small portion of the population repetitively kneeling for a certain occupation – perhaps repairing nets or grinding cereals. However, these studies were unable to reveal whether a certain age or sex category was more involved in the kneeling activity. The current project hopes to achieve a clearer distinction in habitual activities.

## CHAPTER 4: MATERIALS AND METHODS

### 4.1. MATERIAL

For the current study, analysis was carried out on all of the available adult femora, focusing particularly on the proximal (top of the thigh) end. The femora were not analyzed before and yet is an ideal region to study for this research. The proximal end takes in the loading stress of the entire lower limb from the abdomen and so is a good indicator in the study of biomechanics. The morphological features of interest in the proximal ends of the long bone include the head, neck, greater and lesser trochanters, and some portion of the shaft (refer to Figure 8). Based on the requirement to have these parts of the bone present for the analysis, 102 specimens were located, representing 51 right femora and 51 left femora, 70 of which are intact enough to microscopically analyze.

Figure 8. Left femur from the Tell Abraq collection



## 4.2. METHODS

### 4.2.1. Anatomical landmarks

After isolating all of the possible adult femora, standard anatomical landmarks were used to provide the assessment of the left and right side of the femora. Six features are particularly useful in the analysis of this bone for side, sex, age, stature, and musculo-skeletal stress markers (MSMs). These include the femoral head, greater trochanter, lesser trochanter, the intertrochanteric crest, the trochanteric fossa, and gluteal line/tuberosity (White & Folkens, 2005:255-257) (refer to Figure 9).

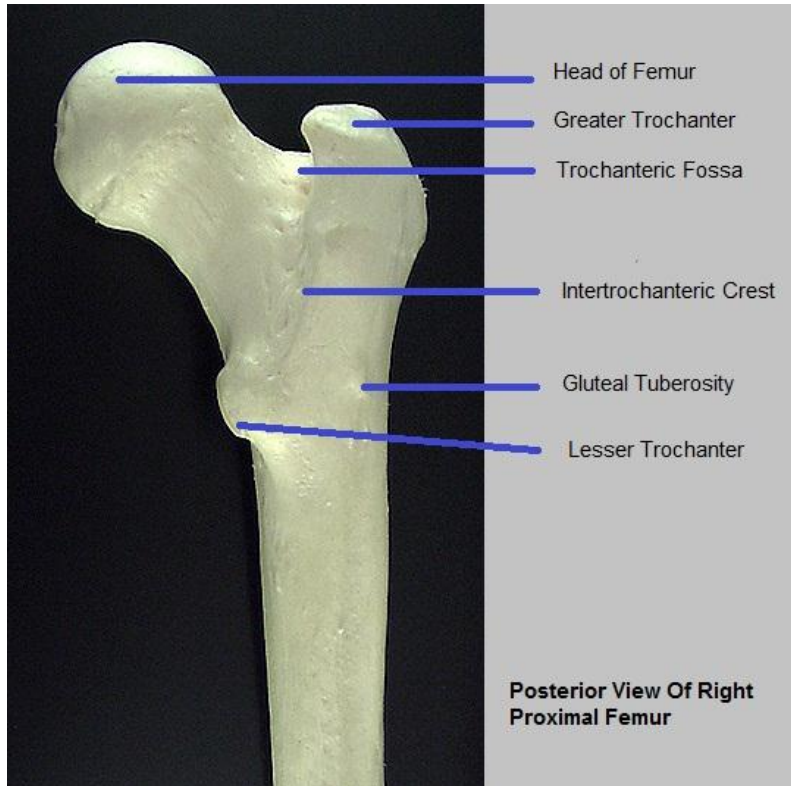
The head, a prominent ball-shaped structure, is located on the proximal, medial end of the femur bone and it articulates itself to the acetabulum in the pelvic bone. It connects to the rest of the bone through an angular neck. The fovea capitis is a depression in the head that acts as the attachment site for *ligamentumteres*, an important structure that provides the hip with its ball and socket joint. The greater trochanter, a large, blunt projection, is located lateral to the neck and serves as the attachment point for the *gluteus minimus* and *piriformis* muscles, which are important in bipedal locomotion.

On the posterior side of the femur, the lesser trochanter is located inferior to the end of the neck, meeting at the shaft. It is smaller than the greater trochanter, with a similarly blunt and prominent tubercle. The intertrochanter crest, an elevated ridge, attaches the greater trochanter to the lesser trochanter on the posterior surface. The trochanteric fossa is a deep depression on the medial surface of the greater trochanter.

Finally, the gluteal line is a long wide feature positioned on the posterior and lateral part of the femur and attaches the base of the greater trochanter to the lineaspera, a ridge that runs down the length of the shaft in the posterior. The gluteal line can either

be a depression or a tuberosity. If the tuberosity is present, it can also be called the third trochanter (White and Folkens 2005: 256)

Figure 9. Posterior view of right proximal femur



#### 4.2.2. Forensic Methods: Sex, Age, Stature

##### Sex Estimation:

##### *i) Femoral head*

One standard method for the assessment of sex is provided by Bass (2005:231), using the maximum diameter of the femoral head. This assessment based on overall size is relatively accurate since males tend to have three extra years of growth due to high levels of circulating testosterone during the ages of 18-21 years (Bass 2005).

This gives males a generally more robust and dense skeleton than females. Thus,

head size simply tracks this dimorphic difference. However, some percent of smaller males and larger females will overlap in measurement. Table 1 shows the general breakdown in millimeters for maximum diameter of head for the majority of males and females:

Table 1. Sex estimate based on maximum diameter of the femoral head from Bass (2005:231).

<b>Female</b>	<b>Probably female</b>	<b>Sex indeterminate</b>	<b>Probably male</b>	<b>Male</b>
X-42.5 mm	42.5-43.5 mm	43.5-46.5 mm	46.5-47.5 mm	47.5-X mm

ii) *Metric Triangle*

The second method that was used to provide sex assessment for the proximal femora is the technique developed by Albanese and colleagues (2008). This is based on the size and angle of the femoral head vis-à-vis the neck and it uses a series of logistical regression equations to provide an assessment of sex. This method was tested on a population with known sex (The Terry Collection housed at the Smithsonian Institution and the Grant Collection curated at the University of Toronto, Canada) (Albanese *et al.* 2008). The accuracy rate of this method was found to be between 90.6% and 95% respectively, for the two autopsy collections.

Using spreading calipers, the following measurements are taken: (1) the distance from the most lateral apex of the greater trochanter (GT) to the superior margin of the lesser trochanter (LT), (2) the distance from the GT to the superior margin of the fovea capitis (FC) and (3) the distance from the FC to the LT (refer to Figure 10).

These measurements create a triangle and size dimorphism and the length and angle



of the neck are calculated using the Law of Cosines. Logistical regression scores are then applied to determine the sex of the individual. According to Albanese and colleagues (2008:1283-1288), scores greater than 0.5 are male, and scores less than 0.5 are female. The authors provide a spreadsheet that calculates the Law of Cosines and the logistical regression as shown in the spreadsheet in Table 2. This greatly facilitates calculating the metric used to assign sex.

Figure 10. Landmarks for the three measurements used in the calculation of sex

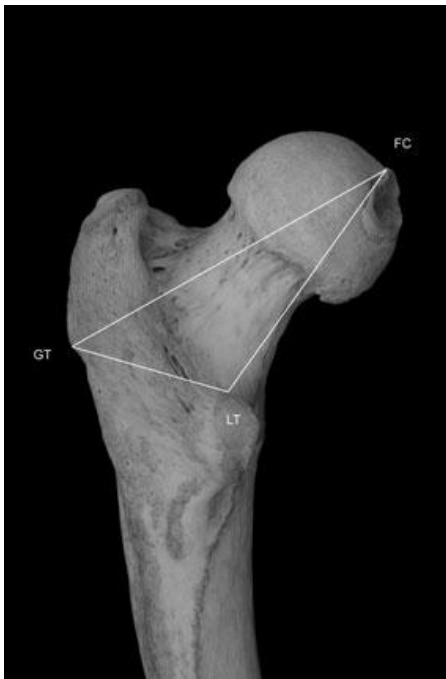


Table 2. Logistical Regression with two examples (Albanese & et al. 2008)

Case #	Measurements			Femur head diameter	Angles			Ratios			Femur	
	GT FC length	GT LT length	LT FC length		Angle at FC	Angle at GT	Angle at LT	aGT/GT to FC	aLT/Fem head	aLT/LT to FC	P	Sex (M/F)
Eg. 1	90	52	76	43	35.25	57.51	87.24	63.9	202.9	114.8	0.06	F
Eg. 2	92	44	72	47	27.86	49.89	102.25	54.23	217.6	142	0.62	M

## Age Estimation:

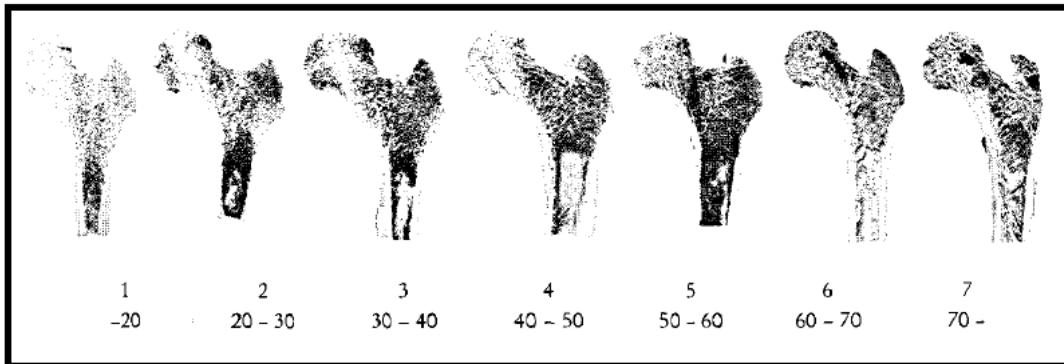
### *i) Macroscopic Changes*

The femur is not a particularly good bone for estimating accurate chronological age, but it can give some indicators of developmental age (Ubelaker 1989). With age and wear-and-tear, the femur begins to show signs of degeneration and osteoarthritis at the margins of the articular surfaces of the femoral head (where it articulates with the acetabulum of the pelvis). Individuals with no osteoarthritic lipping (outgrowth of bone in liplike form at joint margins) would be considered to be young adult (20-40), individuals with a slight amount of osteoarthritic lipping would fall into the middle adult range (40-50+) and individuals with severe cases of arthritis would be categorized as elderly (60+). Various studies have shown that osteoarthritis occurs as a function of age, but with wide variability (Ubelaker 1989; Brothwell 1981).

### *ii) Micro-CT scan (modeled after Szilvassy and Kritscher 1990 and Walker and Lovejoy 1985)*

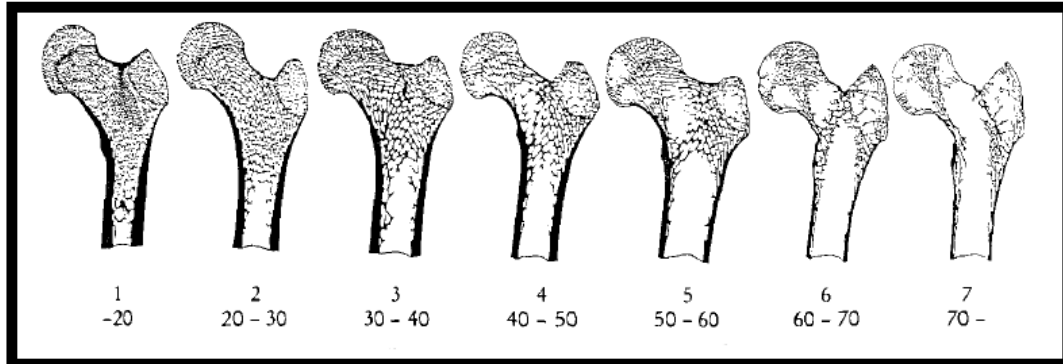
Microstructurally, bone loss occurs with increasing age in the trabeculae. Using radiography, researchers such as Walker and Lovejoy (1985), Szilvassy and Kritscher (1990), Macchiarelli and Bondiolini (1994) and Jones (2003) have studied the applicability of using trabecular architecture as an indicator of age at death. However, primary and secondary groups of the trabeculae are impossible to distinguish using radiography and fine trabeculae that are resorbed first are not visually apparent radiographically until at least 30% of the bone has been lost (Macchiarelli and Bondiolini 1994). (refer to Figure 11). A new methodology that can recognize these trabeculae was tested for its applicability to resolve this problem.

Figure 11. Radiographic representation of the seven stages of the proximal femur (Szilvassy and Kritscher 1990)



The samples were scanned at 93  $\mu\text{m}$  isometric resolution using an eXplore Locus RS Small Animal MicroCT Scanner (GE Healthcare, London, Ontario). The data was reconstructed with the manufacturer's proprietary EVSBeam<sup>TM</sup> software. Image analysis was performed using visualization tool MicroView 2.1.2. (Personal communication – Suresh Prajapati). Qualitative assessment of the high resolution scans was compared to radiographic ten-year interval age model by Szilvassy and Kritscher (1999) to determine age of the Tell Abraç collection (refer to Figure 12). The study also incorporated the Ward's Triangle which is a three dimensional space in the neck region between the mesh of trabeculae that widens as age progresses from the model provided by Walker and Lovejoy (1985).

Figure 12. Diagram representing the seven stages of the proximal femur (Szilvassy and Kritscher 1990)



### Stature Estimation:

#### i) *Method 1*

Stature can be reconstructed from the proximal femur with the methods used by forensic researchers (Byers 2008:267). A measurement was taken from the most proximal point on the femoral head to the middle of the lesser trochanter in cm. The following equation was then used to provide an estimate of the length of the femur:

$$\text{Male femur length in cm} = (\text{distance} * 100) / 17.16$$

$$\text{Female femur length in cm} = (\text{distance} * 100) / 16.48$$

(\*distance = most proximal point on the femoral head to the middle of the lesser trochanter in cm)

Stature can then be estimated using a regression formula worked out for whole bones.

For the femur, Bass (2005:29) provides the following equation:

Stature for Mongoloid males in cm = 2.15 X femur length in cm + 72.57 [+/- 3.80 cm].

Stature for Negroid males in cm = 2.10 X femur length in cm + 72.22 [+/- 3.91 cm].

Stature for Negroid females in cm = 2.28 X femur length in cm + 59.76 [+/- 3.41 cm].

### 4.2.3. Musculoskeletal Markers (MSM)

Kennedy (1989) pioneered a range of methods for understanding the amount of occupational stress individuals may have incurred over the course of an extensive period of time. The theory behind this method suggests that hard physical labor, practiced over many hours a day, many weeks a year, over many years, produces highly diagnostic changes in the places where muscles hard at work are structurally anchored in bones. These changes on bones due to external biomechanical forces are called musculoskeletal markers (MSM) or markers of occupational stress (MOS). This musculo-skeletal interface has been well studied for some occupations (Molleson 1994; Abu Dalou 2007) but is more anecdotal for others (Kennedy 1989, 1998; Capasso *et al.* 1999). MSMs are not necessarily pathological, although with extreme pressure on the muscle-bone interface, there can be true bony degradation and calcification of the tendons that attach muscle to bone. For the most part, many of the MSMs relate to such activities such as squatting, carrying heavy loads on the back, kneeling, holding heavy loads in the arms, and pounding using a heavy implement, are adaptive responses. That is, the bone reacts to the stress being placed on it and it forms new ridges, facets, and concavities which actually make the habitual action more efficient and less strenuous. However, it is clear that some actions are so strenuous and stressful that the moderate adaptations are repeatedly strained and breakdown of bone integrity can occur (Capasso *et al.* 1999).

The scientific study of osseous and dental modifications due to adaptation of repetitive patterns of activities has been conducted since the Middle Ages (mid-sixteenth century AD). For instance, Georgius Agricola, a German mineralogist, studied gold and silver mining and miners' occupational diseases due to poor personal protection. His

work was published posthumously in 1556, and translated into English in 1912 (Agricola 1912). Markers of occupational stress (MOS) started catching the interests of anthropologists and anatomists decades later when the first hominid fossils were discovered in Europe during the mid-nineteenth century and by 1989, Kennedy published a section on Skeletal Markers of Occupational Stress in *Reconstruction of Life from the Skeleton*, which documented over 145 cases of MOS (Kennedy 1998). Because of this research, specific alterations in the upper limbs refer to physical labor of the trunk (e.g. smiths, fishermen or oarsmen), while modifications of the lower limbs and girdle may develop in walkers, runners, and certain agricultural workers (Jozsa *et al.* 2004). Reconstruction of these biological changes is more robust when coupled with cultural, ethnological (ethnographic, historical), and archaeological evidence. At a population level, gross workload patterns can be understood with implicit information of sexual or social division of labor within the group (Mariotti *et al.* 2004).

The proximal femur is a good site for the assessment of MSMs since it is a primary load bearing joint system used in any lower body activity. The following MSMs were assessed for the Tell Abraaq femora using a graded scale of 0 (for no MSM expression) to 4 (extreme MSM expression).

- i) *Articular Border Convexity (ABC)*. This MSM has been found to be related to squatting and sartorial (cross-legged) sitting position (Capasso *et al.* 1999: 103). In the squatting position, the back of the thigh rests on the calves while the heels carry the weight of the trunk (refer to Figure 13). In the sartorial position, the lower legs fold toward the body, crossing each other at the ankle or calf, with both ankles on the floor and sometimes the feet tucked under the thigh (refer to Figure 14). According to

R.H. Charles (1893), squatting and sartorial postures lead to modification of the ischial in the acetabulum, also called the cotyloid cavity, increased articular area of the femoral head, and an elongated neck. The groove for the obturator externus is also well defined. These positions require extreme hip-joint flexibility. Security is obtained by the femur head resting on the greatly developed inferior cornu of the facies lunata of the acetabulum in the pelvic bone. The increased articular area of the proximal femur, in proportion to the size of the head, with the articular anterior-superior border of the femoral neck prominently curved to a well-marked convexity was qualitatively evaluated on the presence or absence of this stress marker (see 'x' in Figure 15). From a grade of 0-4, ABC was evaluated, with 0 as an absence of the stress and 4 as a pronounced feature of the stress.

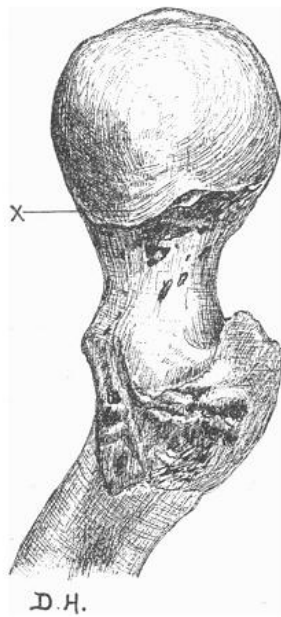
Figure 13. Squatting position (naturesplatform.com)



Figure 14. Sartorial position (gograph.com)



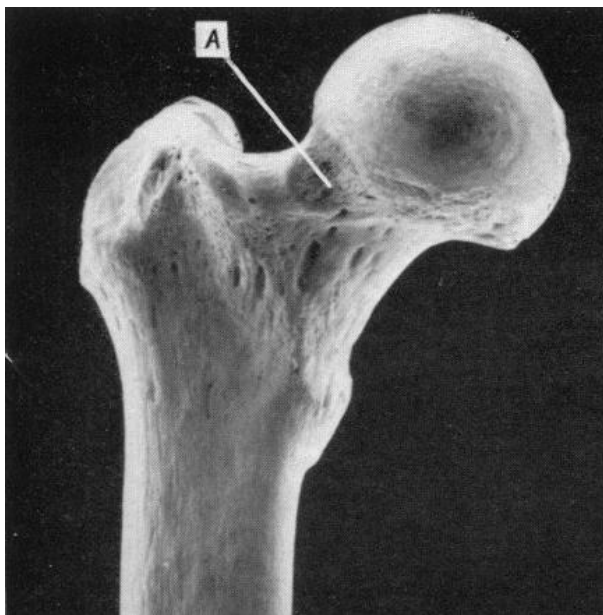
Figure 15. Enlarged femoral head with 'x' marking the anterior-superior border convexity (Charles 1893: 9).





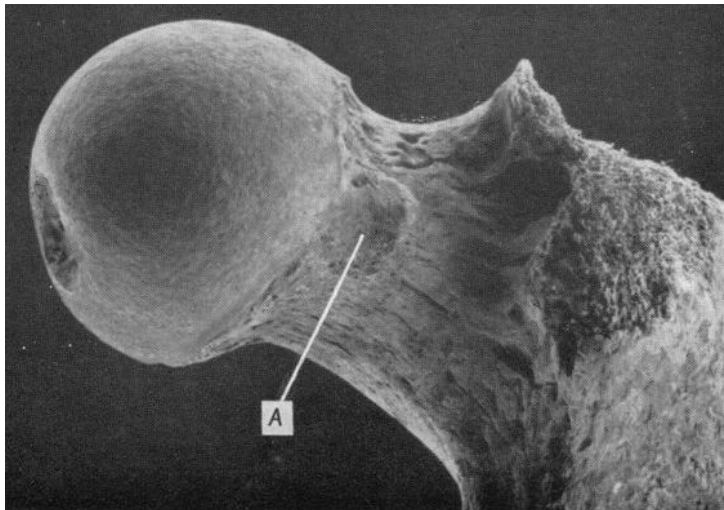
ii) *Poirier's Facet (PF)*. Normal locomotion might be adequate enough to create PF, which is an extension of the articular surface of the head on to the anterior surface of the neck (refer to Figure 16) (Capasso *et al.* 1998: 104, Poirier and Charpy 1911). It is a continuity of the articular lamella on to the neck and may occur with an imprint (Kostick 1963). It can result from extension-like standing and walking and by flexion-like squatting (Odgers 1931). Extreme extension, like walking downhill, could pronounce the facet (Capasso *et al.* 1998: 104). Often confused with the anterior cervical eminence, this facet is an outward bulge of the femoral head while the eminence is a recessed fossa. Poirier's facet is found more in males than in females, as indicated in the study by Angel (1964) on prehistoric Greeks and modern population and Kostick (1963) on Series A and Series I.D.H. housed at University College Ibadan, Nigeria. From a grade of 0-4, PF was evaluated, with 0 as an absence of the stress and 4 as a pronounced feature of the stress.

