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Health status of infants and children from the Bronze Age tomb at Tell Abraç, United Arab Emirates

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HEALTH STATUS OF INFANTS AND CHILDREN FROM THE BRONZE AGE

TOMB AT TELL ABRAQ, UNITED ARAB EMIRATES

by

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Bachelor of Arts
Hamline University
2005

A thesis submitted in partial fulfillment
of the requirements for the

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May 2010

ABSTRACT

Health Status of Infants and Children from the Bronze Age Tomb at Tell Abraq, United Arab Emirates

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Tell Abraq is significant because it is the largest prehistoric site on the southern coast of the Arabian Gulf. It was strategically important as an ancient port, regionally surrounded by large political centers. Commingled remains were located in a small tomb (6 m) used for a 200 year period (2200-2000 BC). The site was continually occupied from the 3rd millennium BC up to the 1st century AD. In the tomb were minimally 286 adults and 127 subadults. What is extraordinary is the number of pre-term (3rd trimester) infants (n=28, 22%), neonates (n=12, 9%), and infants under 2 years (n=46, 36%). The collection also yielded many children aged 2 to 5 years (n=32, 25%). This abundance of very young children is more startling in comparison to the very low number of subadults aged 6-18 (n=9, 7%). Differential preservation and burial practices of older children do not appear to be reasons for this low number.

We have reported elsewhere that the adult portion of the population appears relatively robust and well-represented across age and sex categories. Analysis using radiography, thin-sections, metric data, and paleopathology demonstrates that while there was some suffering from infection and failure to thrive among the subadults (as suggested by poor cortical maintenance at the expense of growth in length), frequencies

are not high enough to explain what placed premature and newly born infants and toddlers at risk. Cultural norms such as consanguinity, marriage and pregnancy at a young age, and benign neglect may be underlying factors contributing to poor infant outcomes.

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CHAPTER 1

INTRODUCTION

Patterns of poor health and early death are important to document because they shed light on how humans survive and adapt over time to changing environments. Paleopathology can play a fundamental role in providing empirical data about the health status of individuals prior to death. The goal of this project is to examine the health of a Bronze Age (C. 2200 – 2000BC) subadult population from the Arabian Peninsula, using paleopathological methods and biocultural considerations. Incorporating an analysis of morbidity and mortality into a bioarchaeological study of infants and children will provide a better understanding of the disease patterns of children while integrating their lives and deaths within a context of population processes. Using a biocultural framework that takes into consideration a range of factors affecting morbidity and mortality in ancient populations provides information on how and why children and infants were at risk.

This research is also focused on providing detailed information about subadults within a population. Often in bioarchaeological literature, the subadult portion of a collection is only briefly mentioned and any details that are offered are commonly generalizations for all ages. This research demonstrates the valuable information that can be gleaned about a whole population from more detailed subadult analysis and provides an opportunity for a better understanding of children in prehistory.

The archaeological site of Tell Abraç is located in the United Arab Emirates. It is a multi-period site on the Oman Peninsula near the Arabian (Persian) Gulf coast. It lies on the border between the emirates of Sharjah and Umm al-Quwain (Figure 1).

Excavation of Tell Abraq took place during five field seasons between 1989 and 1998 by an international team of archaeologists led by Professor Daniel Potts of the University of Sydney. The primary feature excavated at the site was a raised mud brick fortification constructed in several phases throughout the three millennia of occupation (Potts 1993b, 2001). The community at Tell Abraq was occupied from the late Bronze Age (approximately 2200 BC) to the Iron Age (approximately 400 BC) by a mostly sedentary population (Potts 1990).

The 1991 field season resulted in the discovery of a large stone mortuary tomb 10 meters to the west of the fortress where it served as the resting place for deceased individuals for a period of 200 years (2200-2000 BC) during the late third millennium BC (Potts 2000). The tomb was constructed in the Umm an-Nar style prominent in the region at that time but it is unusual in that it was discovered in a relatively undisturbed condition (Figure 2).

Umm an-Nar burial characteristics include the circular design of an above-ground stone construction with interior chambers formed by crosswalls. The size ranges from 4 to 12 meters in diameter (Frifelt 1975). The tomb at Tell Abraq is characteristic of this style and was constructed of worked limestone ashlar blocks and beach rock in a circular shape measuring 6 meters across (Potts 1993a, 2000, 2001) (see Figure 2). A flat stone floor was laid down prior to the construction of an interior dividing wall that forms the barrier of the two internal chambers. A doorway was formed using another flat stone that could be removed when additional deceased individuals were interred in the tomb (Potts 2000).

