A BIOARCHAEOLOGICAL INVESTIGATION OF ACTIVITY PATTERNS IN NEW KINGDOM NUBIA

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ABSTRACT

Schrader, Sarah A. M.S., Purdue University, May 2010. A Bioarchaeological Investigation of Activity Patterns in New Kingdom Nubia. Major Professor: Michele R. Buzon.

This study utilizes a bioarchaeological approach to examine activity patterns at the Nubian site of Tombos. The town of Tombos, located at the Third Cataract of the Nile, was established as an imperial center and remained a functional protectorate of the Egyptian Empire throughout the Third Intermediate Period (1,400-1,050 BC). Human skeletal remains from the New Kingdom (1,550-1,069 BC) were analyzed for indications of osteoarthritis, vertebral degeneration and musculoskeletal stress markers. In addition to better understanding activity patterns at Tombos, this study has two primary objectives: 1) investigate the biological outcomes of imperial incorporation and consolidation, and 2) elucidate the role of Tombos as a constituent of the Egyptian Empire. Low levels of osteoarthritis, vertebral degeneration and entheseal remodeling reflect an imperial community that was not participating in a mechanically strenuous lifestyle. Furthermore, these data suggest Tombos served as a colonial administrative center as the Egyptian Empire successfully consolidated Nubia into the imperial regime of the New Kingdom.

CHAPTER 1. INTRODUCTION

Located in modern southern Egypt and northern Sudan, ancient Nubia maintained a dynamic relationship with ancient Egypt for thousands of years. Beginning in ~1,460 BC, the Egyptian Empire colonized Nubia. The town of Tombos (Figure 1.1), located at the Third Cataract of the Nile, was established as an imperial center and remained a functional protectorate throughout the Third Intermediate Period (1,400-1,050 BC). However, the exact function of the community within the broader Egyptian Empire remains unknown. Burial inclusions and architecture uncovered in previous excavations have suggested the citizens of Tombos were of middle socioeconomic status (Buzon and Richman 2007; Smith 2003).

The role of the Tombos community as a component of the Egyptian Empire can begin to be explored using a bioarchaeological approach to examine activity patterns through the collection and analysis of markers of mechanical stress on the skeleton. This methodology can be used to test whether the people of Tombos were administrative professionals, likely exposed to limited levels of physical labor, or if they engaged in more physically demanding workloads, as experienced in agrarian-based economies. Several degenerative pathological conditions can reflect physical activity patterns including osteoarthritis, vertebral osteophytosis, Schmorl's nodes and musculoskeletal stress markers. The foremost attributing factors to these activity patterns include long-term, repetitive and strenuous activities representative of a mechanically demanding lifestyle (Rogers and Waldron 1995).

In addition to better understanding activity patterns at Tombos, this study has two primary objectives: 1) investigate the biological outcomes of the incorporation of a community into an empire, and 2) elucidate the role of Tombos as a component of the Egyptian Empire. The bioarchaeological approach to understanding empires has the ability to shed light on the relationships between empires and hinterland territories. This research can expand our understanding of the nature of Egyptian Empire as well as other empires through time and space.

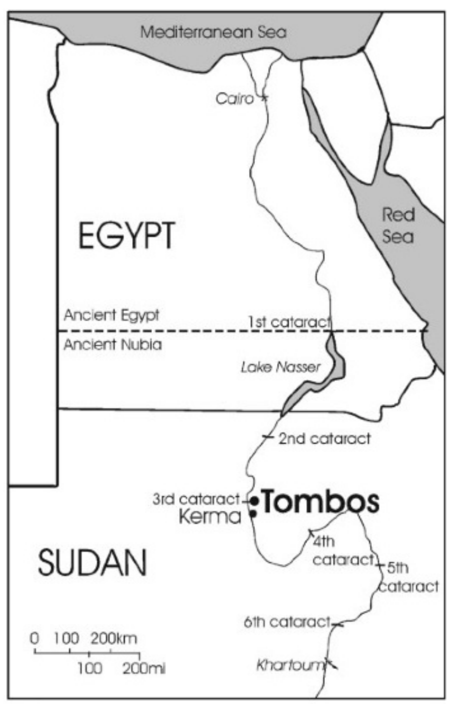

Figure 1.1 Map of Tombos

1.1. The Bioarchaeological Approach

Bioarchaeology, the analysis of human skeletal remains in an archaeological context, provides biological, cultural and archaeological information of past peoples. Through the analysis of skeletal remains, bioarchaeologists can reveal otherwise unaddressed perspectives of past populations including, but not limited to: activity patterns, health, warfare, social status, diet and migration (Buzon et al. 2005; Larsen 1997). In bioarchaeological research, data are collected directly from skeletal material that provides an excellent corporeal representation of the life of the individual. Additionally, the skeletal system is particularly adaptable and responsive in life, reflecting biological and cultural information in death. Furthermore, a demographic interpretation of skeletal remains takes into account entire populations and incorporates a large-scale mode of analysis, rather than a single individual.

Bioarchaeology is an ideal method for the present research due to the physical manifestation of activity patterns on the human skeleton, indicative of strenuous labor and overuse. A demographic approach will be adopted in this research by analyzing the skeletal remains of an entire cemetery. Archaeological information also supports bioarchaeological investigation by providing artifacts rich in cultural perspective. Material remains of the archaeological record, particularly those associated with the skeleton, can convey key details of the individual's identity, culture, status and gender. As with all aspects of archaeology, context of these material remains are crucial to their credibility.

1.2. The Present Study

This project addresses questions regarding the effects of the Egyptian Empire on the Nubian polity of Tombos and the function of Tombos within the broader Egyptian Empire. Was the community of Tombos subjugated by the Egyptian Empire and forced into arduous forms of labor such as slavery and intensive agriculture? Was Tombos housing a mixture of both prosperous imperial officials and exploited laborers? Or, did Tombos serve as a colonial administrative center, supporting a prosperous community of minor officials and scribes, as the Egyptian Empire attempted to successfully expand? The bioarchaeological analysis of activity patterns can elucidate the levels and types of activities in which the community of Tombos was participating. Table 1.1 and the following explication both outline hypotheses and expectations of this study.

Table 1.1 Hypotheses and Expectations

Activity Pattern Level of Expression		Effects of Imperialism on Tombos	Function of Tombos within the Egyptian Empire
1)	**Limited**	Colonial administrative center	• Minor officials • Scribes • Prosperous servants
2)	**Mixed**	Combination of imperial officials and workers	• Egyptian officials • Craftspeople • Servants
3)	**Marked**	Subjugated territory in which local labor sources were controlled and manipulated by the Empire	• Agriculture • Slave-labor

Hypothesis 1:

The limited presence of activity patterns in the Tombos population would reflect a population that was not participating in repetitive, physically demanding activities. Occupations such as, but not exclusive to, minor officials, scribes and prosperous servants would characterize low levels of activity patterns. Activity patterns, including osteoarthritis, vertebral degeneration and musculoskeletal stress markers, are expected to be low throughout the entire body. A New Kingdom community that provided these types of services would be characteristic of a colonial administrative center.

Hypothesis 2:

A mixed level of activity patterns would indicate that the Tombos population was participating in an array of activities, some of which were mechanically stressful. Activity patterns are expected to be high in some individuals and low in others. This scenario would represent the presence of a combination of imperial officials and an incorporated local population at Tombos. Prosperous imperial officials would display less severe activity patterns than individuals who were likely engaged in various forms of manual labor. Individuals with increased levels of activity patterns may have been occupied as servants and craftspeople.

Hypothesis 3:

Marked expression of activity patterns in the Tombos population would suggest a harsh lifestyle, characteristic of a physically demanding workload. Severe activity patterns would be representative of occupations such as farmers and slave laborers. This scenario would reflect Tombos as being a territory subjugated by the Egyptian Empire, where local labor sources were controlled and manipulated by the imperial system.

To address the question of Egyptian imperial influence on local Nubian communities, I analyzed the skeletal remains of the New Kingdom cemetery at Tombos. The Tombos sample is currently housed at Purdue University and was excavated by Dr. Michele Buzon and colleagues in 2000 and 2002. The collection is comprised of a minimum number of 100 individuals and is discussed in greater detail in Chapter 4.

Procedure for analyzing osteoarthritis, vertebral osteophytosis, Schmorl's nodes and musculoskeletal markers included the macroscopic examination of these pathological conditions. In order to assure recording consistency a standardized scoring system was adopted, which associates type and severity of these pathological conditions with a numerical gradation (Buikstra and Ubelaker 1994; Hawkey and Merbs 1995).

Few bioarchaeological analyses of activity patterns have been conducted on ancient Egyptian and Nubian populations (Kilgore 1984; Zabecki 2009). Also, these pathological indicators of activity have not been synthesized into a unified approach (i.e. osteoarthritis, vertebral degeneration and musculoskeletal stress markers) in the region. Thus, the proposed analysis of activity patterns will provide important new data regarding the daily activities of ancient Nile Valley inhabitants.

1.3. Structure of the Thesis

This thesis is divided into seven chapters, each contributing to the analysis of activity patterns within imperial communities. The introduction (Chapter 1) is intended to present and explicate the aims, hypotheses and expectations of this project. Chapter 2, entitled "Archaeological Foundations," provides background information on the prehistoric and historic record of Nubia. The section on regional background will summarize the ancient narratives of Egypt and Nubia that laid the foundation for this research. The topic of the Nile River is also addressed in this chapter; the Nile serves multiple invaluable functions to northeastern Africa. A summary of previous archaeological endeavors in the region will present past interpretations of Ancient Nubia as well as the current state of archaeological research in the region.

The theoretical framework of this research, outlined in Chapter 3, utilizes the theoretical perspectives of cultural anthropology, biological anthropology and archaeology to form a multifaceted theoretical stance. Utilizing an anthropological approach, the topic of imperialism is discussed focusing on the development of an empire, the process of consolidating an empire and variations within empires. Furthermore, discussion on social identity will serve to address the social implications of an imperial system on local communities. Osteological theory, in the form of the materiality of skeletal remains, bone plasticity and the osteological paradox, is also addressed in Chapter 3.

Chapter 4 details the methods utilized in this research. Background information on the pathological conditions analyzed (i.e. osteoarthritis, vertebral osteophytosis, Schmorl's nodes and musculoskeletal stress markers), including etiology and previous bioarchaeological research, will also be discussed in Chapter 4. The scoring methodology and details of the sample are also included in this chapter.

The results of each pathological condition are addressed separately in Chapter 5. Discussion of these results and comparison samples are included in Chapter 6. Comparing the results of activity pattern analysis at Tombos with other published bioarchaeological articles provides context for the interpretation of the physical activities the people of Tombos were performing. Chapter 7, the conclusion, summarizes the broader themes of this research and addresses further research opportunities.

CHAPTER 2. ARCHAEOLOGICAL FOUNDATIONS

A thorough understanding of the regional history and previous archaeological research of Nubia is necessary to comprehensively study the Nubian peoples and their past lifeways. It is within this framework that archaeologists can begin to discern Nubian cultural and social identities as well as biological backgrounds. Beginning with Neolithic settlement of the Nile Valley, the Nubian and Egyptian cultures are distinctive and unique. The regional history provided highlights the extended interaction between the Egyptians and Nubians as each of their borders waxed, waned and often, overlapped. The Nile River plays a vital role to the anthropology of Nubia and Egypt, serving as a fertile means of sustenance to modern populations as it most certainly did ancient populations as well. The history of archaeology in Nubia is long established, illuminating and has developed significantly over several centuries. A brief introduction to the Nubian prehistoric and historic record as well as a concise record of previous archaeological efforts in the region will assist in the formation of background information of this project.

2.1. Regional Background

Nubia, located in the modern countries of Sudan and Egypt, possesses a long and fascinating history. The chronicle of ancient Nubia is often intertwined with that of ancient Egypt as the two distinct cultures shared common territories and interacted for millennia. Furthermore, the interface between the Nubians and Egyptians is complicated by extended periods of competition over resources and trade routes. Dramatic environmental changes which occurred around 5,000 BC created the extremely arid climate of northeastern Africa known today, which defines areas of viable land in the region. Populations would begin to settle in the Nile Valley during the Neolithic, eventually forming cities, states and empires. The aim of this regional background is to provide the reader with a general knowledge of the prehistoric and historic events that laid the foundation for the varied cultures that have inhabited this region.

The climate and environment of Nubia has changed drastically throughout the history of human habitation in the region. Paleoclimatologists have suggested northeast Africa maintained a woodland or savannah-woodland environment that was wet enough to support large land mammals and fruitful lakes, rivers and oases (Hassan 2002). This panorama contrasts the conventional image of the region today, which is typically extremely arid. This plentiful environment encouraged a mobile gathering, hunting and fishing lifestyle. Both domesticated plants and animals were introduced to Africa via southwest Asia by the 5th millennium BC (Wendorf and Schild 1976). However, there is current debate regarding the primary domestication of cattle occurring in

Nubia much earlier (Banks 1989). While the knowledge and technology of domesticates was readily available, archaeological evidence suggests domesticates were only used as a dietary supplement to hunting, gathering and fishing throughout the Neolithic (Hoffman 1979).

A massive Holocene arid-phase, beginning around 5,000 BC and culminating circa 3,000 BC, gradually dried many of the natural water sources that had previously existed (Midant-Reynes 2000). These climatic changes were so extreme the desert regions became uninhabitable, encouraging populations to gather in the Nile Valley. Furthermore, the increasingly arid environment limited hunting, gathering and fishing resources inducing an increased dependence upon pastoralism and grain agriculture (Allen 1997). However, due to modern urban expansion as well as an accumulation of Nile sedimentary deposits, a limited number of archaeological sites from this time period remain, which complicates our understanding of subsistence during this time period (Hassan 1988). With the introduction of a more sedentary lifestyle, gradually occurring between 5,000-3,000 BC, archaeologists begin to detect distinct cultural traditions between the Nubians and the Egyptians.

Throughout the Egyptian Predynastic period (3,500-2,600 BC) populations along the Nile River valley began amassing and became increasingly sedentary as pastoralism and grain agriculture became the primary modes of subsistence (Wengrow 2006). Urbanized cities began to develop, most notably at Naqada, Hierakonpolis and Abydos. These urbanized centers would develop into proto-states, controlling labor, production and trade (Bard 1994). Unification of Upper (southern) and Lower (northern) Egypt occurred in 3,100 BC and marked the emergence of the Egyptian Empire and an institutionalized bureaucracy (Bard 2000). With the capital city, located in Memphis, the early Egyptian state maintained a powerful religious ideology complete with monumental architecture and a complex funerary tradition. However, archaeological evidence suggests Nubia was more dependent upon pastoralism than Egypt (Wetterstrom 1992). The A-Group culture of Lower Nubia and the Neolithic culture of Upper Nubia continued to herd cattle, goat and sheep through the Egyptian Predynastic. There was a considerable amount of trade, particularly gold, ivory and timber, supplied by Nubia to Egypt, which greatly expanded trade networks throughout Africa and Western Asia (Van den Brink and Levy 2002).

Table 2.1 Chronologies of Ancient Egypt and Nubia (Smith 1998)

Date B.C.	**Egypt (Dynasty)**	**Lower Nubia**	**Upper Nubia**
3,500-2,600	Predynastic/Early Dynastic (1-3)	A-Group	Neolithic
2,600-2,150	Old Kingdom (4-6)	Uncertain	Old Kerma
2,150-2,050	1st Intermediate Period (8-11)	C-Group	Old Kerma
2,050-1,650	Middle Kingdom (11-13)	C-Group	Middle Kerma
1,650-1,550	2nd Intermediate Period (14-17)	C-Group	Classic Kerma
1,550-1,050	New Kingdom (18-20)	C-Group	Recent Kerma
1,050-750	3rd Intermediate Period (21-24)	Uncertain	Pre-Napata
750-332	Late Period (25-30)	Uncertain	Napata

Located south of the 3rd cataract in Upper Nubia, the small settlement of Kerma began to expand around 2,500 BC (Kemp 2006). An atypically large floodplain in the region of Kerma facilitated the development of grain agriculture and a sedentary lifestyle. Over the next 500 years, the small city center of Kerma would grow into an immense and influential polity. By the Middle Kerma Period (2,050-1,650 BC), contemporary with the Egyptian Middle Kingdom, Kerma encompassed nearly all of Upper Nubia. Trade with Egypt continued to play a major role in Nubian expansion and connected Africa with Western Asia via Nubia. Likely threatened by Kerma's growth and power, the Egyptian Empire began initial expansion into Nubian territories beginning in the Egyptian Middle Kingdom Period (Bonnet and Valbelle 2006). First occurring in Lower Nubia and gradually moving further southward, Egypt successfully gained control of valuable trade routes in Nubia and therefore much of Africa. Fortifications along the Nile began to be constructed, making the Egyptian presence visible and well known. The implementation of Egyptian authority was poorly instituted during the Middle Kingdom and additionally was not well received in Nubia leading to the gradual abandonment of the strongholds (Trigger et al. 1996).

The Classic Kerma Period (1,750-1,500 BC) of Nubia is defined by large settlements and elite kings, reflected in elaborate burials. Furthermore, massive temple complexes were constructed representing a developed religious ideology. There is also evidence of substantial craft workshops and bronze production throughout Kerma territories (Bonnet 1992). The growing power of Nubia posed a serious threat to the Egyptian Empire, prompting further military expansion of

Egypt into Lower Nubia in 1,520 BC (Bard 2008). The extension of the Egyptian Empire would gradually subsume all of Lower Nubia and parts of Upper Nubia as well. The Egyptian New Kingdom Period (1,550-1,050 BC) is characterized by a territorially expansive state, which at its height not only controlled Nubia but additionally expanded northeastward subsuming Sinai, Canaan and Syria. Some have argued the prolonged concern with territorial expansion during this time was a reaction to the previous invasion of the Hyksos during the Second Intermediate (1,650-1,550 BC) (Oren 2004). Nevertheless, the Egyptian New Kingdom was a period of affluence, political upheaval and expansion.

The Egyptian New Kingdom is defined by the 18th, 19th and 20th dynasties. Much of the initial territorial expansion and military development occurred in the early New Kingdom under the reign of the Pharaoh Thutmoses I (1,506-1,493 BC) (Silverman 1997). Expansion of the Egyptian Empire on behalf of Thutmose I is directly visible at Tombos via several stelae adjacent to the Nile whose hieroglyphics boast of the conquest (Figure 2.1). This was only possible after Queen Hatshepsut (1,479-1,458 BC) greatly expanded and reinforced trade networks, including material exchange with Nubia. By the 14th century BC the majority of Nubia, up to the 4th cataract, was under control of Egypt with an imposed administrative center placed at Napata (Shaw 2000). Additionally, the Egyptian New Kingdom is often typified by a short-lived religious revolution instigated by a single pharaoh, Amenhotep IV (also known as Akhenaten). A Pharaoh of the 18th Dynasty, Amenhotep IV (1,353-1,336 BC) enforced an unconventional monotheistic religion, centered upon the god Aten (Bard 2008).

While Akhenaten's efforts were focused on religious transformation, he largely avoided the topic of international relations in all forms. This began the gradual decline of Egypt's territorial erosion and economic downturn. Egyptian control of Nubia would gradually wane over the next 500 years when Nubia would reclaim its independence and expand its territories (Trigger 1976).

Figure 2.1 Thutmoses I Stela at Tombos

By 850 BC strong Nubian rulers would emerge creating the Napatan Era, often considered Nubia's golden age (Morkot 2000). By 750 BC Nubia, ruled by the Napatans, conquered Egypt and established the 25th dynasty. The Napatan Dynasty is known for having continued traditional Egyptian cultural ideologies having been highly influenced by Egyptian culture from the earlier conquests. The Napatan Dynasty often portrayed themselves as the "saviors of Egyptian civilization" (Connah 2004). The end of the Late Period (750-332 BC) marks what most researchers agree to be the end of the ancient Egyptian era.

2.2. <u>The Significance of the Nile River</u>

The Nile River is crucial to the survival and growth of all life forms, including humans, in northeastern Africa. As discussed above, by 5,000 BC the extremely hot and arid climate that pervades the region today was in its infancy. Previous to this drastic environmental phase, human populations were supported by fruitful wadis and oases. However, this dramatic change in climate is associated with human settlement and dependence on the Nile River (Butzer 1976). Today the Nile River is the second largest river in the world, spanning a total length of 6,500 km (Shahin 2002). The Nile River serves as a lifeline to the inhabitants of Nubia and Egypt as it is not only the primary water supply to the region but is also rich in silt deposits creating fertile soil. The rich alluvium produces a prime landscape for farming. The extreme circumscription of fertile land, closely forming to the banks of the Nile River, as opposed to desert is sudden and is clearly visible with modern satellite imagery.

The Nile River has also served as a prime mode of transportation as well as a point of connection between Africa and Southwest Asia. Some organic materials, such as wood, do not preserve well in this region. Therefore, little is known of the earliest evidence of watercraft. However, there is strong evidence for advanced boating by the 4th millennium BC (Bard 2008). This would have required a great amount of both technical and geographic knowledge, particularly when taking the massive cataracts into consideration. The use of the Nile for transportation of both people and goods was also an extremely valuable function. Compared to alternative forms of transportation of the period (i.e. donkey, camel), the Nile would have served as the fastest method of transport. Nubia has been referred to as the “Corridor to Africa” (Adams 1977), a title which can be primarily attributed to the function of the Nile. The Nile River functionally connects sub-Saharan Africa to the Mediterranean, Southwest Asia, Europe and East Asia through Nubia and Egypt. The networks created through this exchange were significant both to the trade of material objects as well as innovative ideas and technologies. The Nile River continues to play a monumental role in Egypt and Sudan as it did in the past.

2.3. Previous Archaeological Research

As with the beginnings of archaeology in many regions of the world, early archaeology in Nubia and Egypt was substandard and ill-conceived. Furthermore, the motivations of these early archaeological endeavors are equally questionable. However, noteworthy discoveries were made during this period despite a poor methodological base. The inception of archaeology in Nubia began in the early 19th century when adventurous antiquarians began to travel to faraway and exotic locales. Initially, archaeological interest in the Nile Valley stemmed from an interest in rich Egyptian temples and tombs. Oftentimes these expeditions were funded by affluent gentry hoping to expand their private collections.

One of the first antiquarians to take interest in Nubia was John Lewis Burckhardt (1784-1817). With an initial focus in the Levant and the Middle East, Burckhardt spent many years developing his knowledge of Arabic and familiarity with the Islamic tradition. In his book *Travels in Nubia* (1819), Burckhardt put forward a comprehensive account of the region of Nubia. While Burckhardt's work wasn't directly involved with the material record of Nubia, it laid the fundamental groundwork for future archaeology (Edwards 2007).

A contemporary of Burckhardt, Giovanni Belzoni (1778-1824) conducted pseudo-archaeological investigations with a particular focus on ancient Egypt. In his book *Narrative of the Operations and Recent Discoveries within the Pyramids, Temples, Tombs and Excavations in Egypt and Nubia* (1820), Belzoni discussed great finds and the monumental architecture of Egypt. By today's standards, Belzoni's work would be considered looting and academically reprehensible (Phillipson 2005). For better or worse, Belzoni's written work assisted in the popularization of Ancient Egypt, encouraging other archaeological efforts.

Jean-Nicolas Huyot (1780-1844) was an architect by profession, specializing in ancient and classical structures. It was an extension of a professional interest that led Huyot to become involved in the prehistory of southwest Asia, Egypt, Nubia and Greece. In his 1822 work *Antiquités de la*

Nubie, Huyot recorded many of the written inscriptions on religious structures such as the Temple of Ramses II at Abu Simbel. Later, Huyot's replication of ancient inscriptions would help Jean-François Champollion decipher the written hieroglyphic text of Ancient Egypt (Edwards 2004).

The construction of the Aswan Dam has been a constant area of concern for both the wellbeing of the inhabitants of the Nile Valley as well as archaeological preservation. With the aim of controlling the water supply for agriculture and the prevention of river flooding, the lower Aswan Dam was constructed between 1899 and 1902. After soon realizing the original design of the dam did not control the river water as intended (it caused major flooding issues in unexpected areas), a new design involving raising the original dam was implemented in 1907. Due to the close proximity of archaeological sites to the floodplain, the extent of damage to the archaeological record was devastating. Federal funding was provided for archaeological survey and some excavation of the northern half of Egyptian Nubia, the area that would primarily be affected by the construction. The project continues to be a major archaeological issue today.

The dawn of the 20th century witnessed a new type of archaeology, one that would begin to extend beyond antiquarianism. Arthur Weigall (1880-1934) conducted the first scientifically motivated archaeological survey in Lower Nubia in 1905. Later Weigall would become passionately interested in the protection and conservation of archaeological material, particularly monuments. Funded by the Department of Antiquities, Weigall published a 15-volume encyclopedia, *Les*

Temples Immerges de la Nubie, which documented major historical monuments (Edwards 2004).

George A. Reisner (1867-1942) extended modern archaeological inquiry by performing systematic survey, mapping and recording of all archaeological sites investigated. In his first season, 1907-1908, Reisner methodically researched more than 50 cemeteries and occupation sites (Reisner 1908). Over a period of decades, Reisner collected an immense amount of data enabling him to develop the first culture sequence for Nubia (Table 2.2). While Reisner's culture sequence would later be debated, the chronology provided an established footing for further research. Perhaps most importantly, Reisner successfully defined Nubian culture as being separate than Egyptian culture. Reisner is also accredited with excavating the elaborate kingly burials from the Classic Kerma Period in his 1913-1916 field-seasons, uncovering many extraordinary finds. Based on his extensive research in Lower Nubia and the Kerma Period (Reisner 1923), Reisner suggested the elites and kings of Kerma were actually Egyptian governors, furthering the Egyptian power base. This is now considered to be incorrect; Kerma was a functionally independent polity. However, Reisner's interest and dedication to Nubian archaeology advanced the area of research greatly.

Table 2.2 Chronology of Ancient Nubia (Reisner, 1908)

Nubian	Egyptian
A-Group	Early Dynastic Period
B-Group	Old Kingdom
C-Group	First Intermediate Period and Middle Kingdom
D-Group	Indistinguishable from New Kingdom

With the onset of World War I, archaeological interests faded worldwide and all survey and excavations halted until 1929. However, after archaeological efforts were resumed there was a great expansion of previous archaeological research and a developed theoretical approach. Broader funding opportunities, provided by universities and national foundations, encouraged academic research. While a culture history approach persisted in the region, a more refined methodology of survey, excavation, record keeping and preservation became more standardized.

Walter Bryan Emory (1902-1971), a preeminent Egyptologist of the 20th century, conducted archaeological excavation in Nubia for several decades. Emory led *The Second Archaeological Survey of Nubia* (1929-1934) at Ballana and Qustul (Adams 2008). It was here that Emery further investigated the X-Group rulers and concluded they were once grand chiefs of Kerma. As the Field Director of the Archaeological Survey of Nubia, Emory surveyed and excavated numerous sites that were threatened by Nile flooding.