Figure 16. Right femur with A pointing to a Poirier's Facet (Capasso *et al.* 1998: 104 fig. 108).



iii) *Posterior Cervical Imprint (PCI)*. This facet is associated with prolonged walking and standing and squatting postures (Capasso et al.; 1998, Kostick 1963). The facet was particularly noted by Walmsley (1915) and thus popularly referred to as Walmsley's Facet. The facet resembles Poirier's Facet, except the extension of the articular surface of the femoral head is on the posterior surface of the neck (Capasso et al. 1998: 106). It is more constant in size than the anterior facet. It occurs when the limb is completely extended at the hip-joint and contact takes place with the ischial part of the acetabulum rim (Walmsley 1915:311). It is limited laterally by a tubercle bordering the medial margin of the groove for the obturatorternus tendon (Capasso et al. 1998; Kostick 1963) (refer to Figure 17). This MSM was evaluated on a 0-4 grade, with 0 as an absence of the stress and 4 as a strong presence of the stress.

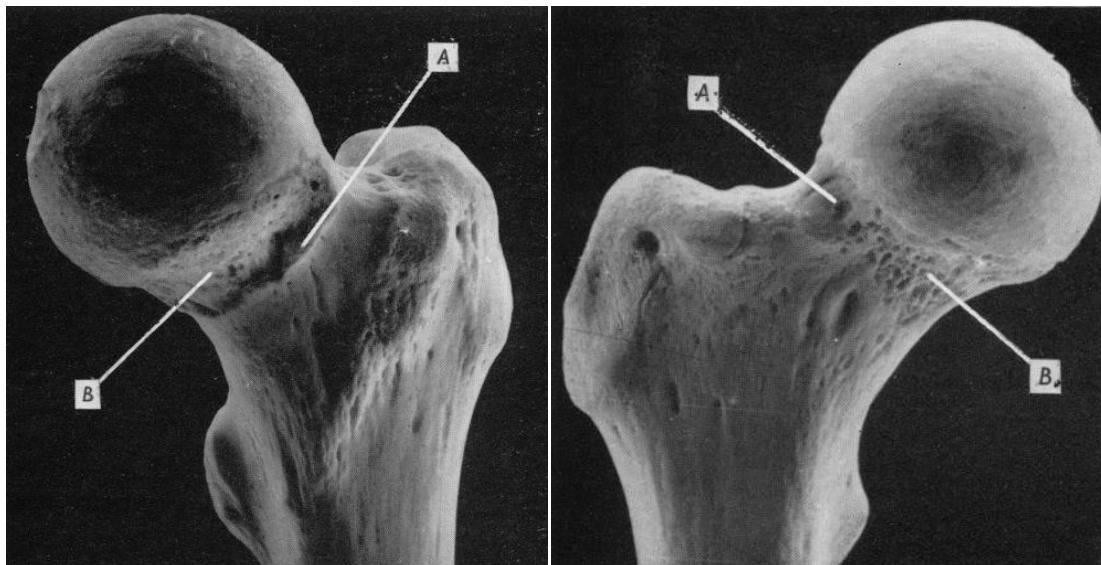
Figure 17. Posterior Cervical Imprint (from Kostick 1963: facing pg. 402 plate 1)



iv) *Anterior Cervical Imprint (ACI)*. This stress marker has been attributed to extension (walking, running) and hyperflexion (squatting). Also known as the fossa of Allen

and the imprint of Berteaux, this occurs on the anterior and inferior aspects of the medial part of the neck, adjacent to the femoral head (Capasso *et al.* 1998: 113; Kostick 1963; Angel 1959). It is an “ulcer-like excavation, exhibiting a floor and edges,” where the cortical bone is thinner than the rest of the femoral neck area and surrounded with a ring of reactive bone (Kostick 1963:395). As published by E.L. Kostick (1963) and Karl Pearsons & Julia Bell (1919), two types of this marker were categorized in this study. Type A) exhibits a clear and clean depression with sharp edges. The floor of the depression could be smooth or finely honey-combed (refer to Figure 18). Type B) is a more pleomorphic type, giving a picture of discontinuity and does not have clear ridges at the edges. The depression has a worn cancellous appearance (refer to Figure 18). It seems to occur in younger bones, between 14-22 years, where the epiphyseal union is apparent and is assumed to deepen with age to Type A (Kostick 1963; Odgers 1931)

Figure 18. Anterior Cervical Imprint. Left photo of femur (Type A), A pointing to the ridge/edge, B pointing to the depression/floor (Kostick 1963: facing pg 402 plate 1); Right photo of femur, A pointing to Poirier’s Facet and B pointing to a Type B imprint. Note the epiphyseal union (Kostick 1963: facing pg 402 plate 1)

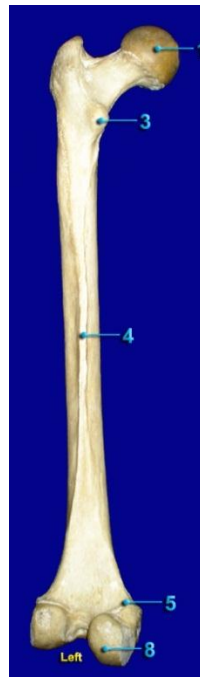


The circular fibers, called the zona orbicularis, tighten around the neck of the femur to resist extreme extension of the femur and rotation of the head in the acetabulum. This stress or fossa appears where the zona divides around the iliofemoral ligament, a ligament which extends from the ilium to the femur in front of the hip-joint (Capasso *et al.* 1998). The contact of the two ligaments during extension (Odgers 1931) or the tightening of the capsular ligament extending from the acetabulum during hyperflexion, could cause the fossa to appear. J.L. Angel (1964:137) states that the ridges (Type A) appear more on inactive (and perhaps older) people. However, only the depression or fossa appeared in active individuals where habitual activities, like running down a hill-slope while herding in mountainous landscape, would oppose the ligament. This ligament checks rotary movement of the head that contributes to the ridges forming (Angel 1964:137). Kenneth Kennedy called this locomotion the mountaineer's gait (Kennedy 1989). In his work with Series A and Series I.D.H., E.L. Kosticks (1963:399) found this type of stress more common in females than males. From a grade of 0-4, each type of this MSM was evaluated, with 0 as an absence of the stress and 4 as a strong presence of the stress.

- v) *Pilasterism and Linea Aspera Enthesopathy*. Activity patterns such as sea fishing (Oetteking 1930), jogging on undulating landscape (Molleson and Hodgson 1993), or lifting heavy objects from a squatting position (Capasso et al. 1998) have been associated with this MSM. Aleš Hrdlicka refers to linea aspera as crista aspera since “the term ‘line’ is wholly inapplicable” (Hrdlicka 1934: 17). Cunningham (1913: 242) describes it as a rough-lipped ridge with three lines (medial lip, lateral lip and

pectineal line) converging about 2-2.5 inches below the lesser trochanter and then running longitudinally along the posterior centre of the femur. While the pectineal line fades away between the two lips, the two lips split, ending the linea aspera in the distal third of the shaft (refer to Figure 19). Pilasterism is “an increase in the bony elements underlying the linea aspera that results in a flattened, mesa-like ridge” (Capasso et al. 1998:118). Many linear muscle attachments are associated with the linea aspera including the vastusmedialis, adductor longus, and adductor magnus (Cunningham, 1913). Development of pilasterism and hypertrophic linea aspera has been associated with many factors connected to the aforementioned muscle attachments including direct pull of the muscles (pilasterism and hypertrophic linea aspera) and pressure forces (pilasterism). Hrdlicka (1934) claims its extent of pronounced features has more to do with activity patterns since his study showed there was more variability within ethnic groups of Whites, Blacks, South Asian Indians, and many Native American tribes, than between these groups. This MSM was evaluated from a grade of 0-4, with 0 as an absence of the stress and 4 as a pronounced feature of the stress. Hrdlicka also notes that while the linea aspera has a long gradually ascending life-line from approximately the middle of the intrauterine life until old age, pilastry rarely starts during late childhood and reaches its maximum during the middle adult age.

Figure 19. Posterior view of left femur. Marker 4 points at the linea aspera



vi) *Enthesopathies on the femur.* Enthesopathy is a bony alteration on the site of tendon and muscle insertions, known as the entheses, which develops as an adaptation to repeated traumatic effects or increased load-bearing strain on the ligament and bone. If the strain stops, the rate of bone modification might stop or regress (Jozsa *et al.* 2004). There is no difference between the structure of the cortical and cancellous areas when comparing normal bone areas to enthesopathic areas (Józsa and Kannus 1997; Józsa and Pap 1997). Enthesopathies are less frequent in recent populations (2-4%) than in osteoarchaeological samples (50%) (Jozsa *et al.* 2004). At the proximal end of the femur, there are combinations of features that are labeled as enthesopathies. Enthesopathies that are identifiable include the lesser trochanter at a more posterior position than typical, an enlarged articular area of the head, and the greater trochanter having an enlarged insertion for gluteus medius and minimus to

check lateral movement of the pelvis. The lineaaspera with hypertrophic adductor is pronounced. Laterally, the biceps femorus insertion is distinct. Common activity patterns include hip extension and stabilization to maintain upright position under unstable conditions (Capasso *et al.* 1998:119). In modern populations, the markers are more evident on sports players including football players, skiers, horseback riders, long distance runners, and brisk walkers (Capasso *et al.* 1998; Jozsa *et al.* 1989). Lai and Lovell (1992) found that Canadian fur traders have prominent development of the gluteal and hamstring muscles, possibly from traversing over steep portage trails while carrying heavy loads. Cart-driving, where the individual pulls the cart from behind him, also utilized the hamstring and adductors (Molleson and Hodgson 1993). Enthesopathies was evaluated on a 0-4 grade, with 0 as an absence of the stress and 4 as a very pronounced feature of the stress.

vii) *Exostosis of the Trochanteric Fossa (Exos. of the TF)*. This MSM has been linked to prolonged sitting posture with the lower limbs extended (Capasso *et al.* 1998:120). There is rarely a tubercle in the superior medial surface trochanteric fossa at the insertion of the obturator externus, which is a flat triangular muscle that starts at the medial side of the obturator foramen of the pelvis and ends in a tendon attached to the trochanteric fossa. More frequently, various amounts of bony spicules or exostosis can be observed in the otherwise smooth fossa. The tubercle may be long, with cusplike features of a molar tooth. Hawkey and Street (1992: poster presentation) found that Aluet males from the Krentzen Islands, who kayak with legs extended, have this feature, although it was not present in Thule Eskimos along the Arctic coast of northern Alaska who kayaked in a kneeling position (Capasso *et al.* 1998). This MSM



was evaluated on a 0-4 grade, with 0 as an absence of the stress and 4 as a very pronounced feature of the marker.

viii) *Platymeric Index (PI)*. PI has been a source of much debate regarding its association with genetics, sex and mobility. It is the region calculated below the lesser trochanter of the femur. The index is calculated by dividing the subtrochanteric anteroposterior diameter by the mediolateral diameter. Both of these measurements are taken using a sliding set of calipers. The number derived from this is multiplied by 100.

$$PI = \frac{\text{Subtrochanteric Anteroposterior Diameter} \times 100}{\text{Subtrochanteric Mediolateral Diameter}}$$

Dimorphic differences have been investigated between the sexes, with some success (Ruff 1987; Brown 2002). According to researchers, males tend to have a more rounded and cylindrical subtrochanteric shape (eurymeric). Females display a mediolateral flattening of the subtrochanteric region, which is referred to as platymeric. The PI has been more successfully used by researchers such as Gill and colleagues (1990, 2001) to estimate ancestry and to distinguish between Native Americans and American Blacks, suggesting differences in genetic makeup. Wescott (2006) and Miller (1995) similarly claimed that the morphology of the subtrochanteric bony region is determined by genetics and shaped early in the years of childhood. Abu Dalou (2007) claimed that while activity level and subsistence tasks usually take place after childhood, activated modeling processes may adjust, though not significantly. Furthermore, various researchers (Cole 1994; Kiesewetter 2006; Larsen 1997) have argued that there was an overall decline in the flattening of the femoral



bone at the subtrochanteric region during the late Pliocene, and this could be the result of less physical mobility as the population adapted to a more sedentary lifestyle. The indices could also correlate with the variation of physical activities. H. Kiesewetter (2006) successfully applied this method in comparing two Neolithic groups in the United Arab Emirates; the mobile group in the mountains to the more sedentary group near the coastal region.

Taking all the above arguments into account, the current project attempted to explore all three avenues. Modifying on William M. Bass's (2005:225) measurement of eurymeric (rounded) and platymeric (flattened) subtrochanteric region, this study included two categories to identify slightly eurymeric and slightly platymeric morphology in order to investigate the variation of differences.

Eurymeric morphology -	PI value 90-99.9
Slightly Eurymeric -	PI value 85-89.9
Slightly Platymeric -	PI value 80-84.9
Platymeric -	PI value 79.9 below

The subtrochanteric region was calculated to determine -

- a) strong genetic control - whether the morphology is homologous within the population, whether it be eurymeric or platymeric.
- b) strong gender control - whether there is a significant difference between males and females.
- c) variation of mobility – whether the population, though sedentary, had a physically mobile subgroup.

#### 4.2.4. Microscopic Analysis

In response to the biomechanical forces, the femur's internal structure remodels itself to function as a load bearing structure. The femur is composed of the cortical and the trabecular bone. The trabecular bone (or cancellous bone) within the cortical/compact bone is composed of osseous tissue which is less dense, softer, weaker, and less stiff and also has a larger surface area. It readjusts itself to deal with repetitive non-uniformly applied external loading, in essence shaping itself to achieve a uniform stress state and fracture avoidance. Therefore, by observing the stress/strain state at the tissue level of the trabecular system, one can deduce the type of mechanical stimulus that the bone was constantly subjected to (Lovejoy *et al.* 2002; Ryan and Krovitiz 2006).

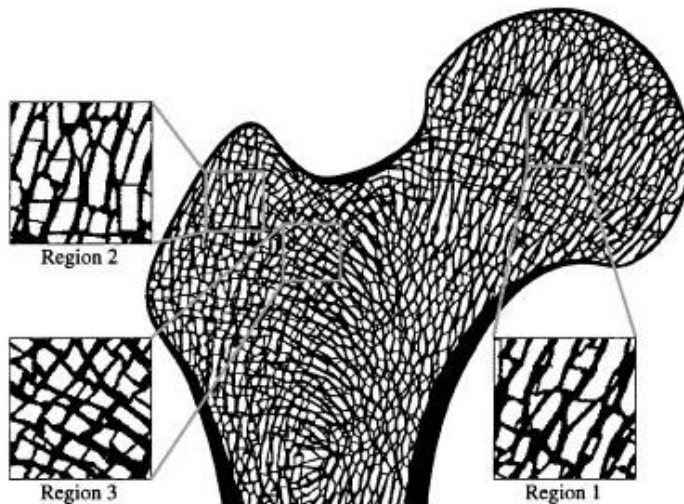
In the proximal end of the femur, five anatomic groups of trabeculae were identified –

- a) Principal compressive group extending from the medial cortex of the femoral neck to the upper position of the femoral head in curved radial lines.
- b) Secondary compressive group extending from the medial cortex of the shaft below the principal compressive group.
- c) Principal tensile group extending superiorly from the lateral cortex below the greater trochanter to across the medial femoral neck, ending right below the head.
- d) Secondary tensile group arising from the lateral cortex below the principal tensile group and extending superiorly and medially and terminating after crossing the middle of the femoral neck.
- e) The greater trochanter group, extending laterally below the greater trochanter and moving upward and terminating near its superior surface. This group is a more slender and poorly defined tensile trabeculae (Bardeen, et al. 1917:255).

This proposed project strives to find correlations in trabecular patterns found within the bone to certain well-researched MSMs recognized on the surface of the bone, and to contribute to the understanding of the various loading mechanisms within the complex human bone structure. Various researchers have created two dimensional simulation models of the proximal femur with controlled loading pressures of adduction and abduction (Tsubota *et al.* 2002; Vander Sloten J. and Van der Perre G 1989). This project will test modifications in the bone structure to the hypothesized loading mechanisms found outside the bone.

The three regions under study in this project are similar to Tsubota and colleagues' (2002) area of interest (refer to Figure 20). Non-invasive high-resolution computer tomography (CT) was used to capture the bone structure within the surface, as detailed in this chapter under the section of 'Age Estimation'. Software programs, including MicroView and ImageVis3D, were used to qualitatively study trabecular patterns of the area of interest (personal communication - Charles Keller).

Figure 20. Three regions of analysis (Tsubota et al. 2002:1545 fig. 4)



#### 4.2.5. Pathology

According to Ortner & Putschar (1985), almost half the individuals of antiquity die during infancy or childhood, and most of the deaths result from infectious diseases. Nonetheless, there are many more pathologies that occur during an individual's life-course, including metabolic disorders and endocrine disturbances, and so survivorship demonstrates a stronger immune system. Since it requires extreme cases for these diseases to manifest on or in the bones, many of these diseases have remained undetected in human skeletal collections (Byers 2008). Another pressing diagnostic issue is the observation and diagnosis of a particular infection on bones, since many infections leave similar modified bone morphology (Ortner & Putschar 1985, White and Folkens 2005, Byers 2008). Yet, through the systematic method of differential diagnosis, patterns of diseases and health status can be discerned. It is also important to evaluate whether a specific pathology has the potential to modify the bone enough to complicate the analysis of MSMs.

- i) *Osteomyelitis*. Osteomyelitis is an infectious disease contracted when pyogenic bacteria reach the bone either through traumatic or surgical wounds, soft tissue infections, or the blood from a remote septic area. The bacterium infecting the bone is 90% of the time *Staphylococcus aureus*, followed by *Streptococcus*. The infection can be acute, spreading through the medullary cavity, or localized and limited to the periosteum and cortex. The localized infection is identified by focal periosteal bone depositions around a partial cortical defect, and may exhibit some sclerotic response or scarred healing. If hematogenous (originated in or spread by blood stream), it is more likely to affect juvenile extremities at the growth plates. In adults, it is often an indicator of recurrent or continued juvenile osteomyelitis. Other bacterial causes include typhoid fever or sickle cell anemia (Ortne & Putschar 1985:105-116).
- ii) *Periostitis*. Periostitis is usually a reaction to pathological changes in the underlying bone. Inflamed periosteal bone deposited over a period of time tends to have irregular surfaces with varied thickness, and is unevenly distributed. It is often marked with smaller and larger pores (Ortner & Putschar 1985:129).
- iii) *Brucellosis*. Though rarely featured in the limbs, Brucellosis is an infection transmitted through the consumption of infected animal meat or milk (such as goats and pigs). It occurs mostly in the form of *B. melitensis*, most prevalent in adult males. The lesion is usually a lytic cavitation with the cortex sometimes showing perforations. There is minimal reactive bone formation except in the healing stages (Ortner & Putschar 1985: 138).
- iv) *Tuberculosis*. Tuberculosis is a chronic infectious disease caused by *Mycobacterium tuberculosis*. Its route of infection is usually through the respiratory tract. When it

appears on bones, it is usually the result of hematogenous dissemination. It often appears with perifocal or general osteoporosis. In the long bones, it usually appears localized in the metaphysial or epiphysial portions. The morphology overlaps considerably with the appearance of other bone infections. Its general characteristics are as follows: In stage one it permeates the marrow spaces to form centrally located sequestra of cancellous bone (caries); in stage 2 there is local destruction and cavitation in the cancellous bones with rarely any perifocal reactive bone formation (Ortner & Putschar 1985: 141-144).

v) *Treponemal infections.* The treponemal infections include venereal syphilis, endemic syphilis (treponarid), yaws, and pinta, with the first three sometimes manifesting itself on the bone. The bone lesions are so similar that diagnostic differences become very difficult to discern. They consist mostly of periosteal bone deposits, which cause swelling. Late yaws presents as gummatousperiostitis and osteomyelitis, very similar to tertiary syphilis (Ortner & Putschar 1985: 180-182).

vi) *Necrosis of femoral head.* Simply put, necrosis of femoral head occurs when active cells of the femoral head partially or fully die due to a subcapital fracture in the neck of the femur bone. The area around the fovea is often unaffected if the ligamentumteres, which is the ligament at the head of the femur, is intact. If the fracture remains for a long time by the afflicted individual, osteoporosis usually forms in the surviving cells of the femoral head. The necrotic portion of the bone appears dense on an X-ray. Traumatic dislocation of the hip joint can also cause necrosis and extreme aseptic necrosis leads to Perthe's disease, where the head

flattens due to compression fracturing and lack of enchondral growth, and the disease shortens the femoral neck (Ortner & Putschar 1985:236-239).

vii) *Osteoporosis*. Senile osteoporosis occurs usually after the fourth decade of an individual's life. In part, it reflects the drastic drop in estrogen at menopause in females, as opposed to the slow and gradual decrease in testosterone in males. In long bones, there is an increase in the medullary cavity due to endosteal resorption and an increasing number of unfilled Haversian resorption spaces due to intracortical resorption. Advanced osteoporosis can be seen in the neck of the femur where the trabecular systems, which crisscross each other, thin out. The system which begins at the lesser trochanter to the greater trochanter becomes the first to disintegrate. This results in a roughly triangular area within the neck (Ward's triangle) with sparse or no trabeculae. This condition can successfully be diagnosed through the micro-CT scan (Ortner & Putschar 1985:289).

## CHAPTER 5: RESULTS

The minimum number of individuals at the Tell Abrq tomb is 286 adults and 127 subadults, based on previous studies (Baustian 2010; Blau 1996).. The current study analyzed all proximal femora, which exhibited almost intact femoral heads, necks and at least one of the greater and lesser trochanter. A total of 102 femora fit these minimum necessities, with 51 femora each representing the left and right sides.

### *5.1. SEX DETERMINATION*

Employing the three different methods of determining sex, results from femoral head size and metric analysis showed very similar results, while the platymeric index showed contradicting results.

#### 1. Femoral Head (Bass 2005)

Results indicating probable male and female frequencies were clubbed together with male and female respectively. The collection had very robust proximal femora with large femoral heads and very gracile proximal femora with smaller head diameter (refer to Figure 21). As indicated in Table 3, while almost 10% of the femora were indeterminate, approximately 60% of the femora were found to be male individuals and approximately 35% to be female individuals.