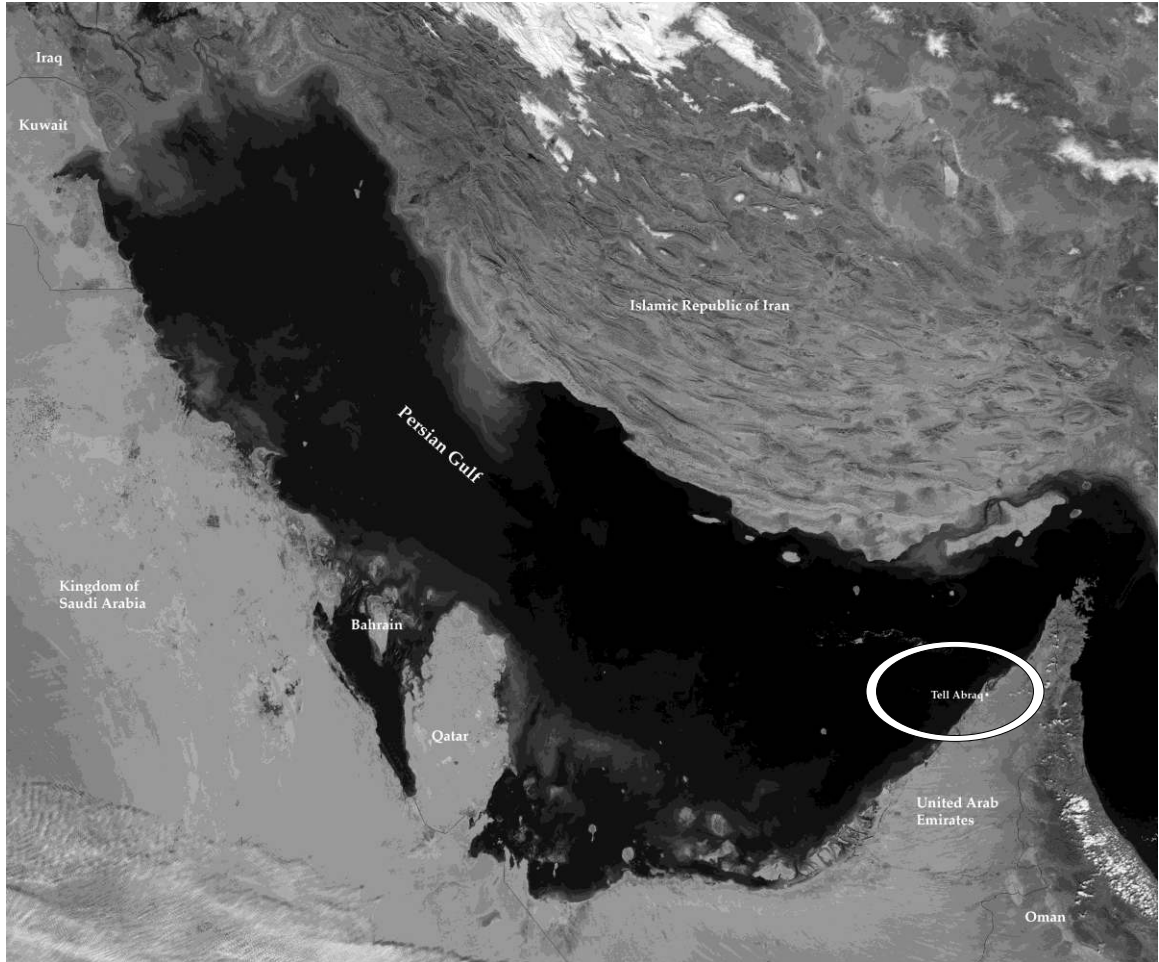


Figure 1. Satellite view of United Arab Emirates with the site of Tell Abraq indicated by the circle.



Figures 2 & 3. Left: The excavated tomb at Tell Abraq. Right: Dense bed of sand, bone, and artifacts.

Decomposition of remains over time allowed bones to settle and commingle with others (see Figure 3). It is not known how bodies were arranged in the tomb, but there was very little articulation of individual burials. A northeast portion of the tomb was disturbed at some point following its use; however, the tomb's contents do not appear to have been looted in antiquity (Potts 2000). Stone blocks from a small area of the chamber's outer wall have not been located and may therefore have been removed at some point in antiquity for re-use.

Excavation of the tomb lasted four field seasons and was complicated by the dense bed of bone, sand, and grave artifacts that had accumulated over a 200-year period in the two chambers. Excavation of the tomb was done under the direction of Professors Debra Martin and Alan Goodman from Hampshire College, Massachusetts. Recovered were all the human skeletal remains and the grave goods. These included ceramic and stone vessels, copper and bronze rings, spearheads, ostrich eggshell fragments, beads, and infant feeding shells (Potts 2000). Following excavation, the human skeletal remains were transported to the United States for curation and analysis.

The tomb at Tell Abraq is important because it is unique among other mortuary tombs in the region. The number of commingled remains in this tomb is unusually high (MNI for adults is 286 and for subadults is 127). Additionally, for the tomb not to have been looted in antiquity is an extremely rare find. The information gathered from the study of this tomb has important implications for understanding community health and local economic and cultural processes.

The tomb is also significant because it is the only mortuary feature at the site of Tell Abraq. However, it only holds individuals who died during the 200 years of occupation in the late 3rd millennium (2200-2000 BC). Since the site was occupied for a much longer period, the tomb may represent the zenith in population.