The Sudan Antiquities Service Excavation at Khartoum and Shaheinab (1944-1945, 1949), led by A.J. Arkell, was the first excavation instituted by the newly founded Sudan Antiquities Department, now known as the National Corporation for Antiquities and Museums. This excavation also marked the first interest in Nubian Paleolithic remains. Arkell identified unique Nubian Neolithic and Mesolithic traditions, separate than that of Egypt's (Adams 2008).

Complications with the Aswan Dam continued into the 20th century as proposed solutions failed to control the powerful Nile waters. In 1959 a plan for a completely new dam, approximately 4 miles upriver, was announced. It was well known that this addition would flood and permanently destroy an archaeologically rich area. Immediate recording, excavation and, in some cases, construction efforts began. Beginning in 1950, the Sudan Antiquities Service began regular excavations in Kor, Sai, Debeira and Buhen, each lasting over a decade. Several monuments were disassembled, moved to alternate locations then reconstructed for preservation. The temple at Abu Simbel is the best-known example of relocation efforts due to the construction of the Aswan High Dam, however other instances include temples at Kalabsha and Amada.

Charles Bonnet, in association with The University of Geneva, has led excavations in and around the city of Kerma for several decades (1965-present). Using both town and cemetery archaeological sites, Bonnet and colleagues have transformed our perception of Nubian complexity and scale prior to Egyptian imperialism. It has been said that Bonnet has "revolutionized our understanding of the geopolitics of northeast Africa" (Adams 2008:11). Continued archaeological efforts at Kerma provide substantial information about traditional Nubian society.

Recent research has focused on the cultural influence Egyptian occupation had on local Nubian populations. Morkot and Török hypothesize that Nubians were highly Egyptianized during the initial period of Egyptian control (Morkot 1991; Török 1995). This is indicated via burial practices, material remains and through evidence of religious ideology. Stuart Tyson Smith has also investigated Egyptian-Nubian interaction and suggests the association between Egyptians and Nubians is more complicated. Rather than the seemingly straightforward explanation of Nubians assimilating to Egyptian norms, Smith proposes a process of transculturation and ethnogenesis as both Nubians and Egyptians acclimated to distinct cultural practices (Smith 1998).

2.4. Summary

The prehistory and history of Nubia and is often contextually intertwined with the narrative of Ancient Egypt. Beginning as early as the Neolithic, distinct cultural traditions begin to define the two groups. The Egyptian Middle Kingdom marked initial Egyptian attempts to occupy Nubian territory. Through the success of several pharaohs concerned with territorial expansion and international trade, the New Kingdom is known for successfully controlling and partially colonizing Nubian territories. By the Napatan Period, Nubia would regain power and control and create a shadow empire of the once great Egyptian Empire. The Nile River serves many valuable functions to the inhabitants of Nubia and Egypt today as in the past. The river is crucial to water resources, land productivity, transport and trade. Archaeological efforts in Nubia have extended for nearly two centuries and have uncovered grandiose treasures as well as important information of ancient daily life. As with many areas of the world, the development of the discipline of archaeology as a science has taken time. Initial archaeological efforts were antiquarian in nature. Later, archaeological research would concentrate on a culture history approach. More recently, an anthropological perspective has been applied to studies of Ancient Nubia, pursuing topics such as culture contact between Egypt and Nubia. The future of archaeological work in Nubia will certainly prove to be fruitful and captivating.

CHAPTER 3. THEORETICAL APPROACH

The theoretical foundation of this research incorporates concepts from archaeology, biological anthropology and cultural anthropology. Through an analysis of imperialism and its variable forms I examine both the social and biological consequences of this sociopolitical process. Insights into identity theory, particularly those aspects associated with social identity, offer perspective on the interaction of biological forces in social groups. I also incorporate osteological theory by focusing on the materiality of skeletal remains, bone plasticity, and the osteological paradox, all of which develop skeletal indicators of activity patterns theoretically. The methodology of bioarchaeology, the study of human skeletal remains in an archaeological context, integrates and unites these three approaches.

3.1. Imperialism

Imperial societies have developed in virtually all areas of the world and have existed for thousands of years. Empires of the past have played a monumental and transformative role to inhabitants within the empire, those residing within occupied territories, as well as those beyond imperial borders. While many definitions of empire exist, most interpretations share the notion that an empire is a territorially expansive state, in which the dominant power exercises control over other sociopolitical entities. Empires often seek control of labor and trade resources as well as religious ideology of subject populations (Doyle 1986). The archaeology of empires poses great challenges to researchers due to their heterogeneous nature and shifting frontiers, the often rapid and dramatic processes of expansion and collapse, as well as geographic and organizational variability. However, archaeologists can begin to understand the processes of imperialism via art, architecture, artifacts, human skeletal remains, text, and landscape modification at local and regional scales.

Nearly all empires can be characterized by typological stages, namely expansion, consolidation and collapse. The following summary of the various stages of imperialisms contributes to an understanding of how an empire develops, functions, and expires. Furthermore, the process of imperial consolidation of power is particularly relevant to the Egyptian New Kingdom (1,550-1,050 BC) and the aggressive territorial expansion campaigns that characterized this period. The process of functionally incorporating Nubia, a region with a unique culture and identity, would have required extensive and varied methods of consolidation, including such tactics as the control of production and organization of labor as well as the promotion of local administrators. Additionally, the degree of diversity in which empires exist through time is significant and variable. Selected examples of the assortment of empires which have existed in the past will provide a framework to better understand the occurrence and effects of an empire. Analysis of the biocultural response of imperialism has been limited. Future research will certainly shed light on these effects an increase our anthropological understanding of empires.

3.1.1. Stages of Imperialism

According to Sinopoli (1994b), an empire is composed of three primary stages: expansion, consolidation, and collapse. Expansion is by definition necessary for the creation of an empire (Brumfiel 1989; Morrison and Sinopoli 1992). While motivations for the formation of an empire are variable, the bourgeoning empire must be territorially expansive. Empires frequently subsume regions with varied ethnic groups, incorporate ecologically diverse landscapes, and utilize a variety of political, economic, ideological and military strategies for expansion (D’Altroy 1992, Schreiber 1992; Smith and Schreiber 2006.) Methods of creating and extending imperial borders have ranged from diplomatic negotiation to outright force. However, many have argued that the fundamental factor to imperial legitimization and control of the hinterland is attained primarily via military power, both physical and ideological (Mann 1986). Furthermore, the variability with which empires can be created, as exampled by shadow empires (discussed below), is significant (Barfield 2001, Brumfiel 1989).

Consolidation of an empire, the process of incorporating foreign lands into imperial power systems, is imperative to maintaining control of both centers and peripheral territories. The process of consolidation is arguably the most important component of imperialism and the most difficult to achieve due to the distinct cultural traditions are inherently involved (Eisenstadt 1963; Schrieber

1987). The establishment of consolidation occurs via four primary mechanisms: political and administrative power, economic influence, military might, and ideological authority. These factors are interconnected and play varying roles of importance for each empire. Political, administrative, economic and ideological tactics of consolidation are particularly applicable to the analysis of Nubian populations subjugated by the Egyptian Empire during the New Kingdom and are therefore discussed in detail below. After a short period of initial military conquest occurring primarily during the reign of Thutmoses I (1,506-1,493 BC), the Egyptian Empire focused efforts on consolidating and incorporating Nubian communities, such as Tombos, into the greater imperial structure via control of production and organization of labor as well as the promotion of local administrators (Trigger et al. 1996).

The final stage of an empire is collapse or fragmentation, which typically involves the disintegration of centralized institutions that served to establish control and dependency between centers and subjugated territories (Yoffee 1988). The collapse of an empire can be due to a multitude of causation factors, including both internal (e.g. overcentralization, lack of communication, unsuccessful integration of elites) and external (e.g. conquest, environment, trade network collapse) elements. However, the collapse of the empire does not imply the collapse or disintegration of the civilization and culture.

3.1.2. Methods of Imperial Consolidation

The Egyptian Empire is known to have used various methods of imperial consolidation throughout its existence. As discussed in Chapter 2, beginning as early as the Old Kingdom and continuing through the Middle Kingdom, the Egyptian Empire implemented a military approach to expanding the boundaries of the empire. Even with the fortresses and semi-permanent Egyptian presence instituted in Nubia during the Middle Kingdom, the forcible coercion tactic was not effective in maintaining new territories. During the New Kingdom, the Egyptian Empire focused on consolidating the empire, creating more secure connections between Egypt and Nubia. Therefore, the following summary will focus on the political and administrative, economic and ideological foundations of imperial consolidation and less so on military consolidation.

The political strategies that empires utilize are a crucial means of controlling the subjugated population, regulating tributes and loyalties, as well as implementing new policy. Indirect rule is one way in which an empire can incorporate subjugated populations. In some instances, it is beneficial and advantageous for the local elite population to be absorbed into the imperial structure. Empires may also seek out control of everyday activities, particularly of the lower status populace, as a way of constant control. By defining physical movement an empire can more easily gain control of a defeated population.

Scenarios of indirect rule, the act of maintaining imperial control over the hinterland without direct governance by a displaced imperial official, often prove more successful in the process of consolidating territories. Oftentimes local administrative elites are placed in positions of power and serve to both supervise as well as enforce imperial policy of the region. The act of appointing local elites to positions of administrative and political power in subjugated areas helps to incorporate the influential community members into an imperial framework (Schreiber 1992). Appointing local leaders to an elevated political status can be effective in consolidating foreign territories for three primary reasons: 1) accepted revenue collection structures are already in place; 2) the existing political and administrative structure requires little to no change or implementation by the empire; and 3) if amendments to the political, administrative, or revenue systems are required, local populations are more willing to accept these changes if they are enforced by a known leader. Archaeologically, locally appointed elites can be identified through imperial elite material goods and symbolic elements of the empire. These material goods would serve to encourage and reward loyalty of followers (Brumfiel 1987).

An example of indirect rule includes the Han Dynasty (202 BC-AD 220), which instituted indirect rule over multiple conquered areas (the Korean Peninsula, The Gansu Corridor, the Yunnan province, the Lignan province and central Vietnam) with varying degrees of success (Allard 2006). As a method of consolidation the Han Empire appointed indigenous leaders to positions of power within the local framework of influence. These leaders were primarily responsible for enforcing imperial taxation, typically in the form of grain, salt or other valuable products. The local leaders were rewarded with symbols of authority including royal seals.

Evidence of locally appointed officials is present in Nubia during the New Kingdom and, more specifically, within the community of Tombos itself. Additionally, investigations into the ethnic and biological identity as well as mortuary analysis of Tombos have suggested these individuals may have been using symbols and modes of identification to work to their advantage within an imperial network (Buzon 2006, Smith 2003). It has been hypothesized elsewhere that Nubian local administrators from the New Kingdom era were incorporated into the imperial administration system (Trigger et al. 1996). This is supported by burial inclusions and architecture at Tombos and by the presence of elite material goods, which are oftentimes imperially symbolic (Smith 2003). Excavations in 2000 and 2002 revealed the remains of a mudbrick pyramid and attached chapel, with funerary inscriptions *in situ*. Funerary cones (clay stamps that create a frieze on the façade of the pyramid) excavated at Tombos indicate the tomb was intended for a high-ranking administrative official, Siamun and his mother Weren (Smith 2003; Smith pers. comm.). The inscription reads, "Honored by Osiris and Anubis, Master of the Divine Pavilion, the Scribe of the Treasury, Overseer of Foreign Lands, Siamun, [and] his wife [mother] the Mistress of the House Weren" (Smith 2003:141). This title represents a relatively high position in the hierarchy of Egyptian appointments, a third-level administrator to be exact. Siamun's title, in addition to the general size and grandeur of the tomb, suggest he was appointed by the Egyptian Empire and represented an elite socioeconomic status.

Another form of political control over subjugated populations includes the act of regulating and manipulating everyday physical activities. Empires may intentionally seek out control of mundane, everyday activities as a means to dictate both the physical body and the daily routine. This can be achieved via a change in community function as well as alterations to the level of trade and production. This form of control particularly applies to those individuals of a lower socioeconomic status due to the fact they are more likely to be employed in labor-intensive and physically demanding occupations. In this way, the manipulation of daily practices has been interpreted as political maneuvering (Silliman 2001). Those in power control daily and repetitive activities, which reshapes the way of life for the individual. This becomes a form of constant scrutiny as those in power compromise the social identity of particular groups, ethnicities or individuals (Foucault 1979).

Imperial ideological control can be imperative to the success of an empire. Research into imperial ideological control has recently focused imperial expansion and the legitimization of inequalities (Sinopoli 1994b). A prime example of the implementation of imperial ideology is discernable in Nubia during the New Kingdom period of expansion and consolidation. As discussed above, the Egyptian Empire expanded its imperial borders during the New Kingdom to include Nubia up to and including the Third Cataract region of Tombos. In addition to the administrative, political and economic controls discussed above, the Egyptian Empire also had an ideological influence over Nubian territories. Whether or not and the extent to which this ideological influence was imposed is not known. However, the presence of Egyptian culture is evident in the New Kingdom, Tombos population. Smith (1998) has hypothesized this was a process of transculturation, as Nubians acquired some aspects of Egyptian culture, yet maintained many of their traditional cultural practices. This is particularly evident in the burial practices of the time, which followed a traditional Egyptian style (extended, head to the west) as opposed to previous traditional Nubian burial practices (flexed, head to the east). Furthermore evidence of common religious practices as well as written text, also support this hypothesis. This process of transculturation had lasting effects on the Nubian culture. Recent excavations at Tombos, dating to the Napatan period, suggest continued Egyptianized burial practices (Smith, 2007). This is particularly interesting considering Nubians had regained control and had instituted themselves in a position of power as a shadow empire replacing the Egyptian Empire. The Nubians ruled both Egypt and Nubia as the 25th Pharaonic dynasty, maintaining Egyptianized traditions.

Imperial powers often expand and maintain control over a territory for economic purposes. Blanton (1996) suggests, "Economic causes of various sorts probably hold a position of causal priority in many instances of imperial expansion" (Blanton 1996:220). Imperialism has direct consequences for patterns of production, organization of labor as well as community administration (Brumfiel 1986, 1991a; Hastorf 1990; Hendon 1996), which directly correlates to bioarchaeological activity patterns (discussed further in Chapter 4, activity patterns are skeletal markers of physiological movement, which vary according to level of physical strain). Whether or not and to the degree with which an empire controls production, labor and administration varies depending on administrative structure, distance to accumulation points (i.e. the imperial capital or other primary or secondary centers), distribution of centralized institutions, and the economic and symbolic significance of the products.

Imperial control of labor and craft production is directly associated with activity patterns. There have been numerous archaeological studies emphasizing how imperial incorporation directly impacts intensification of production, which has direct consequences for intensity and amount of work required (Costin 2004, D'Altroy and Hastorf 2001, Hicks 1994, Sinopoli1994a, Smith 1994, Wattenmaker 1994). Furthermore, imperial tribute demands often take the form of labor resources, typically for public works, army service or communal agriculture. Most notably Brumfiel (1986, 1987, 1991a, 1991b, 1991c) has made significant advancements in this arena. Much of Brumfiel's work has focused on the pre-imperial Aztec, studying changes in the organization of labor with the introduction of the imperial political system. Additionally, Brumfiel has identified gendered production systems (1986, 1991c, 1996), particularly through imperial tribute demands for cloth.

3.1.3. Variations in Imperialisms

A multifaceted and comparative approach to the topic of empires is beneficial to discern the wide variety with which empires have existed in the past. For example, in Barfield's (2001) analysis of pastoral nomads of the Mongolian steppe, the topic of shadow empires is discussed. A shadow empire is a type of imperialism that exists in response to an opportunity created by a primary empire. This is an unconventional view of empires; pastoral nomads aren't traditionally categorized as an empire. However, Barfield makes a convincing argument that the anthropological definition of empire should be broadened. As early as the 3rd millennium BC, inhabitants of the steppe created a shadow empire, dependent upon the imperial expansion of China that was remarkably effective and successful. The Mongolian nomadic empire thrived primarily from pillaging, border trade, international re-export of luxury goods and tribute payments.

Due to the fact shadow empires serve a somewhat parasitic function of the primary empire, the livelihood and well being of the primary empire, or the memory thereof (as is the case with vulture empires and empires of nostalgia, discussed below), is crucial to the survival of the shadow empire. Using Barfield's (2001) example of the pastoral nomads, the political and economic prosperity of China was the lifeline to the Mongolian nomadic empire. Without the Chinese Empire the Mongolian nomads would have no opportunity to pillage, trade, re-export or receive tribute payment.

Barfield proposes three types of shadow empires: maritime trade empires, vulture empires and empires of nostalgia. Maritime trade empires are imperialisms in which a dominance, or monopoly, over exchange occurs, particularly with reference to ocean trade networks. This is often accomplished by controlling ports, river exchange systems or other naturally occurring marine and fluvial features. Minimal territorial expansion is required with this economic tactic; however, maritime trade empires are also vulnerable for this same reason. These empires cannot control trade networks for long periods of time without either expanding terrestrially to become an established empire. Otherwise, they will likely be overthrown by another maritime trade empire or shadow empire. Examples of maritime trade empires include the Athenian Empire as well as the Portuguese Indies Empire (Russell-Wood 1998).

The second type of shadow empire, a vulture empire, has direct relation and is particularly important to the study of Ancient Egypt and Nubia. Vulture empires are shadow empires established directly after a primary empire dissolves. The shadow empire is likely a nearby ally or competing hinterland province. The foundation of vulture empires lay in the failing political and economic structure of a primary empire and the advantageous action of a shadow empire. An excellent example of a vulture empire system occurred in the 10th century BC in Ancient Nubia. As discussed in Chapter 2, Nubia supplied trade goods, labor and raw materials to Egypt for millennia. Beginning in the Egyptian Middle Kingdom Period (2,050-1,650 BC) and continuing into the New Kingdom Period (1,550-1,050 BC), Egypt administered several military campaigns into Nubia with the aim of southward territorial expansion. This expansion was directed at controlling the trade and resources of Nubia. While Nubia was under Egyptian imperial control, the territory was considered to be a part of Egypt's political, economic and social system. During this time Nubia incorporated many aspects of Egyptian culture into their own, yet managed to remain distinct. Egypt utilized fortresses as initial centers for direct control within Nubia, but later incorporated local elite to ensure continued loyalty (Morkot 2001). As the Egyptian Empire began to wane (~1,050 BC) the Nubian polity based at Napata, began to gain considerable control and expand northwards into Egypt. Napata would grow to conquer and subsume the Egyptian Empire and its monarchs would rule as the Pharaonic 25th dynasty. Napatan rule was based on Egyptian political and economic models and functioned in much the same way. The Napatans can be classified as a vulture empire due to the fact it filled the void of the declining Egyptian Empire and created a viable powerbase. Napatan rule would thrive in Nubia for hundreds of years with a political, economic and social framework homogenous to its predecessor, the ancient Egyptian Empire (Welsby 1996).

Empires of nostalgia highlight the important memory effect imperialisms have on future generations and empires. Empires of nostalgia are centered on the remembrance of highly regarded primary empires. Their governments and bureaucratic structures are often modeled after the initial empire. Furthermore, idolized figureheads often continue to be worshipped, sometimes ever more so, during the empire of nostalgia. In this way, shadow empires can create a sense of tradition and lineage. However, Barfield (2001) notes empires of nostalgia cannot meet the basic prerequisites of an empire (i.e. centralized rule, direct control of a territory, a significant imperial center or sufficient amount of territory) (Barfield 2001:38). An example of an empire of nostalgia is the Carolingian Empire that was modeled after an idealized Roman Empire (Fichtenau 2000).

3.1.4. Biological Consequences of Imperialism

Bioarchaeological research examining the physical effects of imperialism on local populations has been limited. The bioarchaeological research that has been conducted on empires has greatly advanced our understanding of imperial systems (Andrushko 2007; Hutchinson 1996; Larsen and Milner 1994; Tung 2003). Empires have been known to decrease the health and quality of life of local populations. Declines in overall health and quality of life in local imperial populations are often due to a lack of dietary diversity, urban aggregation, tribute obligations, increased levels of violent conflict, modified ritual practices and forced relocation (Tung 2003). An excellent example of dietary restrictions enforced by an empire, which led to negative health consequences, is the maize dependence enforced by the Wari Empire of the Andes (Finucane et al. 2006; Hastorf and Johannessen 1993). There remains a gap in bioarchaeological investigation of the biological consequences of imperial incorporation of hinterland populations, particularly with reference to collective activity patterns (i.e. osteoarthritis, vertebral degeneration, musculoskeletal stress markers).

3.2. Social Identity

I argue that the community of Tombos experienced a form of shared social identity from collective experiences of imperialism and common activity patterns. Theories of embodiment and habitus both expound upon the social nature of repetitive activity patterns.

Traditionally examined by sociologists and cultural anthropologists, social identity is increasingly being investigated through archaeological and bioarchaeological approaches. Identity is defined as the ways in which individuals and groups are distinguished and distinguish themselves in their social relations with other individuals and collectivities. The formation of identity is constructed through multiple venues and is composed of several modes of identification such as ethnicity, religion, gender, social status, age, heritage, politics, nation, selfhood, embodiment, and being (Buikstra and Scott 2009, Meskell 2002).

Embodiment is the manner in which the body is shaped individually and socially during ontogeny (Joyce 2000b, Meskell 2001) and therefore is particularly applicable to the study of activity patterns as they too are formed in a similar manner. Through repetitive and continued physical action the skeletal body is shaped through life. Osteoarthritis, vertebral degeneration and musculoskeletal stress markers, therefore, can be viewed as osteological embodiment. Osteological activity patterns accrue over one's life and bioarchaeologically tell a story of the embodied action of the individual. "An embodied body represents, and is, a lived experience where the interplay of irreducible natural, social, cultural and physical phenomena are brought to fruition through each individual's resolution of external structures, embodied experience and choice" (Meskell 1998:159).

Applying Pierre Bourdieu's concept of habitus as defined in his classic book, *Outline of a Theory of Practice* (Bourdieu 1977), everyday repetitive activity and mundane motions can be incorporated into bioarchaeological theory. Osteoarthritis, vertebral degeneration and musculoskeletal stress markers are the physical responses of daily movement that Bourdieu describes. Sofaer (2006) suggests that habitus is illustrated in the literal embodiment of repetitive activity of the osteological record. The incorporation of embodiment and habitus into bioarchaeological theory represents a new wave of biocultural theory that is beginning to emerge within the discipline of anthropology.

The concept of social identity via age would certainly apply to this research, particularly when considering degenerative diseases such as osteoarthritis and vertebral degeneration. Furthermore, research directed at sexual division of labor at Tombos would prove equally fascinating. The limitations of ageing and sexing the population of Tombos do not allow for this control in the present study.

3.3. Osteological Theory

Osteological indicators of activity patterns directly relate to the social nature of the body in life and are corporeal correlates of physical actions. Osteological material, like material culture, can be rich in cultural and social information regarding past populations. Skeletal plasticity and Wolff's law, discussed below, physiologically influence musculoskeletal stress markers as the hypertrophy of these attachment sites occur with increased levels of activity and represent a reaction of the skeletal system to intense use. The osteological paradox is a bioarchaeological dilemma that addresses the disparity between the bioarchaeological interpretation of skeletal remains and the actual narrative of the skeletal remains. The osteological paradox is an issue that all bioarchaeologists should be aware of and incorporate into their research design and interpretations.

Current approaches to osteological theory combine the analysis of the physical and social body into a broader theoretical base. In traditional archaeological theory there is generally an ontological separation between the material record, or artifacts, and the osteological record, or skeletal remains (Sofaer 2006). Artifacts have been conventionally characterized as animate and plastic due to the creative and adaptable nature inherent in the process of production. The use of artifacts often extends beyond a purely utilitarian purpose to include social messages such as group identity and ideological statements. As such, artifacts can reflect rapid temporal variation as well as unique artistic statements.

Furthermore, living bodies are traditionally viewed as artifacts, dynamic and rich in cultural information, whereas dead bodies are typified as fixed and of limited value to social theory. However, if osteological material is approached through a theoretical perspective that acknowledges both the adaptable potential of skeletal material and the continuity of a cultural imprint from life to death, the skeleton possesses a social presence in death.

Drawing on Butler (1990, 1993) and Joyce (2000a, 2000b, 2003) several researchers have suggested that the enactment of cultural practices, as viewed from human skeletal remains, should be considered the materiality of the body

(Hamilakis et al. 2002, Meskell and Joyce 2003, Sofaer 2006, Thomas 2002). Due to the fact the body is actively involved in the formation and structuring of social practices it should be likened to a form of traditional material culture (Shanks and Tilley 1987:85). In this sense the human skeleton can be seen as a cultural construction molded by action via repeated social practices and habitual actions, as with any material artifact. Furthermore, like material culture, "Investigations of the skeleton become not simply about making and reporting a diagnosis, but about identifying the processes leading to the expression of osseous modifications or pathological conditions, in terms of the social practices that may have promoted them" (Sofaer 2006:134).

Bone plasticity, defined as "the capability of being molded" (Roberts 1995:1), accounts for the ability of skeletal material to change and adapt to its environment. While cultural adaptations to the environment are considerably effective, physiological adaptations are often overlooked (Roberts 1995). The skeleton is a living organism, made of a composite material of protein (collagen) and mineral (hydroxyapatite), giving it characteristics of both rigidity but also adaptability (Buzon et al. 2005). Using the principles of bone plasticity, bioarchaeologists can infer behavior patterns from variable skeletal structures (Larsen 1997). This phenomenon is illustrated in instances of non-adult malnutrition causing developmental retardation of the skeleton, resulting in shortened stature (Bogin 1999). In this sense, human skeletal remains can be regarded as a product of human action, "in much the same way as other forms of material culture" (Sofaer 2006:105).

Wolff's law, developed by anatomist and surgeon Julius Wolff, states that skeletal material will adapt to the mechanical loads in which it is placed (Wolff 1986). If repetitive stress or loading on a bone occurs, the skeletal structure will react to these forces and become stronger in an attempt to resist further stress because the bone is a living and changing entity. Well known examples include asymmetrical hypertrophy in primary handedness as seen sports such as tennis (Jones et al. 1977). Conversely, if physiologically loading on the bone decreases, the bone will become weaker. Astronauts often show signs of skeletal atrophy from lack of use associated with an absence of gravity (Morey and Baylink 1978).

In the past two decades there has been an ongoing debate within bioarchaeological literature, as researchers discuss the problematic nature of the skeletal material being studied. Wood and colleagues (1992) have summarized these points of contention and have coined the dilemma "The Osteological Paradox." The osteological paradox consists of three fundamental issues: demographic nonstationarity, selective mortality, and hidden heterogeneity in frailty (Wood et al. 1992). Demographic nonstationarity refers to the fact that the age distribution of a population with non-stationary characteristics (i.e. migration, a non-zero growth rate, a non-equilibrium age distribution) is sensitive to changes in fertility but not mortality. Selective mortality refers to the notion that the osteological record represents individuals who have died, not those that survived. Hidden heterogeneity involves the unknown level of susceptibility to disease and death of both the affected individual as well as within the entire population. This ‘hidden frailty’ could be due to genetic, socioeconomic, microenvironmental, or temporal trends. Hidden frailty has been combated with the introduction of multiple methodologies such as biodistance research and isotope analysis, which address these allegedly hidden issues from other perspectives. There have been several responses to Wood et al.’s (1992) original publication, ranging from complete rebuttal to selective application (Cohen 1994, Danforth 1999, Goodman 1993, 1998, Milner et al. 2000, Storey 1997). As Wright and Yoder (2003) suggest, future research, primarily in the fields of demography, biodistance, paleodiet, growth disruption, and paleopathology, will offer new insight into methods of accounting for the osteological paradox. As suggested by Goodman (1993) this research will employ a multiple-indicator methodology in the analysis of osteoarthritis, musculoskeletal stress markers, and vertebral degeneration.