Figure 21. Femora 22 (extreme left) and 18 (extreme right) are robust specimens compared to femora 14 (middle left) and 35 (middle right)



Table 3. Results of sex determination using femoral head size

FEMORAL HEAD DIAMETER	Frequency	Percent
Male	58	56.9
Female	34	33.3
Indeterminate	10	9.8
<b>Total</b>	<b>102</b>	<b>100</b>

## 2. Metric Method or Triangle (Albanese et al. 2008)

The Metric Triangle developed by Albanese and colleagues (2008) uses landmarks from three different locations of the femora to calculate the distance and interior angles of the triangle that it forms. A total of 53 out of 102 femora from the current study could be tested using this method, exhibiting all three locations – superior margin of the fovea capitis, most lateral apex of the greater trochanter, and the superior margin of the lesser trochanter. Using logistical regression, p values below 0.5 were determined to be female and above 0.5 were determined to be male. As shown in Appendix 1 and summarized in

Table 4, of the 53 femora, 28 femora belonged to male individuals and 25 femora to female individuals. Here, the male-female ratio is much smaller compared to the simple femoral head size results, with 52.8% of the 53 femora being determined as male and 47.2% being determined as female.

Table 4. Results of sex determination using Metric Triangle

METRIC METHOD	Frequency	Percent
Male	28	27.5
Female	25	24.5
<b>Total</b>	<b>53</b>	<b>52</b>
Missing	49	48

SUMMARY: Studying the correlation between the femoral head results and the metric method results, all (n=53) but five of the results from the metric method matched the results from the femoral head method. The five that did not match did not give opposing results but rather were recorded as 'indeterminate'. Since all but some indeterminate results matched perfectly between the aforementioned two methods, the study converted the sex of indeterminate subjects to the sex determined by the other method. The final tally is given in Table 5. Six were still left as indeterminate by both the methods and thus, were not analyzed when studying gender roles in the population. Figures 22 and 23 also give a visual idea of the sex distribution for the left and the right femora respectively.

Table 5. Final Sex Determination Results

FINAL SEX ESTIMATION	Frequency	Percent
Male	61	59.8
Female	35	34.3
Indeterminate	6	5.9
<b>Total</b>	<b>102</b>	<b>100</b>

Figure 22. Sex determination with the left femora

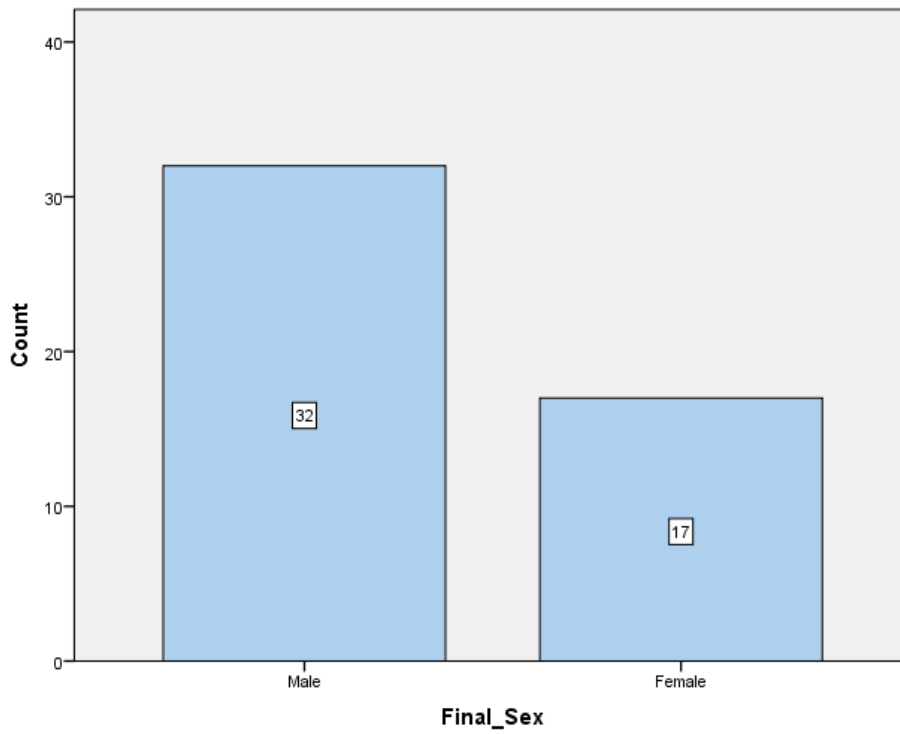
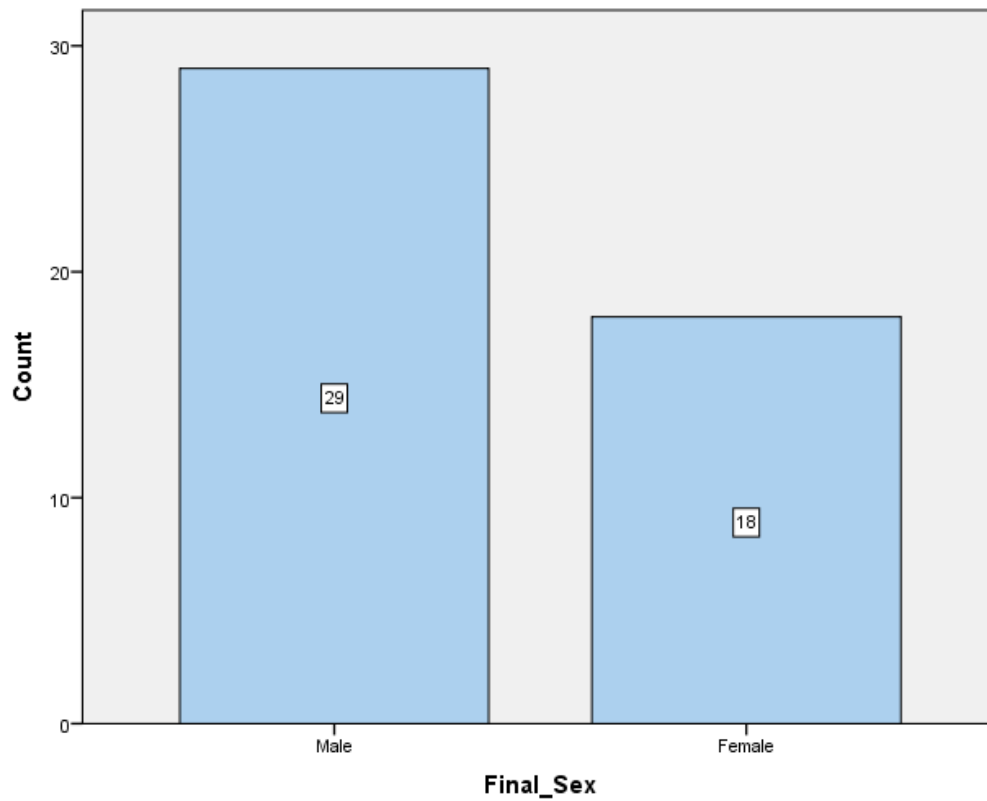


Figure 23. Sex determination with the right femora



## 5.2. STATURE ESTIMATION

Byers' (2008:267) method of estimating the length of femur using the proximal end of the bone was used, after which the stature was determined using Bass' (2005:29) estimation of stature from the length of the femur.

Table 6 shows the range of statures for males and females. Since stature estimation from the femur lengths of the Arabian Peninsula is not available, the closest populations used to estimate stature were from the Negroid population and Mongoloid population (for males only).

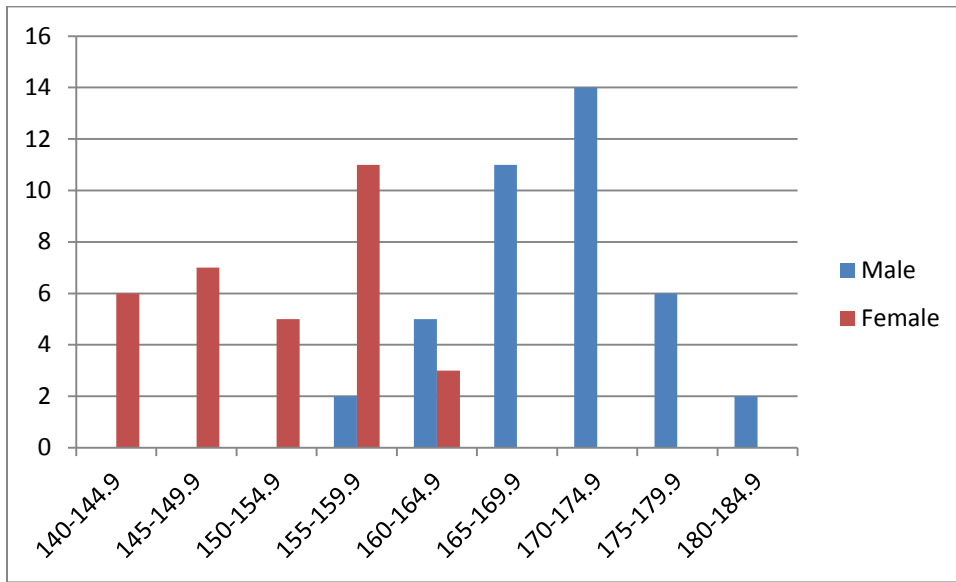
The average height of male stature from the Mongoloid stature equation is 170.08 cm (or 5 feet 6 inches) and from the Negroid stature equation, is 167.46 cm (or 5 feet 5 inches), many falling below and above the average with a range of 27.56 cm and 26.92 cm respectively. Both tables show normal skewness and kurtosis. Female stature average was lower (151.85 cm or 5 feet) with a smaller range of 19.37 cm. The skewness and kurtosis is normal.

Figure 24 shows the distribution of female (in red) and male stature (in blue) and clearly displays a sexual dimorphism with the majority of females being shorter in height compared to their male counterparts.

Table 6. Average Estimated Stature in Tell Abraq

	Mongolian Male (in cm)	Negroid Male (in cm)	Negroid Female (in cm)
N	40	40	32
Range	27.56	26.92	19.37
Mean	170.08	167.46	151.85
Std. Deviation	5.76	5.62	6.01
Skewness	-0.08	-0.08	-0.213
Kurtosis	0.294	0.294	-1.05

Figure 24. Bar chart of stature range of male and females



### 5.3. AGE ESTIMATION

Two methods of age estimation were employed – the traditional method and the degree of tissue degeneration via micro-CT scan.

#### 1. Using traditional method (Ubelaker 1989)

Age estimation was studied via the traditional method of ranking the lack of or degree of osteoarthritic lipping at joint margins, such as the femoral head margins where -

0 = Very Young adults (18-22 yrs)

1 = Young Adults (20-40 yrs)

2 = Middle Adults (40-50+)

3 = Old Adults (60+)

Table 7 and Figure 25 indicate that a very large fraction (65.7%) of the skeletal remains comes from the age category of +40 years and only 4 femora are in the Very Young Adults category.

Table 7. Frequency table of age estimation using traditional method

	Frequency	Percent
Very Young Adult (17-20 yrs)	4	3.9
Young Adult (20-40 yrs)	30	29.4
Middle Adult (40-50+ yrs)	67	65.7
<b>Total</b>	<b>101</b>	<b>99</b>
Missing	1	1

Figure 25. Bar chart of age estimation using traditional method

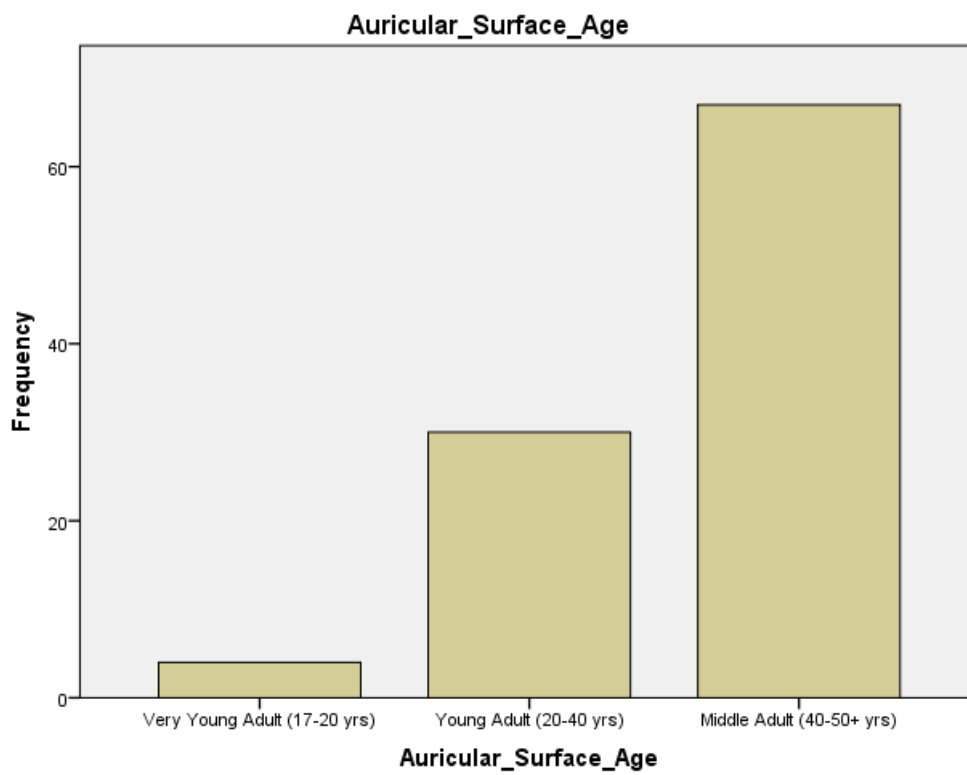
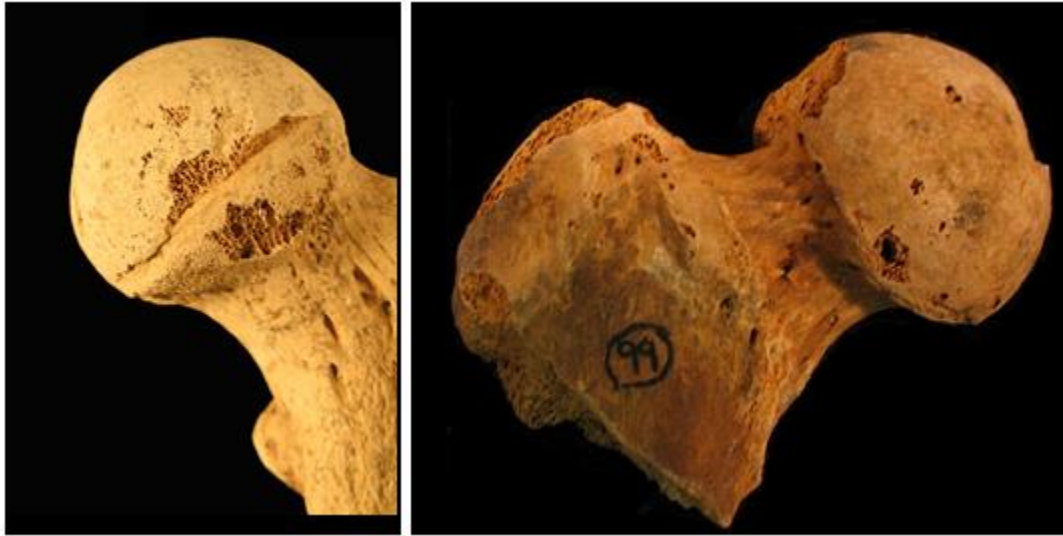


Figure 26. Femora 18 (left) and 99 (right) estimated to belong to very young and middle aged adults



2. Age using micro-CT scan (Szilvassy and Kritscher 1990; Walker and Lovejoy 1985)

A more extensive breakdown was provided by the micro-CT scan, where this study combined the methods of aging observed by Szilvassy and Kritscher (1990) and Walker and Lovejoy (1985). Both studies originally used radiographs, while this study used clearer 3d micro-CT scans. Figures 28-31 show micro-CT scanned images of four femora revealing various degrees of trabecular disintegration.

A total of 68 femora were used for this estimation, excluding any bones that showed high levels of disturbances from external elements such as sand and dirt that might contribute to the “eating” of the trabecular mesh. The graph below (Figure 27) shows a more normally distributed demography with a bell shape curve, while Table 8 shows a more comprehensive breakdown of the age categories with frequencies and percentages.

Table 8. Estimation using micro-CT scans

CT Scan Age Estimation	Frequency	Percent
20-30 yrs	1	1
20-30 yrs	12	11.8
30-40 yrs	25	24.5
40-50 yrs	19	18.6
50-60 yrs	8	7.8
60-70 yrs	3	2.9
Total	68	66.7
Missing	34	33.3