Tell Abraq is a coastal site and its position would have placed it on major trade routes for the region (Potts 1993b). Excavation of the tell and tomb resulted in the discovery of many items that originated in areas throughout the region around Tell Abraq (Potts 1993b). Individuals visiting the area for trade therefore might have been included in the tomb as well. Ongoing research may clarify this as isotopic analysis is carried out. Whether or not outsiders were placed in the tomb, one observation appears clear. Individuals of all ages at Tell Abraq were interred in the tomb, and this research illustrates that.

Particularly important is the inclusion of the youngest members of the community: third trimester and newborn infants. These observations of the various age cohorts from the tomb at Tell Abraq have raised questions regarding morbidity and mortality in Arabia during the Bronze Age. This collection in particular is unusual in the fact that there are so many preterm and term infants included in the mortuary structure.

The primary goals of this research are to explain the high number of preterm and term infants and children in the tomb by examining the paleodemographic and paleopathologic features of the human remains. Questions driving the research included (1) Were children failing to thrive due to disease and/or diet? and (2) What economic and cultural factors played a role in infant mortality? The realm of possibilities contributing to poor health and/or death was carried out within a framework that

incorporates environmental, cultural, and biological factors. This biocultural model, discussed in the next chapter, was adapted from Goodman et al. (1984) and Martin and Goodman (2002) and assists in quantifying and qualifying different categories of information by placing the human skeletal remains in a more holistic and integrated context.

This thesis is divided into five chapters that provide the context for the analysis and interpretation of childhood health at Tell Abraq. This first chapter summarizes the premise of this research and provides a brief background of the site. Chapter 2 reviews the relevant literature on constructing the biocultural context of Tell Abraq. Relevant environmental, cultural, and biological factors in the geographic area of Tell Abraq are summarized and provide background information to the analysis of the human remains. Together this information is used to determine potential scenarios for life and death at Tell Abraq. Chapter 3 provides details regarding the materials used in this research and the analytical methodology applied to them. In Chapter 4, quantitative and qualitative results of the analyses are presented. Paleodemography (age structure of the population) for the subadults is discussed and compared to that of other archaeological collections containing subadults. Also addressed are the paleopathological findings (i.e., the disease rates and health status of the bone). Chapter 5 reviews the results of the analysis and considers possible factors influencing infant mortality. Chapter 6 explores the broader implications of this study for understanding infant health in the past as well as today. Clearly, in populations around the world, infants continue to die at high rates. This research fits into larger questions about the role of agriculture on human health and how children play a part in the community as a whole.

CHAPTER 2

MODELING BIOCULTURAL INTERACTIONS AT TELL ABRAQ

The major features of environment, culture, and biology as they relate to the Tell Abraq population are shown in Figure 4. Data on the age at death and health status for the infants and children are interpreted in light of the variables affecting age-at-death and health. What would cause the death of preterm and term infants at Tell Abraq? The model is sensitive to ideological and cultural factors likely operating in these late Bronze Age communities and provides an explanatory foundation for understanding the relationship of neonates, infants, and children to their adult counterparts. An explanation of the biocultural research model is given here.

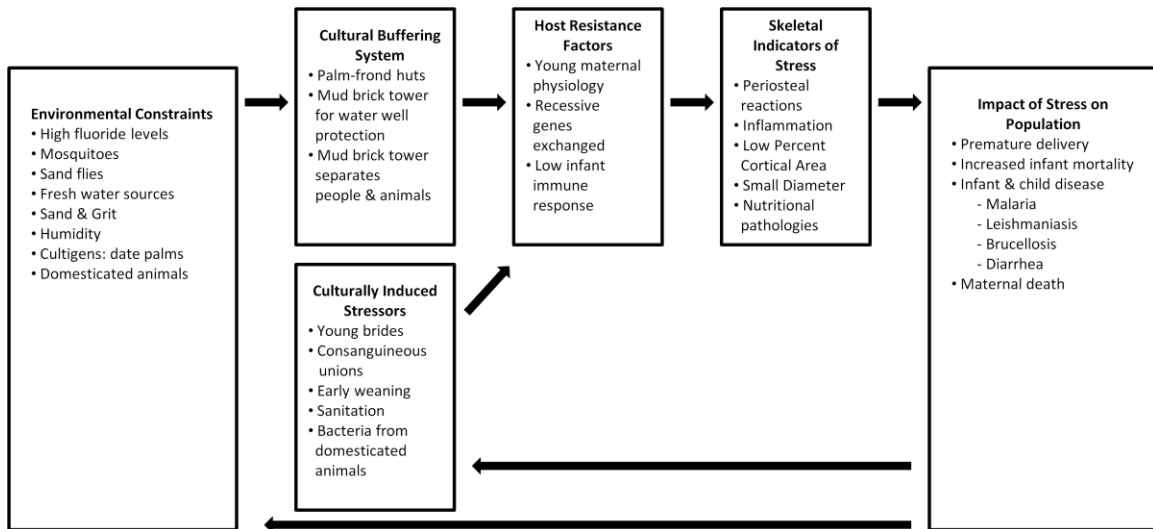


Figure 4. Biocultural model employed by this research project. Adapted from Martin and Goodman (2002) and Goodman et al. (1984).