3.4. Summary

My thesis research, the bioarchaeological analysis of activity patterns in imperial-controlled Nubia, directly relates to archaeology, cultural anthropology and biological anthropology approaches. I will use the theoretical perspectives of imperialism, identity, and osteological principles to better inform this project and situate it within a broader anthropological perspective. The effects of imperialism, from the bioarchaeological vantage of activity patterns, have yet to be researched. The various stages of empires are pertinent to understanding both the organization and function of empires. Further, efforts of Egyptian imperial consolidation are particularly applicable to New Kingdom Nubia. During this time, Egypt focused its consolidation efforts on the administrative, political, economic and ideological arenas to incorporate Nubia as a functional and cooperative protectorate of the Empire. Empires also exist within a wide array of forms and functions. An overview of the various types of empires provides context with which one can analyze specific empires and their affects on populations. I argue, through shared experiences of imperialism, culture and physical activities Nubian communities, such as Tombos, likely shared a collective social identity. The bioarchaeological analysis of activity patterns has the potential to reveal such a social identity as I have suggested, particularly if levels of activity are common throughout the population. With this research I hope to better understand the role of the community Tombos within the greater Egyptian Empire and investigate the biological outcomes of imperialism via activity patterns.

CHAPTER 4. METHODS

Physical activity and movement are defining characteristics of human life. Bioarchaeologists can approach this topic by attempting to reconstruct behavioral patterns of past populations by analyzing human skeletal remains in an archaeological context. Primary modes of analysis for understanding activity patterns include degenerative joint disease (DJD) and musculoskeletal stress markers (MSM). These methods have a long history of success in interpreting behavior via skeletal material within the disciplines of bioarchaeology, paleopathology and anthropology as a whole, and continue to be valuable resources in assessing past populations. As discussed in Chapter 1, it is in this way that bioarchaeology offers unique insight into past populations due to the combination of biological data and cultural interpretation. This chapter elucidates the pathological conditions, etiologies and previous research of DJD and MSMs and serves to detail the sample collection and methodology utilized in this study.

4.1. Degenerative Joint Disease

Degenerative joint disease (DJD) is a broad pathological term, which encompasses many physiological disorders. Although the etiology of DJD is multi-factorial, there is a strong mechanical component to the disorder involving the general wear and tear of joint systems. The impact DJD has had on all human populations cannot be underestimated, "Joint disease is the most frequent type of post-cranial pathology to be found in both skeletal material and in modern populations" (Rogers 2000:163), making it applicable and significant to further studies of both past and present populations.

Osteoarthritis (OA), the most commonly occurring pathological condition of all DJDs, is a degenerative disorder that affects synovial, or freely moving, joint systems. Synovial joints, also known as diarthrodial joints, are highly complex structures, which are designed to allow sustained repetitive movement. Examples of synovial joints in the human skeletal system include the hip, elbow, knee, hands and feet. A synovial joint consists of a complex, codependent system of soft tissue structures. The joint cavity lies between the two adjoining bones and secretes synovial fluid, which in turn nourishes crucial cartilage cells. Additionally, the bones involved in a synovial joint system are coated with hyaline cartilage, a specialized lubricant which serves to ease motion, stress and repetitive activity. A defining feature of a synovial joint is the fibrous joint capsule, which confines the joint system with the support of ligaments. This complex soft tissue system serves to maximize durability within the joint as well as to encourage smooth movement with minimal friction.

Two broad categories, primary OA and secondary OA, define general causation factors of osteoarthritis. Primary OA occurs in the absence of underlying predisposing conditions. Primary OA is the most common type of OA and therefore the predominant focus of study for bioarchaeologists. Secondary

OA is attributed to an existing pathological condition or specific traumatic event. Examples include cases of acute trauma, congenital or developmental diseases (Duncan 1979; Moskowitz 1987). Oftentimes secondary OA is difficult to assess solely from skeletal material due to the wide array of potential causation factors.

As a synovial joint capsule begins to deteriorate, either due to primary or secondary OA, the body's automatic physiological reaction attempts to repair it. Initially this begins within the soft tissue systems, with efforts made to mend the damaged soft tissue element (e.g. hyaline cartilage, joint capsule). Furthermore, this natural response is an attempt to minimize further damage. If, however, the condition cannot be repaired and continues to worsen, further skeletal reactions can occur.

The osteological response of new bone growth occurs in two primary locations, at the joint surface and at the joint margins. The bone growths located on the margins of the joint system are termed osteophytes, also known as osteophytic growths. Osteophytes can range in size from minute bony projections to marked curved spicules. These growths are the body's natural attempt to stabilize the joint and offer extra support from an insufficient soft tissue system. Additionally, a common characteristic of OA is the presence of small, irregularly shaped perforations on the joint surface, a condition generally referred to as porosity. Jurmain (1999) suggests porosity may be due to attempts to repair damaged cartilaginous tissue, although the exact causation remains unknown. Porosity is always accompanied with osteophytic growths, suggesting it reflects exacerbation of the OA condition.

If the entire cartilage system is worn away a condition known as eburnation, or bone on bone contact, can occur. Eburnation results in a polished or ivory-like appearance on the articulating surfaces of the bones of the affected joint system. Eburnation is very painful; at this stage of the pathological condition no cartilaginous buffer exists between the two bones of the joint system. With continued movement and loading, the joint surface can become grooved with striations forming along the line of motion. These are indicators of more severe eburnation as the bone-on-bone contact continues to grind furrows into the bone surface. In the latter stages of the pathological condition, bone growths can become so severe that they impede the physical movement of the joint. Complete fusion of the joint system can occur and would not have been functional in life. The exact progression of the various conditions involved in the degenerative process of joint systems is not perfectly understood (Sokoloff 1969). However, the process of joint degeneration is generally considered to follow the sequence outlined above (Milgram 1983).

The etiology of OA remains debated, but most certainly is highly affected by mechanical strain during life (Cope et al. 2004; Jurmain 1977; Lovell and Dublenko 1999; Ortner 1968; Radin 1982, 1983; Šlaus 2000; Waldron 1997). As technology improves and interdisciplinary research is pursued, the multi-factorial nature of OA is just beginning to be revealed. Some research has indicated a genetic factor to the pathological condition (Harper and Nuki 1980; Spector et al. 1999). Other influences include sex, diet, trauma, metabolic levels and weight (Heliovaarna et al. 1993; Waldron 1994; Weiss 2006). These characteristics are often seen as predispositions to OA, and when combined with leading causes (i.e. increased activity throughout life and aging) result in the pathological condition. Due to OA's multi-factorial etiology, Sokoloff (1980:1) has suggested we view OA not as a single condition with a single etiology, rather conceptually as an incident of "joint failure."

Recently, the relationship between activity patterns and OA has been questioned due to some studies resulting in negative correlations (Jurmain 1999). While most researchers agree there are parallels between activity levels and OA, the relationship should not be assumed to be an absolute one (Jurmain 1999:30). Therefore, when osteologically diagnosing OA two of the four conditions should be present (Rogers et al. 1987:185; Rogers and Waldron 1995):

a) Osteophytic growths

b) Porosity

c) Subchondral bone reaction (including eburnation)

d) Alteration of joint contours (including fusion)

This strict criterion for paleopathologically diagnosing OA has been utilized in multiple osteological analyses and additionally enables inter-population comparisons (Rogers and Waldron 1995; Cassidy 1984; Waldron 1992).

The association between both frequency as well as severity of OA and activity patterns has been a topic of anthropological research for decades (Jurmain 1977, 1999; Larsen et al. 1995). In Angel's (1966) pioneering approach to understanding prehistoric activity patterns, he associated degenerative changes in the elbow with the intense and repetitive activity of spear or javelin throwing. Angel termed this condition at this particular anatomical location ‘atlatl elbow’.

Bioarchaeologists have expanded this idea and have researched the relationship between OA and occupational patterning. Some studies of prehistoric modes of subsistence have reflected positive correlations with the presence of OA (Jurmain 1990; Lieverse et al. 2007; Mieklejohn et al. 1983; Molleson 1989; Pickering 1979; Wells 1964). Elevated levels of OA in the elbow led Merbs and Euler (1985) to infer habitual activity patterns in an Anasazi population. In fact, the increased levels of wear observed on the flexion-extension plain of the elbow joints were interpreted as the result of the grinding action affiliated with the use of metates and has since been coined ‘metate elbow’. Some authors have furthered this research and have deduced a sexual division of labor (Walker and Holliman 1989). However, specific knowledge of past lifeways in needed in order to make strong associations between specific occupations and OA. This can be accomplished via ethnographic, archaeological or historic evidence for support. Without this information the association between OA and distinct occupations, particularly in prehistoric populations, should be avoided (Waldron 1994).

With the assistance of written records and known occupational stresses, historical samples are often used for behavioral reconstruction studies (Anderson et al. 1962; Angel et al. 1987; Edynak 1976; Kelley and Angel 1987; Merbs, 1983; Owsley et al. 1987). For example, Merbs (1983) conducted a multifaceted study of the Saddlermuit Eskimo by analyzing dental pathological conditions, dental wear, MSMs and OA. With detailed ethnographic accounts of labor patterns and repetitive activities as well as a supporting archaeological record, Merbs reconstructed 20 activity patterns. High levels of OA in the wrist led Merbs to conclude activities associated with hide preparation such as scraping, cutting and sewing of skins. Other examples of Merbs' hypothesized activities include harpooning, kayaking, paddling, tobogganing, as well as the use of dentition to soften hides.

In previous osteoarthritis research there has been a general dichotomy between a clinical and a bioarchaeological approach. Each perspective offers distinct advantages over the other. A clinical approach to the analysis of OA has the advantage of a patient's verbal description of the location and intensity of associated pain. This information can be priceless both to diagnosis as well as the epidemiology of the pathological condition. Conversely, bioarchaeology doesn't possess this advantage, as there is no verbal communication between the researcher and the subject of analyses. However, the benefit of being able to view the actual skeletal material is also valuable and, other than radiology, is unavailable to clinicians.

Several clinical studies of osteoarthritis have looked at the pathological conditions associated with modern occupations such as farmers (Thelin 1990; Croft et al. 1992), textile workers (Hadler et al. 1978), miners (Lawrence 1955, Schlomka et al. 1955; Kellgren and Lawrence 1958; Anderston et al. 1962) and construction workers (Stenlund 1993). Furthermore, there is an expansive amount of clinical research on the association between sports and degenerative joint disease. Positive correlations between osteoarthritis and the repetitive use of joint systems of following sports have been identified: general exercise (Panush and Brown 1987), baseball pitchers (Woods et al. 1973; Hansen 1982), football players (Brodelius 1961; Chantraine 1985; Moretz et al. 1984; Rall et al. 1964; Solonen 1966; Vincelette et al. 1972), ballet dancers (Brodelius 1961), weight-lifters (Aggrawal et al. 1979) and swimmers (Stulberg et al. 1980).

4.2. Vertebral Pathology

Vertebral pathological conditions are often grouped together; however, they represent numerous diseases, each with distinct qualities, etiologies and effects. For this study, I will focus my research of the vertebral column to two degenerative joint diseases, vertebral osteophytosis and Schmorl's nodes. These conditions have unique skeletal markers, but share a primary causation factor – physiological stress.

4.2.1. Vertebral Osteophytosis

The joints that comprise the vertebral column are defined as amphiarthrodial, or somewhat mobile, joint systems. As opposed to diarthrodial joints that encourage movement, amphiarthrodial joints serve to stabilize and reinforce. Other examples of amphiarthrodial joints in the human skeleton include the pubic symphysis and the distal tibiofibular articulation. Vertebral bodies are separated by both fibrocartilage and hyaline cartilage, supporting the constant forces the spinal column receives.

Both cartilage systems are susceptible to degenerative joint disease, leading to osteophytic bone growths particularly around the marginal surfaces of the vertebral bodies. Like other forms of non-vertebral OA, these bone growths have several monikers, including osteophytosis and vertebral osteophytosis (VOP). While osteoarthritis in the non-vertebral skeleton is very similar and related to VOP, the conditions are treated separately, both terminologically and in their interpretation (Jurmain 1999:13). By definition osteoarthritis affects diarthrodial joints, not amphiarthrodial joint systems, although the degenerative pathological conditions are very similar (Larsen 1997; Ortner 2003). Therefore, the term osteoarthritis is generally avoided when referring to the vertebral column.

VOP can become so severe two or more vertebral bodies can be fused together. This condition is known as ankylosis and would have resulted in very limited mobility of the spinal column in life. Additionally, VOP on the dens protuberance of the second cervical vertebra and articulating first cervical vertebral facet are frequent locations for VOP and eburnation attributed to repetitive neck movement in life. Typically, the area most affected by VOP is the lumbar region, followed by the cervical vertebrae, while the thoracic vertebrae are usually the least affected (Jurmain 1999:117). This universal patterning has been attributed to a bipedal gait stemming from the change in the distribution of force through human evolutionary history (Bridges 1994; Jurmain and Kilgore 1995).

The etiological factors of VOP, like OA, are conflated by several predisposing conditions. Previous osteological analyses of VOP have proven a positive association between the condition and the activity patterns of past populations (Bridges 1994). However, there remains a strong aging component that has been exhibited in both clinical (Nathan 1962) as well bioarchaeological studies (Merbs 1983). Further research into both the clinical causes and skeletal effects of VOP would provide a broader knowledge base of this pathological condition.

4.2.2. Schmorl's Nodes

Independently defined by Schmorl and Putschar in 1927, Schmorl's nodes are vertebral lesions found on both the superior and inferior surfaces of vertebral bodies. In the osteological record these lesions typically appear as small, shallow, circular or semi-circular depressions and are generally found near the center of the vertebral body (Kelley 1982). Etiologically, these indentations have been interpreted to be cartilaginous nodes (Schmorl and Junghanns 1971) and are thought to reflect herniations of the vertebral disc in life (Resnick and Niwayama 1978). Some research has suggested a predisposition to the disorder with the presence of fissures or weakening of the vertebrae (Jurmain 1990; Schmorl and Junghanns 1971). Life events responsible for vertebral herniations and weakening of the vertebral body can be attributed to physically stressful activities (Angel 1971; Kelley 1982). However, the complete etiology of Schmorl's nodes is probably mutli-factorial. Other contributing factors may include infection, metabolic disorders and cases of acute trauma (Resnick and Niwayama 1978).

A limited body of research exists on Schmorl's nodes both in a biomedical and bioarchaeological context. There does appear to be a consensus among researchers regarding a prevalence of the condition particularly in the lower thoracic and upper lumbar regions (Begg 1954). Strong mechanical causation factors have encouraged previous bioarchaeological analysis of Schmorl's nodes, which have shown positive correlations between the pathological condition and activity patterns. Kelley (1982) compared two samples, Mobridge and Indian Knoll, each representing a temporal classification of Native American populations. Kelley found increased rates of Schmorl's nodes through time and attributed this phenomenon to increased rates of physical activity. Üstündag performed a detailed study, analyzing a medieval skeletal sample from Klostermarienberg, Austria. By comparing the prevalence of Schmorl's nodes between age groups, the sexes and other pathological disorders (e.g. vertebral osteophytosis, apophyseal osteoarthritis), Üstündag formed a distribution of the pathological condition within a specific population (Üstündag 2008).

4.3. Musculoskeletal Stress Markers

Musculoskeletal stress markers (MSMs) are distinct, abnormal bone growths that are attributed to the ossification and hypertrophy of tendon and ligament attachment sites. These atypical attachment sites are interpreted as a biological response to long-term, repetitive and strenuous activities that cause increased muscle mass and therefore necessitate a stronger mode of attachment (Rogers and Waldron 1995). Muscle attachment sites are also known as entheses and when accentuated, as seen in MSMs, the term enthesiopathies can also be used, highlighting the pathological nature of these growths (Dutour 1986). Additionally, these new bone growths serve to distribute strain and abnormal stressors more equally.

The human body depends on secure attachments between muscle and bone for any type of movement. Tendons, dense fibrous connective tissues, serve to fasten muscle to bone. Ligaments are present in joint systems and functionally connect bone to bone. This distinction is important when analyzing MSMs because while MSMs are often referred to as muscle attachments, they are technically tendonous and ligamentous attachment sites. However, in osteological literature the terms muscle, tendon, and ligament attachment sites as well as MSMs are generally used interchangeably.

MSMs can range in size and shape, from a slight outline of the muscle attachment site to a deep, lesion-like furrow. As stated above, the condition is thought to begin with a general strain on a muscle or muscle group due to continued physical overuse. This overworked muscle system initiates the osteological growth of stronger, more secure, tendonous and ligamentous attachments sites. If the same physical activities causing the strain continue at the same, or worsened levels, the ossification process will persist and MSMs will grow to be larger, roughened patches encompassing the entire attachment site. The process discussed above can be summarized as osteological changes associated with muscle robusticity. These bony alterations are thought to be natural, osteological responses to behavior and reflect long-term, physically strenuous activity.

However, if the initiating physical strain continues, or acute trauma occurs to the affected area, lesions and associated porosity can appear. This degenerative process begins with a shallow pitting, typically localized at the center of the once robust MSM. This condition, often referred to as a stress lesion, can worsen to a state of almost complete obliteration of the muscle attachment site and can resemble a lytic lesion (moderate to severe destruction bone surface due to a disease process). Some believe the distinction between robusticity and stress lesions is the body's natural response limit to repetitive activity (i.e. the body can no longer maintain the muscle attachment site needed to sustain such levels of physical activity).

The etiology of MSM remains complicated by a deficient source of medical research and literature due to a virtually complete lack of symptoms and impact on health in life. Like OA, MSMs are most certainly caused by many factors, including trauma, inflammation, endocrine conditions and metabolic levels (Resnick and Niwayama 1983). Although much research has suggested the strongest component in the formation and severity of MSMs is repetitive and strenuous activity (Hawkey and Merbs 1995; Dutour 1986).

The relationship between repetitive stress and MSMs has been shown in previous analysis of athletes and sports-related injuries (Lehman 1984). This is a particularly good venue for studying MSMs because of the acute and known stressors on specific areas of the body. Common sport-related injuries such as tennis elbow, golfer's knee as well as jumper's knee are all associated with MSM.

In the past, one of the major arguments against bioarchaeological investigations into MSMs was a lack of a cohesive scoring methodology (Jurmain 1990; Robb 1997). In a bioarchaeological effort to accurately record and draw conclusions from MSMs several methodologies have since been developed. Used in this study, Hawkey and Merbs (1995) defined a scoring system based on a 0-6 scale. Scores from 0-3 established the robusticity of the MSM and reflect patterns of repetitive use. Scores from 4-6 reflect lesion development and are thought to be due to acute trauma to the ligament or tendon. These attributes are generally thought to occur on a continuum, beginning with slight outline of the MSM and increasing to a deep furrowed indentation, as discussed above. Another similar scoring system is outlined in Steen's approach (Steen et al. 1996) although Hawkey and Merbs is the most common scoring procedure utilized in bioarchaeological analysis. Both inter- and intra-observer error has proven Hawkey and Merbs' (1995) method to be a reliable one, with results that can be accurately replicated (Peterson 1998). Additionally a systematic and consistent scoring procedure is necessary for comparisons between populations.

MSMs are particularly useful to bioarchaeologists attempting to reconstruct behavioral activities of past peoples. Several studies have shown a direct and strong relationship between the degree and type of muscle attachment site and stress of a specific muscle or group of muscles. Many have associated MSMs with both habitual and specific activities (Sperduti 1997; Dutour 1986). In the same vein of Angel (1966), Kennedy (1989, 1998) has interpreted a combination of specific MSMs as the outcome of specific prehistoric activity patterns, namely atlatl and spear throwing. Dutour (1986) associated three distinct types of lesions with specific actions involved in javelin throwing, woodcutting and archery.

Some researchers have gone so far as to associate specific occupations with particular MSM patterning (Lai and Lovell 1992). However, more recently, inferring occupation based strictly on MSM data has been strongly discouraged (Jurmain 1999). Movement in any given occupation can be very complicated and involve the use of several muscles and groups of muscles. Interpreting levels of activity from MSMs is generally accepted, however, making conclusions regarding specific occupations from that data is ill advised. Additionally, previous bioarchaeological analysis has shown associations between mode of subsistence and MSMs (Bridges 1991; Eshed et al. 2004; Robb 1997).

Several studies have shown a direct correlation between age and occurrence of MSM (Molnar 2006; Weiss 2003, 2004; Wilczak 1998). Stirland (1993) notes the importance of both sex and age analyses as well as the functional importance of recognizing muscles work together and not individually. However, the fact that any given movement is typically controlled by a group of muscles working at various degrees of operational capacity rather than a single muscular action should always be incorporated into analysis (Stirland 1998).

4.4. A Multidimensional Approach

As discussed above, when analyzed separately both degenerative joint diseases and musculoskeletal stress markers are limited in the anthropological information they can provide. Due to the fact that several of the pathological conditions discussed have multi-factorial etiologies, associating particular activities with specific conditions is not recommended (Weiss, 2009). However, by combining data from several indicators of mechanical stress (i.e. osteoarthritis, vertebral osteophytosis, Schmorl's nodes and musculoskeletal stress markers), we can interpret these data to elucidate overall activity patterns of prehistoric populations. While this methodological approach is also limited in that we cannot determine specific occupations or activity patterns of individuals, on a population scale, we can determine overall levels of activity within communities and relate these data to information gleaned about their lifestyle from other archaeological and historical sources.

4.5. The Sample

The Tombos skeletal collection was previously excavated by Dr. Michele Buzon and colleagues during the University of California at Santa Barbara's 2000 and 2002 archaeological field seasons. An Egyptian-style pyramid, funerary chapel, an adjacent alleyway, and underground mudbrick chamber tombs were excavated and inventoried. The minimum number of individuals of (n=100) was established based on the skeletal remains whose funerary context could be confirmed. The skeletal sample consisted of 44 females, 30 males, 11 individuals of indeterminate sex and 15 non-adults (Table 4.1). All individuals dated to the late 18th or early 19th dynasty of the Egyptian New Kingdom (1,400-1,250 BC). The majority of skeletal samples (94) derived from the middle-class cemetery as compared to the six individuals who were buried in the Egyptian-style pyramid.

Table 4.1 Sex Distribution of Tombos Skeletal Sample

	Tombos Skeletal Sample
Female	44
Male	30
Indeterminate	11
Non-adult	15
Total	100

The majority of skeletal samples were previously aged and sexed by Buzon and colleagues. Sex was determined by visual analysis of the os coxae and cranial morphology with reference to Buikstra and Ubelaker (1994) as well as by the use of regression equations calculated from long bone measurement. Age was determined by pubic symphysis physiology, cranial suture closure and dental development (Buikstra and Ubelaker 1994), as well as tooth wear (Walker et al. 1991). Individuals were divided into age categories of young adult (18-29 years), middle adult (30-45 years) and old adult (46+ years).

4.6. Methods Utilized

A total of 9 joint systems were analyzed for osteoarthritis, 54 muscle attachment sites (24 upper body and 30 lower body) were analyzed for musculoskeletal stress markers and all sections of vertebrae were analyzed for vertebral osteophytosis and Schmorl's nodes. All applicable skeletal material from the Tombos collection was examined at the macroscopic level. Buzon's previously determined sex and age identifications were utilized in this study. Skeletal material that had not previously been assigned a sex was done so via analysis of os coxae morphology using Buikstra and Ubelaker (1994). Additionally, age categorization was also adopted from Buzon (2004) (i.e. young adult (18-29 years), middle adult (30-45 years) and old adult (46+ years). However, non-adults were not included in the sample due to their constantly adapting and growing skeletal system that alters the location, position and size of muscle attachments sites as well as a the formation of osteoarthritis (Currey 2002; Enlow 1976). Poorly preserved specimens were not included in analysis, enabling a more accurate interpretation of the osteological record. Additionally, samples affected by other pathological conditions were not considered due to the potential repercussions on both the joint systems as well as musculoskeletal systems from altered forms of use.

4.6.1. Osteoarthritis

The degree of osteoarthritic lipping, surface porosity and eburnation was scored according to the standardized method proposed by Buikstra and Ubelaker (1994) (Appendix A). The following joint systems were analyzed:

Table 4.2 Joints and Corresponding Anatomical Locations Analyzed for Osteoarthritis

	Bones of Joint	**Anatomical Location**
Upper Body	Scapula/Humerus	Shoulder
	Humerus/Ulna	Elbow
	Humerus/Radius	Elbow
	Ulna/Carpal	Wrist
	Radius/Carpal	Wrist
Lower Body	Femur/Os Coxae	Hip
	Femur/Tibia	Knee
	Tibia/Fibula	Knee & Ankle
	Tibia/Tarsal	Ankle

Analysis of these joint systems included the following bone segments: the glenoid fossa of the scapula, proximal humerus, distal humerus, proximal radius, distal radius, proximal ulna, distal ulna, the acetabulum of the os coxae, proximal femur, distal femur, proximal tibia, distal tibia, proximal fibula and distal fibula. These joint systems were selected based on their involvement in major appendage function as well as representation of general patterns of movement in daily life. Skeletal material was scored if a minimum of 50% of the joint system was present. As indicated by Buikstra and Ubelaker (1994), the maximum expression of the osteoarthritic feature was recorded.

4.6.2. Vertebral Pathology

Vertebral osteophytic lipping and Schmorl's nodes were scored according to Buikstra and Ubelaker (1994) (Appendix A). Vertebrae were divided between cervical, thoracic, lumbar and sacral sections. When possible, the specific vertebra (e.g. C1, T4, L2) was noted for further analysis. Data was collected if 50% of the joint system (i.e. complete vertebral body surface) was present. Similar to osteoarthritis, the maximum expression of the pathological feature was recorded.

4.6.3. Musculoskeletal Stress Markers

Muscle attachment sites were scored according to Hawkey and Merbs (1995) (Appendix A). Samples were scored if the entire muscle attachment site was present. A total of 54 muscle attachment sites (Tables 4.3 and 4.4) were chosen for their broad representation of general activity patterns involved in principle physiological motions. Additionally, these muscle attachment sites have been utilized and proven successful in previous research (Hawkey and Merbs 1995; Chapman 1997; Peterson 1998). Success in prior analysis not only bolsters confidence in the methodology but also allows for comparison between samples.