Figure 27. Bar chart of age distribution using micro-CT scans

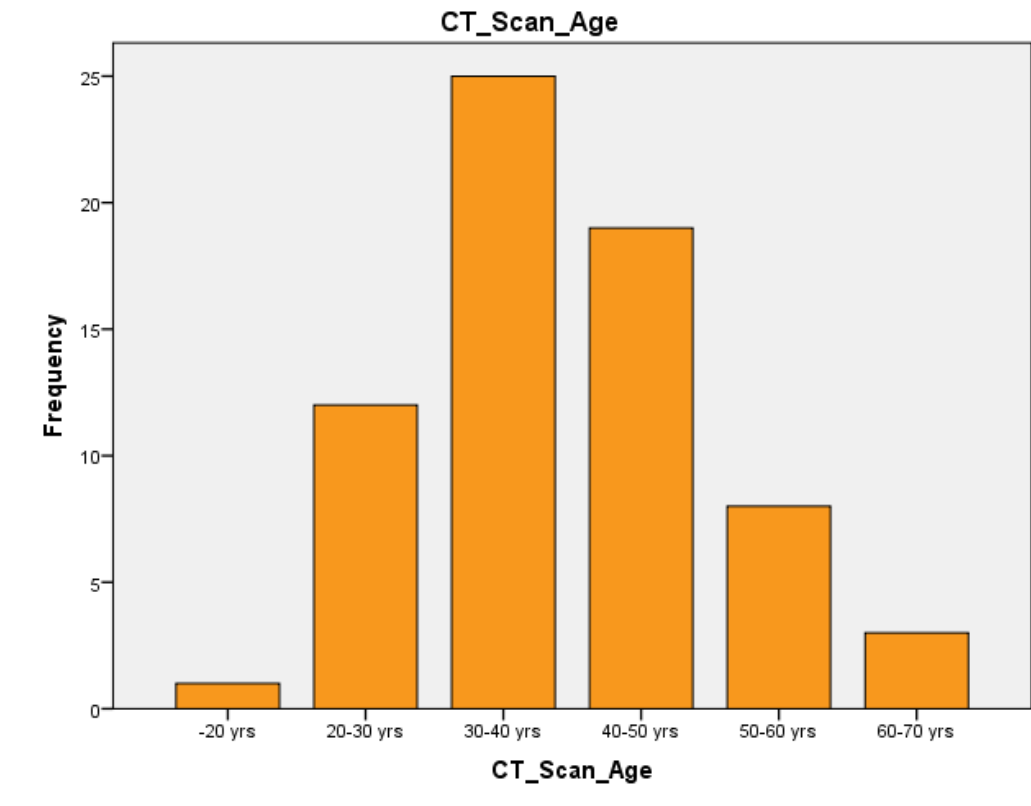




Figure 28. Femur 27, estimated to be 20-30 yrs old

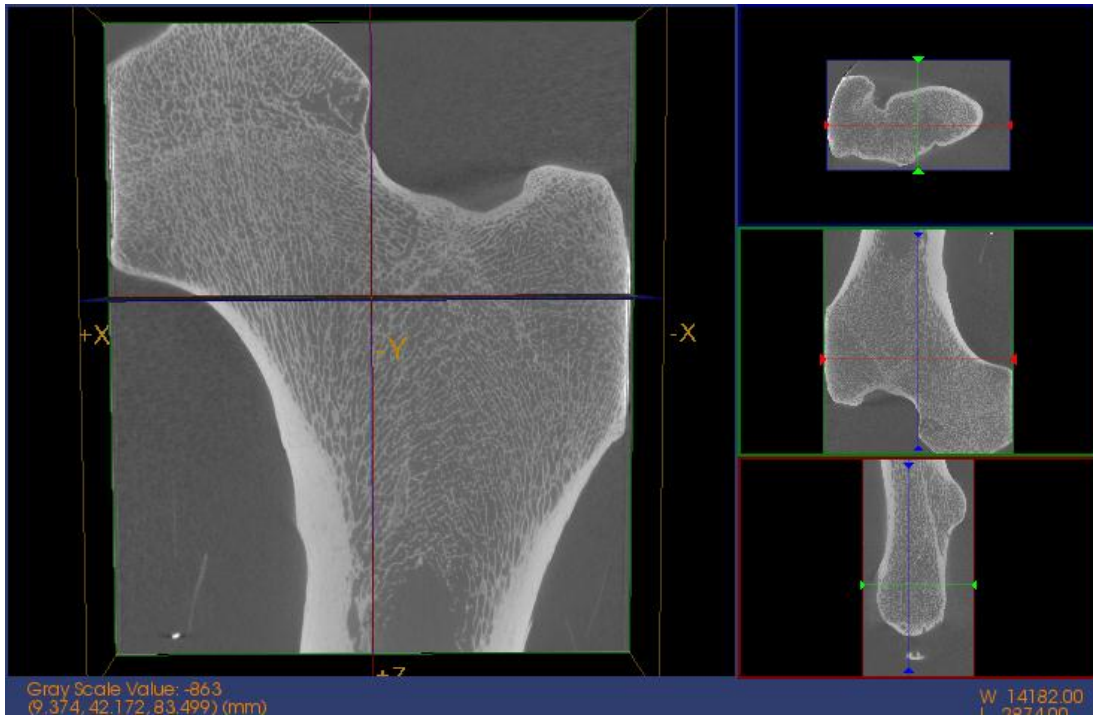


Figure 29. Femur 70, estimated to be 30-40 yrs old

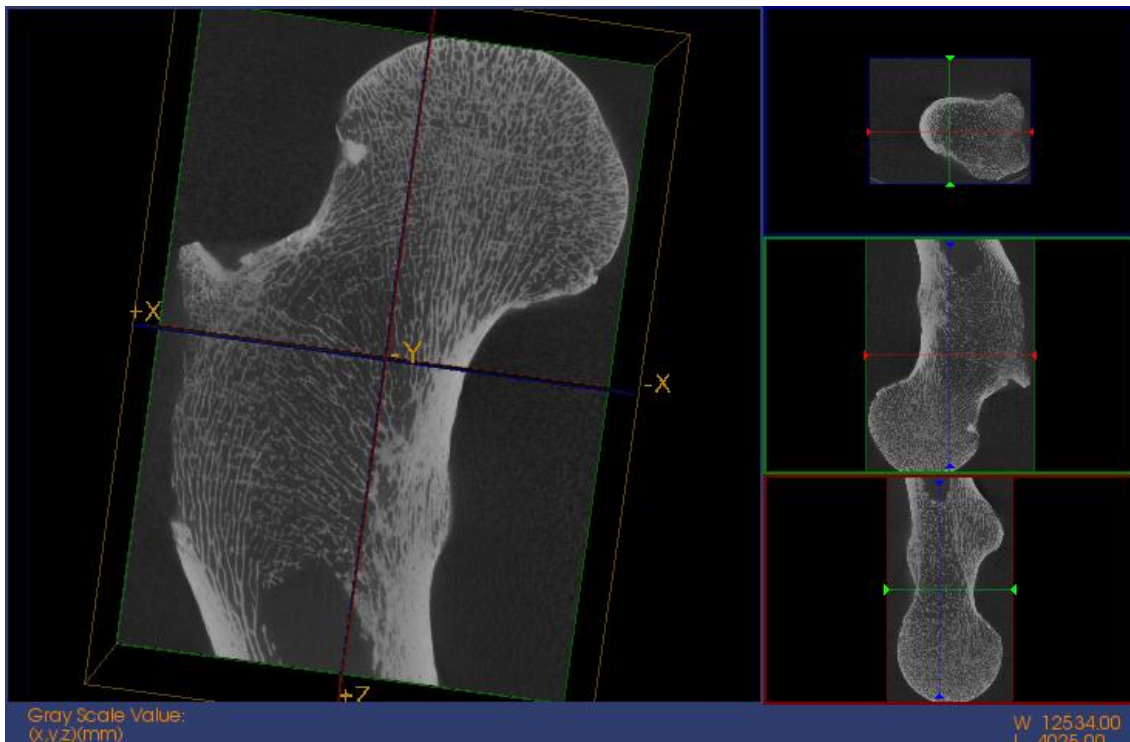


Figure 30. Femur 25, estimated to be 40-50 yrs old

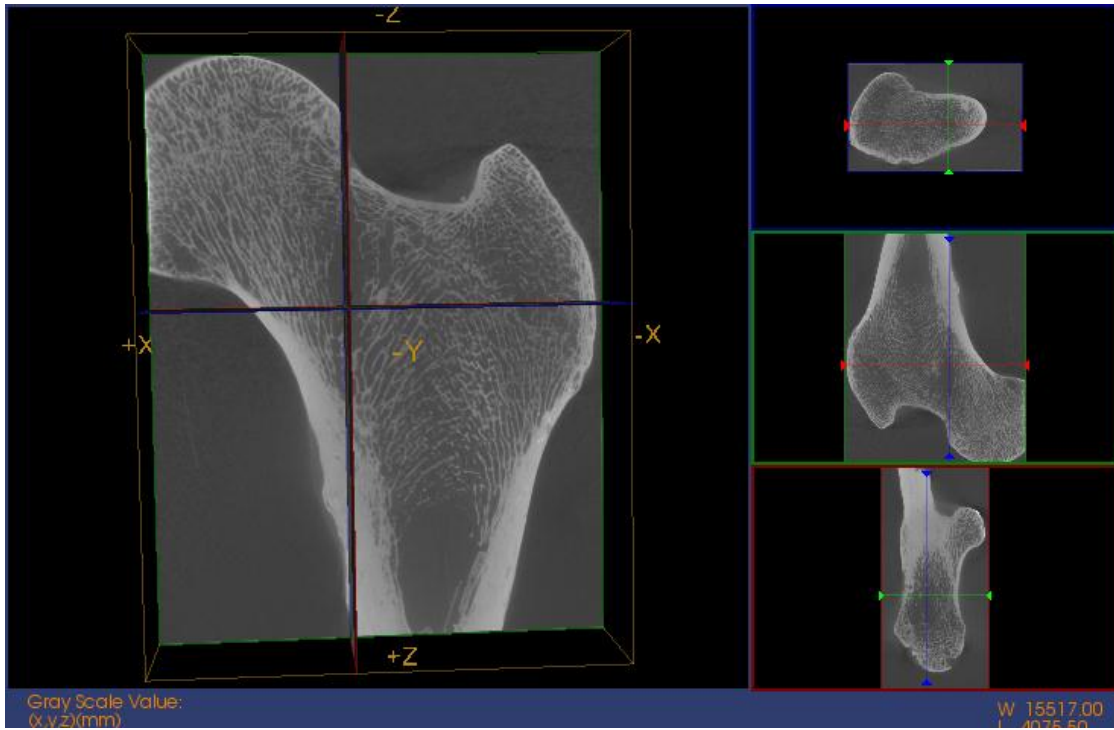
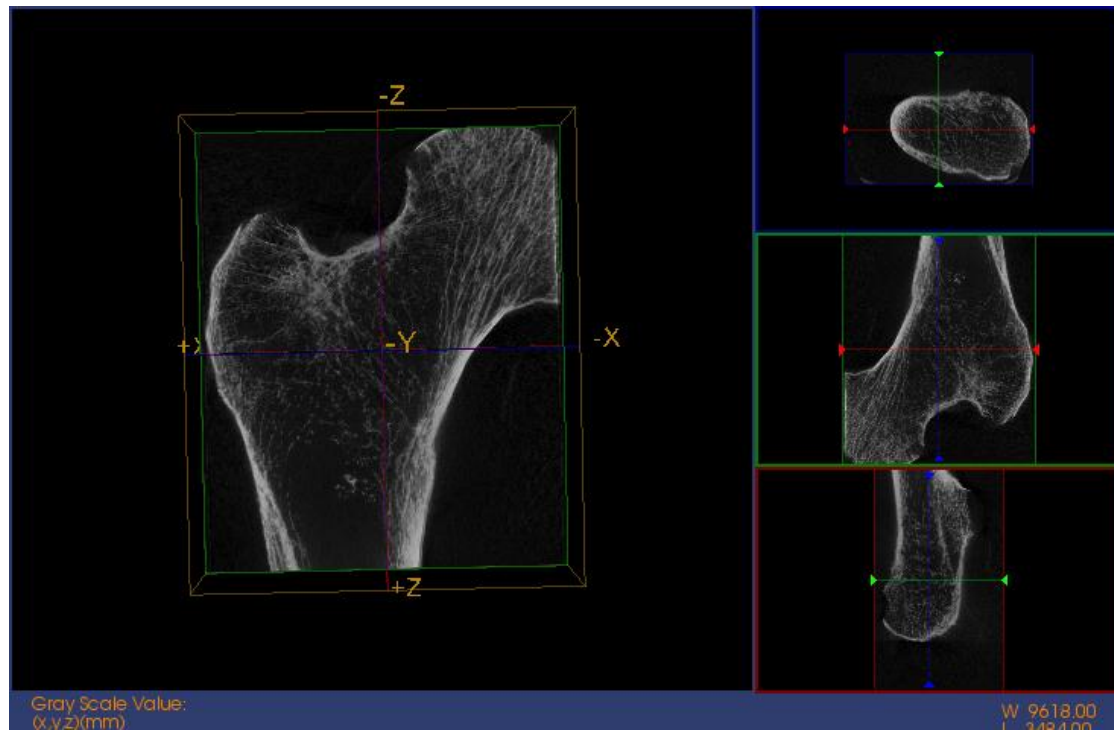
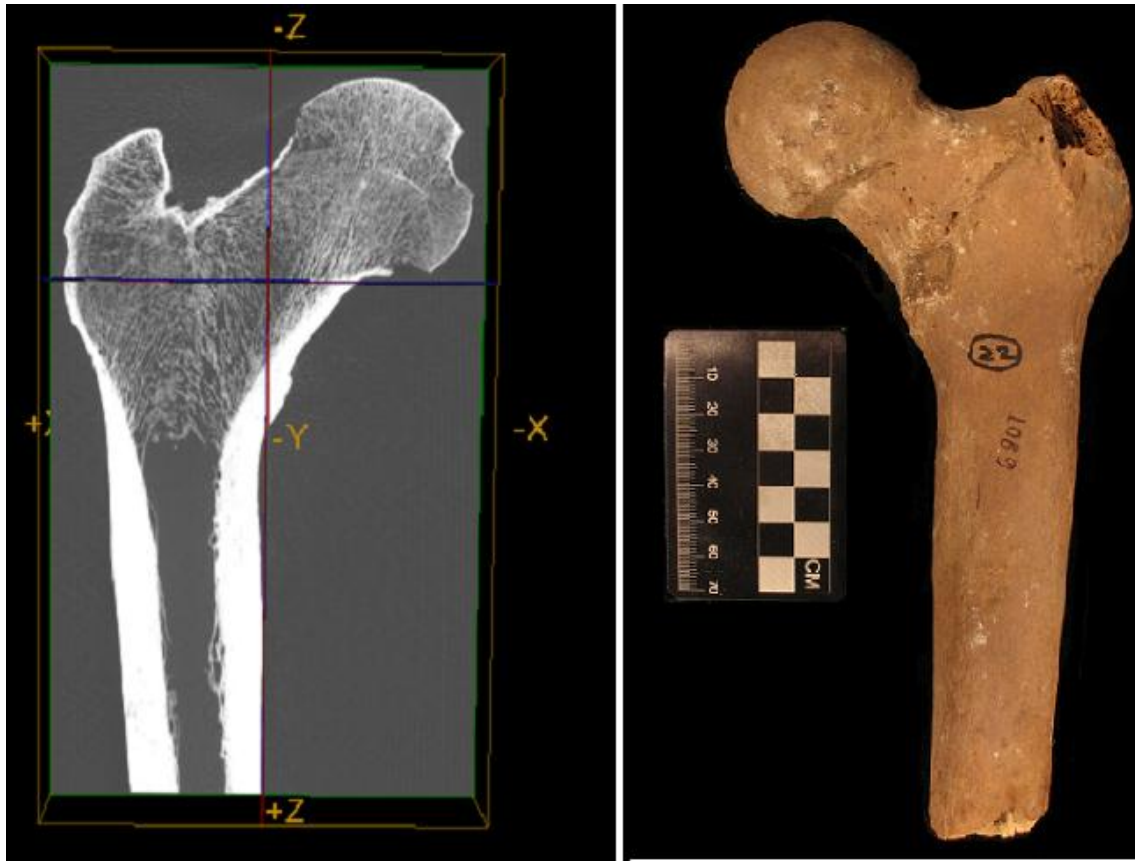


Figure 31. Femur 69, estimated to be 60-70 yrs old



In order to determine whether the traditional method and the micro-CT scan method agreed on age, the results of the 68 samples that were used for the micro-CT scan method were regrouped within the broader traditional categories. These regrouped samples were next compared to the results of the 68 femora derived from the traditional method (refer to Figure 32). Since the data are ranked and N is well above 10, Spearman's Rho was used to calculate the degree of correlation. The relationship between the two methods was found to be statistically significant with a moderate positive correlation ( $r=.5$ ,  $n=68$ ,  $p<.01$ ).

Figure 32. Femur 22 micro-CT scan image (estimated as 30-40 years old) and macroscopic image(estimated as 40+ years old)



### 3. Age dispersal between sexes

The frequency table and charts below (refer to Table 9, Figures 33 and 34) show that females are most vulnerable between 30-50 years of age. For males, the frequency rises steeply in the 30-40 years category. Interestingly, the collection has no female survivors above the age of 60 years. The bar charts clearly show a much wider range of mortality amongst males.

Table 9. Age demography in males and females

Age Demography between sexes	Frequency		Percent	
MALE	-20 yrs	1	1.6	
	20-30 yrs	8	13.1	
	30-40 yrs	14	23	
	40-50 yrs	9	14.8	
	50-60 yrs	3	4.9	
	60-70 yrs	3	4.9	
	<b>Total</b>	<b>38</b>	<b>62.3</b>	
Missing	23	37.7		
FEMALE	20-30 yrs	4	11.4	
	30-40 yrs	10	28.6	
	40-50 yrs	10	28.6	
	50-60 yrs	5	14.3	
	<b>Total</b>	<b>29</b>	<b>82.9</b>	
	Missing	6	17.1	

Figure 33. Age demography in males

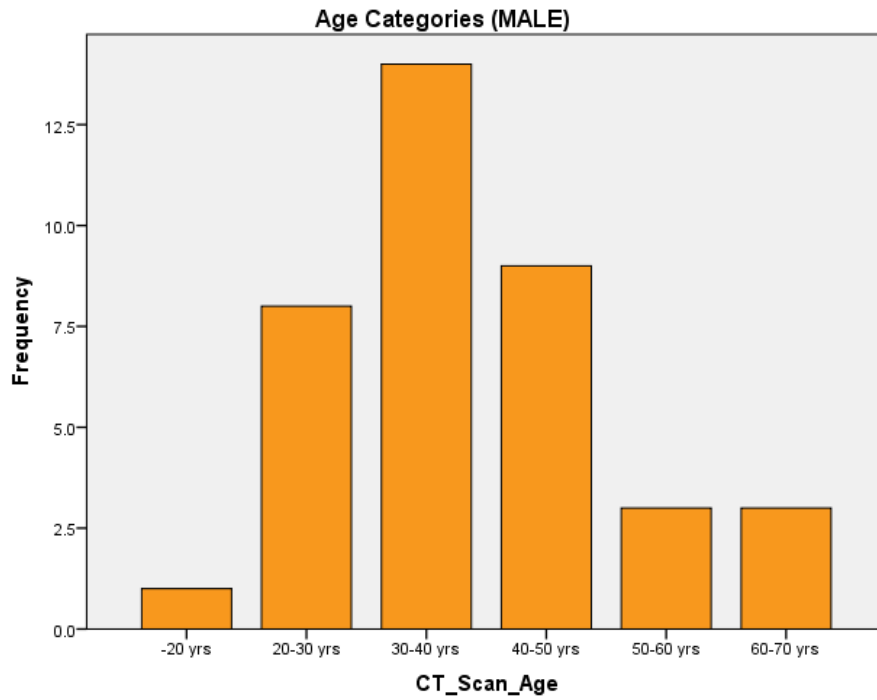
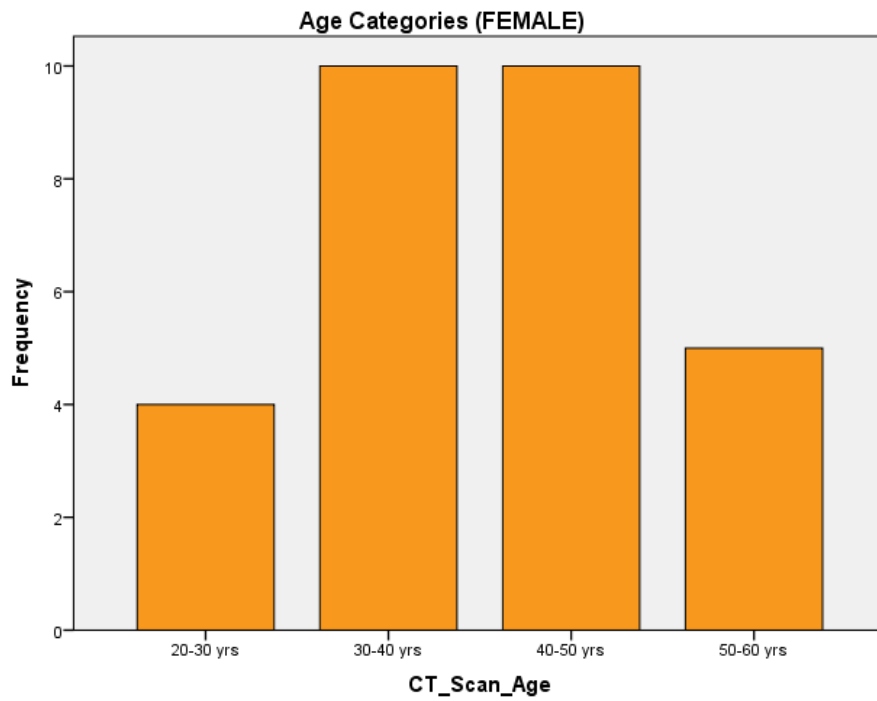


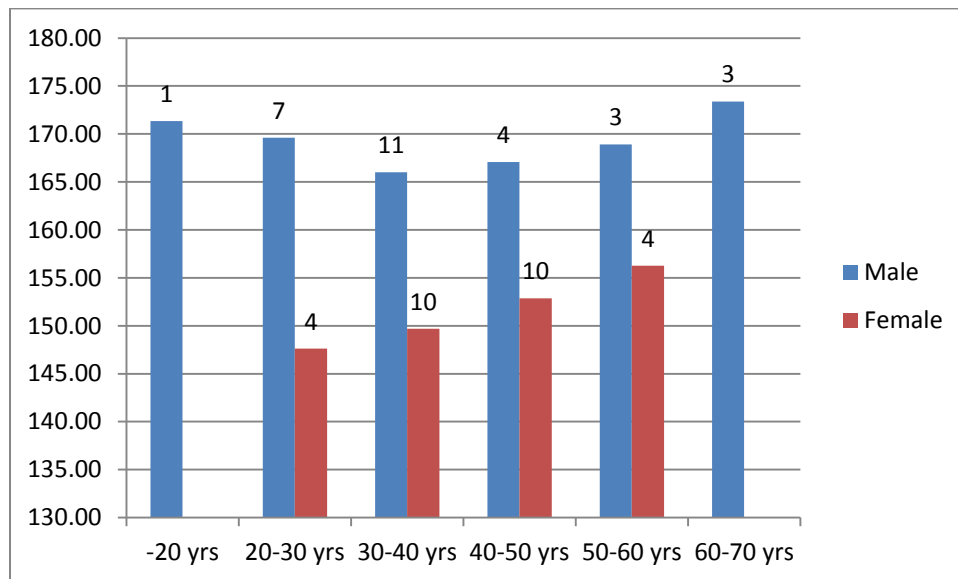
Figure 34. Age demography in females



#### 4. Age integrated with sex and stature

We next looked at a snapshot of males' and females' average stature during their age of demise (Figure 35). Our sample size is 58 when including all samples that were CT-scanned for age and had information on sex and stature. Females (in red) had the highest mortality rate between 30-50 years old. Unsurprisingly, the average height of each age category shows a gradual increase. However, males (in blue) show an interesting and very different pattern. Shorter males had the highest degree of mortality between 30-40 years. Taller males had higher mortality rates at either extremes – very young and very old stages.

Figure 35. Frequency chart of age, sex and stature



#### **5.4. FREQUENCY OF VARIOUS MSM OCCURRENCES IN THE COLLECTION**

As detailed in the Material and Method chapter, the collection of proximal femora was analyzed for any morphological changes that can be interpreted as bone adaptation to constant, habitual external biomechanical forces, also called MSMs, which are most

likely caused by a physical occupation the individual regularly and repetitively adhered to over many years.

Each of the femora was noted for the absence (ranked 0) and presence (ranked 1 to 4, with 4 indicating the most pronounced presence) for Articular Border Convexity (ABC), Poirier's Facet (PT), Posterior Cervical Imprint (PCI), Anterior Cervical Imprint (ACI), Pilasterism, which includes Linea Aspera Enthesopathy, Exostosis of the Trochanteric Fossa, and Enthesopathies of Gluteus Maximus and Minimus (Enthes. of GM-M). For many of the samples, certain small parts of the bone surface were destroyed or disintegrating, which made it difficult to accurately assess the appropriate MSMs of that location. Those femora were excluded from the data summary below, resulting in each MSM measured within different sample sizes. Below are the following tables of each MSM's absence and presence, tallied against sex and broad age categories of the traditional method.

Presence and Absence:

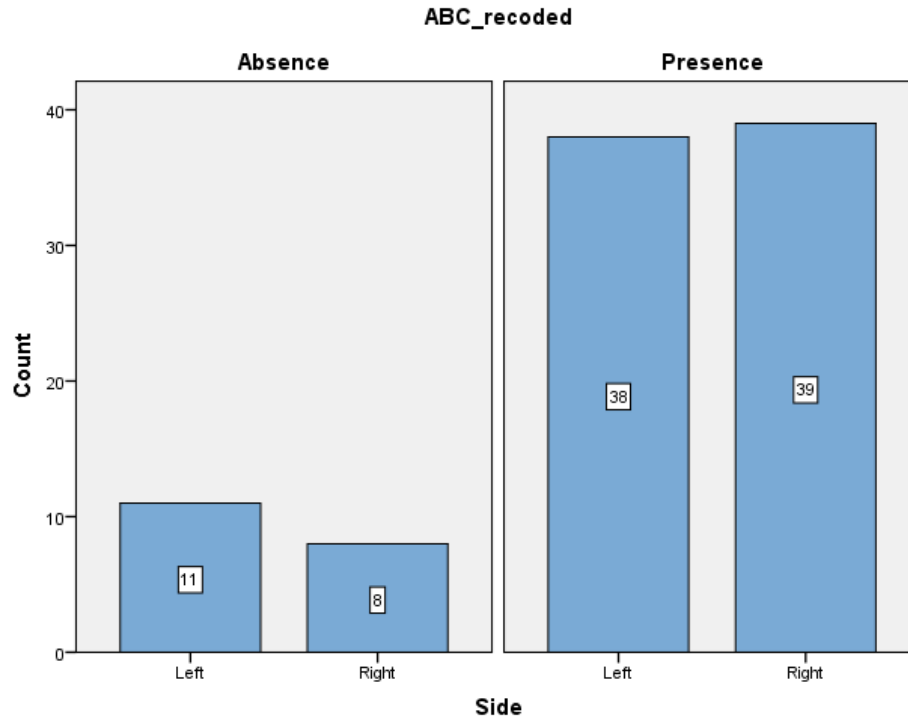
1. Articular Border Convexity (ABC) [n=92]

With a large sample size of 92 femora, a definite bias of this MSM can be discerned on the Tell Abraq bones as presented in Table 10. This bias seems to largely affect males, especially during the young to middle adult stages. 93.22% of all males are found with various degrees of the MSM presence as opposed to 53.13% of all females. In both sexes, there is a much larger presence of the MSM in middle-aged adults, with 63.64% of all males affected and 76.47% of all females. Figure 36 does not show any bias to either side of the leg, whether absent or present.