Environmental Constraints

Populations living in the region of Tell Abraq since the Bronze Age include many of the archaeological sites excavated near the Arabian Gulf coast of the modern-day United Arab Emirates. Many of these sites include Iron Age occupations. The arid environment has been considered one of the poorest available for habitation of large populations (Magee 1996). Subsistence practices in the region were dependent on a level of sedentism and proximity to the coast's vast marine resources although the possibility existed for seasonal occupations of the coastal and inland sites such as that at Ra's al-Hadd (Cartwright 1998).

Throughout the millennia since the Bronze Age, lifestyles changed according to accessibility of resources. For example, at the 2nd millennium BC site of Shimal on the Oman Peninsula, a shift in lifestyle and subsistence patterns is suggested (Grupe and Schutkowski 1989). Here, a lifestyle change from nomadic herding to non-nomadic settlement is reflected by the dietary shift from milk, meat, terrestrial plants, and moderate amounts of marine foods to predominantly marine resources. The Iron Age site of Muweilah in the United Arab Emirates also exhibits a changing lifestyle as some later areas of the site feature evidence of huts and more nomadic housing structures, while more recent areas of the site feature more complicated permanent structures, indicating sedentism (Magee 1996). Magee's (1996) description of Muweilah subsistence patterns includes the possibility of a similar dietary shift but indicates that not all food resources are yet confirmed (i.e., cereals).

The site of Tell Abraq has a coastal, desert-oasis landscape that offered its Bronze Age population the opportunity to practice a desert farming economy. The community

here during the 3rd millennium BC utilized many parts of the landscape representing different ecologies. In addition, fresh water sources were highly valued and necessitated protection. The people at Tell Abraq and other sites therefore protected their water wells by building fortress-like towers out of large mud bricks (Potts 2001).

Subsistence practices in this area during the Bronze Age were limited by the semi-desert environment, but people managed to procure enough food for themselves in a variety of ways. For Tell Abraq, its position along the coast of the Arabian Gulf allowed sufficient marine foods including fish, turtle, dugong, and mollusks to be procured (Potts 1993b; Uerpmann 2001). The flora of the area also permitted grazing for domesticated animals such as goats, sheep, and cattle, which could be used for both meat and protein (Potts 1993b, 2000; Uerpmann 2001); however it is likely that domesticated animals would not have been heavily utilized until later years of occupation at the site. Wild animals like fox, hare, and gazelle would have also comprised a portion of the diet. Grains such as barley and wheat and fruits including melons and dates would have also been consumed. The relative diversity in this diet indicates a fairly balanced subsistence base for older children and adults. If the subsistence sources of the population at Tell Abraq were sufficient enough to provide an adequate diet then the skeletal remains analyzed should not show signs of major dietary deficiencies. Alternatively, deficiencies in certain nutrients would leave evidence of a subpar diet on the human remains.

The warm and dry climate during the occupation of Tell Abraq and nearby sites in this region was significant in prescribing the type of housing structure to build. Barasti-like huts constructed of palm fronds and posts were common in Arabia until recent centuries and their use has been noted at Tell Abraq after discovery of post holes near the

large tell (Magee 1996; Potts 2000b). Their placement is likely related to the close proximity to the water source in the tower but may also have been used while keeping watch over animal herds.

Environmental factors listed in the model's framework (see first box in Figure 4) offer a glimpse of the relationships between ecological factors and the people living at Tell Abraq. Through this assessment, specific constraints are able to be identified. For example, humid environments like that of the oasis area at Tell Abraq would have been prime locations for mosquitoes and sand flies that have the potential to carry diseases. Domesticated animals in close proximity to people's residences could have implications for zoonotic diseases and/or sanitation, particularly if using the same fresh water source. Fresh water in the area is known to contain high levels of fluoride as well (Littleton 1999; Littleton and Frolich 1989). While the effects of high fluoride levels can be positive initially, excessively high levels can complicate health (Littleton 1999). Certain cultigens in the area (i.e., dates) can cause dental pathologies or, in excess consumption, nutritional deficiencies. Finally, the sand in the environment would likely be everywhere, including on or in food. This could have detrimental effects on dentition (excessive attrition) and lead to dental pathologies. Through an understanding of all of these factors and the interactions of the people at Tell Abraq and their communal environment, it is possible to discern patterns that may have resulted in morbidity and mortality for some subgroups at higher risk than others. Many of the nutritional and health problems that may result from the above constraints do leave diagnostic changes in the bones.

Cultural Buffering System

Many elements within the cultural system at Tell Abraq were able to function as buffers against some of these constraints that could negatively impact health or survival. Some of these cultural practices worked to protect the population from harmful environmental conditions. For example, the decision to build the mud brick tower around the community's fresh water source was important. By secluding the well, the population limited access to it, thereby ensuring its function and longevity. Additionally, the placement of the well away from contact with animals helped in preventing contamination of the water from animal waste and disease.