Table 4.3 Muscle Attachment Sites, Associated Bone and Type of Attachment of the Upper Body Included in this Analysis

Muscle Attachment Site	**Bone**	**Type of Attachment**
Conoid	Clavicle	Ligament
Costoclavicular	Clavicle	Ligament
Subclavius	Clavicle	Tendon Insertion
Trapezius	Clavicle	Tendon Insertion
Trapezoid	Clavicle	Ligament
Pectoralis minor	Scapula	Tendon Insertion
Trapezius	Scapula	Tendon Insertion
Deltoideus	Humerus	Tendon Insertion
Common Extensors	Humerus	Tendon Origin
Common Flexors	Humerus	Tendon Origin
Infraspinatous	Humerus	Tendon Insertion
Latissimus dorsi	Humerus	Tendon Insertion
Pectoralis Major	Humerus	Tendon Insertion
Subscapularis	Humerus	Tendon Insertion
Supraspinatus	Humerus	Tendon Insertion
Teres Major	Humerus	Tendon Insertion
Teres Minor	Humerus	Tendon Insertion
Anconeus	Ulna	Tendon Insertion
Brachialis	Ulna	Tendon Insertion
Pronator quadratus	Ulna	Tendon Origin
Tricpes brachii	Ulna	Tendon Insertion
Biceps brachii	Radius	Tendon Insertion
Pronator Teres	Radius	Tendon Insertion
Supinator	Radius	Tendon Insertion

Table 4.4 Muscle Attachment Sites, Associated Bone and Type of Attachment of the Lower Body Included in this Analysis

Muscle Attachment Site	**Bone**	**Type of Attachment**
Adductor magnus	Os Coxae	Tendon Origin
Biceps femoris	Os Coxae	Tendon Origin
Gluteus maximus	Os Coxae	Tendon Origin
Gluteus medius	Os Coxae	Tendon Origin
Gluteus minimus	Os Coxae	Tendon Origin
Illiacus	Os Coxae	Tendon Origin
Pectineus	Os Coxae	Tendon Origin
Quadratus femoris	Os Coxae	Tendon Origin
Rectus femoris	Os Coxae	Tendon Origin
Semimembranosus	Os Coxae	Tendon Origin
Adductor magnus	Femur	Tendon Insertion
Gastrocnemius	Femur	Tendon Origin
Gluteus maximus	Femur	Tendon Insertion
Gluteus medius	Femur	Tendon Insertion
Gluteus minimus	Femur	Tendon Insertion
Illiacus	Femur	Tendon Insertion
Obturator Externus	Femur	Tendon Insertion
Pectineus	Femur	Tendon Insertion
Piriformis	Femur	Tendon Insertion
Popliteus	Femur	Tendon Origin
Quadratus femoris	Femur	Tendon Insertion
Vastus intermedius	Femur	Tendon Origin
Vastus lateralis	Femur	Tendon Origin
Vastus medialis	Femur	Tendon Origin
Flexor digitorum	Tibia	Tendon Origin
Popliteus	Tibia	Tendon Insertion
Soleus	Tibia	Tendon Origin
Semimembranosus	Tibia	Tendon Insertion
Tibialis anterior	Tibia	Tendon Origin
Tibialis posterior	Tibia	Tendon Origin

4.7. Statistical Analysis

Chi-Square (X^2) was used to test statistical significance between the Tombos sample and other published bioarchaeological samples. The chi-square statistic determines whether the difference between the scores of the two samples being compared is statistically significant or not. After calculating the chi-square statistic, probability values (P-values) were determined to interpret the data. Probability values allow for the interpretation of chi-square data and reflect the likelihood that the statistic is a random occurrence or a consequence of a real association between the variables. For chi-square, the P-value determines the probability that the degree of statistical dependence determined from the chi-square statistic is random, or not. The lower the P-value the less likely statistical dependence is due to chance. If the measure of association proves to be equal to or less than the set P-value, the null hypothesis can be rejected. For this analysis probability values were set at $p \leq .05$, or 5 instances out of 100 the relationship between variables was due to chance. All statistical analyses were performed using Stata 11 software.

4.8. Summary

Degenerative joint disease is likely caused by physiological stressors in life and can be viewed on skeletal material in several forms such as osteoarthritis, vertebral osteophytosis and Schmorl's nodes. Similarly, musculoskeletal stress markers are bony projections illustrating ossified muscle attachment sites and are representative of extended periods of repetitive musculature use. Bioarchaeologists can use these indicators of physical strain to interpret prehistoric activity patterns. It is within a multidimensional approach, combining osteoarthritis, vertebral osteophytosis, Schmorl's nodes and musculoskeletal stress markers that an overall picture of prehistoric activity patterns and life emerges. The methods outlined in this chapter are representative of accepted bioarchaeological techniques. The chi-square statistic and associated probability value were used in these analyses in order to determine the statistical significance between the Tombos sample and other comparative samples.

CHAPTER 5. RESULTS

This chapter reviews the results of this project, further discussion of both results and interpretations can be found in Chapter VI. Results indicate relatively low levels of osteoarthritis, vertebral degeneration and severe musculoskeletal stress markers in the population of Tombos. Raw data collected from this analysis can be found in the attached Appendices C, D, and E.

5.1. Osteoarthritis

The majority (79%, 538/678) of the collection studied displayed no indication of osteoarthritis (Appendix D). Of the 678 elements analyzed, 140 (21%) showed preliminary indicators of osteoarthritis (i.e. osteoarthritic lipping) (Figure 5.1). The elements least affected by osteoarthritic lipping include the left distal ulna (4.17% affected, 1/24) and the left proximal radius (5.66% affected, 3/53). The elements most affected by osteoarthritic lipping include both sides of the proximal ulna and the proximal femur. Results indicate that 31.58% (12/38) of the left proximal ulna sample and 31.25% (25/80) of the right proximal ulna sample displayed osteoarthritic lipping. Results indicate that 34.78% (16/46) of the left proximal femur sample and 32% (16/50) of the right proximal femur sample displayed osteoarthritic lipping. The highest score recorded for osteoarthritic lipping was a three (on a scale of 4, Appendix A). Seven samples reflected an osteoarthritic lipping score of three: right distal ulna (*n*=1), left acetabulum (*n*=2), right acetabulum (*n*=1), left proximal femur (*n*=1) and the right proximal femur (*n*=1).

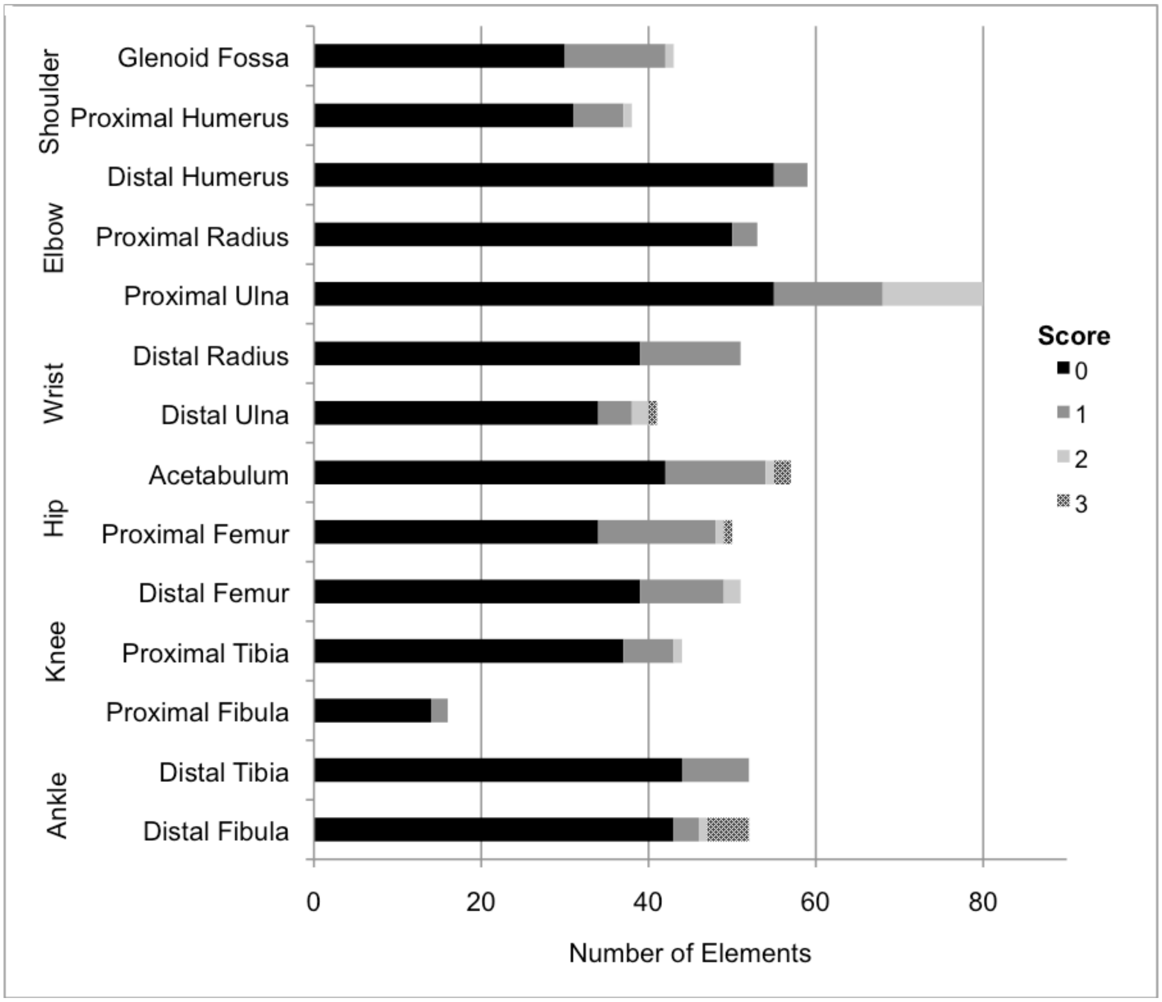

Figure 5.1 Distribution of Osteoarthritic Lipping

Even fewer samples exhibited osteoarthritic porosity than did osteoarthritic lipping (Figure 5.2). There were several elements in which all samples analyzed resulted in a complete absence of osteoarthritic porosity (e.g. right proximal humerus, left distal humerus, right distal humerus, left proximal radius, left distal radius, left distal ulna, left distal femur, left distal tibia, right distal tibia, left proximal fibula, right proximal fibula and right distal fibula). The element most affected by porosity was the right proximal ulna (11.25%, 9/80). However, the right proximal femur possessed the highest single score; one sample scored a three (2%, 1/50). As expected, most elements did not exhibit eburnation. One left proximal femur resulted in an eburnation score of two (2.17%, 1/46). No other indications of eburnation were present in the Tombos sample, which is particularly suggestive of limited levels of activity.

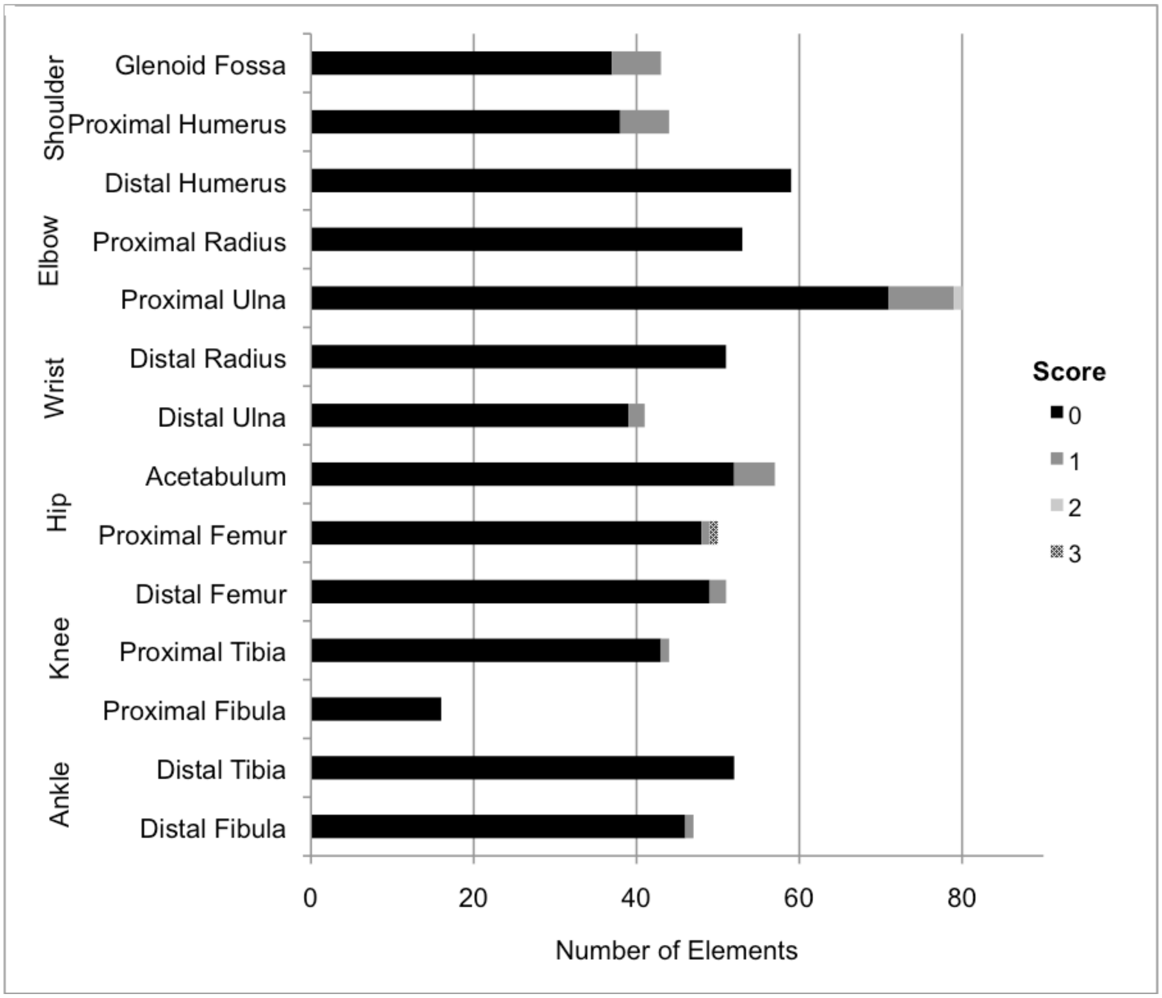

Figure 5.2 Distribution of Osteoarthritic Porosity

One must also consider skeletal material that could not be included in this study. As discussed in Chapter V, due to poor preservation, incomplete elements, or contributing pathological conditions, several specimens were not included in this analysis. These preservation issues differentially affected the inclusion of several elements into this study. For example, all proximal radius samples were included. However, the distal fibula was by far most affected by preservation issues. In sum, 69.23% (36/52) of the left proximal fibulae sample and 68.29% (28/41) of the right proximal fibulae sample could not be included in the analysis. This is likely due to the fragility of the proximal fibulae and the general poor preservation of this bone compared to other long bones. The absence of these samples must be acknowledged.

5.2. Vertebral Degeneration

The majority of vertebral samples did not have vertebral osteophytosis or Schmorl's nodes (Appendix C). Vertebral osteophytosis appeared least in the thoracic region and most in the lumbar region (Figure 5.3). Specifically, the vertebral region that was least affected by vertebral osteophytosis was the inferior thoracic vertebrae (23% affected, 120/518). The vertebral region most affected by vertebral osteophytosis was the superior lumbar vertebrae (47.78% affected, 129/270). Please note, when discussing total counts and calculations for the vertebral column, all figures reference number of vertebrae affected not number of individuals.

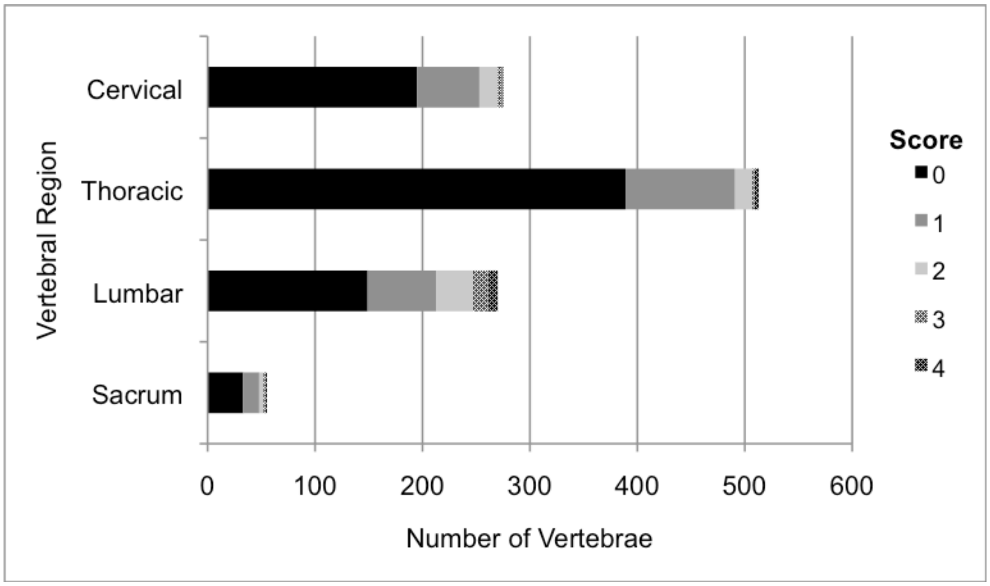

Figure 5.3 Distribution of Vertebral Osteophytosis

As for Schmorl's Nodes, the cervical vertebrae (both superior and inferior) showed no indications of the pathological condition (Figure 5.4). The thoracic region showed a slight increase in the level of Schmorl's nodes with the superior surface resulting in one example (0.2%, 1/507) and the inferior surface resulting in five examples (0.01%, 5/512). Schmorl's nodes occurred most frequently in the lumbar region and relatively equally between superior and inferior surfaces. In the superior lumbar region, 3.13% (8/256) of the sample exhibited Schmorl's nodes. In the inferior thoracic region, 3.45% (8/261) of the sample exhibited Schmorl's nodes. Results for Schmorl's nodes of the sacral region were similar to that of the lumbar region; 3.7% of the sample exhibited Schmorl's nodes on the superior surface of the sacrum (2/54).

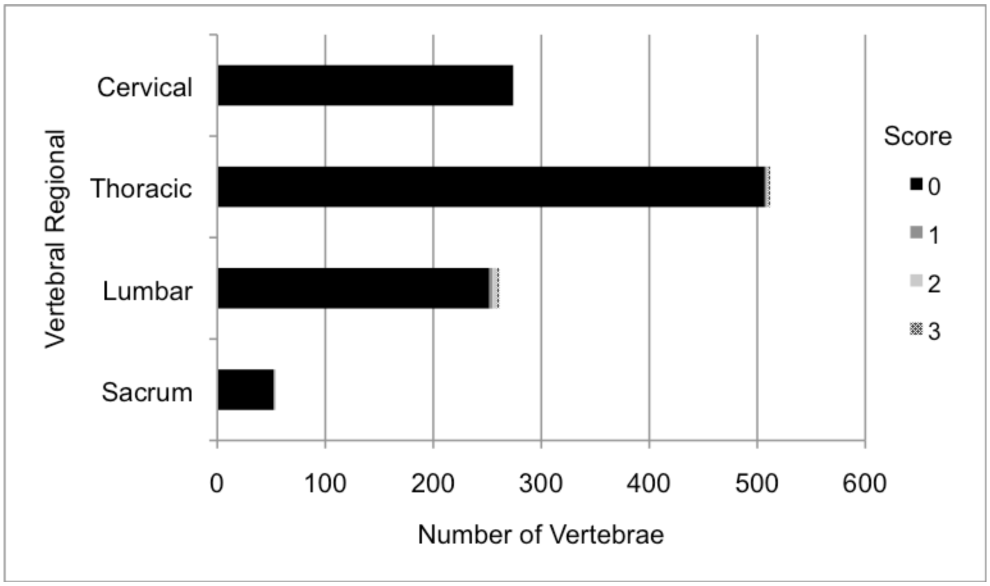

Figure 5.4 Distribution of Schmorl's Nodes

Some samples were not included in vertebral analysis due to poor preservation, incomplete elements, or contributing pathological conditions. Due to the fact vertebral osteophytosis occurs on the periphery of the vertebral body, an area where bone is dense and thick, limited taphonomic damage occurs and fewer specimens have to be excluded. For example, the cervical (both superior and inferior) as well as sacra were all included in this examination. Exclusions include: superior thoracic (1.16%, 6/519), inferior thoracic (0.19%, 1/519), superior lumbar (1.46%, 4/274) and the inferior lumbar (1.46%, 4/274). Due to the fact Schmorl's nodes occur on the vertebral body, a much more delicate area than the periphery, more specimens were excluded in Schmorl's node analysis than vertebral osteophytosis analysis. Two cervical vertebral elements (1 superior and 1 inferior), 19 thoracic elements (12 superior and 7 inferior), 32 lumbar elements (18 superior and 13 inferior) and one sacrum were excluded due to damage.

5.3. Musculoskeletal Stress Markers

Results of musculoskeletal stress marker analysis are best outlined separately by bone and will be discussed in Chapter VI in terms of their collective appendage function. Analysis of the clavicle (conoid, costoclavicular, subclavius, trapezius and trapezoid) resulted in a limited number of affected muscle attachment sites (Figure 5.5) (Appendix D). A total of seven examples resulted in scores of 4 (one left costoclavicular, five right costoclaviculars and one left subclavius). Although, as shown in Figure 5.5, the majority of muscle attachment scores for the clavicle were zero. Analysis of the scapula included two attachment sites: pectoralis minor and trapezius (Figure 5.6). Again, the majority of all attachment sites resulted in a score of zero. A score of two was the most significant score the scapula.

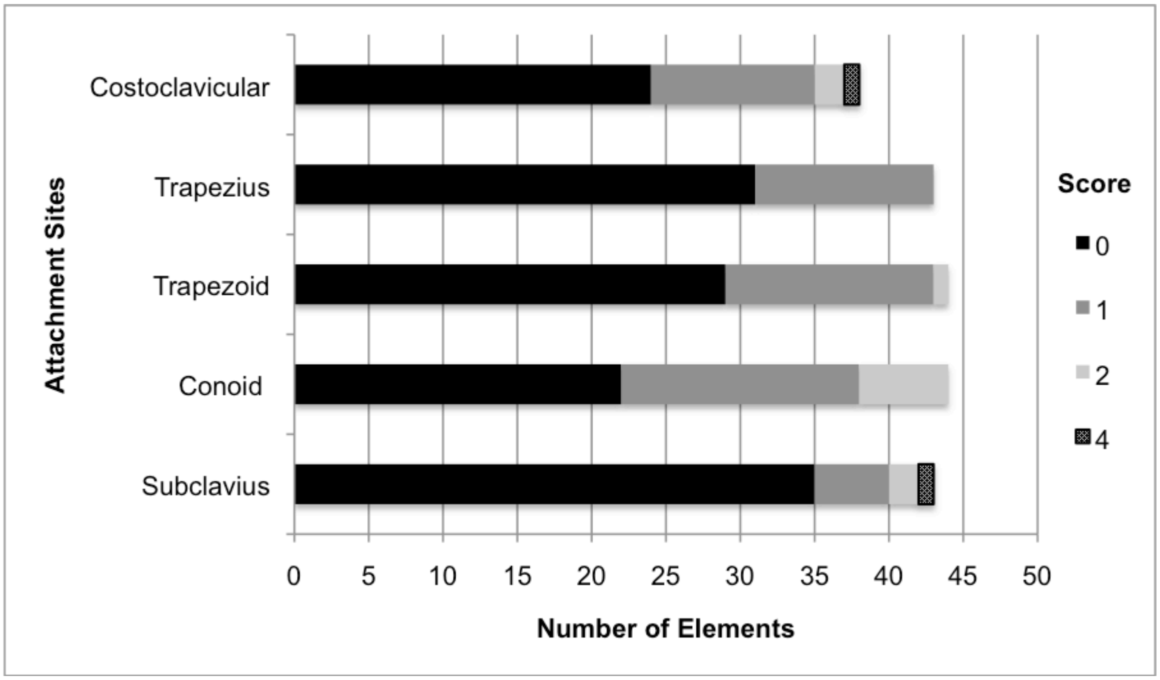

Figure 5.5 Muscle Attachment Results of the Clavicle

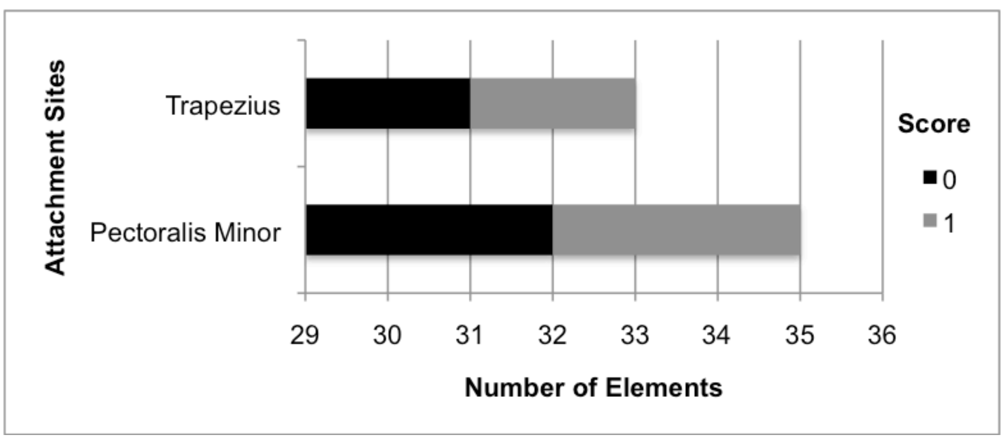

Figure 5.6 Muscle Attachment Results of the Scapula

The attachment sites of the humerus were the most pronounced of the upper body, although, levels of moderate to severe muscle attachment sites were minimal. Of the nine muscle attachment sites studied (deltoideus, common extensors, common flexors, infraspinatus, latissimus dorsi, pectoralis major, subscapularis, supraspinatus and teres major), common extensors and deltoideus resulted in the most pronounced muscle attachments (Figure 5.7). The left common extensors resulted in 47.73% of the sample exhibiting varying degrees of the muscle attachment (21/44). The right common extensors resulted in 53.7% of the sample exhibiting varying degrees of the muscle attachment (29/54). As discussed in the following chapter, the majority of these results were faint. The left deltoideus attachment site resulted in 46.81% of the sample exhibited defined muscle attachment sites (22/47). The right deltoideus attachment site resulted in 46% of the sample exhibiting defined muscle attachment sites (24/50).