Table 10. Presence and Absence of ABC

ABC	MALES		FEMALES		
ABSENT	Very Young Adult:	0	4	Very Young Adult:	2
	Young Adult:	1		Young Adult:	4
	Middle Adult:	3		Middle Adult:	9
PRESENT	Very Young Adult:	1	55	Very Young Adult:	0
	Young Adult:	19		Young Adult:	4
	Middle Adult:	35		Middle Adult:	13

Figure 36. Presence and absence of ABC based of femur side



## 2. Poirier's Facet (PF) [n=92]

More than half the sample size (52.17%) did not show any presence of PF, with a good fraction of this absence represented by the middle aged adults' category of both sexes. Therefore, young and especially middle adults with the PF MSM make up 38.04% of the entire sample size. A much smaller fraction of the females (11.96% of the total



sample size) show signs of PF, and majority of females exhibited a lack or absence of it (67.65% of all females). This MSM, like the ABC, primarily affects young and middle male adults, though a good fraction of males manage to avoid it, unlike the ABC. The summary of presence and absence is shown in Table 11. Figure 37 does not show any bias to either side of the leg, whether absent or present.

Table 11. Presence and Absence of PF

Poiriers Facet	MALES		FEMALES		
ABSENT	Very Young Adult:	1	25	Very Young Adult:	3
	Young Adult:	9		Young Adult:	5
	Middle Adult:	15		Middle Adult:	15
PRESENT	Very Young Adult:	0	35	Very Young Adult:	0
	Young Adult:	13		Young Adult:	3
	Middle Adult:	22		Middle Adult:	8

Figure 37. Presence and absence of PF based of femur side

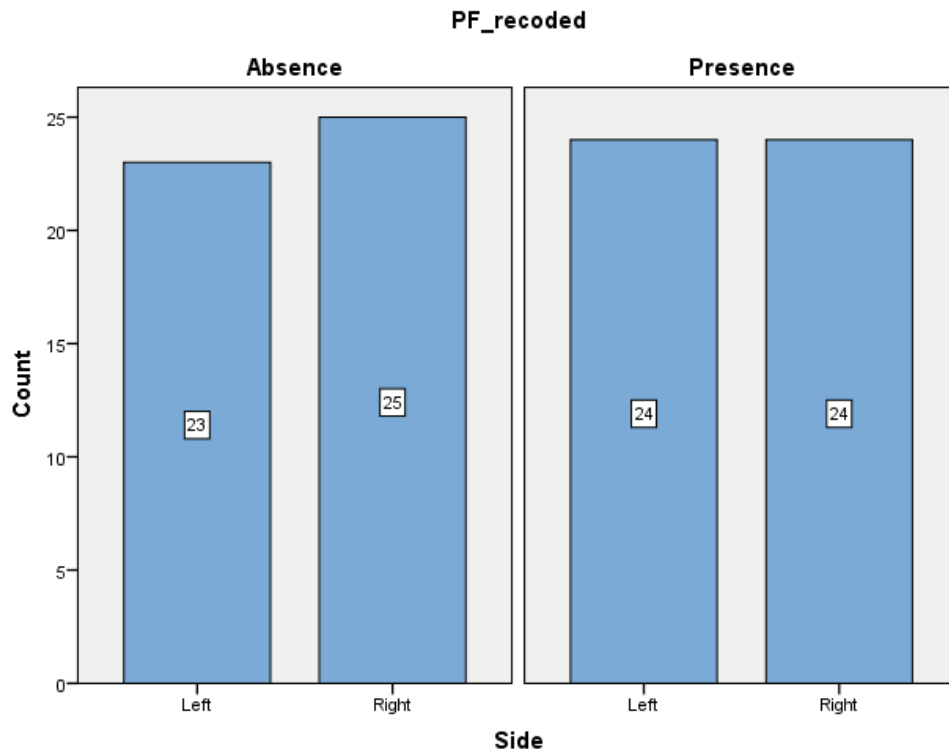


Figure 38. PF featured on Femur 49



### 3. Posterior Cervical Imprint (PCI) [n=87]

As shown in Table 12, most of the population demonstrate an absence of the MSM, with similar ratios between the sexes – 74.07% of all males and 78.79% of all females. When the MSM was present, it usually presented itself on middle aged adults and some young adults across both sexes. The right femur shows almost twice the presence of the MSM than the left, as shown in Figure 39. Moreover, the left femur shows slightly more absence (57.14% of absence) of the MSM than the right.

Table 12. Presence and Absence of PCI

PCI	MALES		FEMALES		
ABSENT	Very Young Adult:	1	40	Very Young Adult:	3
	Young Adult:	15		Young Adult:	6
	Middle Adult:	24		Middle Adult:	17
PRESENT	Very Young Adult:	0	14	Very Young Adult:	0
	Young Adult:	4		Young Adult:	2
	Middle Adult:	10		Middle Adult:	5

Figure 39. Presence and absence of PCI based of femur side

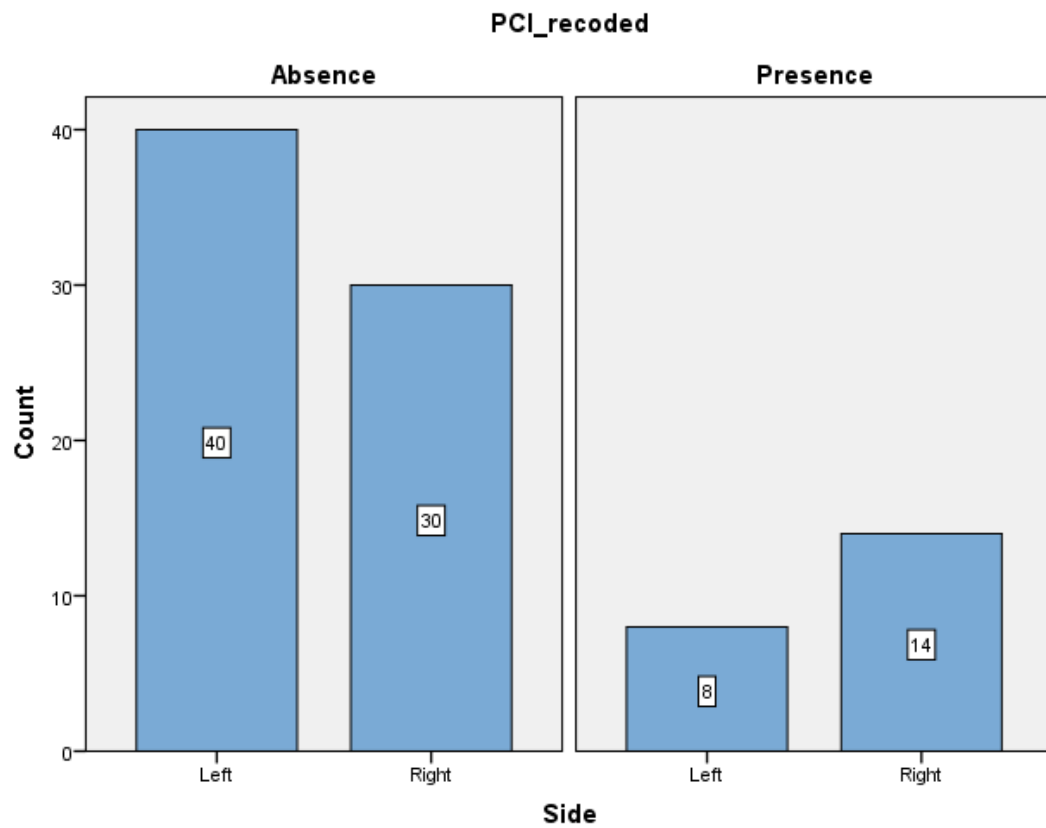


Figure 40. Femur 74 (left) exhibiting PCI as oppose to Femur 65 which has an absence of the MSM



#### 4. Pilasterism [n=80]

Pilasterism was almost ubiquitous in the femora collection (95% of a sample size of 80), as displayed in Table 13. Every male individual had some degree of pilasterism. While females showed pilasterism values ranging from Rank 1 to 2, with a few of Rank 3, this MSM manifested itself largely in males as Rank 3 and 4, especially in the linea aspera region. Figure 41 does not show any bias to either side of the femur, whether absent or present.

Table 13. Presence and Absence of Pilasterism

Pilasterism	MALES			FEMALES		
	ABSENT	Very Young Adult:	0	0	Very Young Adult:	1
Young Adult:		0	Young Adult:		3	
Middle Adult:		0	Middle Adult:		0	
PRESENT	Very Young Adult:	1	50	Very Young Adult:	0	26
	Young Adult:	17		Young Adult:	4	
	Middle Adult:	32		Middle Adult:	22	

Figure 41. Presence and absence of pilasterism based of femur side

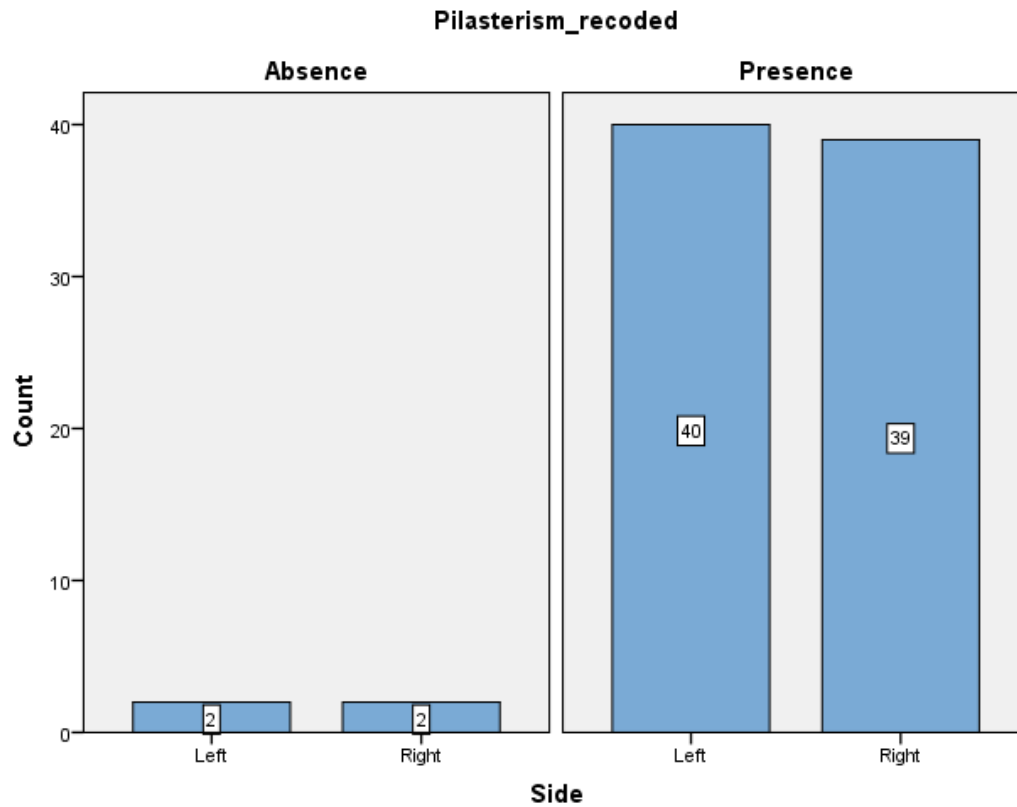


Figure 42. Femur 49 exhibiting extreme pilasterism



Figure 43. A close up of the pilasterism on Femur 49



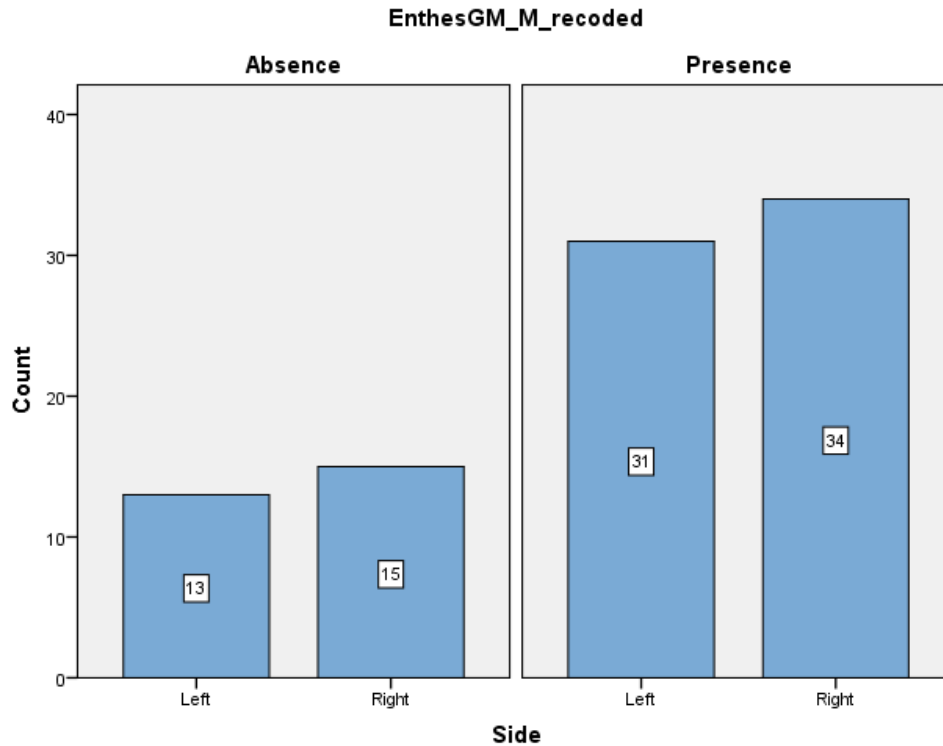
5. Enthesopathies of Gluteus Maximus and Minimus (Enthes. of GM-M) [n=90]

Enthesopathies of GM-M were more present than absent in the population (71.11% of 90 femora) and in both the sexes (70.18% in all males and 72.73% in all females). For age, it was most predominate amongst the middle adults (71.67% of all middle adults) and male young adults (68.42% of all young male adults). Interestingly, all four very young adults displayed the MSM. Even though the sample size of very young adults is too small to call significant, it is noteworthy to record. The results are summarized in Table 14. Figure 44 does not show any bias to either side of the femur, whether absent or present.

Table 14. Presence and Absence of Enthes.of GM-M

GM-M	MALES		FEMALES		
ABSENT	Very Young Adult:	0	17	Very Young Adult:	0
	Young Adult:	6		Young Adult:	3
	Middle Adult:	11		Middle Adult:	6
PRESENT	Very Young Adult:	1	40	Very Young Adult:	3
	Young Adult:	13		Young Adult:	4
	Middle Adult:	26		Middle Adult:	17

Figure 44. Presence and absence of Enthes. of GM-M based of femur side



6. Exostosis of the Trochanteric Fossa [n=73]

Table 15 shows Trochanteric Fossa manifesting mostly in middle aged adults of both sexes, with 86.21% of all male middle adults and 77.78% of all female middle adults. Half of the young male adults display its presence though most female young adults (75% of all female young adults) exhibit an absence of the MSM. Figure 45 does not show any bias to either side of the femur, whether absent or present.

Table 15. Presence and Absence of Exostosis of the Trochanteric Fossa

Exostosis Trochanter Fossa	MALES		FEMALES	
	ABSENT	Very Young Adult: 0	11	Very Young Adult: 3
	Young Adult: 7	Young Adult: 6		
	Middle Adult: 4	Middle Adult: 4		
PRESENT	Very Young Adult: 1	33	Very Young Adult: 0	16
	Young Adult: 7		Young Adult: 2	
	Middle Adult: 25		Middle Adult: 14	



Figure 45. Presence and absence of Exostosis of the Trochanteric Fossa based of femur side

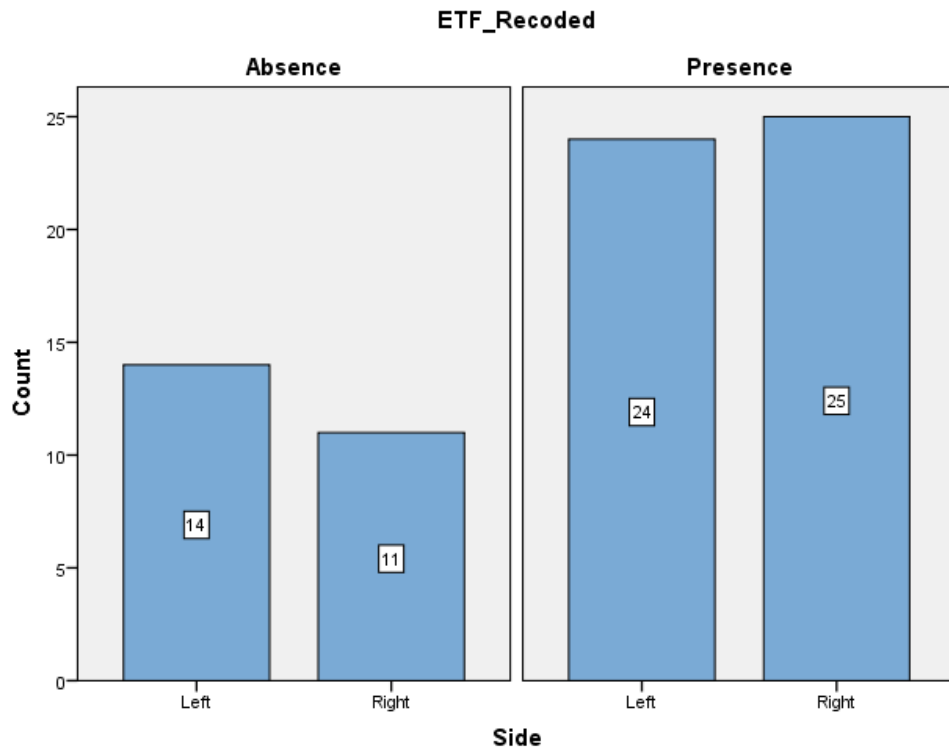


Figure 46. Extreme case of Exos of the TF on Femur 49



7. Anterior Cervical Imprint (ACI) [n=88]

Table 16 shows ACI Type A manifesting mostly in young and middle aged adults for males (66% of all males) and middle aged adults for females (56.5% amongst all middle aged females). Type B seems more prominent amongst females. A number of males also show an absence of both types of ACI. Figure 47 does not show any bias towards either side of the femur, whether absent or present, apart from both samples of Type B featuring on the right femur.

Table 16. Presence and absence of ACI Type A and Type B

ACI	MALES			FEMALES		
ABSENT	Very Young	0	20	Very Young	0	9
	Young	5		Young	1	
	Middle	15		Middle	8	
PRESENT TYPE A	Very Young	0	33	Very Young	0	14
	Young	14		Young	1	
	Middle	19		Middle	13	
PRESENT TYPE B	Very Young	1	2	Very Young	2	10
	Young	1		Young	4 (+2 exp)	
	Middle	0		Middle	2	

Figure 47. Presence and absence of ACI Type A and Type B based on femur side

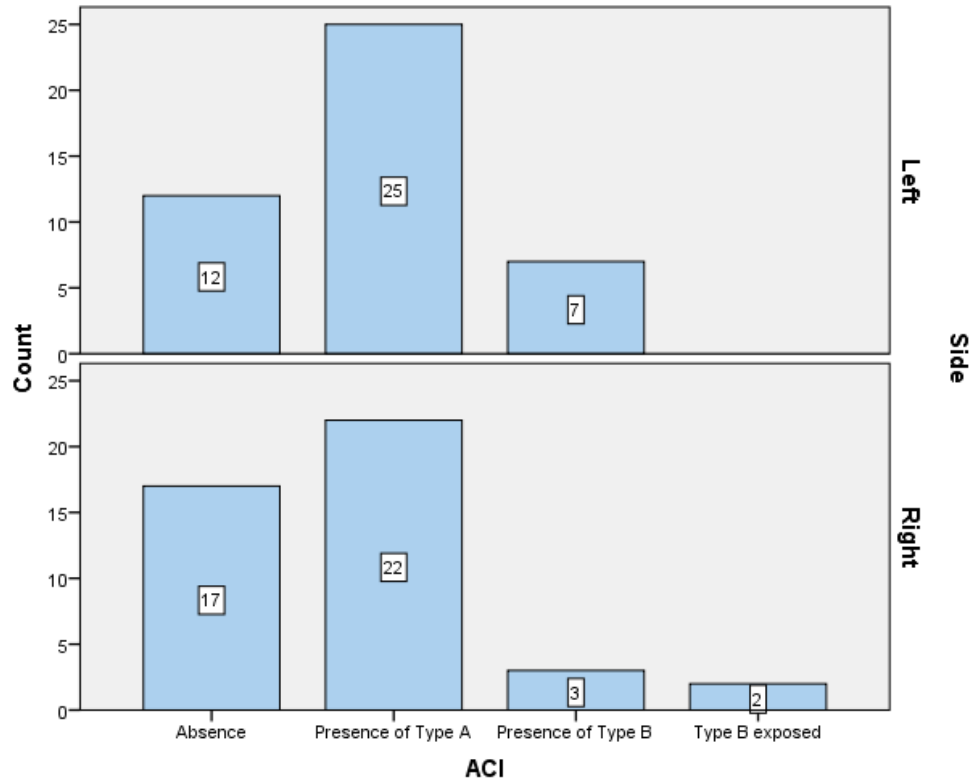


Figure 48. Femur on left displaying ACI (Type A); Femur 49 exhibiting pronounced PF with slight depression associated with ACI



Figure 49. Femur 40 exhibiting pronounced ACI [Type B]



8. Platymetric Index [n=56]

The bar chart below (Figure 50) shows the distribution of the subtrochanteric morphology within the adult human skeletal collection of Tell Abraq. There seems to be no distinct homogeneity amongst the population. Table 17 and Figure 51 also illustrate no clear bias of morphology between the sexes.