Also within this buffering system is the type of housing structure used during the Bronze Age at this site. The palm-frond huts, as suggested by Potts (2000b), would have provided a level of protection from the weather and pests such as mosquitoes and sand flies. This, in turn, would have the potential to decrease rates of disease carried by those insects.

Culturally Induced Stressors

Particular attention has been paid to behaviors and cultural practices that may have effects on reproduction and infant and maternal morbidity and mortality. This portion of the research model is vital for understanding what conditions could place infants and children at risk. Through an extensive literature review, behaviors that may have contributed to illness or death of infants and children at Tell Abraq have been isolated for consideration in this study.

Adolescent Marriage

Marriage ritual in the area of the Arabian Gulf is fairly uniform and has been for centuries, if not millennia. Particularly relevant to this research is the long tradition of marriage of adolescent females to older males. According to the ethnographic and ethnohistoric literature, girls are typically married by the time they are 16 years old (Bener and Hussain 2006) but many in southwest Asia have been documented as being married much younger than that (Sarwar 2002). Culturally acceptable pregnancies at such a young age can result in serious consequences for the offspring and the mother (Koblinsky 1995; Scholl et al. 2002). These consequences are thus considered in this study of infant morbidity and mortality.

Consanguinity

The Arabian Gulf region has long practiced marriage between first cousins. These unions are known as consanguineous marriages. Motivated by principles of economic stabilization (Al-Gazali et al. 2005; Rajab and Patton 2000), this cultural practice has numerous potentially undesirable effects on infants and children and the genetic legacy of those practicing it. Consideration of this practice is therefore warranted as it could contribute to morbidity and affect mortality rates of the infants at Tell Abraq.

Early Weaning

Rates of subadult morbidity and mortality at Tell Abraq may have also been affected by post-partum ritual. A review of literature of the semi-sedentary Bedouin in the region of Tell Abraq revealed post-partum cultural practices that may play a role in subadult health and wellness. One particular concern focuses on breastfeeding and weaning practices. A study by Forman and colleagues (1990) noted a ritual of post-

partum seclusion practiced by traditional Bedouin Arab society (more recent populations assumed to have engaged in similar lifestyles as Bronze Age populations like the people at Tell Abraq). During this post-partum period, mothers and their newborns spend 40 days in seclusion from all but closely related women who assist them. The seclusion is intended for rest and good health of the mother and newborn as they are considered to be at an increased risk for death (Beckerleg 1984). During these 40 days, mothers may switch from exclusively breastfeeding their infant to other feeding methods, sometimes even feeding cereals to babies as young as 2 months (Forman et al. 1990). Feeding practices such as these could have detrimental effects on infant nutrition and health as proper nutrient needs might not be met. Additionally, the infant no longer receives immunity protection from the mother's breastmilk if it has been weaned.

Bacteria

Bacteria-contaminated water is a significant source of infection and diarrheal disease for populations consuming it. The people of Tell Abraq had domesticated animals and they likely shared fresh water resources. Bacteria carried by the animals would become present in the drinking water and could have the potential to affect population health.

Host Resistance Factors

This part of the model predicts the kinds of biological factors that will be important in determining health.

Recessive Genes Exchanged

The principles of genetics show that the frequent union of the same or similar genes can result in much higher prevalence of birth defects and autosomal recessive diseases (Al-Gazali et al. 2005; Al Khabori and Patton 2008). Consanguinity at Tell Abraq could have provided opportunities for recessive genes to be exchanged between families.

Low Birth Weight

A newborn infant is considered to have low birth weight if the total weight is less than 2500g (Hediger et al. 1997; Kirchengast and Hartmann 2003; Nkwabong and Fomulu 2009; Scholl et al. 1992). Infants may or may not have been born prematurely as full-term gestation of a fetus can also result in low birth weight, alternatively termed “small-for-gestational-age” (Lang et al. 1996). Either pathway results in an underweight neonate that has obviously experienced stress, preventing him/her from reaching his/her full growth potential. Poor fetal development resulting in low birth weight may be indicative of physiological dysfunction of either the mother or the neonate.

Young Maternal Age & Physiology

A relevant factor in determining causes of low birth weight among infants is young maternal age. This is significant because many studies have shown a correlation between adolescent mothers and underweight offspring (Borja and Adair 2003; Frisancho et al. 1984; Frisancho et al. 1985; Hediger et al. 1997; Kirchengast and Hartmann 2003; Nkwabong and Fomulu 2009; Scholl et al. 1992; Scholl and Hediger 1993; Scholl et al. 1994). It is relevant because many areas of the world have reproductive practices that often involve young adolescent mothers. Since these are long-lasting traditions, it is useful in studying past reproductive behaviors and infant morbidity and mortality rates.

Placental Malaria

Fetal development can also be hindered by infection and disease. These health problems can have either maternal or fetal origins and have the potential to affect both individuals. The examination of malaria during pregnancy is relevant to research at Tell Abraq because of the site's environment and likely susceptibility to mosquito infestation and malarial infection.

In areas of epidemic and endemic periods of malaria, the impact of the disease can be tremendous for certain population groups. Pregnant women and their infants can have significant risk of contracting the disease, which further increases their risk of mortality (Abrams and Meshnick 2009). This is particularly relevant to populations not exhibiting genetic protections from malaria (i.e., sickle cell anemia or the Duffy locus).