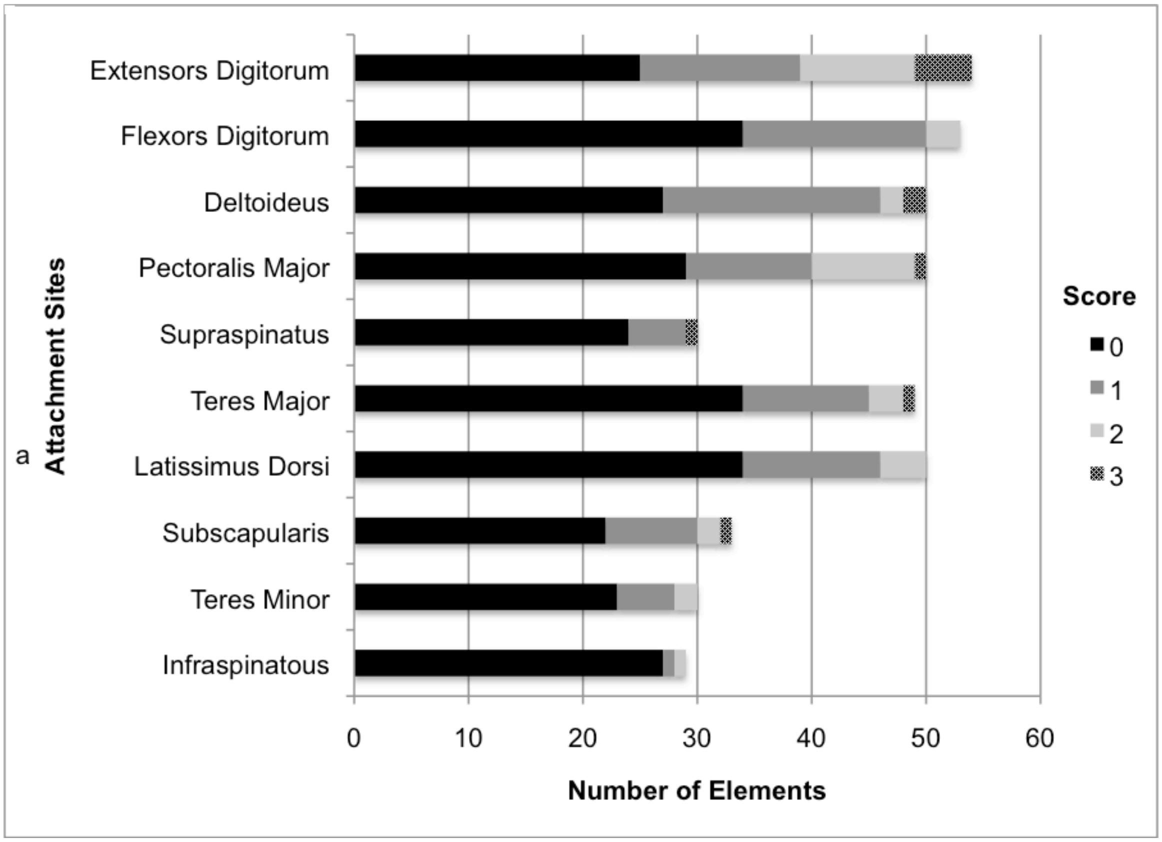

Figure 5.7 Muscle Attachment Results of the Humerus

Results of both the ulna and radius were relatively moderate compared to the humerus, with a few muscle attachment sites scoring two or higher (Figures 5.8 and 5.9). Of the lower arm, the attachment site most frequently affected was the left pronator quadrates of the ulna, with 35.48% of the sample resulting in affected muscle attachment sites (11/31). Only one specimen exhibited a muscle attachment site that was moderately defined (left pronator quadrates; 2.38%, 1/42). Furthermore, there were no examples of distinct attachment sites or lesionous attachments for the left pronator quadratus (i.e. score of 3 or higher).

The most extreme scores of the lower arm included the left supinator (i.e. one score of 3; 1.82%, 1/55) and right biceps brachii (i.e. one score of 3; 1.89% or 1/53). Again, both of these scores are suggestive of defined muscle attachment sites, but not lesionous furrows, which are associated with intense physical labor. Musculoskeletal stress marker analysis of the upper body generally resulted in limited levels of elevated scores, with the majority of samples reflecting no muscle attachment definition whatsoever.

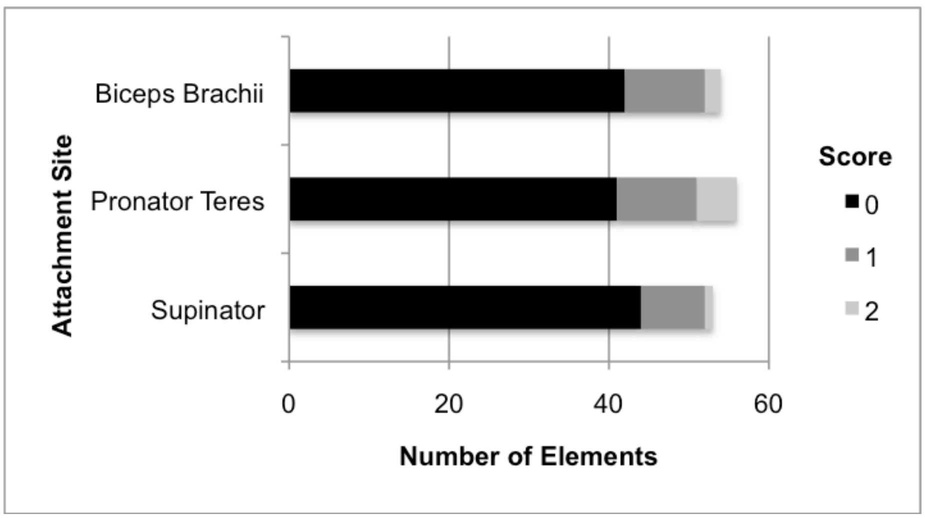

Figure 5.8 Muscle Attachment Results of the Radius

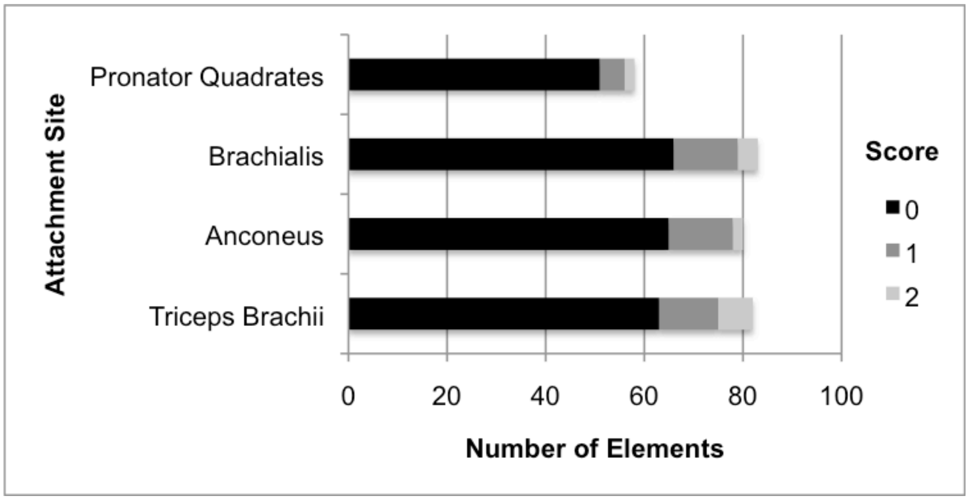

Figure 5.9 Muscle Attachment Results of the Ulna

The lower body displayed more common and more defined muscle attachment sites than the upper body, although these levels remain relatively limited. Of the 10 muscle attachment sites studied on the os coxae (adductor magnus, biceps femoris, gluteus maximus, gluteus medius, gluteus minimus, illiacus, pectineus, quadrates femoris, rectus femoris and semimembranosus), adductor magnus resulted in the most defined attachment site (Figure 5.10). The left adductor magnus resulted in 33.33% of the sample exhibiting discernable attachment sites (7/21). While a third of the sample resulted in early indications of the muscle attachment sites, only two (9.52%, 2/21) resulted in moderately discernable sites. Results of the adductor magnus showed 41.18% (7/17) of the sample exhibited defined attachment sites. Again, only three instances of moderately discernable muscle attachment sites (17.65%, 3/17) were present and no cases of severe or lesionous attachment sites occurred. The majority of muscle attachment sites studied on the os coxae possessed no indication of muscle attachment site formation.

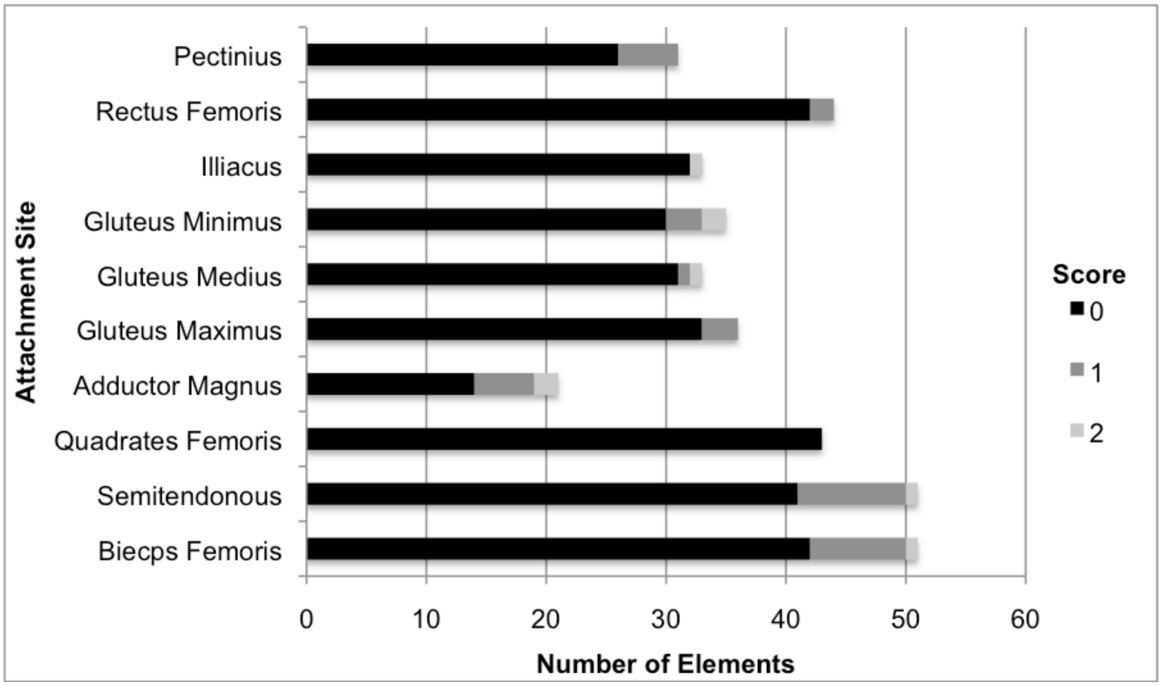

Figure 5.10 Muscle Attachment Results of the Os Coxae

Of the 14 muscle attachment sites studied on the femur (adductor magnus, gastrocnemius, gluteus maximus, gluteus medius, gluteus minimus, illiacus, obturator, pectineus, piriformis, popliteus, quadrates femoris, vastus intermedius, vastus lateralis and vastus medialis), gluteus minimus resulted in the most frequent affected muscle attachment sites (Figure 5.11). In particular, 57.14% of the right gluteus minimus resulted in variable indications of affected musculoskeletal stress sites (24/42).

Furthermore, there were a greater number of higher scores exampled in the femur, as suggested by the score of 4, also exhibited in the right gluteus minimus. Several scores of 3 (*n*=25, left and right gluteus maximus, right adductor magnus, right gastrocnemius, left gluteus minimus, left illiacus, right gluteus medius, left and right obturator, right pectineus, right piriformis, left quadrates femoris and right vastus intermedius, left vastus lateralis and right vastus medialis) and 4 (*n*=5, left and right gluteus maximus, right gluteus minimus) are exhibited in the femur. Additionally, an extreme score of six is exhibited in the femur on the right gastrocnemius attachment. Further discussion regarding the possible causation factors for such high scores for the femur are pursued in Chapter VI.

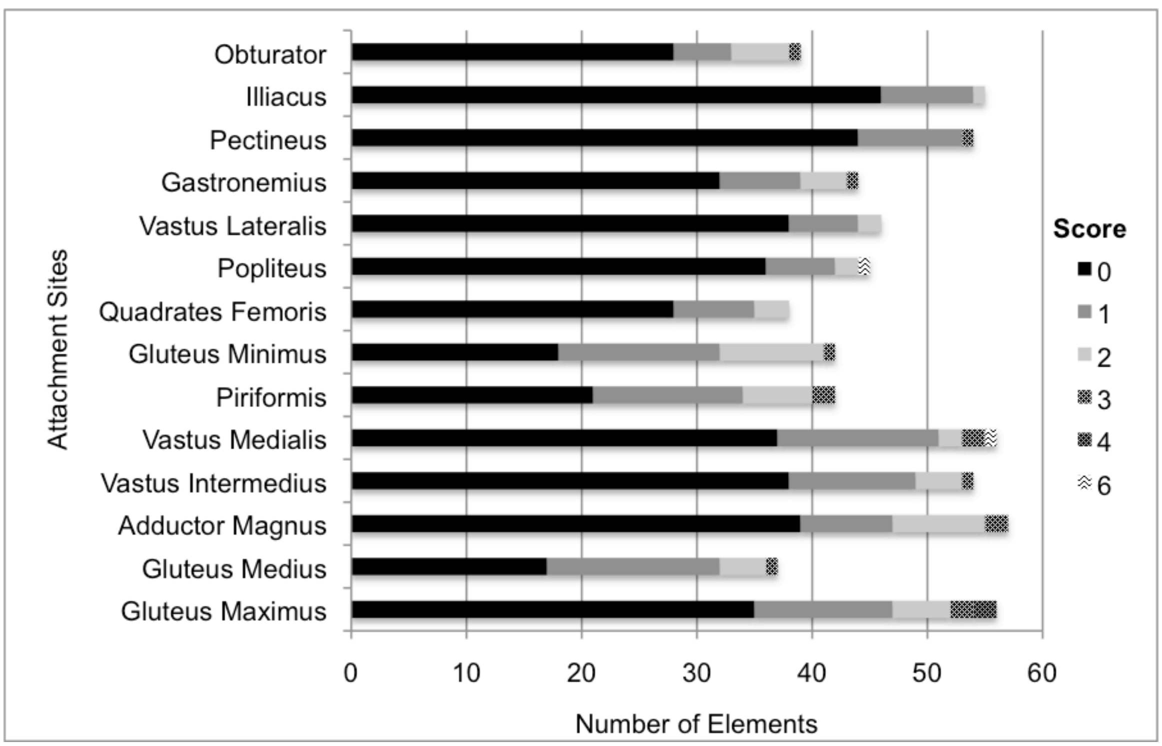

Figure 5.11 Muscle Attachment Results of the Femur

When considering these unusually high muscle attachment site scores of the femur, one must not overlook the general trend of the overall low number of unaffected individuals. The majority of femoral attachment sites, with the exception of gluteus medius, gluteus minimus and piriformis, were not affected (i.e. score of 0) by musculoskeletal stress markers.

The six tibiae muscle attachment sites analyzed (flexors digitorum, popliteus, soleus, semimembranosus, tibialis anterior, tibialis posterior) resulted in moderate muscle attachment sites. The attachment site most affected was the soleus muscle, which forms a sharp crest known as the soleal line across the posterior tibia. Analysis of the left soleus resulted in 59.57% (28/47) of the sample exhibiting varying degrees of the attachment site. Moderate to well-defined attachment sites totaled 21.28% (10/47) of the sample. There were two instances of minor furrowing of the left soleus attachment (4.26%, 2/47), suggesting physiological overuse and strain. Analysis of the right soleus resulted in 50.98% of the sample exhibiting varying degrees of the attachment site (26/51). Although, the majority of muscle attachment sites that makeup this large percentage were deemed barely discernable (i.e. score 1). Moderate to well-defined muscle attachment sites (i.e. score of 2 or 3) totaled 13.76% of the sample (7/51). There was one right soleus sample that was severely affected by attachment site furrowing (1.96%, 1/51) and is an interesting outlier when compared with the rest of the tibiae sample as well as all other bones studied.

Due to the burial context of this collection, it is impossible to discern if these severely affected tibiae samples are associated with the severely affected femora samples that also reflected unusually high scores.

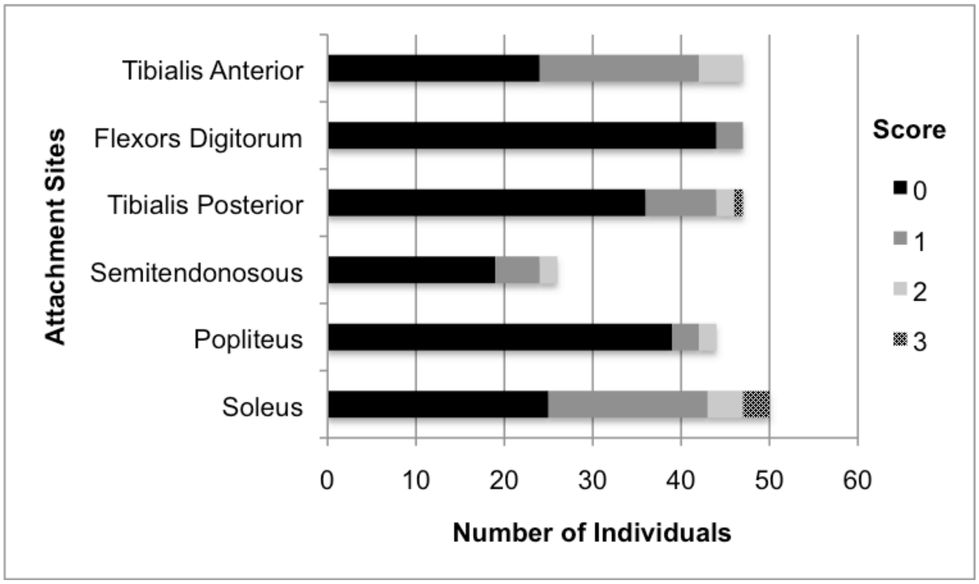

Figure 5.12 Muscle Attachment Results of the Tibia

5.4. Summary

The majority of samples analyzed from the Tombos collection indicated no evidence of osteoarthritis. The elements most affected by osteoarthritic lipping included both the left and right proximal ulnae as well as both the left and right proximal femora. The highest score for osteoarthritic lipping was a three and was present in six specimens (one right distal ulna, two left acetabula, one right acetabulum, one left proximal femur and one right proximal femur). Results indicated that the frequency of osteoarthritic porosity was much less than osteoarthritic lipping. Many elements resulted in no indication of porosity. The element that resulted in the most frequent osteoarthritic porosity was the right proximal ulna. There was only one example of eburnation in the entire sample, which occurred on a left proximal femur.

The majority of vertebrae resulted in no indication of vertebral osteophytosis or Schmorl's nodes. Vertebral osteophytosis occurred most frequently in the lumbar region, namely the superior surface of the lumbar vertebrae. Schmorl's nodes occurred most frequently in the lumbar region and sacral regions.

Similar to osteoarthritis and vertebral degeneration, results for muscle attachment sites suggest limited levels of physiological stress on ligamentous and tendonous points of attachment. The majority of clavicle specimens showed no indication of muscle attachment sites, although seven samples exhibited moderate to severe attachment sites (i.e. score of 4). Very few scapula samples reflected any level of muscle markings, the highest score being a two. The attachment sites of the humerus were the most pronounced of the upper body, although, levels of moderate to severe muscle attachment sites were minimal. The common extensors and deltoideus attachment sites resulted in the most pronounced muscle attachments of the humerus. Results of both the ulna and radius were relatively moderate compared to the humerus, with a limited selection of sites scoring two or higher.

The lower body resulted in more frequent and more severe indications of muscle attachment sites than the upper body, particularly the femur. The adductor magnus of the os coxae was the most commonly affected muscle attachment site, although, the majority of these attachment sites were not well defined (i.e. maximum score of two). The gluteus minimus exhibited the most frequent attachment site of the femur, while the one right gastrocnemius sample was the most severely affected bone of the entire collection (i.e. score of 6). The soleus muscle attachment of the tibia exhibited the most severe musculoskeletal stress markers of the element with two samples illustrating well defined and partially furrowed examples (i.e. scores of 4). Data for osteoarthritis, vertebral degeneration and musculoskeletal stress markers all reflect limited levels of activity in the Tombos population. Implications for these results will be reviewed in the following discussion chapter (Chapter 6).

CHAPTER 6. DISCUSSION

The analysis of osteoarthritis, vertebral osteophytosis, Schmorl's nodes and musculoskeletal stress markers in the Tombos sample, as shown in the previous chapter, exhibited low levels of these degenerative conditions. However, it is within the multifaceted approach of analyzing these pathological conditions that overall levels of activity can be determined. This chapter will combine the results discussed in Chapter 5 to elucidate the levels and types of activities experienced by the Tombos population. Furthermore, comparative samples from various groups will provide context for the results from Tombos.

6.1. Osteoarthritis

Overall, osteoarthritic prevalence was limited in the Tombos sample; the majority (79%, 538/678) of the sample resulted in no indication of osteoarthritis. The low levels of osteoarthritis found in this sample are suggestive of a lifestyle that is not particularly physically strenuous or demanding. There is a current bioarchaeological and clinical debate regarding the beginning manifestations of osteoarthritis in the skeleton. Special attention will be put toward classification of the pathological condition within this discussion of the Tombos sample.

Furthermore, the extent of lipping, porosity and eburnation within the sample will also be discussed in this section.

As mentioned in Chapter IV, the diagnosis of osteoarthritis, particularly in an osteological context, is difficult to establish. Many have suggested that the earliest stages of osteoarthritis, coined 'barely discernable lipping' by Buikstra and Ubelaker (1994), should not be considered a pathological condition. One school of thought posits two of the four following conditions must be present (Rogers et al. 1987:185; Rogers and Waldron 1995):

a) Osteoarthritic growths

b) Porosity

c) Subchondral bone reaction (including eburnation)

d) Alteration of joint contours (including fusion)

However, others have suggested when osteologically diagnosing osteoarthritis sharp ridges produced by osteoarthritic lipping, defined as a score of two by Buikstra and Ubelaker (1994), should be the minimal requirement for diagnosing osteoarthritis (Larsen 1995, Lieverse et al. 2007). This includes any further severe manifestations of osteoarthritis, including porosity, eburnation and fusion. This discussion will adopt the latter interpretation of osteoarthritis and will consider all 0-1 lipping scores as not present. Conversely, lipping scores of 2-4, in addition to all cases of porosity, eburnation and fusion will be considered positive indications of osteoarthritis. Regardless of the interpretation, bioarchaeologists should take extreme caution in diagnosing osteological samples with osteoarthritis.

Major joint systems, such as the shoulder (i.e. the glenoid fossa and proximal humerus), the elbow (i.e. distal humerus, proximal ulna and proximal radius), the wrist (i.e. distal ulna and distal radius), the hip (i.e. acetabulum and proximal femur), the knee (distal femur, proximal tibia and proximal fibula) and the ankle (i.e. distal tibia and distal fibula), must also be considered in terms of the symbiotic relationship. These elements work in unison to promote optimal joint function. Osteoarthritis will be interpreted in terms of the entire joint rather than the specific element to illustrate the collective joint systems of the body.

When the more stringent diagnosis criterion for osteoarthritis is imposed, there were very few cases of true osteoarthritis in the Tombos collection. The elbow and hip show the highest levels of osteoarthritis within the Tombos sample. A total of 13 samples out of 378 total samples had osteoarthritis in the elbow region. The hip joint had 5 samples out of 230 total samples that indicated osteoarthritis, although only two of these were severe.

The mild nature of osteoarthritis at Tombos is further reflected by the general lack of eburnation and joint fusion, the ultimate indicators of osteoarthritis. While there was evidence for eburnation in one individual, the case was mild and illustrates a non-severe example. There were no cases of diarthrodial joint fusion in the Tombos sample. Table 6.1 summarizes all cases of osteoarthritis in the Tombos sample. There were a total of 73 occurrences of osteoarthritis out of the 1,081 total number of elements analyzed. It should be noted, that total figures shown in Table 6.1 do not reflect individuals. As discussed in Chapter 4, the Tombos skeletal collection did not provide the appropriate controls to identify individuals. Therefore, the total figures shown in Table 6.1 are incidents of osteoarthritis in individual bones that could have come from common individuals.

Table 6.1 Total Cases of Osteoarthritis

	Score*	**Left Glenoid Fossa**	**Left Proximal Humerus**	**Right Proximal Humerus**	**Right Distal Radius**	**Left Proximal Ulna**	**Right Proximal Ulna**	**Right Distal Ulna**	**Left Acetabulum**	**Right Acetabulum**	**Left Proximal Femur**	**Right Proximal Femur**	**Right Distal Femur**	**Left Proximal Tibia**	**Right Proximal Tibia**	**Right Distal Tibia**	
Lipping	2	1	1	1			12	2	1	1	2	1	2	1	1	1	
	3							1	2	1	1	1					
	4																
Porosity	1	6	2		1	1	8	2	5	2	4	1	2	1	1		
	2						1			1		1					
	3																
Eburnation	1																
	2										1						**Total**
Total		7	3	1	1	1	21	5	8	5	8	4	4	2	2	1	**73**

* Score according to Buikstra and Ubelaker (1994)

Of the 1,081 elements that were analyzed for osteoarthritis, 140 elements showed traces of varying degrees of osteoarthritic lipping. As presented in the previous chapter, the skeletal region which was most affected by osteoarthritic lipping was the proximal ulna (left: 31.58%, 12/38; right: 31.25%, 25/80) and the proximal femur (left: 34.78%, 16/46; right: 32%, 16/50). The shoulder joint had 12 cases of osteoarthritis, which were all relatively mild as reflected by a lipping score of two. There is currently no explanation for the unusual amount of osteoarthritic lipping observed in the right proximal ulna. If this anomaly were due to physiological strain or repetitive movement one would expect to find similar rates of deterioration in the distal humerus. However, the right distal humerus resulted in no instances of osteoarthritis. A similar quandary is also presented with the proximal femur in relation to the acetabulum. The results of the distal ulna, proximal femur, distal humerus and the acetabulum are shown in Table 6.2.

Table 6.2 Results of Osteoarthritic Lipping in the Shoulder and Hip Joints

	Proximal Ulna	
Score*	*Left*	*Right*
0	26	55
1	12	13
2	0	12

	Distal Humerus	
Score*	*Left*	*Right*
0	48	55
1	2	4
2	1	0

	Proximal Femur	
Score*	*Left*	*Right*
0	30	34
1	13	14
2	2	1
3	1	1

	Acetabulum	
Score*	*Left*	*Right*
0	42	35
1	12	8
2	1	1
3	2	1

* Score according to Buikstra and Ubelaker (1994)

This analysis suggests the population of Tombos was involved in limited levels of repetitive, strenuous activities that are major causation factors of osteoarthritis. Investigation into the role of age in osteoarthritis could not be conducted in this analysis due to limitations of the skeletal collection due to burial context (the remains of many individuals were disturbed and commingled). However, future research of other 3rd Cataract cemeteries, near Tombos, could provide an excellent point of comparison. Further context will be provided in the following section, comparative analysis, in which I contrast the results of the Tombos data with other published works.