Figure 50. Distribution of subtrochanteric morphology

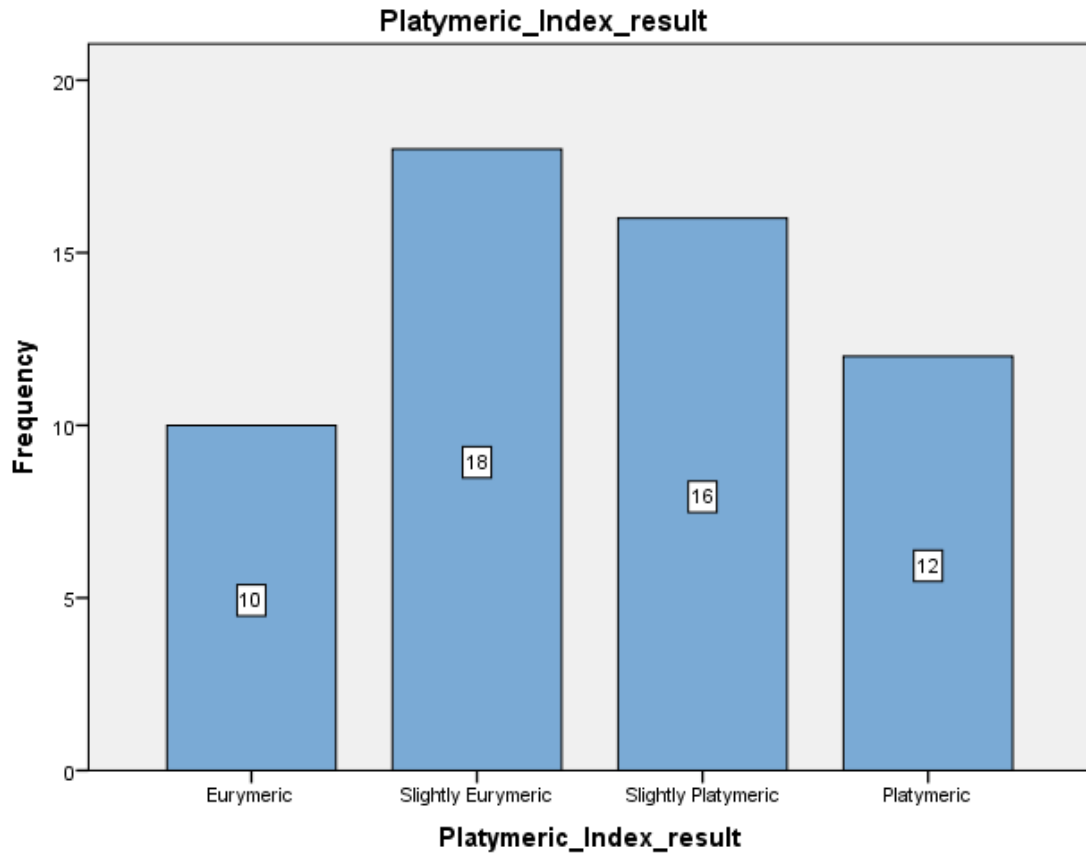
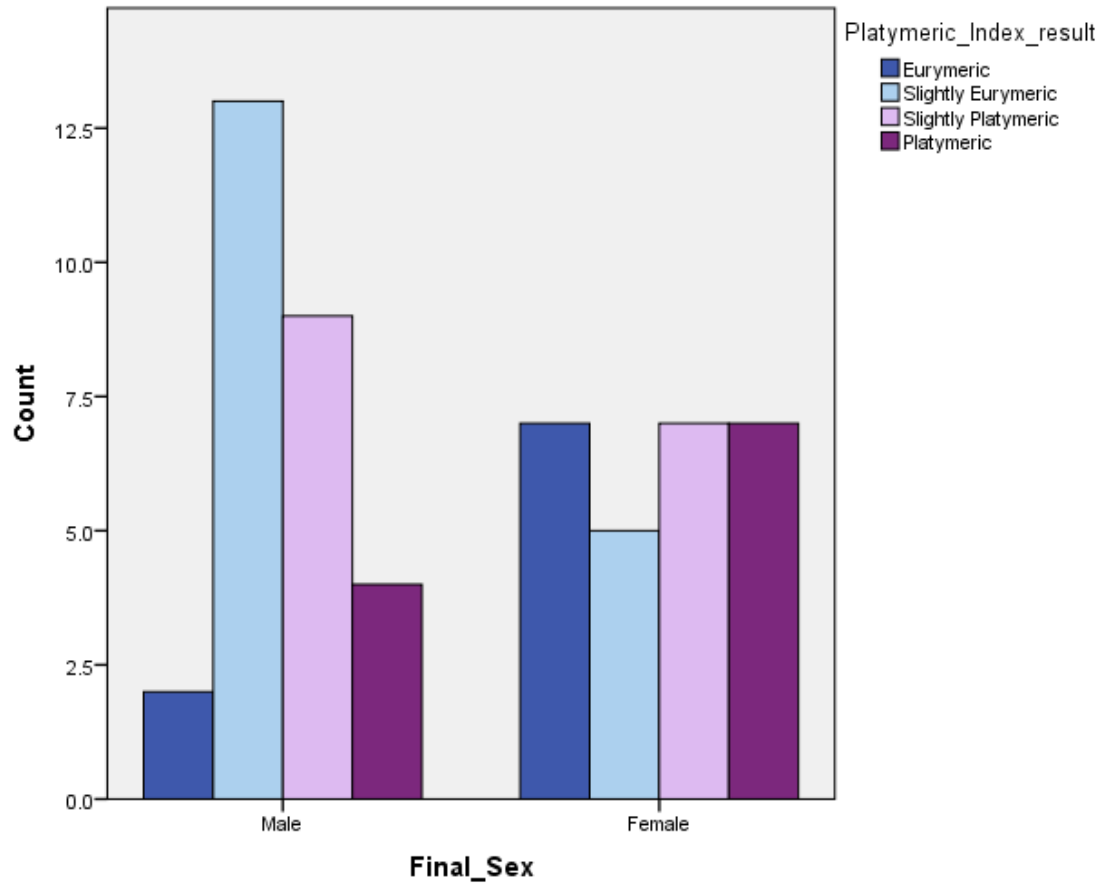


Table 17. Distribution of subtrochanteric morphology between sexes

Platymeric Index	Eurymeric	Slightly Eurymeric	Slightly Platymeric	Platymeric	TOTAL
Male	2	13	9	4	28
Female	7	5	7	7	26
<b>Total</b>	<b>9</b>	<b>18</b>	<b>16</b>	<b>11</b>	<b>54</b>

Figure 51. Distribution of subtrochanteric morphology between sexes



Differences of MSM between sexes using non-parametric analysis

The absence-and-presence tables above (Tables 10-17.) revealed differences in frequency levels for some of the MSMs. A non-parametric statistical test was used to determine whether these differences were of statistical significance. Table 18 shows the results of the Kruskal-Wallis Test on all the MSMs. There are significant differences (highlighted in yellow) between males and females when looking at Poirier's Facet ( $H_{(2,93)}=7.161$ ,  $p = 0.001$ ), Articular Border Convexity ( $H_{(2,93)}=17.135$ ,  $p < 0.001$ ) and Pilasterism ( $H_{(2,80)}=14.818$ ,  $p < 0.001$ ). Further, the three MSMs were split into age categories using the micro-CT scan results (refer to Table 19), to determine whether these

three MSMs are statistically different between age groups as well as in males and females.

Table 18. Kruskal-Wallis Test on sex differences between MSMs

Kruskal Wallis Test	ABC	Poirier's Facet	PCI	Pilasterism	Enthes. GM-M	Exos. Of TF
Chi-Square	33.229	13.107	0.333	22.385	1.734	2.668
df	2	2	2	2	2	2
Asymp. Sig.	.000	0.001	0.847	.000	0.42	0.263

Table 19. Kruskal-Wallis Test (with sex cases split into age categories)

Final Sex		Age	N	Mean Rank
MALE	ABC	-20 yrs	1	18.5
		20-30 yrs	8	20.38
		30-40 yrs	14	18.04
		40-50 yrs	8	16.63
		50-60 yrs	3	22.17
		60-70 yrs	3	23.17
		Total	37	
	Pilasterism	-20 yrs	1	11.5
		20-30 yrs	8	16.06
		30-40 yrs	13	15.15
		40-50 yrs	7	24.71
		50-60 yrs	3	12.33
		60-70 yrs	3	27.67
		Total	35	
	Poirier's Facet	-20 yrs	1	8
		20-30 yrs	7	19.36
		30-40 yrs	14	19.25
		40-50 yrs	9	21
		50-60 yrs	3	15.33
		60-70 yrs	3	18.33
		Total	37	
FEMALE	ABC	20-30 yrs	4	11.25
		30-40 yrs	9	13.22
		40-50 yrs	10	16.7
		50-60 yrs	4	11.75
		Total	27	
	Pilasterism	20-30 yrs	3	11.67
		30-40 yrs	8	7.63
		40-50 yrs	9	17.89
		50-60 yrs	5	13.6
		Total	25	
	Poirier's Facet	20-30 yrs	4	14.25
		30-40 yrs	10	12.3
		40-50 yrs	10	17
		50-60 yrs	5	17
		Total	29	



Only Pilasterism in females exhibited significant differences depending upon the age range. Looking at the mean differences in this category, we see a drop and then a spike in occurrence from 30-40 yrs to 40-50 yrs. Either age itself adds much more biomechanical stress during the 40-50 year bracket, or there was a change in duties/lifestyle that assisted in this increase of pilasterism.

### **5.5. CORRELATION BETWEEN TWO OR MORE MSMS**

The non-parametric statistical test Kendall's tau-b was applied to all MSMS to determine if there was any correlation, positive or negative, between any two or more possible combinations of MSMS. Four correlations were revealed to be statistically significant.

#### 1. Between ABC and PF

ABC and PF showed a positive correlation with a medium effect size ( $r=.309$ ), suggesting that when ABC is more pronounced in a bone, most likely PF would be pronounced as well ( $T = .309, p \leq .001, n = 96$ ).

#### 2. Between PF and Pilasterism

PF and pilasterism showed a positive correlation with a medium effect size ( $r=.326$ ), suggesting that when PF is more pronounced in a bone, most likely pilasterism increases as well ( $T = .326, p \leq .001, n = 80$ ).

#### 3. Pilasterism and Enthesopathies

Pilasterism and enthes. of GM-M showed a positive correlation. However the effect size is very small ( $r=.187$ ), suggesting that when pilasterism is more

pronounced in a bone, robusticity of enthesopathies would probably increase though only by a small degree ( $T = .187$ ,  $p \leq .05$ ,  $n = 79$ ).

#### 4. Pilasterism and Exostosis Trochanteric Fossa

Much like the above case, pilasterism and exos. Of TF showed a positive correlation but with a very small effect size ( $r=.239$ ), suggesting that when pilasterism is more pronounced in a bone, the other MSM may react likewise but to a small degree ( $T = .239$ ,  $p \leq .05$ ,  $n = 63$ ).

### **5.6. MICROSCOPIC ANALYSIS**

Out of the 70 chosen samples that were subjected to micro-CT scanning, trabeculae network of fifty samples were found uncompromised by foreign bodies such as dirt and sand in the Region 1 area. Using Gimp application software, the trajectory of the principal compressive group was attained by measuring the angle of its direction against the plane representing the diameter of the femoral head in the anterior position (refer to Figure 52). Angles of the principal compressive group of region 1 were then correlated to various MSMs using Spearman's correlation. Apart from enthesopathies (GM-M), which demonstrated a trend ( $\rho=.281$ ,  $p=.053$ ,  $n=48$ ), no other MSM has any significant correlations with the pattern of the Principle Compressive Group (refer to Table 20).

The researcher was unable to assess similar correlations from Region 2 and Region 3 for two reasons: the said regions showed much higher degree of bone disintegration and trying to accurately discern trabeculae trajectories became very

difficult, and there was higher frequency of foreign bodies entering these regions and compromising the visual assessment.

Figure 52. Measured angle (marked in red) of Region 1



Table 20. Correlations between trabecular angle of Region 1 and other MSMs

**Spearman's Correlations**

			Region_1_Trabecular _AngularDegree
Spearman's rho	Region_1_Trabecular_Angul arDegree	Correlation	1.000
		Coefficient	
		Sig. (2-tailed)	.
		N	50
ABC		Correlation	.005
		Coefficient	
		Sig. (2-tailed)	.970
		N	49
Poiriers_Facet		Correlation	.190
		Coefficient	
		Sig. (2-tailed)	.187
		N	50
PCI		Correlation	-.203
		Coefficient	
		Sig. (2-tailed)	.172
		N	47
Pilasterism		Correlation	
		Coefficient	
		Sig. (2-tailed)	.269
		N	47
Enthesopathies_GM_M		Correlation	.281
		Coefficient	
		Sig. (2-tailed)	.053
		N	48
Marginal_Osteophytes		Correlation	-.283
		Coefficient	
		Sig. (2-tailed)	.272
		N	17

## 5.7. PATHOLOGY

The proximal femora were analyzed to detect if the bone was afflicted with any type of pathology. The most common kind recorded were those associated with degenerative joint disease.

Varying degrees of osteoarthritis, in the form of marginal lipping around the femoral head were found in all the middle aged adults. This is an inherent part of the aging process (White and Folkens 2005) and was used to estimate age of the bones as well.

However, the researcher recorded another type of bone modification associated with osteoarthritis and mechanical stress, independent of age estimation - marginal osteophytes around the fovea capitis (refer to Table 21). The inflammation of the joint, seen as marginal osteophytes, were exhibited across the board affecting all age categories (refer to Table 22). However, there was a strong bias towards males (45.9% of all males), while fewer females were affected (14.29% of all females).

Table 21. Frequency table of marginal osteophytes

Marginal Osteophytes		Frequency	Percent
Degree of severity	1	19	18.6
	2	11	10.8
	3	2	2.0
	Severe Trauma on Fovea Capitis	1	1.0
Total Present		<b>33</b>	<b>32.4</b>
Total Absent		<b>69</b>	<b>67.6</b>

Table 22. Marginal osteophytes distribution between age groups

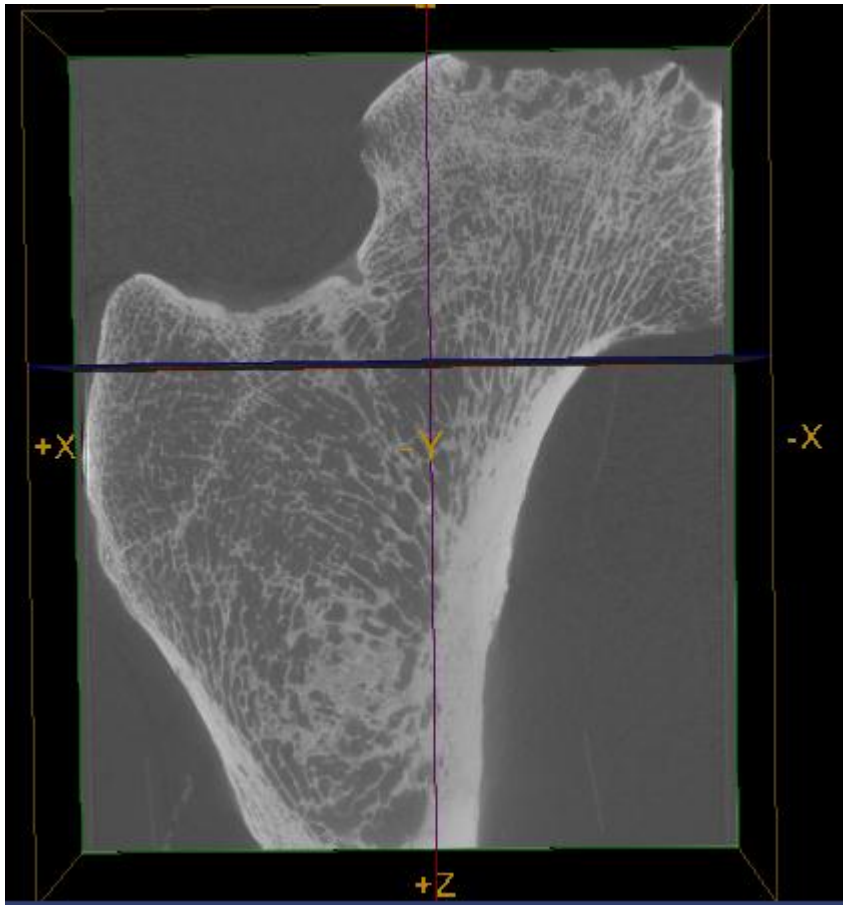
	CT Scan Age						Total
	-20 yrs	20-30 yrs	30-40 yrs	40-50 yrs	50-60 yrs	60-70 yrs	
Marginal Osteophytes 1	1	1	3	1	3	2	11
2	0	3	1	3	0	1	8
3	0	0	1	0	0	0	1
Sever Trauma on FC	0	0	0	1	0	0	1
Total	1	4	5	5	3	3	21

There was one severe case of possible marginal osteophyte (Femur 62) that could have led to hip dislocation or at the very least, created stiffness and pain in the affected joint, limiting mobility and stability (refer to Figure 53). The bone is estimated to belong to a male individual of 40-50 years of age. The micro-CT scan of this specimen (refer to Figure 54) does not show dense bone formation, which usually indicates necrosis, under the area of trauma. It, in fact, revealed bone cysts beneath the surface. The surface seemed to only partially heal, suggesting full recovery did not take place.

Figure 53. Trauma on the femoral head of Femur 62



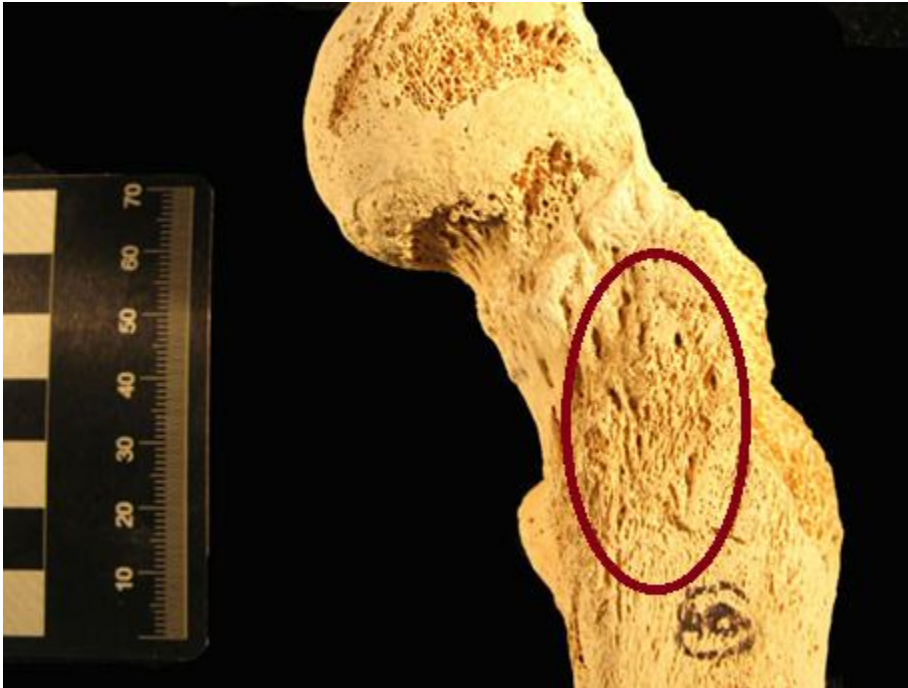
Figure 54. Micro-CT scan of Femur 62 exhibiting femoral head trauma



Ward's triangle within the trabeculae network was also recorded and ranked from 0 to 4, 0 showing absence of the triangle and 4 showing a pronounced version of the triangle. A Mann-Whitney test showed that there were no statistical difference between the sexes ( $U=162$ ,  $p=.074$ ,  $n=44$ ) but it revealed a trend where females had a higher risk of developing Ward's triangle.

The collection also revealed one case of periostitis belonging to a middle aged female (refer to Figure 55). The area circled in red had an irregular surface pitted with various sized pores. The rest of the collection did not display any other marks of pathology. The area was also exhibited a small degree of inflammation.

Figure 55. Femur 40 exhibiting periostitis circled in red



Apart from the above cases, the Tell Abraq femora collected did not exhibit any other signs of pathology on the bone surface.



## CHAPTER 6: CONCLUSION/DISCUSSION

The analysis carried out in this project focused on the adults in the tomb at Tell Abraq by systematically studying the proximal femora to determine age at death, sex ratios, stature of the sexes, differential musculoskeletal markers, and pathologies observable on that bone element. A summary and interpretation of these data are presented here.

### *6.1. DEMOGRAPHIC PROFILE*

The demographic analysis of the population interred within the tomb revealed a few surprising outcomes, as well as confirming some hypotheses. The ratio of males to females (approximately 12:7) is skewed with an abundance of males. Pre-industrial populations often demonstrate an approximately equal numbers of males and females in the burial assemblage (Brothwell 1981). Sex assignment was calculated using a variety of measures on both the left and the right femora. With each method there was consistently more males calculated in the assemblage than females. This raises important questions about the over-representation of males in the death assemblage, and its relationship to the living population.

Interpreting the meaning of this skewed ratio is challenging. The tomb contained individuals representing every category of age and sex, from infants to old adults, and both males and females. The Tell Abraq subadult skeletal collection represents at least 127 individuals of which 22% (n=28) were preterm infants (Baustian 2010) and a minimum of 286 were adults of both sexes (Blau 1996). As stated, there are fewer adult females in the tomb than males.

It is possible that the females were buried elsewhere or that due to their occupations or lifestyle, they were interred in places farther from the site. An alternative and possible theory is that the immigration of working males into the community skewed the ratio of sex in the population. During the late third millennium BC (c. 2300-2000 BC), larger and powerful centers such as Mesopotamia and Egypt were plagued with economic crises while eastern Arabia showed evidence of expansion and prosperity through larger and more settlement sites and graves and the refining of ceramic, stone, and metal industries (Martin 2007; Potts 1993; Weeks 1997). Tell Abraq was such a thriving coastal settlement site, boasting one of the largest circular fortifications during the Umm an-Nar period within eastern Arabia. For sustenance, the inhabitants had access to a variety of resources including freshwater fish, open water fish, wild and domesticated animals for meat and dairy products, fruits, wheat, and barley. The excavation revealed some exotic artifacts within the settlement site and the tomb, implying wealth and an active trade post. Tell Abraq may have witnessed an influx of young men looking for work or apprenticeship, especially when the major centers were suffering. This could help account for the higher frequency of males in the communal tomb.

Other possibilities do exist. For example, Cope and colleagues (2005) estimated that 85% of the carpal and metacarpal bones from the Tell Abraq tomb were probably males. They suggested that the large sample of males could be due to deceased sea travelers buried among the locals. Given its location, Tell Abraq could have been a stopping point for the active trade routes within the Arabian Gulf.