Skeletal Indicators of Stress

The kinds of markers of stress and lesions on human skeletal remains are listed here. These can be used to isolate individuals who had major health problems at the time of death. Human skeletal remains have the ability to serve as a permanent record for an individual's health status. Physiological stress can take many forms in the body but those that impact the skeletal system can be diagnostic. Unlike traumatic injuries that are clearly the result of violence, pathologies are not as easily identified as cause of death (Larsen 1997). In most instances, skeletal lesions are nonspecific and cannot be attributed to particular pathogens or diseases (Roberts and Manchester 2005, p.168). However it is fortunate that common transmissible infectious diseases (such as *Staphylococcus* and *Streptococcus*) do affect bone surfaces and it is these pathogens

which were most frequent among ancient groups (Ortner and Putschar 1981). The analysis of these nonspecific periosteal reactions seen on bone surfaces is therefore important in indicating health.

Periosteal Reactions & Nonspecific Inflammation

Nonspecific periosteal inflammation occurs after harmful bacteria, commonly *Staphylococcus* and *Streptococcus*, invade the body and vascular system and then travels throughout the body's tissues (including the skeletal system) via blood (Ortner and Putschar 1981; Mensforth et al. 1978). As Ortner and Putschar (1981) describe, the network of tiny blood vessels within bone reacts to bacteria and can disrupt blood flow to bone cells. These cells can die and become resorbed while new bone cells take their place. The overall inflammatory reaction seen on bone surfaces is the culmination of this process of systemic, whole body response to invading bacteria.

If a pathogenic process remains active in a body for a long enough period of time, bones may experience a much more severe extent of remodeling than what would be seen in a shorter-lived pathogenic process or in a localized infection due to trauma and soft tissue damage. For those individuals who are able to overcome these pathogens, bones that have been affected should eventually return to normal since the remodeling process (sloughing off old bone cells and replacing them with new ones) is constant throughout life. Depending on the status of the reaction at the time of death of an individual, the evidence left on the bone can be active (infection was fully active at the time of a person's death), healing (partial new bone), or healed (new bone has almost completely replaced old). An active periosteal reaction is often the result of infection or trauma and has a mottled appearance as new bone is deposited. Healing periosteal reactions show a slightly smooth deposition of new bone and fully healed reactions will show no mottled

bone and instead feature smooth new bone resembling a callous (Aufderheide and Rodriguez-Martin 1998).

The research described here focuses on both localized inflammation of the periosteum of the bone shaft and general inflammation on any bone surface. Observation of locations of inflammation demonstrates potential causation from nonspecific bacterial infections or general flaring of the bone surface due to unknown causes. Patterns observed in this research will assist in determining whether or not bacterial infections seemed to have a role in childhood health at Tell Abraq. Results of this analysis will be discussed in Chapter 4 of this thesis.

Bone Diameter

Health status and growth rates can also be observed through analysis of bone diameter at the midshaft. The diameter of bone increases in size as the bone grows and cortical thickness increases. The rate of growth is steady throughout childhood while bones grow both in length and thickness (Ortner and Putschar 1981). As a bone grows in length it should, therefore, also grow in diameter at the midshaft. Length, however, is more under genetic control while thickness, determined by deposition of bone in the cortex, is heavily affected by health of the individual (Armelagos et al. 1981). There is an expected patterning during normal growth and overall good health, so an observation of bone diameter that deviates (i.e., is smaller) from the norm could indicate either poor health and/or a disruption in growth.

Percent Cortical Area

Skeletal indicators of stress can also include short bone length and low percent cortical area. All of these can reflect poor overall growth of the skeletal system. Percent

cortical area (PCA) is particularly informative, however, because it follows generally uniform patterns except when the skeleton is nutritionally or pathologically stressed. PCA, therefore, has the potential to identify periods of stress in an individual's life.

Percent cortical area is an encompassing assessment of cortical thickness, medullary cavity width, and diameter of a bone shaft. It is thus a measurement of the bone's cross-sectional area (Garn 1970, p.12, 65). It takes bone density into consideration and can then be used to gauge normal, healthy growth or failure for an individual to thrive.

Growth of bones, especially length, is largely determined by genetic factors, so any disruptions are likely to be attributed to illness or a failure to thrive. Protein-calorie malnutrition, for example has been linked with loss of bone at the endosteal surface, thereby decreasing percent cortical area to below 50% (Garn 1970, p.36, 71).

Percent cortical area has been used by many researchers to show patterns in bone growth during childhood as this may be indicative of stress or illness. Garn and Wagner's (1969) work, for example, described a decrease in percent cortical area among malnourished Guatemalan children. Hummert (1983) and VanGerven and colleagues (1985) found similar findings in an ancient Nubian subadult population.

PCA results from the Tell Abraaq subadult collection are therefore important to this research. Low overall PCA could indicate stresses such as illness or inadequate diet while higher (normal) overall PCA could suggest a fairly good environment for growth and development of the skeletal system.