6.2. Vertebral Degeneration

Vertebral osteophytosis and Schmorl's nodes resulted in variable levels of vertebral degeneration. As discussed in Chapter 5, vertebral osteophytosis resulted in the following distribution:

Superior Cervical = 29% (80/275)
Inferior Cervical = 32% (87/275)
Superior Thoracic = 24% (124/513)
Inferior Thoracic = 23% (120/518)
Superior Lumbar = 48% (129/270)
Inferior Lumbar = 45% (121/270)
Sacrum = 40% (22/55)

Upon first observation these results appear to be unexpectedly high, particularly when considering the results of other indicators of stressful activity analyzed in this thesis (i.e. osteoarthritis, Schmorl's nodes and musculoskeletal stress markers). However, the majority of specimens that were affected by vertebral osteophytosis exhibited mild cases. For example, the superior cervical vertebrae resulted in 80 of the 275 vertebrae analyzed being affected by vertebral osteophytosis. However, the majority of samples had minimal indications of osteophytosis, termed ‘barely discernable’ by Buikstra and Ubelaker (1994). Seventeen of the 80 affected superior cervical vertebrae had moderate osteophytosis, as indicated by an elevated ring of bony growth. Furthermore, four of the 80 affected superior cervical vertebrae had more extensive spicule formation. Finally, there was only one example out of the 80 cervical vertebrae analyzed that exhibited vertebral fusion. This general pattern is true of all areas of the vertebral column. Table 6.3 illustrates the severe cases of vertebral osteophytosis in the cervical, thoracic, lumbar and sacral regions.

Table 6.3 Cases of Moderate to Severe Vertebral Osteophytosis

	Score*	**Cervical**		**Thoracic**		**Lumbar**		**Sacrum**	**Total**
		Superior	*Inferior*	*Superior*	*Inferior*	*Superior*	*Inferior*	*Superior*	
Curved Spicules	3	4	8	2	3	26	14	2	59
Vertebral Fusion	4	1	1	4	4	8	9	1	28
Total		5	9	6	7	34	23	3	87

* Score according to Buikstra and Ubelaker (1994)

No incidents of Schmorl’s nodes were identified in the cervical vertebrae, as expected. Due to weight-bearing causation factors, discussed in Chapter 4, one would not expect to find any examples of Schmorl’s nodes in the upper spinal column. The superior thoracic region exhibited one Schmorl’s node of the 507 thoracic vertebrae analyzed (Table 6.4). The inferior thoracic region had five cases of Schmorl’s nodes, two of which were markedly expressed. This reflects the greater tendency of expression towards the lower back. The expression of

Schmorl's nodes is expanded in the lumbar vertebrae, with the superior surfaces exhibiting eight examples (one of which is of marked expression) and the inferior surfaces exhibiting nine examples (two of which were of marked expression). The incidence of Schmorl's nodes supports the hypothesis that this pathological condition affects weight-bearing vertebrae more than non-weight-bearing vertebrae. This does not invalidate the association between increased levels of activity and Schmorl's nodes.

Table 6.4 Distribution of Schmorl's Nodes

	Score*	**Cervical**		**Thoracic**		**Lumbar**		**Sacrum**	**Total**
		Superior	*Inferior*	*Superior*	*Inferior*	*Superior*	*Inferior*	*Superior*	
Barely Discernable	1	0	0	1	2	3	3	1	11
Moderate Expression	2	0	0	0	1	4	4	1	12
Marked Expression	3	0	0	0	2	1	2	0	8
Total		0	0	1	5	8	9	2	31

* Score according to Buikstra and Ubelaker (1994)

6.3. Musculoskeletal Stress Markers

Musculoskeletal stress markers in the Tombos population were generally mild and suggested limited levels of strenuous activity. The collective function of the musculoskeletal system is complex and codependent. Analysis of the muscle attachments in terms of their collective function is important in understanding the level of use in major appendage movement. This will be approached by organizing and interpreting musculoskeletal results not in terms of bone, but rather in terms of function within a particular joint system (i.e. shoulder, elbow, wrist, hip, knee and ankle.) The interpretation of musculoskeletal stress markers in terms of their mean score is an excellent approach to understanding the overall use of the attachment site throughout a population. Furthermore, a mean score allows for comparison with other published material. The musculoskeletal mean scores for Tombos are low, and reflect low levels of physically strenuous repetitive activity.

Any bodily motion is a complex interaction of several muscles, tendons and ligaments working together. Furthermore, different physical movements use various muscles in an assortment of ways. This is a primary reason why bioarchaeologists should use extreme caution when reconstructing specific behavioral activities. However, this collective muscle function should be taken under consideration when analyzing activity patterns as well. Discussion for musculoskeletal stress markers will be interpreted as muscular components of a joint system. Tables 6.5 and 6.6 outline the musculature arrangement of each major joint system that are used in this discussion (Stone and Stone 2000).

Table 6.5 Collective Muscle Attachment Site Categorization for the Upper Body

Shoulder		**Elbow**		**Wrist**	
Muscle Attachment	*Bone*	*Muscle Attachment*	*Bone*	*Muscle Attachment*	*Bone*
Conoid	Clavicle	Biceps Brachii	Radius	Extensors Digitorum	Humerus
Costoclavicular	Clavicle	Pronator Teres	Radius	Flexors Digitorum	Humerus
Subclavius	Clavicle	Supinator	Radius	Pronator Quadrates	Ulna
Trapezius	Clavicle	Anconeus	Ulna		
Trapezoid	Clavicle	Brachialis	Ulna		
Pectoralis Minor	Scapula	Triceps Brachii	Ulna		
Trapezius	Scapula				
Deltoideus	Humerus				
Infraspinatous	Humerus				
Latissimus Dorsi	Humerus				
Pectoralis Major	Humerus				
Subscapularis	Humerus				
Supraspinatus	Humerus				
Teres Major	Humerus				
Teres Minor	Humerus				

Table 6.6 Collective Muscle Attachment Site Categorization for the Lower Body

Hip		**Knee**		**Ankle**	
Muscle Attachment	*Bone*	*Muscle Attachment*	*Bone*	*Muscle Attachment*	*Bone*
Adductor Magnus	Os Coxae	Biceps Femoris	Os Coxae	Flexors Digitorum	Tibia
Gluteus Maximus	Os Coxae	Rectus Femoris	Os Coxae	Soleus	Tibia
Gluteus Medius	Os Coxae	Semitendinosus	Os Coxae	Tibialis Anterior	Tibia
Gluteus Minimus	Os Coxae	Gastrocnemius	Femur	Tibialis Posterior	Tibia
Illiacus	Os Coxae	Popliteus	Femur		
Pectineus	Os Coxae	Vastus Intermedius	Femur		
Quadrates Femoris	Os Coxae	Vastus Lateralis	Femur		
Adductor Magnus	Femur	Vastus Medialis	Femur		
Gluteus Maximus	Femur	Popliteus	Tibia		
Gluteus Medius	Femur	Semitendinosus	Tibia		
Gluteus Minimus	Femur	Rectus Femoris	Os Coxae		
Illiacus	Femur				
Obturator	Femur				
Pectineus	Femur				
Piriformis	Femur				
Quadrates Femoris	Femur				

Musculoskeletal stress markers are most frequently discussed in terms of a total mean score, taking into account the frequency of both low and high scores. Table 6.7 and Figure 6.1 present the musculoskeletal mean scores for the Tombos sample. The difference in muscle attachment severity between sides can be illustrated by calculating average asymmetry.

Table 6.7 Musculoskeletal Mean Scores, Average Asymmetry and Statistical Significance for the Upper Body

	Muscle Attachment Site	Mean MSM Score		Average Asymmetry*
		Left	Right	
Shoulder	Conoid (C)	0.64	0.56	114
	Costoclavicular (C)	0.50	0.89	56
	Subclavius (C)	0.30	0.18	167
	Trapezius (C)	0.28	0.32	88
	Trapezoid (C)	0.36	0.21	171
	Pectoralis Minor (S)	0.00	0.09	0
	Trapezius (S)	0.06	0.10	60
	Deltoideus (H)	0.62	0.58	107
	Infraspinatus (H)	0.10	0.11	91
	Latissimus Dorsi (H)	0.52	0.40	130
	Pectoralis Major (H)	0.60	0.64	94
	Subscapularis (H)	0.27	0.45	60
	Supraspinatus (H)	0.10	0.10	100
	Teres Major (H)	0.59	0.48	123
	Teres Minor (H)	0.28	0.30	93
Elbow	Biceps Brachii (R)	0.26	0.25	104
	Pronator Teres (R)	0.38	0.27	141
	Supinator (R)	0.20	0.47	43
	Anconeus (U)	0.22	0.21	105
	Brachialis (U)	0.23	0.25	92
	Triceps Brachii (U)	0.30	0.32	94
Wrist	Common Extensors (H)	0.66	0.91	73
	Common Flexors (H)	0.39	0.42	93
	Pronator Quadrates (U)	0.39	0.16	244

C= Clavicle, S= Scapula, H= Humerus, R= Radius and U= Ulna
*Average Asymmetry = (Left mean/Right mean)*100, <100: right side dominance, >100:left side dominance, 100=symmetry (Weiss, 2001)

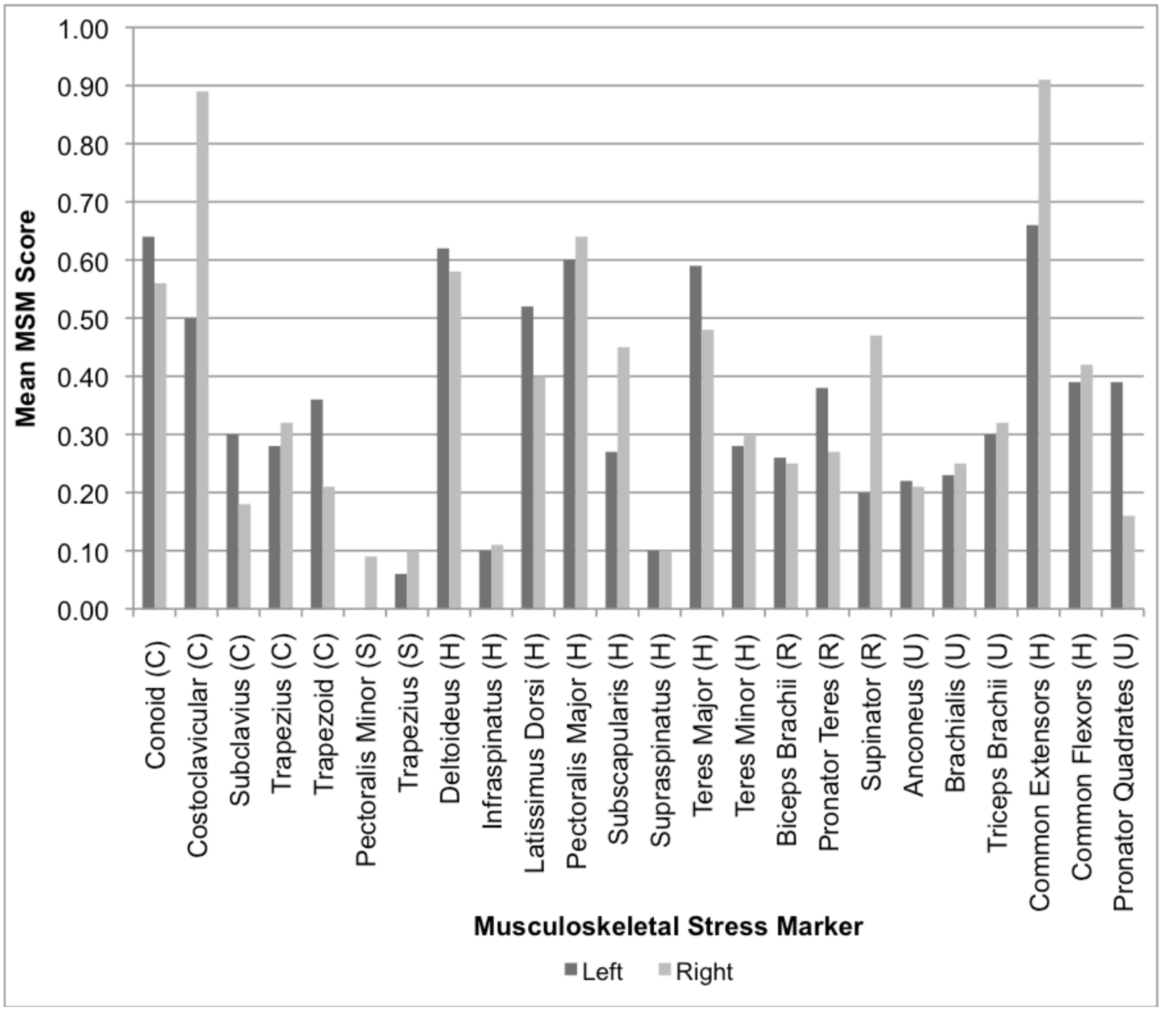

Figure 6.1 Left and Right Musculoskeletal Mean Scores for the Upper Body

Musculoskeletal stress markers of the upper body were variable, but overall reflected little evidence of physically demanding activity patterns (Table 6.7 and Figure 6.1). The highest mean MSM score for the shoulder was the right costoclavicular of the clavicle, with a mean score of 0.89. The costoclavicular ligament attaches the rib to clavicle and is a major component of the sternoclavicular framework. The physical movements that would cause osteological hypertrophy of the costoclavicular ligament include arm abduction, adduction and circumduction (Gray 1995:420). The lowest mean MSM score for the shoulder was the left pectoralis major of the scapula, with a mean score of 0. Pectoralis major is responsible for arm adduction, flexion and medial rotation (Stone and Stone 2000:98).

The elbow displayed moderate MSM mean scores, ranging from 0.20-0.47. The highest mean MSM score for the elbow was the right supinator (0.47). Interestingly, the lowest mean MSM score for the elbow was the left supinator (0.20). The supinator muscle is responsible for twisting the forearm so the palmar surface of the hand is facing upward (i.e supination) (Stone and Stone 2000:138; White 2000). This suggests this twisting action was performed more by the right arm than the left in the Tombos population. Below, there is a continued discussion on handedness.

MSM mean score analysis of the wrist reflected variation among the muscle attachment sites. The highest mean MSM score for the wrist and the entire upper body was the right common extensors (0.91). The common extensors muscle is responsible for extending the fingers and wrist (Stone and Stone 2000:135). These results are particularly interesting considering the hypothesized daily activities of the Tombos population as well as handedness. While specific activities cannot be determined from muscle attachment sites, the fact that the right common extensors were used more than any other muscle of the upper body is apparent. If this population were actively involved in arduous manual labor, one would expect to find other muscle attachment sites, vital to appendage movement (e.g. deltoideus, latissimus dorsi), to be much more defined than the common extensors. Due the fact the common extensors are responsible for finger and wrist extension, the majority of the Tombos population were likely participating in a mildly repetitive activity involving the hands. Furthermore, the more pronounced muscle attachments of the right hand versus the left is evidence for right-handed dominance within this population. The lowest mean MSM score for the wrist was the right pronator quadrates (0.16). The pronator quadrates muscle is responsible for twisting the forearm so the dorsal surface of the hand is hand is facing upward (i.e. pronation) (Stone and Stone 2000: 131; White 2000). This is directly related to the above discussion of the elbow in which data reflected the supinator muscle attachment sites were more defined. The results of the pronator quadrates attachment site further suggest the action of supination rather than pronation was more common. Further analysis of the carpals and phalanges of the hand would supplement this data and provide more information regarding the physiological actions of the Tombos community.

Average asymmetry for the upper body suggests a tendency toward right-handedness in the Tombos population (Table 6.7 and Figure 6.1). As discussed previously, one must consider these results do not reflect individuals. Handedness results are representative of all elements from the respective side from the entire skeletal collection from Tombos. Out of the 24 upper body muscle attachment sites analyzed, 13 displayed more severe attachment sites on the ride side than on the left:

Costoclavicular (clavicle)
Trapezius (clavicle)
Pectoralis minor (scapula)
Trapezius (scapula)
Infraspinatus (humerus)
Pectoralis major (humerus)
Subscapularis (humerus)
Teres minor (humerus)
Supinator (radius)
Brachiailis (ulna)
Triceps brachii (ulna)
Common extensors (humerus)
Common flexors (humerus)

One muscle attachment site, supraspinatus (humerus), suggested absolute even distribution between the two sides (i.e. score=100). Many have suggested a natural right-handed dominance in the majority of human populations (Falk 1987; Annett 1992). The data supporting right-handedness in the Tombos population fits these suggested models.

Chi-square analysis was conducted comparing the frequency of elements affected (i.e. score of two or higher) versus those unaffected (i.e. score of one or zero) between the right and left sides of each muscle attachment site. Only one attachment site of the upper body, pronator quadrates of the ulna ($p=0.009$), proved to be significant at the $P \leq .05$ level. This further supports the high asymmetry average (244) for this attachment site and suggests the left side was used more than the right side.

Table 6.8 Musculoskeletal Stress Marker Rank Order Analysis of the Tombos Population (Upper Body, Right Side)

Rank Order	Muscle Attachment Site	Location	Mean MSM Score
1	Common Extensors	Humerus	0.91
2	Costoclavicular	Clavicle	0.89
3	Pectoralis Major	Humerus	0.64
4	Deltoideus	Humerus	0.58
5	Conoid	Clavicle	0.56
6	Teres Major	Humerus	0.48
7	Supinator	Radius	0.47
8	Subscapularis	Humerus	0.45
9	Common Flexors	Humerus	0.42
10	Latissimus Dorsi	Humerus	0.40
11	Trapezius	Clavicle	0.32
12	Triceps Brachii	Ulna	0.32
13	Teres Minor	Humerus	0.30
14	Pronator Teres	Radius	0.27
15	Biceps Brachii	Radius	0.25
16	Brachialis	Ulna	0.25
17	Trapezoid	Clavicle	0.21
18	Anconeus	Ulna	0.21
19	Subclavius	Clavicle	0.18
20	Pronator Quadrates	Ulna	0.16
21	Infraspinatus	Humerus	0.11
22	Trapezius	Scapula	0.10
23	Supraspinatus	Humerus	0.10
24	Pectoralis Minor	Scapula	0.09

Rank-order analysis of the upper body (Table 6.8) provides a gradation with which we can better bioarchaeologically interpret which muscles were used more or less intensively (Weiss, 2009). When rank-order analysis was performed on the Tombos skeletal collection, the common extensors (0.91), as discussed above, were the highest scoring muscle attachment of the upper body. Various muscle attachments of the humerus, clavicle and radius are predominately utilized. Conversely, pectoralis minor of the scapula was the least stressed muscle attachment (0.09), in the 24th position. As discussed previously, it must be stressed that these mean musculoskeletal stress marker scores are extremely low.

While there is marked variation in mean MSM scores for the upper body, overall, the mean MSM scores remain remarkably low. All mean scores for the upper body were below 1. When the scoring methodology is taken into consideration, these scores can only be interpreted as characteristic of minimal muscle attachment site presence and therefore limited repetitive physical activity in life. According to Hawkey and Merbs (1995), a score of 1 is representative of a muscle attachment site having no distinct crests or ridges. As discussed above, the highest MSM mean score for the upper body was the right common extensors of the wrist (0.91). While the right common extensor score within the Tombos population is interesting, particularly regarding the implications for daily activity at Tombos as well as handedness, comparatively, this score is rather low. This trend in low mean MSM scores for the upper body is representative of a lifestyle that is not mechanically strenuous or physically demanding.

Table 6.9 Musculoskeletal Mean Scores, Average Asymmetry and Statistical Significance for the Lower Body

	Muscle Attachment Site	Mean MSM Score		Average Asymmetry*
		Left	Right	
Hip	Adductor Magnus (OC)	0.43	0.59	73
	Gluteus Maximus (OC)	0.08	0.09	89
	Gluteus Medius (OC)	0.09	0.03	300
	Gluteus Minimus (OC)	0.20	0.10	200
	Illiacus (OC)	0.06	0.00	0
	Pectineus (OC)	0.16	0.09	178
	Quadrates Femoris (OC)	0.00	0.03	0
	Adductor Magnus (F)	0.49	0.54	91
	Gluteus Maximus (F)	1.13	0.64	177
	Gluteus Medius (F)	0.59	0.70	84
	Gluteus Minimus (F)	0.75	0.86	87
	Illiacus (F)	0.24	0.18	133
	Obturator (F)	0.67	0.46	146
	Pectineus (F)	0.27	0.22	123
	Piriformis (F)	0.78	0.48	163
	Quadrates Femoris (F)	0.34	0.34	100
Knee	Biceps Femoris (OC)	0.20	0.11	182
	Rectus Femoris (OC)	0.00	0.04	0
	Semitendinosus (OC)	0.22	0.11	200
	Gastrocnemius (F)	0.37	0.53	70
	Popliteus (F)	0.18	0.23	78
	Vastus Intermedius (F)	0.33	0.41	80
	Vastus Lateralis (F)	0.34	0.22	155
	Vastus Medialis (F)	0.42	0.44	95
	Popliteus (T)	0.16	0.18	89
	Semitendinosus (T)	0.35	0.30	117
Ankle	Flexors Digitorum (T)	0.63	0.21	300
	Soleus (T)	1.02	0.93	110
	Tibialis Anterior (T)	0.60	0.60	100
	Tibialis Posterior (T)	0.32	0.39	82

OC= Os Coxae, F= Femur, T=Tibia

*Average Asymmetry = (Left mean/Right mean)*100, <100: right side dominance, >100:left side dominance, 100=symmetry (Weiss, 2001)

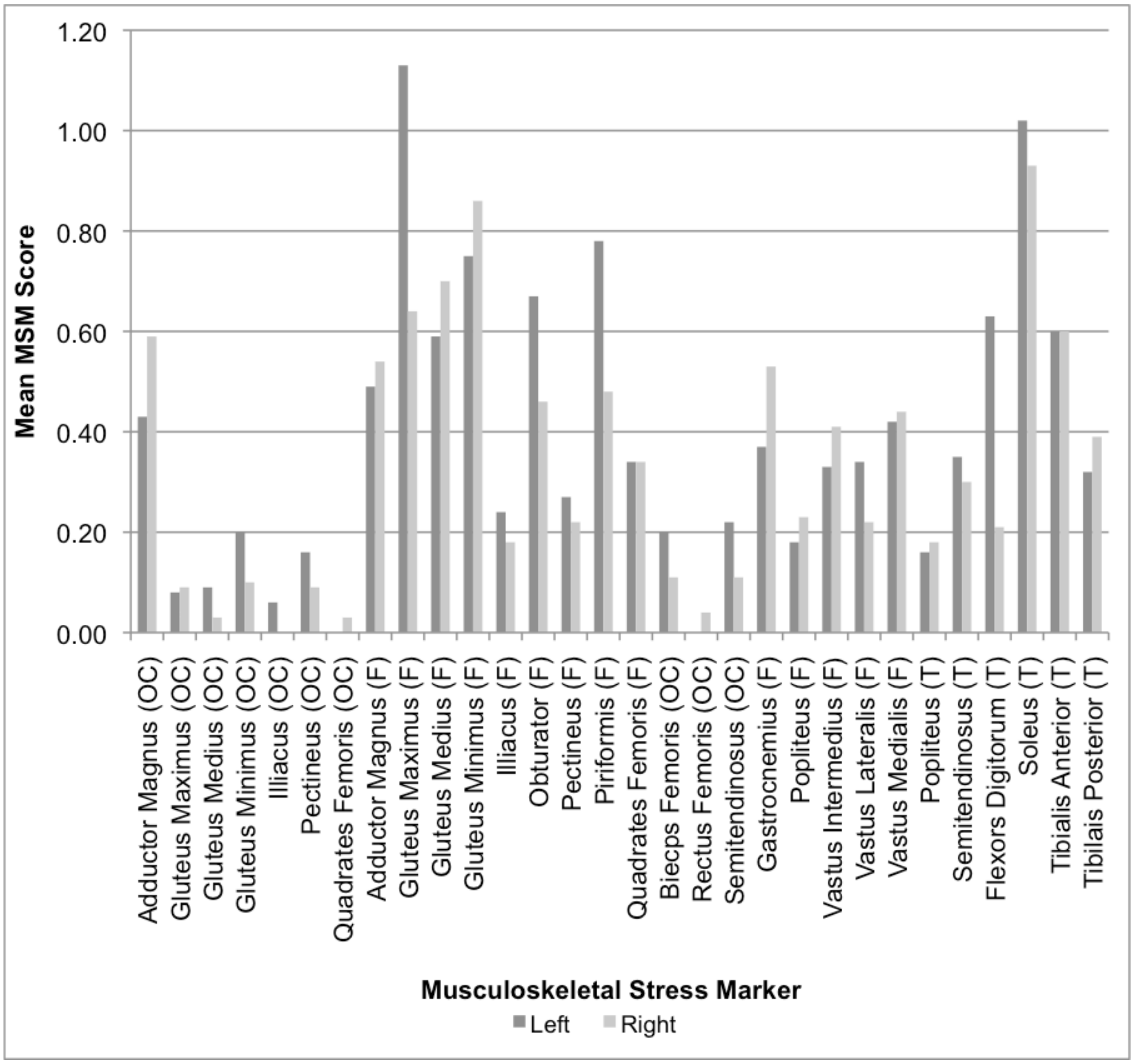

Figure 6.2 Musculoskeletal Mean Scores for the Lower Body

Musculoskeletal stress marker analysis of the lower body was variable, possessing some of the lowest scores, as well as the highest score, of the entire body (Table 6.9 and Figure 6.2). However, like the upper body, one cannot overlook the fact that the resulting MSM mean scores for the Tombos population are exceedingly low. Musculoskeletal stress marker analysis of the hip resulted in a wide array of mean MSM scores. The highest mean MSM score for the hip and the entire body was the left gluteus maximus of the femur, with a mean score of 1.13. The gluteus maximus muscle is responsible for lateral extension of the leg (Stone and Stone 2000:164). The lowest mean MSM score for the hip was the right illiacus of the os coxae, with a score of 0. The illiacus muscle flexes the hip at the thigh (Stone and Stone 2000:157). However, there were many particularly low MSM mean scores for the femur, six of which (in addition to the right illiacus, discussed above) were equal to or under 0.10 (right quadrates femoris (femur) = 0.03, left illiacus (os coxae) = 0.06, left gluteus maximus (os coxae) = 0.08, right pectineus (os coxae) = 0.09, right gluteus maximus (os coxae) = 0.09, right gluteus minimus (os coxae) = 0.10).

Mean MSM analysis of the knee resulted in uniformly low scores for all attachment sites. The highest mean MSM score for the knee was the right gastrocnemius of the femur, with a mean score of 0.53. The gastrocnemius muscle flexes the leg at the knee and the foot (Stone and Stone 2000:191). The lowest mean MSM score for the knee was the left rectus femoris of the os coxae, with a mean score of 0. The rectus femoris muscle flexes the hip and extends the knee (Gray 1995:513).

Muscle attachment sites of the ankle proved to be variable, although ossification of the soleus muscle attachment was pronounced. The highest mean MSM score for the ankle was the left soleus of the tibia, with a mean score of 1.02. The left soleus attachment site resulted in the second highest score of the lower body. Furthermore, the right soleus attachment site was also unusually high (0.93) for the Tombos population. The soleus muscle controls plantarflexion of the foot (Stone and Stone 2000:192). Plantarflexion, the action of increasing the angle between the foot and the leg, is vital to activities such as walking and running. Like the wrist, further osteological examination of the tarsals (e.g. calcaneus) would provide more information regarding the types of physical activities in which these people were participating. The lowest mean MSM score for the ankle was the right flexors digitorum of the tibia, with a mean score of 0.21. The flexors digitorum originate on the tibia and extend to several toes. The flexors digitorum facilitates distal pedal phalange flexion and foot inversion (Stone and Stone 2000:197). Due to the fact pedal phalange flexion and foot inversion play a small role in daily life, it is not surprising that flexors digitorum produced the lowest MSM score of the ankle.