Females could have emigrated to other communities close by or distant ones for matrimonial purposes. Consistent with this, Hoyland (2001:128-134), citing many different scriptures and textual evidence of/about southern Arabia, commented that during the pre-Islamic periods, a substantial variety of marital customs were followed.

As with any archaeological sample, it is possible that this skewed ratio could be the result of sampling biases coupled with differential taphonomy or excavation strategies. There were proximal femora that could not be used in this study because they did not have the features required for the 3-dimensional scanning. Yet, all things considered, it is intriguing that with other elements in the collection that have been assigned a sex (most notably the pelvis), there is a consistent trend towards more males than females with a ratio of 13:7 (Osterholtz *et al.* 2012). However, sex estimation from the cranial bones indicate an even number of males and females, suggesting either a sampling bias or that specific male heads were removed or not interred within the tomb. Nevertheless, it seems fairly certain that the abundance of males in the tomb is a real phenomenon that reflects an aspect of gendered cultural behavior.

The stature results demonstrated that males and females were dimorphic. The average stature for females was calculated to be 151.9 cm (5 feet) while males had an average stature of 170.08 cm (5 feet 7 inches). Stature is governed by genetics, environmental, and developmental factors such as diet, so it is challenging to pinpoint the exact reason why males were taller and more robust than females.

Bondioli and colleagues (1998) calculated the average height of males and females at 177 cm (6 feet) and 170 cm (5 feet 7 inches) respectively from the eighteen articulated skeletons at the contemporaneous Tomb A Hili North grave. Shorter average

statures were reported from the disarticulated and fragmentary skeletal remains of the Hili N tomb. Calculated from the foot bone length, males averaged a stature of 171.1 cm (5 feet 7 inches) and females averaged at 163.5 cm (5 feet 4 inches) (McSweeney 2003). The average male stature from the latter site is similar to that estimated from the Tell Abraq skeletal remains. Nevertheless, the Hili N stature estimations may be biased, as also noted by McSweeney (2008 *et al.*), because of inaccuracies in the methods that were used in these particular studies. If this is the case, the average stature of males and females may have been closer to those calculated from articulated skeletal remains sharing the same regional space and time, as well as the cultural lifestyle, at the Tomb A Hili North grave.

This study also used derivative methods to measure stature. Estimations of bone length were based on a small part of the upper femur. Stature was then formulated using regression formulae based on the estimated bone length. This method, while not ideal, provides at least some parameters of male-female differences in stature even if the estimated height is off by some small degree. It seems safe to say that males in this population were taller than females.

The age distribution of the femora collection suggests a relatively normally distributed population. It also suggests a far more healthy population when compared to many contemporary graves. Skeletal remains from al-Buhais 18 in the Emirate of Sharjah estimated that half of the adults were between the ages 20 and 35 (Martin 2007), with high young adult mortality at Hili N (McSweeney 2003).

With the Tell Abraq collection, males' risk of mortality was highest during the ages of 30-40 years. Compounded by pronounced pilasterism, these could have been the

toughest years of hard and intensive labor which may have led to high morbidity and mortality. Females did not show a higher risk of mortality during their reproductive years (20 to 30 years of age). They were most susceptible to mortality between 30-50 years range. They also did not appear to live longer than males, since no females were found to be over 50-60 years old. An intriguing pattern can be seen in the frequency chart of age, sex, and stature (see Figure 5.8.). While the stature estimates might be on the lower end, the chart shows a statistically positive correlation of female age at death and height ( $\rho=.465$ ,  $p=.013$ ,  $n=28$ ). Thus, younger females are estimated to be shorter than the older females in the collection. However, males do not show a positive correlation of age of death and height ( $\rho=.030$ ,  $p=.878$ ,  $n=29$ ). The chart shows a trend of males with shorter stature located in the age bracket of 30-50 years. The taller males are disproportionately found to be in the younger (below 30 years) and older (above 50 years) age categories.

These findings hint at a relationship between stature and age-at-death. Shorter males may have been differentially at risk than taller males due to the kinds of tasks and occupations that they gravitated towards.

## ***6.2. DIFFERENT PATTERNS OF OCCUPATION AND LABOR***

While the observed bone modifications may confidently be ascribed to the extensive use of certain groups of muscles, the identification of the activity involved remains more speculative. Nonetheless, the study of musculo-skeletal markers (MSMs) present on ancient skeletons may provide additional data that, when taken with other archaeological findings, can help in interpreting the most likely scenario and activities of past populations.

Analyses of different MSMs revealed some interesting results, especially between females and males. The Tell Abraq site has produced evidence of wheat, barley and dates, freshwater and open water fish, wild and domestic animals. Archaeological remains such as ground stones, soft-stone and ceramic vessels, spearheads, fishing hooks and stone sinkers, and bronze and copper rings were also recovered. Finally, Tell Abraq exposed massive architectural structures such as the tower and communal tomb, along with evidence of small dwelling structures outside the tower (Potts 1993a, 2000; Magee et al. 2009; Cope et al. 2005; Uerpmann 2001). All of the above indicate a variety of food sources, a number of probable craftsmanship, and some semblance of community driven planning. Synthesizing archaeological, paleobotanical, archaeozoological, and palaeoclimate records associated with Bronze Age Tell Abraq, the researcher attempted to recreate the most likely activities based on the results of various MSM distributions.

Based on the MSM data collected and analyzed in this study, the pattern of right versus left side preference was not detected in the Tell Abraq population. Steen and Lane (1998) stated that MSMs created by unilateral activities, such as casting a net, may be overridden by activities using bilateral action, and that a layering of biomechanical forces may obscure the marks of side preference.

Posterior Cervical Imprint (PCI) was one of the only MSMs to reveal a bias on the right femur, where lesions occurred almost twice as frequently (n=14) compared to the left side (n=8). A large proportion of both males (74.07%) and females (78.79%) showed an absence of this MSM. However, twice as many males exhibited the marker compared to females. This facet is associated with prolonged walking, standing, and squatting postures – all actions that use both the lower limbs symmetrically. These

actions are all associated with one particular activity – herding. As stated in the Flora and Fauna section of Chapter 3, herding sheep and goats was likely an important part of the subsistence activities at Tell Abraq. The warm and dry climate at that time implied a careful management of fresh water. High temperatures meant high evaporation rates, and rain was most likely heavy but fleeting. At Tell Abraq, like many other contemporary sites, the inhabitants dug deep wells and kept those wells protected within their fortification. Building large and menacing fortifications around the well water implies that fresh water was a resource that needed to be defended.

Hoyland (2001) stated that depending on the local topography and ecology of Arabia, communities would vary from complete sedentism (relying mainly on agriculture and/or fishing), to agropastoralism (largely prevalent in southern Arabia), to transhumance (seasonal movement of people and animals in search of grazing land) and nomadic pastoralism. Evidence of transhumance and interior-coastal interaction has been found in coastal Oman (Ovington 1929; Potts 1993c) and Bahrain (Lorimer 1908). Through the archaeological reconstruction of subsistence and diet, it is likely that the Tell Abraq community specialized as transhumance, moving their herds between winter pastures in the lowlands near the gulf and summer pastures in the cooler highlands within the interior of the peninsula (Potts 1993c). Like many transhumants, they may have had permanent homes, in this case at Tell Abraq, where they lived in barasti huts and other make-shift structures during the winters. This would present a way to prevent overgrazing and to safeguard crops near the settlement site. These activities required days, weeks, or even months away from the main settlement site. Blau (1996) observed alterations on the tali and calcanei in the Tell Abraq collection which she linked to

activities involving squatting and strenuous walking (refer to Figure 56). This fits well with the herding model.

Figure 56. Sheep herding (from worldofstock.com)



While a few females also displayed PCI, ethnographic accounts from different settled lifestyle with pastoralism show males predominantly taking up the duties of herding due to greater physical strength required in some aspects of handling herds and in defending them against theft (Draper 1997; Jordon ND). Additionally, the mobility needed from a herder makes it challenging to bear and tend to children (Jordon ND).

On other bone modifications, Tell Abraq males displayed statistically significant higher frequencies of MSMs compared to females. Almost all males have the presence of the anterior cervical imprint (ACI) (93.22%), articular border convexity (93.22%), enthesopathies of gluteus maximus and minimus (enthes. of GM-M) (70.18%), and exostosis of the trochanteric fossa (exos. of TF) (86.21%). Varying degrees of pilasterism were present in all the males (100%). However, females also displayed varying degrees



of the MSM to a large extent (86.67%). These MSMs were predominantly more present among middle-aged adults over 40 years of age. Since bones modify due to biomechanical stresses over years of repetitive actions, this is expected, although it also demonstrates that not every individual accrues changes in a similar way.

Varying degrees of pilasterism were ubiquitous amongst Tell Abraq males and showed no bias towards either sides of the femur. This MSM has been associated with many activities that stretch the linear muscle attachments on the linea aspera, raising the bony elements along the femur in a flattened ridge. Some of these activities include sea fishing (Oetteking 1930), jogging on undulating landscape (Molleson and Hodgson 1993), and lifting heavy objects from a squatting position (Capasso *et al.* 1998).

Builders and other manual laborers, whose daily activities included lifting and carrying heavy objects, could have developed pilasterism. Both the tomb and other existing structures at Tell Abraq were built of limestone ashlar blocks (in the case of the tomb) and mudbricks (in the case of the tell and the fortress) (Potts 1989, 2000). Carrying the weight of these bricks and repairing the buttresses and walls of the main tower could have generated enough stress on the hip and femur to create pilasterism over the years.

Another probable example of creating pilasterism through manual labor in Tell Abraq is loading and unloading heavy cargo from boats on a daily basis. In addition, herders who walked several miles on a daily basis on undulating landscape would have strained the adductor longus and adductor magnus enough to develop a raised ridge along the linea aspera over years of this activity.

Fishing hooks and stone sinkers (presumably for fishnets) found at the site, along with marine (and faunal) remains, indicate that fishing in open seas was much more than

just a complementary subsistence for the population. Though the inhabitants participated in pastoralism and agricultural activities that provided them with their livelihood, it was trade that brought in maritime sailors and businessmen looking for goods to exchange and tools and boats to repair. Sea fishing may have been more aggressively maintained during some periods in order to engage in more trade and avoid depletion of the indigenous resources.

Pilasterism was positively correlated to enthes. of GM-M. Gluteal muscles medius and minimus carry out medial rotations of the hip (movement of the anterior surface of the femur inwards) and hip abductions (femur moving laterally outwards) (Ghosh *et al.* 2008). Spreading the legs to stabilize on the boat, throwing the fishing net, and drawing it in may have contributed to developing pilasterism and enthes. of GM-M (refer to Figure 57). Likewise, both MSMs may have developed when straining under heavy loads and walking while carrying heavy cargo. Enthes. of GM-M was also prominent amongst females (72.73% of all females), including all of the very young adults. Young females may have contributed to the community at a very young age, helping carry heavy loads by bringing in gathered roots and berries or harvested grains. The model is similar to parts of Peterson's (2002) model, where she reported more work and toil from both males and females in an agricultural set up. However, she also registered less division of labor, which does not seem to be the case with the Tell Abraq collection judging by the predominantly large bias of MSMs between sexes. Nonetheless, the Tell Abraq cannot be strictly called an agricultural community since the inhabitants seemed to exploit much more than grain (Potts 1993a, 2000; Blau 1996; Cope *et al.* 2005).

Figure 57. Balancing while net fishing



In the Oman peninsula, cotton was traditionally used for making nets (Carter 1851) and cloths, while ‘silk tree’ was used for cords and strings (Miles 1910). In Tell Abraq, palm fronds could have been used to fabricate fishing nets (Cope *et al.* 2005). With fishing having a presence in the Tell Abraq diet and economic subsistence, constant repairs of fishnets, cords, and strings would have to be tended to. A common posture for repairing nets is sitting with one or both legs extended in front, so that the toes can grasp and stretch the net while the worker repairs the damage with his hands (refer to Figure 58). Extension of the lower limb causes exostosis of the trochanteric fossa (as explained in the previous sections). Pronounced versions of this MSM were distinct within the population, especially among males (86.21%) in their mid-adult years. A little more than half of the females (55.17%) had this MSM, but the expression of the bone changes was generally mild to moderate. Thus, while some females may have participated in this kind of activity, the MSMs suggest that it was largely a male enterprise.

Figure 58. Extended legs while repairing fishnets (clockwise from top left, photographs from websites flickrhivemind.net, lillamanagementconsulting.com, art.com and frank.itlab.us)



Articular border convexity (ABC) was found on a majority of the males (93.22%) and about half of the females (53.13%), with a statistically significant difference of frequency between the sexes ( $H_{(2,93)}=17.135$ ,  $p < 0.001$ ). Squatting and the sartorial posture of sitting have been commonly associated with this MSM (Charles 1893). A few of the activities relevant to the Tell Abraq site that could involve these postures include weaving and grain processing. This is an activity that could easily employ both males and females.

Potts (2000) reported that ground stones and grinding stones were found at the Tell Abraq site. Cope (2007) found modifications on the humeroulnar joint of the Tell Abraq collection and described the action of grinding repeatedly to process grains or

crack open mollusks. This in turn could have generated repeated forceful loads that developed these bone modifications. Sitting on the knees could possibly produce similar modifications on the femur as squatting since the femur head rotates completely towards the upper body and rests on the calves, thereby creating a similar loading stress on the femur head to produce the ABC facet. Kneeling has also been suggested as a common action after researchers examined the metatarsals within the same collection, and hints at additional activities such as processing of cereals, preparation of foods such as shellfish, and mending of nets (Blau 1996).

Although no tools for weaving were found at the Tell Abraq site, it is possible that cloth making was locally manufactured. Some inferences can be drawn by examining the ethnographic records of Bedouin weaving techniques, traditionally a woman's occupation, used for centuries across the Arabian Peninsula and Near East. Weavers in these regions used sheepwool and goat hair, which were both readily available at Tell Abraq, and spun the threads while sitting in a sartorial position in front of the loom (Hilden 2004) (refer to Figure 59). Females at Tell Abraq may have specialized in weaving and satin a similar fashion, which produced the ABC facet on their femora. Another repetitive activity done while sitting in a sartorial posture may have been the weaving of palm fronds into mats and baskets (refer to Figure 60). Cleuziou (1984) reported clear impressions of matting and interwoven reed baskets at the contemporaneous site of Hili in the U.A.E. In fact, basketry is still an occupation widely undertaken today (Blau 1996).



Figure 59. Bedouin woman sitting in a sartorial position while weaving (photograph from website picable.com)



Figure 60. Man weaving while sitting in sartorial position (photograph from fao.org)



There is no easy way to distinguish the above occupations by sex when textual evidence is lacking. However, ABC facets were largely observed on middle aged adults. Crafts such as weaving usually involve competence and skill. A subsection of the Tell Abraq society could have started honing their skills from a young age. By the time males and females were middle aged adults, the habitual stress on the legs could have produced pronounced facets. Females may have played a role in food control and distribution and thus, may have been the ones involved in grinding grains and cereals.

Hunting could contribute to anterior cervical imprint (ACI) and poirier's facet (PF), as this activity requires walking, running, and squatting while waiting for or watching small and large prey. Possible prey such as gazelle and onyx were recovered from the wild faunal remains at Tell Abraq, as was two spearheads from the tomb. There was a statistically significant difference between males and females, with males displaying a higher presence of PF. ACI (Type A) was much more prevalent among males than females, while ACI (Type B) showed the opposite pattern. While both types are associated with similar biomechanical stresses, the depression exhibited by Type B also reveals the mesh of cancellous bones by wearing out the surface. This tends to occur in younger bones and later transforms to Type A, a clean depression, over time (Kosticks 1963; Odgers 1931).

Nets, snares, and stone enclosures with guide walls could have been used to trap the game. A certain amount of teamwork would have been necessary to drive the overwhelmed prey into traps. The transhumants may have also taken part in some hunting while herding at or near Tell Abraq. While hunting may not have been the main source of food for the population, it was still carried out to a certain extent. Inferring from the

inscriptions and rock drawings of the pastoralists of central and northern Arabia, Robert Hoyland (2001) suggested that hunting could also have been a source of recreation and an opportunity to demonstrate one's skill. Hunting may have been part of the male identity in terms of being a high status activity if one is good at it. There have also been religious connotations to hunting in ancient Yemen. A number of pre-Islamic south Arabian inscriptions confirm that the connection between hunting and divine blessings is very ancient (Serjeant 1976). Hunted prey included cheetah, gazelle, and oryx. The Bronze Age Tell Abraq, which appears to be a very complex social and economic community, may have also had men who hunted for ideological and religious reasons.

Young females had a statistically significant higher frequency (83.33%) of ACI Type B than males. ACI Type B appears more often when the epiphyseal union is present when habitually attaining a capsular cup of the femur head through extension (walking and standing) and flexion (squatting) (Kostick 1963). Therefore, a section of young women in the population may have been assigned to gather berries and roots, or help with capturing small game. These young women therefore played an important role in society of stable food contribution. An interesting point to note is that the Type B cases did not convert to Type A, which appears more frequently amongst adults. This may allude to a transition in habitual activities among some females after a certain age.

A positive correlation was found between PF and pilasterism in the collection. This may lend support that some of the hunting was conducted by some of the herders. Transhumants may have developed pilasterism by walking large distances on undulated landscapes to bring their herd to greener pastures. Potts (2001) reported that the



mountains in ancient U.A.E. had resources such as fodder plants, small mammals and fresh water fish, a landscape ideal for pastoralism and hunting.

The platymerix index results show an almost equal number of platymeric and eurymeric subtrochanteric morphology that is more distributed in the center (slightly eurymeric and slightly platymeric). The results do not support the notion that the platymeric index is controlled by sex alone, since males and females are similarly scattered over the index spectrum. In the case of mobility variation, an almost equal number of males and females exhibited signs of sedentism and high degrees of mobility. The distribution across age and sex suggests much variability in the expression of this feature and therefore it is unlikely to be under strict genetic control.

This diversity in expression may be reflected in the heterogeneous nature of the population. This idea supports the possibility of male immigrants converging at Tell Abraq for jobs and eventually settling there. Foreign and deceased sea travelers (likely all males) could in part explain the larger number of males in the tomb compared to females (Cope *et al.* 2005). Heterogeneity amongst females supports the notion that females and males chose mates from other groups (exogamy).

Most likely, the platymeric index is the amalgamation of all of the above and teasing apart the meaning remains a very difficult challenge.

### **6.3. HEALTH**

The Tell Abraq population did not show any signs of infectious diseases apart from Femur 62, which exhibited severe trauma on the femur head and possible dislocation to the hip, and Femur 40, which had a case of periostitis. There were a

number of cases of clinically significant osteoporosis and osteoarthritis which correlated well with the advanced age of these individuals. Ward's Triangle (the area of disintegration or absence of trabeculae network) is situated in the neck of the femur, which is the region most susceptible to fractures (Jones 2003). In addition, females were more susceptible to hip fractures than males, as confirmed by mean values of Ward's Triangle that approached statistical significance ( $p = .07$ ).

Females are prone to greater bone loss due to the cessation of estrogen production in the post-menopausal years. Since males have a greater bone mass going into adulthood, due to their higher testosterone levels, they are also at risk of osteoporosis but only at a later age (White & Folken 2005). Bone loss can be further aggravated when nutrients such as calcium and vitamin D are lacking in the diet. Coupled with the large sexual dimorphism, which can also be caused by differential diet, in the Tell Abraq collection there may have been an unequal distribution of high quality food resources.

New research in Korea has indicated that adolescent pregnancy could increase the chances of developing osteoporosis later in life. Cho and colleagues (2011) carried a cross-sectional study that included 719 postmenopausal women and found that those who had a history of adolescent pregnancy had overall lower bone mineral density in the hip, femoral neck, and lumbar spine compared to women who did not get pregnant at an early age.

There is a long history of arranged marriages and early pregnancy in the Near East that is present today as well, leading to a large proportion of miscarriages and high infant mortality (Al-Gazali et al. 2005; Rajab and Patton 2000). Katie Baustian (2010) hypothesized that the women of Tell Abraq most likely were involved in early arranged

marriages and adolescent pregnancy, which could have contributed to the high proportion of preterm and term infants in the tomb. If this is the case, tradition and cultural practices, rather than clinical and economic abuse, may have contributed to the women's overall weak dispositions.

Adolescent pregnancy carries many health risks. There is an increased risk of delivering babies preterm and with low birth weight (Frisancho et al., 1985). Early pregnancy in an adolescent body that is still growing also leads to the fetus and the mother competing for nutrients, such as calcium for bone growth, that both desperately need (Frisancho *et al.* 1985; Scholl *et al.* 1997). This could potentially be damaging to both the mother and her child. Evolutionarily, there is more drive for the mother to survive than for her growing fetus since she may be able to reproduce later in life (Bogin *et al.* 2007). In this manner, the mother may redirect the nutrients back to her instead of the fetus in order to maintain her own growth and survival (Frisancho *et al.* 1985). This may also help explain the small fraction of young females found in the tomb.

Pregnancy loss can also cause damaging psychological health issues (Frost & Condon 1996; Klier *at al.* 2002), including anxiety (Brier 2004), depression (Klier *at al.* 2002) and post-traumatic stress (Bowles *et al.* 2000). Physically, a young body may recover more easily, but proper growth and development of both the reproductive organs and other parts of the body may be inhibited. It is difficult to determine if growth slows as a result of the pregnancy, but it is known that iron and folic acid supplements and antimalarial treatment promoted growth in a study comparing undernourished, pregnant Nigerian adolescents to placebo controls (Harrison et al., 1985).

Marginal osteophytes around the fovea capitis were recorded in much higher frequencies among males (45.9% of all males) compared to females (14.29% of all females) across all age categories. The bony spur formation in this region has been associated with an early sign of coxarthrosis, a degenerative disease which leads to the destruction of the hip joints (Galimberti & Marabelli 1966). It could be the result of many factors including age, sex, hormones, acute trauma, mechanical stress and genetic predisposition (White and Folkens 2005; Larsen 1997; Cox and Mays 2000). However, people who habitually participate in physically challenging routines are likely to develop osteophytes, especially in larger joint systems like the hip joint (Larsen 1997; Cope et al. 2005). While it is impossible to assess the primary cause of the marginal osteophytes in the collection, associated clinical symptoms may have included joint tenderness and stiffness and pain in the hip region. The trauma seen on Femur 62 may have been a case of coxarthrosis, making mobility painful and limited, if not impossible. The remains from the Tell Abraç collection suggest that the population was comprised of hard working individuals with pronounced MSMs. Repetitive and habitual activities may have been a key factor in developing marginal osteophytes. These osteophytes may have obstructed the lifestyles of those afflicted, particularly when individuals had a more pronounced degree of marginal osteophytes. However, compassion and care by the larger society of Tell Abraç, as reported by Jamie Vilos (2011), may have helped such individuals survive and contribute to the community in a different capacity.