Nutritional Pathologies

As described previously in this chapter, subsistence resources at Tell Abraq appear to have been varied and plentiful. Food choices would have provided the majority of the population with a sufficient and nutritionally balanced diet. Because of this evidence, there should not be an abundance of nutritional pathologies or dietary deficiencies. If these did occur, however, only those that leave a mark on bones would be available for analysis.

The youngest children at Tell Abraq were certainly not consuming all of the available foods that the adults consumed, particularly if they were weaned at ages coinciding with standards of populations around the world. The smallest infants would likely have been breastfed so nutritional stress should not be observed on their skeletons. The foods available for children of a slightly older age (around weaning: 2-3 years) may not have been as plentiful as those for adults simply due to the limits of subadult dentition. A lack of a sufficient dietary need, such as vitamin C or iron, would manifest itself on the bones of those with deficiencies (Ortner 2003). Documentation of these and other nutritional pathologies (e.g., scurvy or rickets) are made in this thesis.

Impact of Stress on the Population

How would the processes and stresses discussed in the previous text affect the population as a whole? What is the impact of high infant mortality on the community of adults? Several potential areas are discussed here to address these.

Premature Delivery

At Tell Abraq, premature delivery of a fetus could have severe consequences on rates of survival for the infant. Increased frequencies of factors that negatively affect fetal growth and development are important to recognize in this study. Factors including maternal age, maternal physical maturity, parental relatedness, and illness during gestation are all considered in this project's discussion of premature birth (Abrams and Meshnick 2009; Al-Gazali et al. 2005; Scholl et al. 1997).

Increased Infant Mortality

If high rates of infant mortality are observed in this collection, it could indicate that several things are responsible the paleodemography of the population. Topics such as low birth weight and cultural rituals during infancy are presented as having an effect on infant morbidity and mortality.

Infant & Child Disease

Infants and children are generally at a higher risk for serious health concerns than older individuals as their immune function has not fully developed (Scott 1999:31). Diseases contracted during childhood therefore may have worse consequences on health than in adulthood and may greatly impact survivability to adolescence and adulthood. Illnesses including malaria, leishmaniasis, brucellosis, and diarrhea, all of which are potentially survivable among adults with fully-matured immune systems, could lead to significant illness and even death among children and infants.

Maternal Death

Population stress can be gauged from mortality rates of both children and adults. For the present study, maternal death is of concern as well. All of the factors just

described and many more not mentioned could potentially contribute to maternal death. Because these women may have been quite young and physiologically immature, it can be hypothesized that complications in pregnancy were frequent and might have resulted in higher rates of maternal mortality. Without a mother, the infant would have an immense struggle for survival that could only be remedied if adopted by an already-nursing mother. Both maternal and infant death would thus have a significant effect on population structure.

Implementing the Biocultural Research Model

As this chapter illustrates, a biocultural model considers several categories of factors in setting up the context for morbidity and mortality at Tell Abraq. More specifically, it demonstrates that these factors impact each other in symbiotic ways and can have numerous effects on the population. For the purposes of understanding health and wellness of the children at Tell Abraq, this research model is an excellent tool for exploring the many elements that affect morbidity and mortality. Finally, this model illustrates the cyclical cause-and-effect process that every population experiences.

The discovery of subadults comprised mostly of preterm and term infants prompts consideration of many things. This large number of young subadults in this collection is unique and unprecedented in the bioarchaeological literature. Most prominent among questions raised by this unusual prevalence of subadults is why the population demographics differ from most patterns seen in archaeological populations from across the globe and spanning millennia. Why are there so many dead preterm and term infants? What was contributing to morbidity and mortality?

The demographics of the subadult population prompt three major questions for this bioarchaeological research:

1. What were the rates of infant and child mortality in this population?
2. Does the health of the infants and children compare with other Bronze Age populations?
3. What can account for the high frequency of premature (3rd trimester) neonates in this population?

The following chapter discusses the methodology utilized to obtain data on health and age at death.

CHAPTER 3

MATERIALS AND METHODOLOGY

Materials

The complete skeletal collection from Tell Abraq is currently curated by the Department of Anthropology at the University of Nevada, Las Vegas. Coming from a well-sealed tomb in an arid environment, the collection is fairly well-preserved although post-mortem breakage is common.

The commingled nature of the tomb prevents analysis of separate individuals; therefore, remains have been sorted and separated by bone type (humeri, femora, tibiae, tali, etc). Further sorting was carried out to isolate subadults from adults (i.e., those approximately 18 years of age and older). The collection as a whole is represented by all age categories and both sexes.

To establish the minimum number of individuals (MNI), bone types that could be sided and those with the most preserved elements were counted. The right talus was selected for determining MNI of adults. A minimum of 286 adults comprise the Tell Abraq adult collection. MNI for subadults was determined with the long bones (including tibiae and femora), which were among the more numerous bone types. This is fortunate since these subadult bones were relatively more complete and better preserved than other skeletal elements. Careful sorting and siding of these bones resulted in the selection of the right femur for establishment of the MNI and further analysis. To prevent duplication of individuals using fragmented bones, only proximal right femora were selected, resulting in an MNI of 127 subadults. Several distal ends of femora were present among the collection but were unable to be paired with their respective proximal

ends and, therefore, could not be counted or used in analysis. The total minimum number of individuals in the Tell Abraq collection is 413.