Analysis of average asymmetry resulted in an equal distribution of muscle use between the left and right sides (Figure 6.2). This is somewhat expected, considering sidedness is not as much of an issue in the lower body due to the absence of manual dexterity. Both the left and the right side produced 14 muscle attachments that had been utilized more by one side than the other. Two cases of symmetry (i.e. average asymmetry = 100) occurred in lower body analysis of the Tombos population: quadrates femoris of the os coxae and rectus femoris of the os coxae.

Like the upper body, one muscle attachment site for the lower body was found to be statistically significant when chi-square analysis was performed. When the frequency of elements affected (i.e. score of two or higher), versus those unaffected were compared, the gluteus maximus of the femur ($P = 0.028$)

was statistically significant. This suggests the left gluteus maximus was used significantly more than the right gluteus maximus.

Table 6.10 Musculoskeletal Stress Marker Rank Order Analysis of the Tombos Population (Lower Body, Right Side)

Rank Order	Muscle Attachment Site	Location	Mean MSM Score
1	Soleus	Tibia	0.93
2	Gluteus Minimus	Femur	0.86
3	Gluteus Medius	Femur	0.70
4	Gluteus Maximus	Femur	0.64
5	Tibialis Anterior	Tibia	0.60
6	Adductor Magnus	Os Coxae	0.59
7	Adductor Magnus	Femur	0.54
8	Gastrocnemius	Femur	0.53
9	Piriformis	Femur	0.48
10	Obturator	Femur	0.46
11	Vastus Medialis	Femur	0.44
12	Vastus Intermedius	Femur	0.41
13	Tibialis Posterior	Tibia	0.39
14	Quadrates Femoris	Femur	0.34
15	Semitendinosus	Tibia	0.30
16	Popliteus	Femur	0.23
17	Pectineus	Femur	0.22
18	Vastus Lateralis	Femur	0.22
19	Flexors Digitorum	Tibia	0.21
20	Illiacus	Femur	0.18
21	Popliteus	Tibia	0.18
22	Biceps Femoris	Os Coxae	0.11
23	Semitendinosus	Os Coxae	0.11
24	Gluteus Minimus	Os Coxae	0.10
25	Gluteus Maximus	Os Coxae	0.09
26	Pectineus	Os Coxae	0.09
27	Rectus Femoris	Os Coxae	0.04
28	Gluteus Medius	Os Coxae	0.03
29	Quadrates Femoris	Os Coxae	0.03
30	Illiacus	Os Coxae	0.00

Rank-order analysis of the lower body (Table 6.10) revealed the soleus muscle attachment of the tibia (0.93) to be the first ranked attachment. Furthermore the illiacus attachment of the os coxae (0.00) resulted in the lowest rank, 30th, of the lower body. These results reflect overall low mean muscle attachment scores and are representative of minimal physical activity.

Results of musculoskeletal stress marker analysis of the lower body were variable, but were generally very low and therefore representative of a way of life that was not mechanically strenuous. The highest mean MSM score of the Tombos population, the left gluteus maximus (1.13), is interesting. However, it is representative of a relatively minimal attachment site. The soleus attachment of the tibia was the second-highest mean MSM score of the Tombos population. Both left and right soleus muscles were higher than most other attachment sites from this skeletal collection (left = 1.02, right = 0.93). The soleus is involved in primary physiological movement such as walking and running. However, further interpretation of these data is not advised due to the relative low mean MSM score and the multi-factorial nature of the musculature system. Gluteus maximus and soleus, as with all other muscle attachment sites for the Tombos collection, remain so low one can only conclude this population as not involved in daily activities that were particularly physically demanding. Mean scores are discussed further in the comparative analysis section, where mean scores from other published samples are compared to those from Tombos.

6.4. Comparative Analysis

The following section provides comparisons between multiple bioarchaeological publications and the Tombos data. Various subsistence strategies, cultural groups and time periods were chosen for modes of comparison to present the wide array of variability with which these pathological conditions exist. These points of comparison will provide context with which the Tombos data can be further interpreted. As mentioned in previous chapters, a multifaceted approach to activity patterns such as this (i.e. osteoarthritis, vertebral degeneration and musculoskeletal stress markers) has not been previously performed. Therefore, the following comparative publications will focus on one of these pathological conditions at a time, which can then be compared to the Tombos data. Chi-square analysis was performed to test the statistical significance between the comparative samples and the Tombos data.

6.4.1. Osteoarthritis

Due to the low levels of osteoarthritis presented in the Tombos population, Tombos generally reflected the least amount of osteoarthritis between three other comparative samples (Table 6.11). Bridges' (1991) analysis of North American Mississippian groups, peoples who were sedentary agriculturalists, resulted in rates of osteoarthritis ranging from 1.19-26.53% (sample sizes included in Table 6.11). Incidents of osteoarthritis in the Mississippian population were found least in the hip, ankle and wrist and most in the knee, elbow and shoulder. With the exception of the hip joint, the Tombos sample results for osteoarthritis are considerably lower than reported by Bridges (1991). This is likely due to the population of Tombos being a less agriculturally-intensive, and physically stressed, group than North American Mississippians.

Table 6.11 Comparative Analysis of Osteoarthritis

	Tombos	**Bridges, 1991**		**Lieverse et al., 2007**		**Kilgore, 1984**	
	New Kingdom, Egypt	*Mississippian, North America*	*P-Value**	*Post-hiatus foragers, Siberia*	*P-Value**	*Medieval Nubia*	*P-Value**
Shoulder	6.7% (14/208)	26.53% (26/98)	**0.000**	18.4% (18/98)	**0.006**	16.2% (77/476)	**0.003**
Elbow	6.3% (24/378)	26.32% (30/114)	**0.000**	28.6% (28/98)	0.000	3.2% (22/698)	**0.018**
Wrist	2.4% (6/252)	6.12% (6/98)	0.980	9.2% (9/98)	**0.008**	-	-
Hip	9.6% (22/230)	1.19% (1/84)	**0.017**	5.1% (5/98)	0.211	18% (87/485)	**0.011**
Knee	2.4% (8/335)	20% (21/105)	**0.000**	26.5% (26/98)	**0.000**	18.6% (68/366)	**0.000**
Ankle	2.4% (5/209)	2.88% (3/104)	0.800	36.7% (36/98)	**0.000**	-	-

*P ≤ .05. Significant values in bold

Lieverse and colleagues (2007) present data on osteoarthritis of highly mobile, post-hiatus foragers of Siberia's Cis-Baikal region. The post-hiatus forager groups showed rates of osteoarthritis ranging from 5.1-36.7% (sample sizes included in Table 6.11), with the hip joint affected the least and the ankle joint affected the most. Results from the osteoarthritis analysis at Tombos are well within the range of those reported by Leiverse et al. (2007) and in several instances are considerably lower than the maximum reported (i.e. elbow, shoulder, wrist and knee). Overall, osteoarthritis data from the post-hiatus forager groups shows elevated levels of osteoarthritis when compared to either the Tombos population or the Mississippian population analyzed by Bridges (1991). This suggests the mobile foraging subsistence strategy for this region is particularly strenuous on the skeletal system and promotes joint degeneration.

Kilgore's research of osteoarthritis (1984) in a medieval Nubian population provides an excellent point of comparison to Tombos due to the spatial proximity of the samples. The skeletal remains analyzed by Kilgore, settled agriculturalists from the village of Kulubnarti (between the Second and Third Cataracts of the Nile), range in osteoarthritic severity from 3.2-18.6% (samples sizes included in Table 6.11). Please note, Kilgore did not present data on the wrist or ankle. All of Kilgore's results were higher than exampled in the Tombos sample, with the exception of the elbow. The results for the elbow joint of the Tombos sample were mid-range when compared to the medieval example. The comparative examples discussed generally reflect higher levels of osteoarthritis than the Tombos sample and are likely indicative of a harsher more physically strenuous lifestyle than experienced at New Kingdom Tombos.

6.4.2. Vertebral Degeneration

Upon first glance, the rates of vertebral osteophytosis at Tombos appear to be uncommonly high. The results indicated:

Superior Thoracic = 24% (124/513)
Inferior Thoracic = 23% (120/518)
Superior Lumbar = 48% (129/270)
Inferior Lumbar = 45% (121/270)
Sacrum = 40% (22/55)

However when moderate to severe cases of vertebral osteophytosis are considered, the presence of this degenerative pathological condition within the Tombos population diminishes. When Tombos is compared to other bioarchaeological publications such as Sperduti's analysis (1997) of Lucus Feroniae, the Tombos vertebral osteophytosis results are actually minute (Table 6.12). Lucus Feroniae, a small rural town of the Roman Imperial Age, is thought to have been occupied by a population of lower socioeconomic class who were actively engaged in strenuous physical labor. The cervical and thoracic rates of vertebral osteophytosis at Tombos are considerably lower than those reported by Sperduti. Results for the thoracic vertebra were also much lower than data presented by Sperduti. Sperduti did not report data for the sacrum.

Table 6.12 Comparative Analysis of Vertebral Osteophytosis

	Tombos	Sperduti, 1997	
	New Kingdom, Egypt	Lucus Feroniae Roman Imperial Age	P-Value*
Cervical	5.09% (14/275)	29.63% (16/54)	**0.000**
Thoracic	2.5% (13/519)	26.79% (15/56)	**0.000**
Lumbar	20.8% (57/274)	31.25% (15/48)	0.215
Sacrum	5.45% (3/55)	-	-

*P ≤ .05. Significant values in bold

The unexpectedly high occurrence of barely discernable cases of vertebral osteophytosis is interesting and may be due to an aging component of the pathological condition. The analysis of vertebral osteophytosis remains a prominent methodology in the field of bioarchaeology and has proven successful in many populations (Bridges 1992; Gunness-Hey 1980; Merbs 1983). However, several studies have suggested there is a strong aging component to the disorder (Merbs 1983; Sperduti 1997). Some have suggested vertebral osteophytosis begins to form as early as the early-20s in most individuals, contributing to elevated rates of those affected. As discussed in chapter 4 if vertebral osteophytosis is not extremely severe, the pathological condition often goes unnoticed in a clinical context. Further research, both clinical and bioarchaeological, is needed to better understand the influence of aging on this pathological condition.

There were 14 instances of Schmorl's Nodes of the 1,033 vertebrae analyzed in this study (Table 6.13). Ustundag's (2008) analysis of Schmorl's nodes in a post-medieval population from Austria, dating to the 16th-18th centuries, reflected moderate levels of Schmorl's nodes. No instances of cervical Schmorl's nodes were reported in either the Tombos sample or the post-medieval sample. The rates of Schmorl's nodes in the Tombos sample were much less than in the post-medieval sample. The lumbar vertebrae of both populations were affected about the same. Bourbou's (2003) analysis of Schmorl's nodes was performed on a skeletal collection of an urban population from Proto-Byzantine Greece. Again, there were no cases of cervical Schmorl's nodes reported in either the Tombos sample or the Proto-Byzantine sample. The rates of Schmorl's nodes were drastically lower at Tombos than the Proto-Byzantine sample, which reflects very high levels. The Tombos skeletal sample has the lowest rates of Schmorl's nodes than either comparative sample, with the exception of lumbar vertebrae from post-medieval Austria, and is likely representative of activity patterns that aren't severely physically stressful.

Table 6.13 Comparative Analysis of Schmorl's Nodes

	Tombos	**Ustundag, 2008**		**Bourbou, 2003**	
	New Kingdom, Egypt	*Post-Medieval, Austria*	*P-Value**	*Proto-Byzantine Greece*	*P-Value**
Cervical	0% (0/274)	-	-	-	-
Thoracic	1.16% (6/519)	10.83% (34/314)	**0.000**	61.6% (69/112)	**0.000**
Lumbar	6.2% (17/274)	3.95% (3/76)	0.476	38.39% (43/112)	**0.000**
Sacrum	5.45% (3/55)	-	-	-	-

*P ≤ .05. Significant values in bold

6.4.3. Musculoskeletal Stress Markers

Musculoskeletal stress markers are overall much lower at Tombos when compared to two other published samples (Table 6.14). Note that all results reported in Table 6.14 are presented in muscle marker mean score. Due to the fact there is considerable variability in muscle attachment sites studied between articles, Table 6.14 is a sample of the 54 attachment sites studied in this thesis. Chapman's (1997) analysis of Pecos Pueblo agriculturalists is contrasted by the low mean attachment scores of the Tombos population. All mean attachment scores for Tombos were considerably lower than the lowest score reported for the Pecos Pueblo group. In some cases, such as Brachialis and Pectoralis, the Pecos Pueblo group nearly one entire mean point higher than Tombos. Similar to the other agriculturalist comparison sample, the Mississippian group (Bridges 1991), these high mean scores are likely due to physically stressful activity patterns associated with agriculture.

Zabecki (2009) analyzed the Middle Kingdom Egyptian urban center, Abydos (2,040-1,650 BC), for mean levels of musculoskeletal stress markers. Abydos resulted in more moderate scores than the Pecos Pueblo example, but most scores remain higher than the Tombos sample. There are two outliers in Zabecki's analysis, teres major and deltoideus, which have unusually high scores when compared to any of the three samples in Table 6.14. Zabecki did not report data for the trapezius attachment site. Overall, the mean muscle attachment scores at Tombos are very low when compared to either an agriculturalist or urban population.

Table 6.14 Comparative Analysis of Musculoskeletal Stress Markers

	Chapman, 1997 Pecos Pueblo Agriculturalists	Zabecki, 2009 Middle Kingdom, Abydos, Egypt	Tombos New Kingdom Egypt
Brachialis	1.657	0.43-1.0	0.24
Pectoralis	1.363	1.63-2.63	0.64
Biceps brachii	0.875	1.13-2.11	0.25
Teres major	1.041	2.38	0.47
Flexors and Extensors	0.909, 0.833	0.38-1.0	0.67
Trapezius	0.900	-	0.06
Deltoideus	0.557	1.75-1.88	0.58

The comparative samples discussed above support the hypothesis that the inhabitants of New Kingdom Tombos were not habitually participating in physically stressful activities. Osteoarthritis, vertebral osteophytosis, Schmorl's nodes and musculoskeletal stress markers analyzed from the Tombos sample are typically significantly lower than the other published comparative samples.

6.5. Summary

This chapter discussed the overall low frequency of osteoarthritis, vertebral osteophytosis, Schmorl's nodes and musculoskeletal stress markers, comparative samples as well as concluding remarks on the proposed hypotheses. Analysis of osteoarthritis resulted in 73 of the 1,081 elements analyzed exhibiting the pathological condition. Of the 1,113 vertebral elements analyzed, 87 exhibited moderate to severe vertebral osteophytosis. Furthermore, 31 of the 1,113 vertebral elements analyzed exhibited indications of Schmorl's nodes. Musculoskeletal stress marker analysis resulted in generally low mean MSM scores. The highest mean MSM score for the upper body was the right common extensor (0.91), which controls extension of the fingers and wrist. In addition to the prevalence of right common extensor muscle attachment sites, 13 of the 24 attachment sites analyzed for the upper body indicated right-handed dominance. The highest mean MSM score for the lower body was the left gluteus maximus of the femur (1.13), which assists in the complex movements involved in walking and running. Collectively, activity patterns from the Tombos skeletal sample remain low, illustrating limited levels of strenuous physical activity in this population. When the Tombos sample was compared to various published bioarchaeological sources, in almost every scenario, the Tombos frequencies of osteoarthritis, vertebral osteophytosis, Schmorl’s nodes and musculoskeletal stress makers were considerably lower.

CHAPTER 7. CONCLUSIONS

This thesis researched the consequences of the Egyptian Empire on the Nubian community of Tombos. Through the bioarchaeological investigation of activity patterns, both the function of Tombos within the broader Egyptian Empire as well as the effects of imperialism on this community have been established. In this chapter final conclusions are presented, areas for future are discussed and hypotheses and expectations are revisited.

7.1. Activity Patterns

As discussed in Chapters 5 and 6, activity pattern indicators of a mechanically strenuous lifestyle at New Kingdom Tombos were limited. This is reflective of a lifestyle characterized by low levels of repetitive, strenuous physical activity.

7.1.1. Osteoarthritis

A total of 79% (538/678) of the elements analyzed from the Tombos cemetery exhibited no indication of osteoarthritis. When osteoarthritis is defined as the appearance of sharp ridges created by lipping (i.e. score of 2 or higher according to Buikstra and Ubelaker, 1994), porosity, eburnation or fusion, 11% (73 of 678 elements analyzed) of the sample exhibited osteoarthritis. There was only one case of eburnation; it was relatively minor.

When the results from Tombos are compared with other published bioarchaeological material, such as North American Mississippians (Bridges, 1991), Siberian post-hiatus foragers (Lieverse et al., 2007) or Medieval Nubians (Kilgore, 1984), results from Tombos generally reflected drastically lower levels of both frequency and severity of osteoarthritis.

7.1.2. Vertebral Degeneration

Analysis of vertebral osteophytosis was also limited in both frequency and severity (cervical = 5.09% (14/275), thoracic = 2.5% (13/519), lumbar = 20.8% (57/2740, sacrum 5.45% (3/55). The Tombos sample reflected much lower results than that of the Roman city of Lucus Feroinae (Sperduti, 1997). These results are likely representative of a community with a much different function than Tombos as well as a different imperial strategy than the New Kingdom Egyptian Empire. Lucus Feroinae, according to Sperduti, was likely composed of a lower socioeconomic status population. Furthermore, this population was engaged in repetitive strenuous daily labor as reflected by vertebral osteophytosis. This evidence can be furthered to suggest the Roman Empire's command over this area was motivated by productivity and output of the local population as suggested by increased levels of vertebral osteophytosis. When the Lucus Feroinae example is compared to the Tombos sample, this example illustrates two very different community functions as well as types of imperial rule over hinterland groups.

The presence of Schmorl's nodes in the Tombos population was also nominal and reflected minimal indication of mechanically stressful daily life. The majority of cases of Schmorl's nodes occurred in the lower back (thoracic = 1.16% (6/519), lumbar = 6.2% (17/274), sacrum = 5.45% (3/55), as expected. However, when cases of Schmorl's nodes at Tombos were compared with other published samples, the Tombos sample was drastically lower than either the post-medieval Austria sample (Ustundag, 2008) or proto-Byzantine Greece sample (Bourbou, 2003).

7.1.3. Musculoskeletal Stress Markers

The Tombos sample reflected generally mild musculoskeletal stress markers that suggest limited levels of strenuous activity. It is important when studying musculoskeletal stress markers bioarchaeologically, to interpret them in terms of their collective musculature function. The right common extensors (0.91) exhibited the highest mean MSM score of the upper body. This is reflective of increased use of the hand in the Tombos population than any other muscle of the upper body. Furthermore, this evidence in addition to an overall prevalence of defined right muscle attachment sites, contributes to the theory that the majority of the population of Tombos was likely right-hand dominant. The highest mean MSM score for the lower body was the left gluteus maximus

(1.13), which contributes to physical movements such as walking and running. When the muscle attachment site results for Tombos were compared with other published sources (i.e Pueblos Pueblo Agriculturalists (Chapman, 1997), Middle Kingdom Abydos (Zabecki, 2009), muscle attachment sites at Tombos are markedly lower.

7.2. Research Hypotheses and Results

Activity pattern analysis of the Tombos population has elucidated the function and imperial motivation behind Egyptian control over this region. In Chapter I three hypotheses and expectations were proposed (Table 1.1):

Hypothesis 1:

The limited presence of activity patterns in the Tombos population would reflect a population that was not participating in repetitive, physically demanding activities. Occupations such as, but not exclusive to, minor officials, scribes and prosperous servants would characterize low levels of activity patterns. Activity patterns, including osteoarthritis, vertebral degeneration and musculoskeletal stress markers, are expected to be low throughout the entire body. A New Kingdom community that provided these types of services would be characteristic of a colonial administrative center.

Hypothesis 2:

A mixed level of activity patterns would indicate that the Tombos population was participating in an array of activities, some of which were mechanically stressful. Activity patterns are expected to be high in some individuals and low in others. This scenario would represent the presence of a combination of imperial officials and an incorporated local population at Tombos. Prosperous imperial officials would display less severe activity patterns than individuals who were likely engaged in various forms of manual labor. Individuals with increased levels of activity patterns may have been occupied as servants and craftspeople.

Hypothesis 3:

Marked expression of activity patterns in the Tombos population would suggest a harsh lifestyle, characteristic of a physically demanding workload. Severe activity patterns would be representative of occupations such as farmers and slave laborers. This scenario would reflect Tombos as being a territory subjugated by the Egyptian Empire, where local labor sources were controlled and manipulated by the imperial system.

Results of activity pattern analysis of the Tombos New Kingdom population suggest the community served as a colonial administrative center of the Egyptian Empire (Hypothesis 1). The limited levels of osteoarthritis, vertebral osteophytosis, Schmorl's nodes and musculoskeletal stress markers indicate this population was not participating in repetitive and strenuous physical activities.

While it is impossible to specifically define what types of activities this community was participating in, activity patterns analysis suggests they may have been involved in occupations such as minor officials, scribes and prosperous servants. While this list is by no means exhaustive, it provides contextual examples with which we can better understand the function of the New Kingdom community of Tombos.

From this analysis, one can conclude that Tombos likely served as a colonial administrative center for the Egyptian Empire. The members of this community were likely not participating in physically demanding activities generally associated with imperial subjugation. Furthermore, burial inclusions, written text and architecture (Smith 2003) support this bioarchaeological investigation of activity patterns and further suggest that Tombos was a relatively prosperous community.

Being a colonial administrative center, Tombos also serves as an example of imperial consolidation as the Egyptian Empire attempted to incorporate the local Nubian population into an imperial framework. The influence of the Egyptian Empire on the Tombos community is clearly visible in burial styles, written text and architecture from this period. Furthermore, the incorporation of local elites, such as Siamun, is an example of an imperial political strategy. The permanent Egyptian presence that would have been distinct in a colonial administrative center would also have served as an imperial political statement. This distinctly separates Middle Kingdom imperial strategies, focused on military conquest and fortress construction, from that of the New Kingdom. Egyptian occupation of hinterland territories, such as Tombos, would have clearly illustrated a long-term imperial philosophy.

The Egyptian Empire also utilized Tombos as a point of control for trade and as a means of further contact with lower Nubia. Tombos, located on the Third Cataract of the Nile River, is in prime location that would have played a pivotal role in the Egyptian campaign for control of lower Nubia. An Egyptian presence in Tombos would have served as an urban stronghold with which further southward expansion could be conducted. The Egyptian Empire was successful in their attempts at consolidation of the Nubian hinterlands. Evidence suggests Egypt maintained control of Tombos through the Third Intermediate Period (1,050 BC).

Social identity and osteological theory have both informed this project. The bioarchaeological analysis of New Kingdom Tombos has not only elucidated the role of the community within the broader Egyptian Empire but has provided insight into the types of activities in which these individuals were participating. Osteological evidence of these daily activities offers an anthropological understanding of the social identities of the people buried at Tombos. The osteological paradox, with particular reference to hidden heterogeneity, has been addressed through this research as well. The analysis of archaeological material remains and features in conjunction with the skeletal material permits the study of otherwise 'hidden' factors such as socioeconomic differences, micro-environmental variation, genetics and temporal trends (Wright and Yoder 2002). By understanding the social identities of Tombos sample, an important variable in disease susceptibility is revealed. Future research, discussed below, will further assist in offsetting the risks of hidden heterogeneity.

7.3. Future Research

This thesis, the first comprehensive study of activity patterns in Nubia, has been successful in revealing information concerning the biocultural effects of the

Egyptian Empire on the Nubian population of Tombos and in elucidating the function of the village during the New Kingdom. However, this preliminary research has made clear opportunities for future research in the region.

The analysis of other skeletal material from Tombos, particularly from different time periods (i.e. Third Intermediate and Napatan periods) would bolster a local point of comparison. This data would expound upon this thesis research by illustrating a local population under non-imperial control. Both during the Third Intermediate period as well as the Napatan period, the Egyptian Empire no longer controlled the Third Cataract region. Furthermore, it was during this time that the Kushite rule was enforced, leading to the installation of Nubian pharaohs who ruled Egypt during the 25th dynasty. The comparison of activity patterns during New Kingdom Egyptian imperial control versus Kushite control during later periods would provide evidence for variant modes of influence. With continued excavation efforts in 2010 and 2011, this extended sample will be tenable.

Furthermore, previously excavated skeletal material, currently housed in international museums (i.e. Duckworth Laboratory at the University of Cambridge, the British Museum), would also serve as a basis of comparison. These collections represent various populations from both Egypt and Nubia and illustrate examples of both Egyptian colonial control as well as those not under imperial jurisdiction.

Further excavation and analysis of other Third Cataract cemeteries would facilitate investigations into the function of other communities under Egyptian imperial control. While Tombos may have served as a prosperous community with limited levels of strenuous physical labor, other towns in this region may have served other functions. Continued cemetery excavations in and around the region of Tombos will provide the skeletal remains necessary for this line of research.

To better understand the effects of imperialism on local communities, supplementary comparison samples from other imperial regimes would expand our understanding of imperial effects on local populations. While this thesis has developed our understanding of Egyptian imperial effects on a Nubian population, exploration into the effects of other empires on hinterland populations would provide a solid foundation with which to better understand empires around the world.

The analysis of activity patterns is theoretically interwoven with routine daily life. Further bioarchaeological investigations into the everyday existence of ancient Nile Valley inhabitants would broaden our knowledge of the habitual. Another methodology, stable isotope analysis, also has the potential to answer questions regarding ancient patterns of daily life. Nitrogen (N^{15}/N^{14}) and carbon (C^{13}/C^{12}) stable isotope analysis would provide information on the diets of both the Tombos population as well as the above mentioned comparison samples.

7.4. Anthropological Contribution

This thesis made several contributions to the anthropological pursuit of investigating ancient populations. This research has direct implications for understanding the biological repercussions of imperialism and for furthering our knowledge of the function of imperial communities. The biological ramifications of imperialism have been studied in the past (Andrushko 2007; Hutchinson 1996; Larsen and Milner 1994; Tung 2003), but never with reference to collective activity patterns. From this research we can better understand the everyday lives of past peoples, the function of communities under imperial control and the effects of imperialism on hinterland populations. These anthropological questions can be applied to various imperial populations throughout time and space.

Information regarding the daily life of the Tombos inhabitants has been revealed. Due to the fact the modern village of Tombos is directly above the ancient city, archaeological endeavors of the ancient city and associated households cannot be conducted at this time. Therefore, hypotheses regarding the ordinary existence of the Tombos population have been limited. Through this bioarchaeological study, insights into the everyday activities of the Tombos inhabitants have been elucidated. Furthermore, the conclusions reached regarding the colonial administrative center function of Tombos can be built upon in further research both at this site and throughout imperial Nubia.