Apart from degenerative diseases, the absence of pathology on most of the femur bones suggests an adult population that was not hindered by infectious or nutritional diseases. Yet, a considerable proportion of the population died below the age of 50 years

(left femur - 85.30%, right femora – 82.35%). Their early deaths imply that there were other risks involved. According to the “osteological paradox” proposed by Wood and colleagues (1992), skeletal remains without signs of infectious disease may actually be an indicator of being immunologically compromised. That is, individuals who become ill with bacterial or viral infections who are immunologically compromised may die fairly quickly. In order to have signs of infection on the bones, individuals had to survive the disease for some weeks or months. Individuals with very weak immune systems may not survive long enough for the infection to reach the bones, and therefore may die without any pathological evidence left behind on hard tissues.

Other paleopathological and paleodemographical studies of adult skeletal remains from the tomb reveal that overall, the adult population was relatively robust, physically active and relatively well nourished (Potts 1993a, 2000; Blau 1996; Martin *et al.* 1999; Cope *et al.* 2005). They also, however, were endowed with bad teeth (severe attrition, caries and enamel hypoplasia) and anemia (Potts 1993b), possibly due to grit in mollusks and roughly processed grains.

#### **6.4. INNOVATIVE ASPECT OF “READING” MSMS MICROSCOPICALLY**

For the first time, bones as old as 3000 years old were put on the gantry of instruments that cost well over a million dollars and micro CT-scanned to provide an impressive image of the internal histological trabeculae network. This study demonstrated that human remains of great antiquity retained their internal microstructural architecture and that this could provide valuable data on age, sex, and bone changes at the

gross or macroscopic level. The micro-CT scan aided in a more accurate age estimation, data on the degree of Ward's triangle, and the rate of deterioration of the trabecular bone.

There were challenges presented as well. For example, it was difficult to calculate the degree of the angle from the greater trochanter and the superior-lateral section of the femoral neck. This was primarily due to problems with preservation and bone decline, making the task of finding the exact direction of the secondary compressive group, secondary tensile group and greater trochanteric group challenging. Additionally, foreign bodies such as dirt and sand, lodged deep within many of the bones, compromised the image and accuracy of the angle required for assessment.

However, the principal compressive and tensile groups at the femur head (Region 1) were clearer, precisely recorded, and relatively easy to measure. The results yielded a trend approaching statistically significant correlations with one MSM on the femur surface – the gluteus medius and minimus enthesopathy ( $\rho=.28$ ,  $p=.053$ ,  $n=48$ ). Since various biomechanical loadings put stress and strain on all five trabeculae groups within, it is challenging to associate one group angle to a specific MSM, as the system is more complex and dynamic. For future research, reading all three regions together, which the researcher was unable to do here, and finding a pattern might provide some better results and insights.

## ***6.5. SUMMARY OF BIOCULTURAL INFLUENCES WITHIN THE ANALYTIC FRAMEWORK***

With the help of Sorensen's (2000:85) six factors listed in Chapter 2, Tell Abraq's mortuary analysis can be summarized as such:

1. Locations of burials are chosen consciously and deliberately by the community depending on landscape properties and the prevailing principles of the inhabitants' social formation (Fahlander 2003). While large and monumental tombs were usually used to define territorial borders (Madsen & Jensen 1982), this does not seem to be the case with Tell Abraq. The circular communal tomb was located in close proximity to the settlement site (fortification tower), implicating the pivotal role of death in the living population's culture. Its location facilitated easy visibility of the monumental structure during the people's everyday interactions and activities, likely signifying their close relationship with the dead.

2. The finely masoned limestone ashlar blocks that made the external surface of the mortuary indicates that intensive construction work, substantial planning, and considerable time went into building the structure. Mery *et al.* (2010) discussed the labor that went into building mortuary tombs in the Oman Peninsula during the Umm an-Nar period. She describes how limestone blocks were hauled with only limited difficulty onto the site of construction. The cutting and dressing the facing blocks were completed at the place of the mortuary site in order to fit the blocks into 'perfect joins' (Mery *et al.* 2010:37). Such dedication and expenditure of energy also support the idea of the population's intimacy with and respect for their lost ancestors.

3. The demography of the people interred represented a wide span of individuals and included women and children. Choosing to offer similar mortuary rites and rituals to everyone may indicate that even if economic and social equality did not

prevail during life, the prevailing religious ideology was that all individuals deserved equal respect and treatment after death. Arguably, it could also symbolize their belief of one path for all in the afterlife.

4. The dead were also interred in no particular position and were periodically pushed to the western chamber to create more space for newer occupants (Potts 1993a, 2000).

5 & 6. Grave goods were scattered in no particular order and found mingled with the commingled skeletal remains. Thus, assigning grave goods to select individuals was impossible. However, the type and number of grave goods did vary. Among the high number of local goods, rarer and precious grave goods such as the Bactrian comb (Potts 1993b), and linen made of flax fiber (Reade & Potts 1993), are believed to have been exclusively used by high ranking individuals during that period (Waetzoldt 1983). This implies two notions – a) that personal effects symbolizing social ranking in life were interred alongside the individuals and b) that this in turn implies that there was some sort of prevailing social hierarchy where only a few had access to selected material products. However, it is difficult to discern if all the grave goods were chosen by the living family or by the community because they considered the items apt or because the items were valuable and intimate to the interred individuals.

Referring back to the analytical framework detailed in Chapter 2, the femora collection does display differential MSMs based on sex, life-cycle, and other subgroups.



There is at least a partial sexual division of labor that can be extrapolated through the analysis of the proximal femora.

Only a small proportion of the collection displayed the posterior cervical imprint (PCI) but of those who did exhibit this MSM, approximately twice as many belonged to males than females. Synthesizing this information with archaeological, zooarchaeological, and palaeoecological evidence, it can be suggested that this MSM was primarily exhibited by herders or transhumants who most likely were males. This MSM also provides evidence that there was a social and economic division of labor within males, given the infrequency of this MSM identified among the remains.

As for occupations based on life-cycle, the anterior cervical imprint (ACI) Type B provides evidence that young females endured repetitive running, walking, and squatting, and then subsequently changed to another habitual activity which left the trabeculae exposed on the depressed facet. There may have been many other life-cycle based activities but MSMs develop over time and it is difficult to segregate MSMs achieved during adolescence from those achieved later in life, unless a cessation to the action leaves a certain marker, such as the ACI (Type B).

Differential pathology was slightly suggested in the collection, as the bones typically exhibited degenerative joint changes such as osteoarthritis (marginal osteophytes) and osteoporosis. Analyses of the Ward's Triangle, however, suggests a trend where females had higher mean values of the Triangle's size and density and thus, were more likely to sustain hip fractures. Diagnosing differential healing within the population is not possible with only a sample size of two exhibiting evidence of periostitis and trauma on the femoral head. These could be exceptional cases.

Overall, Bronze Age Tell Abraq seemed to be a large community with complex socio-economic dynamics. Cross-culturally, communities have organized themselves along three fundamental factors: gender, age, and expertise, further customized by their cultural and ideological principles (Frink 2009). Tell Abraq is no exception to this. The robusticity of the bones with pronounced bone modifications implies a very hard working group. The lack of pathological lesions also indicates a fairly healthy population. While the results of the MSMs on the proximal femora clearly show different occupational activities amongst different subgroups, grave goods ranging from local and ubiquitous to rare and exotic, indicate some form of social hierarchy as well. This may imply that though most of the community worked hard and were relatively healthy, few economic and social subgroups, beyond the lines of gender for they may include women, had the resources to own rare commodities the rest could not afford.

The community thrived and benefited from the robust trade industry, much so that it may have attracted foreigners, who were most likely young or seasoned men, who settled down and partook in the prosperity. Women were perhaps married off early and to different communities, and conceived offspring at a relatively young age, making them susceptible to high levels of osteoporosis.

Men and women seemed to utilize their surrounding landscape substantially, if not optimally. Fishery, pastoralism, small scale agriculture, hunting, and gathering were carried out. The inhabitants protected freshwater drawn from a center well within the fortification and likely used it wisely. These extended to secondary, yet essential, occupations that required expertise. A few of these occupations include manufacturing net and baskets (weaving), shaping spearheads and making rings (metallurgy), making

vessels for storage and carrying water (pottery or stone cutting), grinding food for processing, constructing structures for living, and making clothes out of sheep wool.

Tertiary objects used to create the previous objects led to further occupational activities, such as making strings to hold the basket and grinding stones to grind. These networks of interconnected objects were created out of necessity or by want of the community and in turn, these objects supplied the people with various occupations and helped shape their identity as an individual, within their household, and within their community.

## CHAPTER 7: LIMITATIONS & FUTURE RESEARCH

Analyzing musculo-skeletal markers has always been challenging. One can never tease apart biomechanical stresses from age completely since bone modification appears with years and years of repeated actions on a daily basis. However, the current project did try to extract age estimation by analyzing the rate of disintegration within the trabecular network microscopically. This, in turn, led to another limitation. The remains in general were disarticulated and fragmentary. All proximal femora gathered for the study were broken mid-shaft from taphonomy or excavation. The fine network of trabecular was thus compromised to a certain extent.

Future extensions of this research would explore the trabeculae trajectory of principal and secondary compressive and tensile groups within all three regions indicated in the proximal femur from a collection better preserved to study the change in trajectory within the bone due to MSMs shaped by selected biomechanical loadings. This may help develop a new non-invasive method of determining habitual markers.

Researching other parts of the skeletal remains for differential healing of pathology would help better understand women's social role within the society. If there are more frequency of pathology in females without a sign of healing, they probably did not have equal access to health benefits and treatment.

## APPENDIX

Appendix 1. *Metric Method sex estimation results*

ID #	Measurements			Femur head diameter	Angles			Ratios			P	Sex (M/F)
	GT FC	GT LT	LT FC		Angle at FC	Angle at GT	Angle at LT	aGT/GT to FC	aLT/Fem hd.	aLT/LT to FC		
1	93.2	59.3	65	51.1	39.16	43.80	97.04	47.00	189.90	149.29	1.00	M
4	92.2	46.1	66.6	45.3	28.32	43.26	108.42	46.92	239.33	162.79	0.56	M
6	82.8	48.7	60.2	38.3	35.58	45.99	98.44	55.54	257.01	163.51	0.00	F
8	91.9	58.3	74	50	39.32	53.54	87.15	58.25	174.30	117.77	0.94	M
9	97.5	54.2	69.9	47.5	32.82	44.35	102.83	45.49	216.48	147.11	0.94	M
11	88.2	52.1	66.9	42.8	36.06	49.09	94.85	55.66	221.61	141.78	0.09	F
12	78	48.8	62.2	40.6	38.71	52.86	88.43	67.77	217.81	142.17	0.00	F
14	79.1	40.8	57.3	39.2	29.68	44.06	106.26	55.70	271.06	185.44	0.00	F
18	98.6	60.2	71.1	51.3	37.30	45.70	97.00	46.35	189.08	136.42	1.00	M
19	87.1	52.5	60.8	41.8	36.38	43.39	100.23	49.82	239.78	164.85	0.17	F
20	75.6	52.1	53.7	39	43.55	45.25	91.20	59.85	233.85	169.83	0.00	F
21	90.7	59.7	69.7	47	41.15	50.20	88.65	55.34	188.62	127.19	0.79	M
22	107	64.4	85.7	52.9	37.00	53.22	89.78	49.74	169.71	104.76	1.00	M
23	102.2	66.7	79.1	47.6	40.73	50.69	88.58	49.60	186.10	111.99	0.97	M
24	94.3	61.5	76.2	46.5	40.57	53.69	85.74	56.94	184.39	112.52	0.78	M
25	89.8	58.6	66.9	44	40.73	48.15	91.13	53.61	207.11	136.22	0.37	F
26	90.8	60	67.8	48	41.36	48.30	90.34	53.20	188.20	133.24	0.92	M
27	92	63.2	79.8	49.7	42.43	58.42	79.15	63.50	159.26	99.19	0.90	M
28	82.4	49.5	66.2	39.4	36.92	53.45	89.62	64.87	227.47	135.38	0.00	F
29	89.8	56.6	64.4	45.4	38.85	45.54	95.61	50.71	210.60	148.47	0.76	M
30	91.4	51.6	71.4	48.4	34.24	51.14	94.62	55.95	195.49	132.52	0.87	M
32	86.7	53.4	61.7	46.3	37.64	44.88	97.49	51.76	210.55	158.00	0.85	M
34	92.7	57.9	64.8	47.5	38.21	43.81	97.98	47.26	206.28	151.20	0.97	M
35	75.7	42.6	59.9	39.6	34.17	52.15	93.68	68.89	236.57	156.40	0.00	F
36	83.9	54	65.6	39.5	40.05	51.41	88.54	61.28	224.16	134.97	0.00	F
39	87.2	53.6	63.3	42.6	37.67	46.20	96.12	52.98	225.64	151.86	0.16	F
49	108.3	64.9	78	51.5	36.39	45.48	98.14	41.99	190.56	125.82	1.00	M
50	105.6	64.9	79.5	51	37.84	48.72	93.44	46.14	183.21	117.53	1.00	M
51	99.9	61.6	69.9	52	37.56	43.76	98.68	43.81	189.77	141.17	1.00	M
52	84.2	53.8	66.9	41.6	39.68	52.55	87.77	62.42	210.98	131.19	0.01	F

53	86.3 2	58.3 1	67.3 8	41.7	42.39	51.18	86.43	59.29	207.27	128.28	0.03	F
54	115. 2	61	79.1	53.5	29.85	40.20	109.95	34.89	205.52	139.01	1.00	M
55	92	60.1 5	72.4 2	46.3	40.78	51.85	87.38	56.35	188.72	120.65	0.69	M
56	78.8	53.2	66.1	40	41.94	56.15	81.91	71.25	204.77	123.92	0.00	F
57	82.4 3	48.2 3	59.6 8	41.3	35.30	45.64	99.06	55.37	239.86	165.99	0.03	F
58	97.5 9	58.9 7	69.8 6	49.6	36.74	45.13	98.14	46.24	197.85	140.47	0.99	M
59	75.2	49.1 8	57.5	40.5	40.84	49.87	89.29	66.31	220.47	155.29	0.00	F
60	109. 9	68.9 1	77.4	52.9	38.48	44.34	97.19	40.35	183.72	125.56	1.00	M
61	85.0 7	49.4	61.1 9	40.2	34.88	45.10	100.02	53.01	248.82	163.47	0.02	F
62	97.5	61.5	75.5	54.2	39.11	50.75	90.15	52.05	166.32	119.40	1.00	M
63	87.7 5	57.1 1	61.3 7	50	40.38	44.12	95.50	50.28	191.01	155.62	0.99	M
64	81.9 1	52.2 4	65.8 6	43.7	39.56	53.41	87.02	65.21	199.14	132.13	0.02	F
65	100. 1	64.8 9	73.9 7	46.8	40.37	47.59	92.04	47.53	196.67	124.43	0.95	M
66	84.9 5	57.6 8	60.8 6	44.1	42.75	45.74	91.51	53.84	207.52	150.37	0.45	F
67	93.5 2	60.8 8	67.8 8	46.3	40.55	46.46	93.00	49.67	200.85	137.00	0.88	M
69	98.2 2	55.7 6	75.8 3	51	34.42	50.24	95.35	51.15	186.95	125.74	0.99	M
72	94.4 3	62.6 4	72.9 9	49.17	41.52	50.57	87.90	53.56	178.78	120.43	0.96	M
75	85	45.1	67.7	40.7	31.87	52.42	95.71	61.67	235.16	141.38	0.00	F
81	84.2 8	52.2 6	64.9 3	39.6	38.31	50.37	91.32	59.77	230.60	140.64	0.00	F
85	93.0 6	53.6 9	65.2 7	43.2	34.28	43.22	102.50	46.44	237.28	157.05	0.41	F
90	81.2 6	47.7 8	63.2 1	41.1	35.95	50.96	93.08	62.72	226.48	147.26	0.00	F
91	77.2 5	50.5 8	63.3 2	39.9	40.68	54.69	84.62	70.80	212.09	133.64	0.00	F
95	88.6 6	57.2	65.6 8	45.6	40.15	47.76	92.10	53.87	201.97	140.22	0.64	M
97	83.5 7	48.4 6	63.4 3	39.7	35.24	49.05	95.72	58.69	241.10	150.90	0.00	F

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Fall 2008–Spring 2009 *Teaching Assistant* for Introduction to Physical Anthropology (ANTH 102) and Introduction to Cultural Anthropology (ANTH 101)

## **Work and Academic Experience:**

- 2012 *Osteological Laboratory Coordinator* at the Museum of Osteology, Moore (OK)
- 2011 *Bioarchaeological Analyst* – UNLV Summer Field Excavation of Archaeological Site Mimbres, New Mexico under Primary Investigator Dr. Barbara Roth.
- 2009 Review of manuscript "The mechanical properties of marine and terrestrial skeletal materials with implications for the organization of forager technologies", *Journal of Archaeological, Ethnographic, and Experimental Studies*, 1(2): 163-184.
- 2007 *Project Associate* for Prof. Nalini Thakur, Consultant of Archaeological Survey of India (A.S.I.) on 'Integrated Management Planning of Hampi, World Heritage Site'
- 2006 *Research Associate*, Underwater Archaeology Wing (UAW) of A.S.I.
- 2006 *Field Technician* – Analysis and documentation of human skeletal remains found in the burial site of Sanauli, Uttar Pradesh (India) excavated by A.S.I.
- 2005 *Conference Coordinator*, National Seminar on Anthropology for Archaeology during the occasion of Professor Iravati Karve's Birth Centenary at Pune on the 8<sup>th</sup> & 9<sup>th</sup> December 2005.

## **Presentations (First Author):**

- April 2012 Poster presentation on "First Time Analysis of Tell Abraq Proximal Femora using Micro 3-D Scanning: Analytic Implications for Age Estimation and Beyond" at the Annual Meeting of the American Association of Physical Anthropologists (AAPA), Portland [Co-author with Martin DL, Prajapati S, Keller C, Gelovani A and Tomlinson G]
- Sept. 2011 Poster Presentation on "Analysis of 4000 year old Human Bone using Micro 3-D Scanning: Analytic Implications for Forensic and Archaeological Sciences" at World Molecular Imaging Congress - Annual Meeting (September 2011). [Co-author with Prajapati, S., Keller, C., Gelovani, A., Tomlinson, G. and Martin, D.L.]
- April 2011 Podium Presentation on "Preliminary results of activity-induced skeletal markers on proximal femora from the Bronze Age Tell Abraq tomb, U.A.E." at the Annual Meeting of the American Association of Physical

Anthropologists (AAPA), Minneapolis. [Co-author with Martin, D.L., Thompson, J.L.]

- April 2010 Poster Presentation on ‘The Pathological Lesions observed on the Osteological Remains from the Site of Sanjan, Valsad District, Gujarat State, India’ at the Palaeopathology Association (PPA), Albuquerque. [Co-author with Pitale, G. and Bhattacharya, S.]
- April 2009 Podium Presentation on “Mortuary Rituals of the Zoroastrians of India” at the Southwestern Anthropological Association Annual Conference, Las Vegas.
- April 2009 Poster Presentation on “Analysis of cranial remains from the Zoroastrian Tower of Silence, Sanjan, India (1410-1450 AD)” at the Annual Meeting of the American Association of Physical Anthropologists (AAPA), Chicago.

#### **Publications:**

Dutt, A., Martin, D.L. and Thompson, J.L., 2011, “Preliminary results of activity-induced skeletal markers on proximal femora from the Bronze Age Tell Abraq tomb, U.A.E.”, *Program of the 80<sup>th</sup> Annual Meeting of the American Association of Physical Anthropologists*, pp. 130.

Dutt, A., 2009, “Analysis of cranial remains from the Zoroastrian Tower of Silence, Sanjan, India (1410-1450 AD)”, *Program of the seventy-eight Annual Meeting of the American Association of Physical Anthropologists*, pp. 152.

Dutt, A., 2009, “Book Review: Late 17th- to 19th-century burial and earlier occupation at All Saints, Chelsea Old Church, Royal Borough of Kensington and Chelsea”, *International Journal of Osteoarchaeology*, 19(2): 341 – 343.

Abu Dalou, A.Y., Al Shoul, A. and Dutt, A. “On the Phenotypic Plasticity of a Group of Cephalometrics and Facial Dimensions of Living Jordanians”. [*In progress*]

Walimbe, Mushriff and Dutt, “Sanjan Official Report”, Indian Archaeological Society. [*In progress*]

#### **Awards, Grants and Fellowships:**

- Emergency Funding from Graduate and Professional Student Association Grant, University of Las Vegas, Fall 2011, \$450.
- Graduate and Professional Student Association Grant, University of Nevada Las Vegas, Spring 2011, \$704
- Second Place at the GPSA Poster Presentation (28th March 2010)

- Emergency Funding from Graduate and Professional Student Association Grant, University of Las Vegas, Spring 2010, \$600.
- Graduate and Professional Student Association Grant, University of Nevada Las Vegas, Spring 2010, \$450
- Sunflower Charitable Trust, Four Mangoe Lane, Kolkata (India), Fall 2009, \$5000.
- 'Honorably Mentioned' at the GPSA Poster Presentation (28th March 2009)
- Graduate and Professional Student Association Grant, University of Nevada Las Vegas, Spring 2009, \$500
- Sunflower Charitable Trust, Four Mangoe Lane, Kolkata (India), Fall 2008, \$5000.
- Graduate Assistantship, Department of Anthropology, University of Nevada Las Vegas, 2008-2011

**Skills:**

- Fluent in Bengali and Hindi languages (written and spoken).
- Proficient in Microsoft Word, Excel, PowerPoint, OneNote, Minitab, SPSS, MicroView, Seg-3D.