This research has contributed to the field of biological anthropology and bioarchaeology by presenting a multifaceted methodological approach in which three primary modes of analyses were united to introduce a more accurate image of activity patterns in past populations. This methodology is easily reproducible, as described in Chapter 4. It is my hope to continue researching this approach and to further its use in bioarchaeological research to achieve a better understanding of ancient activity patterns and imperial control.

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APPENDICES

Appendix A.

Standardized Scoring Methodologies

Table A.1 Osteoarthritis Lipping Standardized Scoring

Osteoarthritis	
Lipping	
Score	**Description**
1	Barely discernable
2	Sharp ridge
3	Extensive spicule formation
4	Ankylosis

According to Buikstra and Ubelaker, 1994

Table A.2 Osteoarthritis Porosity Standardized Scoring

Osteoarthritis	
Porosity	
Score	**Description**
1	Pinpoint
2	Coalesced
3	Pinpoint and coalesced

According to Buikstra and Ubelaker, 1994

Table A.3 Osteoarthritis Eburnation Standardized Scoring

Osteoarthritis	
Eburnation	
Score	**Description**
1	Barely discernable
2	Polish only
3	Polish with groove(s)

According to Buikstra and Ubelaker, 1994

Table A.4 Vertebral Osteophytosis Standardized Scoring

Vertebral Osteophytosis	
Score	**Description**
1	Barely discernable
2	Elevated ring
3	Curved spicules
4	Fusion present

According to Buikstra and Ubelaker, 1994

Table A.5 Schmorl's Nodes Standardized Scoring

Schmorl's Nodes	
Score	**Description**
1	Barely discernable
2	Moderate Expression
3	Marked expression

According to Buikstra and Ubelaker, 1994

Table A.6 Musculoskeletal Stress Marker Standardized Scoring

Musculoskeletal Stress Markers	
Score	**Description**
0	No signs of robusticity are present
1	The outer portion of the bone is slightly rounded with elevation apparent when touched, although no distinct crests or ridges are present
2	The outer portion of the bone is uneven with a mound-shaped elevation clearly visible
3	Distinct sharp crests or ridges are present and there may be a small depression between crests
4	Shallow pitting into the cortex, less than 1mm in depth
5	The pitting is between 1mm and 3mm in depth and covers a greater surface area
6	Pitting is greater than 3mm in depth and more than 5mm in length

According to Hawkey and Merbs, 1995

Appendix B.

Osteoarthritis Raw Data

Table B.1 Osteoarthritis of the Glenoid Fossa Raw Data

	Lipping			Porosity			Eburnation		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	30	66.67	0	37	82.22	0	43	100.00
	1	12	26.67	1	6	13.33	**Total**	43	100.00
	2	*1*	2.22	**Total**	43	100.00			
	Total	43	100.00						
Right	0	30	78.95	0	35	92.11	0	38	100.00
	1	8	21.05	1	3	7.89	**Total**	38	100.00
	Total	38	100.00	**Total**	38	100.00			

Table B.2 Osteoarthritis of the Proximal Humerus Raw Data

	Lipping			Porosity			Eburnation		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	26	78.79	0	31	93.94	0	33	100.00
	1	6	18.18	1	2	6.06	**Total**	33	100.00
	2	*1*	*3.03*	**Total**	33	100.00			
	Total	33	100.00						
Right	0	31	81.58	0	38	100.00	0	38	100.00
	1	6	15.79	**Total**	38	100.00	**Total**	38	100.00
	2	*1*	*2.63*						
	Total	38	100.00						

Table B.3 Osteoarthritis of the Distal Humerus Raw Data

	Lipping			Porosity			Eburnation		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	48	94.12	0	51	100.00	0	51	100.00
	1	2	3.92	**Total**	51	100.00	**Total**	51	100.00
	2	*1*	*1.96*						
	Total	51	100.00						
Right	0	55	93.22	0	59	100.00	0	59	100.00
	1	4	6.78	**Total**	59	100.00	**Total**	59	100.00
	Total	59	100.00						

Table B.4 Osteoarthritis of the Proximal Radius Raw Data

	Lipping			Porosity			Eburnation		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	50	94.34	0	53	100.00	0	53	100.00
	1	3	5.66	**Total**	53	100.00	**Total**	53	100.00
	Total	53	100.00						
Right	0	46	93.88	0	48	97.96	0	49	100.00
	1	3	6.12	1	1	2.04	**Total**	49	100.00
	Total	49	100.00	**Total**	49	100.00			

Table B.5 Osteoarthritis of the Distal Radius Raw Data

	Lipping			**Porosity**			**Eburnation**		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	39	76.47	0	51	100.00	0	51	100.00
	1	12	23.53	**Total**	51	100.00	**Total**	51	100.00
	Total	51	100.00						
Right	0	37	90.24	0	40	97.56	0	41	100.00
	1	4	9.76	1	1	2.44	**Total**	41	100.00
	Total	41	100.00	**Total**	41	100.00			

Table B.6 Osteoarthritis of the Proximal Ulna Raw Data

	Lipping			**Porosity**			**Eburnation**		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	26	68.42	0	37	97.37	0	38	100.00
	1	12	31.58	1	1	2.63	**Total**	38	100.00
	Total	38	100.00	**Total**	38	100.00			
Right	0	55	68.75	0	71	88.75	0	80	100.00
	1	13	16.25	1	8	10.00	**Total**	80	100.00
	2	*12*	*15.00*	*2*	*1*	*1.25*			
	Total	80	100.00	**Total**	80	100.00			

Table B.7 Osteoarthritis of the Distal Ulna Raw Data

	Lipping			Porosity			Eburnation		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	23	95.83	0	24	100.00	0	24	100.00
	1	1	4.17	**Total**	24	100.00	**Total**	24	100.00
	Total	24	100.00						
Right	0	34	82.93	0	39	95.12	0	41	100.00
	1	4	9.76	1	2	4.88	**Total**	41	100.00
	2	*2*	*4.88*	**Total**	41	100.00			
	3	*1*	*2.44*						
	Total	41	100.00						

Table B.8 Osteoarthritis of the Acetabulum Raw Data

	Lipping			Porosity			Eburnation		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	42	73.68	0	52	91.23	0	57	100.00
	1	12	21.05	1	5	8.77	**Total**	57	100.00
	2	*1*	*1.75*	**Total**	57	100.00			
	3	*2*	*3.51*						
	Total	57	100.00						
Right	0	35	77.78	0	42	93.33	0	45	100.00
	1	8	17.78	1	2	4.44	**Total**	45	100.00
	2	*1*	*2.22*	*2*	*1*	*2.22*			
	3	*1*	*2.22*	**Total**	45	100.00			
	Total	45	100.00						

Table B.9 Osteoarthritis of the Proximal Femur Raw Data

	Lipping			Porosity			Eburnation		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	30	65.22	0	42	91.30	0	45	97.83
	1	13	28.26	1	4	8.70	*2*	*1*	*2.17*
	2	*2*	*4.35*	**Total**	46	100.00	**Total**	46	100.00
	3	*1*	*2.17*						
	Total	46	100.00						
Right	0	34	68.00	0	48	96.00	0	50	100.00
	1	14	28.00	1	1	2.00	**Total**	50	100.00
	2	*1*	*2.00*	*3*	*1*	*2.00*			
	3	*1*	*2.00*	**Total**	50	100.00			
	Total	50	100.00						

Table B.10 Osteoarthritis of the Distal Femur Raw Data

	Lipping			Porosity			Eburnation		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	34	77.27	0	44	100.00	0	44	100.00
	1	10	22.73	**Total**	44	100.00	**Total**	44	100.00
	Total	44	100.00						
Right	0	39	76.47	0	49	96.08	0	51	100.00
	1	10	19.61	1	2	3.92	**Total**	51	100.00
	2	*2*	*3.92*	**Total**	51	100.00			
	Total	51	100.00						

Table B.11 Osteoarthritis of the Proximal Tibia Raw Data

	Lipping			Porosity			Eburnation		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	35	85.37	0	40	97.56	0	41	100.00
	1	5	12.20	1	1	2.44	**Total**	41	100.00
	2	*1*	*2.44*	**Total**	41	100.00			
	Total	41	100.00						
Right	0	37	84.09	0	43	97.73	0	44	100.00
	1	6	13.64	1	1	2.27	**Total**	44	100.00
	2	*1*	*2.27*	**Total**	44	100.00			
	Total	44	100.00						

Table B.12 Osteoarthritis of the Distal Tibia Raw Data

	Lipping			Porosity			Eburnation		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	44	84.62	0	52	100.00	0	52	100.00
	1	8	15.38	**Total**	52	100.00	**Total**	52	100.00
	Total	52	100.00						
Right	0	28	82.35	0	34	100.00	0	34	100.00
	1	5	14.71	**Total**	34	100.00	**Total**	34	100.00
	2	*1*	*2.94*						
	Total	34	100.00						

Table B.13 Osteoarthritis of the Proximal Fibula Raw Data

	Lipping			**Porosity**			**Eburnation**		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	14	87.50	0	16	100.00	0	16	100.00
	1	2	12.50	**Total**	16	100.00	**Total**	16	100.00
	Total	16	100.00						
Right	0	10	76.92	0	13	100.00	0	13	100.00
	1	3	23.08	**Total**	13	100.00	**Total**	13	100.00
	Total	13	100.00						

Table B.14 Osteoarthritis of the Distal Fibula Raw Data

	Lipping			**Porosity**			**Eburnation**		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	43	91.49	0	46	97.87	0	47	100.00
	1	3	6.38	1	1	2.13	**Total**	47	100.00
	2	*1*	*2.13*	**Total**	47	100.00			
	Total	47	100.00						
Right	0	34	87.18	0	39	100.00	0	39	100.00
	1	3	7.69	**Total**	39	100.00	**Total**	39	100.00
	2	*2*	*5.13*						
	Total	39	100.00						

Appendix C.

Vertebral Degeneration Raw Data

Table C.1 Vertebral Degeneration of the Cervical Vertebrae Raw Data

	Vertebral Osteophytosis			Schmorl's Nodes		
	Score	*n*	%	Score	*n*	%
Superior	0	195	70.91	0	275	100.00
	1	58	21.09	**Total**	275	100.00
	2	17	6.18			
	3	*4*	*1.45*			
	4	*1*	*0.36*			
	Total	275	100.00			
Inferior	0	188	68.36	0	275	100.00
	1	53	19.27	**Total**	275	100.00
	2	25	9.09			
	3	*8*	*2.91*			
	4	*1*	*0.36*			
	Total	275	100.00			

Table C.2 Vertebral Degeneration of the Thoracic Vertebrae Raw Data

	Vertebral Osteophytosis				Schmorl's Nodes		
	Score	*n*	%		Score	*n*	%
Superior	0	389	74.95		0	518	99.81
	1	102	19.65		1	1	0.19
	2	16	3.08		**Total**	519	100.00
	3	*2*	*0.39*				
	4	*4*	*0.77*				
	Total	519	100.00				
Inferior	0	398	76.69		0	507	97.69
	1	87	16.76		1	2	0.39
	2	26	5.01		2	1	0.19
	3	*3*	*0.58*		3	2	0.39
	4	*4*	*0.77*		**Total**	519	100.00
	Total	519	100.00				

Table C.3 Vertebral Degeneration of the Lumbar Vertebrae Raw Data

	Vertebral Osteophytosis				**Schmorl's Nodes**		
	Score	*n*	%		Score	*n*	%
Superior	0	141	51.46	-	0	248	90.51
	1	55	20.07		1	3	1.09
	2	40	14.60		2	4	1.46
	3	*26*	*9.49*		*3*	*1*	*0.36*
	4	*8*	*2.92*		**Total**	274	100.00
	Total	274	100.00				
Inferior	0	149	54.38		0	252	91.97
	1	64	23.36		1	3	1.09
	2	34	12.41		2	4	1.46
	3	*14*	*5.11*		*3*	*2*	*0.73*
	4	*9*	*3.28*		**Total**	274	100.00
	Total	274	100.00				

Table C.4 Vertebral Degeneration of the Sacral Vertebrae Raw Data

	Vertebral Osteophytosis				**Schmorl's Nodes**		
	Score	*n*	%		Score	*n*	%
Superior	0	33	60.00	-	0	52	96.30
	1	15	27.27		1	1	1.85
	2	4	7.27		2	1	1.85
	3	*2*	*3.64*		**Total**	54	100.00
	4	*1*	*1.82*				
	Total	55	100.00				

Appendix D.

Musculoskeletal Stress Marker Raw Data

Table D.1 Musculoskeletal Stress Marker Raw Data for the Clavicle

	Conoid			**Costoclavicular**			**Subclavius**		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	22	50.00	0	24	54.55	0	35	79.55
	1	16	36.36	1	11	25.00	1	5	11.36
	2	6	13.64	2	2	4.55	2	2	4.55
	Total	44	100.00	*4*	*1*	*2.27*	*4*	*1*	*2.27*
				9	6	13.64	9	1	2.27
				Total	44	100.00	**Total**	44	100.00
Right	0	23	56.10	0	22	53.66	0	34	82.93
	1	13	31.71	1	8	19.51	1	5	12.20
	2	5	12.20	2	3	7.32	2	1	2.44
	Total	41	100.00	*4*	*5*	*12.20*	9	1	2.44
				9	3	7.32	**Total**	41	100.00
				Total	41	100.00			

	Trapezius			**Trapezoid**		
	Score	*n*	%	Score	*n*	%
Left	0	31	70.45	0	29	65.91
	1	12	27.27	1	14	31.82
	9	1	2.27	2	1	2.27
	Total	44	100.00	**Total**	44	100.00
Right	0	26	63.41	0	32	78.05
	1	12	29.27	1	6	14.63
	9	3	7.32	2	1	2.44
	Total	41	100.00	9	2	4.88
				Total	41	100.00

Table D.2 Musculoskeletal Stress Marker Raw Data for the Scapula

	Pectoralis Minor			Trapezius		
	Score	*n*	%	Score	*n*	%
Left	0	27	61.36	0	31	70.45
	9	17	38.64	1	2	4.55
	Total	44	100.00	9	11	25.00
				Total	44	100.00
Right	0	32	86.49	0	26	70.27
	1	3	8.11	1	3	8.11
	9	2	5.41	9	8	21.62
	Total	37	100.00	**Total**	37	100.00

Table D.3 Musculoskeletal Stress Marker Raw Data for the Humerus

	Deltoideus			**Common Extensors**			**Common Flexors**		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	25	42.37	0	23	38.98	0	35	59.32
	1	16	27.12	1	14	23.73	1	9	15.25
	2	5	8.47	2	6	10.17	2	5	8.47
	3	*1*	*1.69*	*3*	*1*	*1.69*	9	10	16.95
	9	12	20.34	9	15	25.42	**Total**	59	100.00
	Total	59	100.00	**Total**	59	100.00			
Right	0	27	40.30	0	25	37.31	0	34	50.75
	1	19	28.36	1	14	20.90	1	16	23.88
	2	2	2.99	2	10	14.93	2	3	4.48
	3	*2*	*2.99*	*3*	*5*	*7.46*	9	14	20.90
	9	17	25.37	9	13	19.40	**Total**	67	100.00
	Total	67	100.00	**Total**	67	100.00			

	Infraspinatous			**Latissimus Dorsi**			**Pectoralis Major**		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	27	45.76	0	32	54.24	0	29	49.00
	1	1	1.69	1	7	11.86	1	15	25.42
	2	1	1.69	2	9	15.25	2	4	6.78
	9	30	50.85	9	11	18.64	*3*	*1*	*1.69*
	Total	59	100.00	**Total**	59	100.00	9	10	16.95
							Total	59	100.00
Right	0	27	40.30	0	34	50.75	0	29	43.28
	3	*1*	*1.49*	1	12	17.91	1	11	16.42
	9	39	58.21	2	4	5.97	2	9	13.43
	Total	67	100.00	9	17	25.37	*3*	*1*	*1.49*
				Total	67	100.00	9	17	25.37
							Total	67	100.00

	Subscapularis			Supraspinatus			Teres Major		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	22	37.29	0	26	44.07	0	32	54.24
	1	3	5.08	1	1	1.69	1	11	18.64
	2	3	5.08	2	1	1.69	2	3	5.08
	9	31	52.54	*3*	*1*	*1.69*	*4*	*3*	*5.08*
	Total	59	100.00	9	30	50.85	9	10	16.95
				Total	59	100.00	**Total**	59	100.00
Right	0	22	32.84	0	24	35.82	0	34	50.75
	1	8	11.94	1	5	7.46	1	11	16.42
	2	2	2.99	*3*	*1*	*1.49*	2	3	4.48
	3	*1*	*1.49*	9	37	55.22	*3*	*1*	*1.49*
	9	34	50.75	**Total**	67	100.00	*4*	*1*	*1.49*
	Total	67	100.00				9	17	25.37
							Total	67	100.00

	Teres Minor		
	Score	*n*	%
Left	0	22	37.29
	1	6	10.17
	2	1	1.69
	9	30	50.85
	Total	59	100.00
Right	0	23	34.33
	1	5	7.46
	2	2	2.99
	9	37	55.22
	Total	67	100.00

Table D.4 Musculoskeletal Stress Marker Raw Data for the Ulna

	Anconeus			**Brachialis**			**Pronator Quadrates**		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	29	69.05	0	31	73.81	0	20	47.62
	1	8	19.05	1	7	16.67	1	10	23.81
	9	5	11.90	2	1	2.38	2	1	2.38
	Total	42	100.00	9	3	7.14	9	11	26.19
				Total	42	100.00	**Total**	42	100.00
Right	0	65	73.86	0	66	75.00	0	51	57.95
	1	13	14.77	1	13	14.77	1	5	5.65
	2	2	2.27	2	4	4.55	2	2	2.27
	9	8	9.09	9	5	5.68	9	30	34.09
	Total	88	100.00	**Total**	88	100.00	**Total**	88	100.00

	Triceps Brachii		
	Score	*n*	%
Left	0	29	66.67
	1	7	16.67
	2	2	4.76
	9	4	9.52
	Total	42	100.00
Right	0	63	71.59
	1	12	13.64
	2	7	7.95
	9	6	6.82
	Total	88	100.00

Table D.5 Musculoskeletal Stress Marker Raw Data for the Radius

	Biceps Brachii			Pronator Teres			Supinator		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	42	66.67	0	41	65.08	0	48	76.19
	1	10	15.87	1	10	15.87	1	4	6.35
	2	2	3.17	2	5	7.94	2	2	3.17
	9	9	14.29	9	7	11.11	*3*	*1*	*1.59*
	Total	63	100.00	**Total**	63	100.00	9	8	12.70
							Total	63	100.00
Right	0	42	71.19	0	38	64.41	0	44	74.58
	1	10	16.95	1	9	15.25	1	8	13.56
	3	*1*	*1.69*	2	2	3.39	2	1	1.69
	9	6	10.17	9	10	16.95	9	6	10.17
	Total	59	100.00	**Total**	59	100.00	**Total**	59	100.00

Table D.6 Musculoskeletal Stress Marker Raw Data for the Os Coxae

	Adductor Magnus			**Biceps Femoris**			**Gluteus Maximus**		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	14	24.56	0	42	73.68	0	33	57.89
	1	5	8.77	1	8	14.04	1	3	5.26
	2	2	3.51	2	1	1.75	9	21	36.84
	9	36	63.16	9	6	10.53	**Total**	57	100.00
	Total	57	100.00	**Total**	57	100.00			
Right	0	10	21.28	0	32	68.09	0	30	63.83
	1	4	8.51	1	2	4.26	1	3	6.38
	2	3	6.38	2	1	2.13	9	14	29.79
	9	30	63.83	9	12	25.53	**Total**	47	100.00
	Total	47	100.00	**Total**	47	100.00			

	Gluteus Medius			**Gluteus Minimus**			**Illiacus**		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	31	54.39	0	30	52.63	0	32	56.14
	1	1	1.75	1	3	5.26	2	1	1.75
	2	1	1.75	2	2	3.51	9	24	42.11
	9	24	42.11	9	22	38.60	**Total**	57	100.00
	Total	57	100.00	**Total**	57	100.00			
Right	0	31	65.96	0	27	57.45	0	30	63.83
	1	1	2.13	1	3	6.38	9	17	36.17
	9	15	31.91	9	17	36.17	**Total**	47	100.00
	Total	47	100.00	**Total**	47	100.00			

	Pectineus			Quadrates Femoris			Rectus Femoris		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	26	45.61	0	43	75.44	0	42	73.68
	1	5	8.77	9	14	24.56	1	2	3.51
	9	26	45.61	**Total**	57	100.00	9	13	22.81
	Total	57	100.00				**Total**	57	100.00
Right	0	21	44.68	0	33	70.21	0	32	68.09
	1	2	4.26	1	1	2.13	1	5	10.64
	9	24	51.06	9	13	27.66	2	1	2.13
	Total	47	100.00	**Total**	47	100.00	9	9	19.15
							Total	47	100.00

	Semitendinosus		
	Score	*n*	%
Left	0	41	71.93
	1	9	15.79
	2	1	1.75
	9	6	10.53
	Total	57	100.00
Right	0	33	70.21
	1	2	4.26
	2	1	2.13
	9	11	23.40
	Total	47	100.00

Table D.7 Musculoskeletal Stress Marker Raw Data for the Femur

	Adductor Magnus			**Gastrocnemius**			**Gluteus Maximus**		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	34	58.62	0	28	48.28	0	22	37.93
	1	12	20.69	1	11	18.97	1	12	20.69
	2	7	12.07	2	2	3.45	2	11	18.97
	9	5	8.62	9	17	29.31	*3*	*6*	*10.34*
	Total	58	100.00	**Total**	58	100.00	*4*	*2*	*3.45*
							9	5	8.62
							Total	58	100.00
Right	0	39	60.94	0	32	50.00	0	35	54.69
	1	8	12.50	1	7	10.94	1	12	18.75
	2	8	12.50	2	4	6.25	2	5	7.81
	3	*2*	*3.13*	*3*	*1*	*1.56*	*3*	*2*	*3.13*
	9	7	10.94	*6*	*1*	*1.56*	*4*	*2*	*3.13*
	Total	64	100.00	9	19	29.69	9	8	12.50
				Total	64	100.00	**Total**	64	100.00

	Gluteus Medius			**Gluteus Minimus**			**Illiacus**		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	21	36.21	0	19	32.76	0	41	70.69
	1	13	22.41	1	14	24.14	1	9	15.52
	2	5	8.62	2	5	8.62	*3*	*1*	*1.72*
	9	19	32.76	*3*	*2*	*3.45*	9	7	12.07
	Total	58	100.00	9	18	31.03	**Total**	58	100.00
				Total	58	100.00			
Right	0	17	26.56	0	18	28.13	0	46	71.88
	1	15	23.44	1	14	21.88	1	8	12.50
	2	4	6.25	2	9	14.06	2	1	1.56
	3	*1*	*1.56*	*4*	*1*	*1.56*	9	9	14.06
	9	27	42.19	9	22	34.38	**Total**	64	100.00
	Total	64	100.00	**Total**	64	100.00			

	Obturator			Pectineus			Piriformis		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	25	43.10	0	39	67.24	0	17	29.31
	1	7	12.07	1	10	17.24	1	11	18.97
	2	9	15.52	2	2	3.45	2	9	15.52
	3	*1*	*1.72*	9	7	12.07	9	21	36.21
	9	16	24.59	**Total**	58	100.00	**Total**	58	100.00
	Total	58	100.00						
Right	0	28	43.75	0	44	68.75	0	21	32.81
	1	5	7.81	1	9	14.06	1	13	20.31
	2	5	7.81	*3*	*1*	*1.56*	2	6	9.38
	3	*1*	*1.56*	9	10	15.63	*3*	*2*	*3.13*
	9	25	39.06	**Total**	64	100.00	9	22	34.38
	Total	64	100.00				**Total**	64	100.00

	Popliteus			Quadrates Femoris			Vastus Intermedius		
	Score	*n*	%	Score	*n*	%	Score	*n*	%
Left	0	32	55.17	0	26	44.83	0	36	62.07
	1	5	8.62	1	7	12.07	1	10	17.24
	2	1	1.72	2	1	1.72	2	3	5.17
	9	20	34.48	*3*	*1*	*1.72*	9	9	15.52
	Total	58	100.00	9	23	39.66	**Total**	58	100.00
				Total	58	100.00			
Right	0	36	56.25	0	28	43.75	0	38	59.38
	1	6	9.38	1	7	10.94	1	11	17.19
	2	2	3.13	2	3	4.69	2	4	6.25
	9	20	31.25	9	26	40.63	*3*	*1*	*1.56*
	Total	64	100.00	**Total**	64	100.00	9	10	15.63
							Total	64	100.00

	Vastus Lateralis			Vastus Medialis		
	Score	*n*	%	Score	*n*	%
Left	0	34	58.62	0	38	65.52
	1	6	10.34	1	8	13.79
	2	3	5.17	2	7	12.07
	3	*1*	*1.72*	9	5	8.62
	9	14	24.14	**Total**	58	100.00
	Total	58	100.00			
Right	0	38	59.38	0	37	57.81
	1	6	9.38	1	14	21.88
	2	2	3.13	2	2	3.13
	9	18	28.13	*3*	*2*	*3.13*
	Total	64	100.00	9	9	14.06
				Total	64	100.00

Table D.8 Musculoskeletal Stress Marker Raw Data for the Tibia

Flexors Digitorum

	Score	*n*	%
Left	0	44	78.57
	1	3	5.36
	9	9	16.07
	Total	56	100.00
Right	0	43	81.13
	1	2	3.77
	2	1	1.89
	3	*2*	*3.77*
	9	5	9.43
	Total	53	100.00

Popliteus

	Score	*n*	%
Left	0	39	69.64
	1	3	5.36
	2	2	3.57
	9	12	21.43
	Total	56	100.00
Right	0	42	79.25
	1	7	13.21
	2	1	1.89
	9	3	5.66
	Total	53	100.00

Soleus

	Score	*n*	%
Left	0	19	33.93
	1	16	28.57
	2	6	10.71
	3	*4*	*7.14*
	4	*2*	*3.57*
	9	9	16.07
	Total	56	100.00
Right	0	25	47.17
	1	18	33.96
	2	4	7.55
	3	*3*	*5.66*
	6	*1*	*1.89*
	9	2	3.77
	Total	53	100.00

Semimembranosus

	Score	*n*	%
Left	0	19	33.93
	1	5	8.93
	2	2	3.57
	9	30	53.57
	Total	56	100.00
Right	0	22	41.51
	1	7	13.21
	2	1	1.89
	9	23	43.40
	Total	53	100.00

Tibialis Anterior

	Score	*n*	%
Left	0	24	42.86
	1	18	32.14
	2	5	8.93
	9	9	16.07
	Total	56	100.00
Right	0	26	49.06
	1	19	35.85
	2	2	3.77
	3	*2*	*3.77*
	9	4	7.55
	Total	53	100.00

Tibialis Posterior

	Score	*n*	%
Left	0	36	64.29
	1	8	14.29
	2	2	3.57
	3	*1*	*1.79*
	9	9	16.07
	Total	56	100.00
Right	0	35	66.04
	1	11	20.75
	2	1	1.89
	3	*2*	*3.77*
	9	4	7.55
	Total	53	100.00