For this project, the subadult MNI bone (the right femur) is used in all subsequent analyses of growth and health. The femur is a particularly good bone because of the numerous kinds of analytical methods one can apply to it. For example, femora, along with tibiae, display much higher frequencies of infectious reactions than any other area of the skeleton (Mensforth et al. 1978; Ortner 2003:182). Endemic infections and everyday communicable diseases such as staphylococcus and streptococcus will show up on the surface of long bones (Ortner and Putschar 1981). The femur is also excellent for analysis because its growth and development patterns are well-understood and deviations from those patterns can be measured (Anderson et al. 1964; Fazekas and Kosa 1978; Garn 1970; Gindhart 1973; Jeanty 1983; Scheuer et al. 1980).

Previous research using long bones, particularly the femur and tibia, has demonstrated that significant information can be revealed regarding growth, development, and overall health. For example, Lovejoy and colleagues (1990) found that subadults at the Mississippian Libben site in Ohio (c. AD 1200) matched standard growth patterns in all age groups except for the first two to three years of life. Combining this observation with patterns of infectious disease present on long bones, the authors concluded that the observed depressed growth rate early in life was likely a direct result of physiological stress from poor health or diet. Additional research by Mensforth and colleagues (1978) was able to show very specific patterns of poor health of the children at certain ages by analyzing paleopathologies of long bones. These researchers used patterns of porotic hyperostosis (anemia) and periostitis (infectious disease) among the

same subadults at the Libben site to demonstrate much higher risks of morbidity and mortality among children between 6 and 24 months of age. These examples of subadult paleopathology research show that much can be gleaned from analysis of long bones such as the femur.

Methods

Analysis of the skeletal remains utilized the standardized methodologies described in The Standards for Data Collection from Human Skeletal Remains (Buikstra and Ubelaker 1994), Identification of Pathological Conditions of Human Skeletal Remains (Ortner 2003; Ortner and Putschar 1981), The Cambridge Encyclopedia of Human Paleopathology (Aufderheide and Rodriguez-Martin 1998), and The Archaeology of Disease (Roberts and Manchester 2005). Measurements followed the recommendations outlined in Osteology of Infants and Children (Baker et al. 2005), Developmental Juvenile Osteology (Scheuer and Black 2000), and The Juvenile Skeleton (Scheuer and Black 2004). These manuals provide techniques for metric data collection as well as qualitative data based on observations of changes to the morphology of bone.

In addition to these standards, aging of preterm and neonate individuals was aided by the following: Fazekas and Kosa (1978), Scheuer et al. (1980), Anderson et al. (1964), Gindhart (1973), and Jeanty (1983). Typically these aging methods use metric measurement of length of long bones such as the femur or tibia. These are compared with measurements of subadult bones of known ages from a modern reference population. Growth in long bone length is primarily under strong genetic control but is also sensitive to environmental conditions. Thus, while long bone growth is

hypothetically uniform across populations, regional differences provide insight into the unique patterns that can emerge for any given population. While it is challenging to use the length of long bones to provide an age estimate if the population is under severe stress, other studies have shown that all populations follow a relatively stable patterning in growth (Lovejoy et al.1990). The published methodologies using long bone length to determine subadult age use categories subdivided by weeks (for fetuses and neonates), months (for infants), and half year increments (for children up to the age of 18 years) so that the most accurate age can be ascertained.

The methods used in this research represent the available techniques for aging subadults using only the femur. Dental aging methods used in conjunction with long bone methods are preferred due to the accuracy and reliability of results; however, the commingled nature of the Tell Abraq collection prohibits that possibility. Long bone length is therefore the best proxy available to estimate age at death at Tell Abraq. Studies correlating long bone length with dental age have shown that they are comparable (Lovejoy et al. 1977; Lovejoy et al. 1990). The growth and development of the femora appear to coincide with age groups fairly closely.

Consideration of the study populations used in establishing criteria for aging is important in determining appropriateness of the methodology for this research. Since the sample being analyzed is of an ancient Near Eastern population, the methods based on modern populations of European descent present methodological challenges. The limitations of these methods were considered but may not have significant effects on the final interpretations of this research because of the use of age categories. Age categories

(versus exact age at death) provide a methodological buffer in the event that growth patterns are a little different.

Using the aging methods described, subadults were sorted into the following age categories: preterm, neonate (birth to 1 month), 1 month up to 2 years, 2 years up to 6 years, and 6 years to 18 years. Aging methodologies available for this study varied in age groups and measurements reported. Using lengths of fetal femora reported by Jeanty (1983), Fazekas and Kosa (1978), and Mehta and Singh (1972) and lengths of perinatal (around birth) femora reported by Trotter and Peterson (1969), the youngest Tell Abraq femora were measured and aged accordingly. The older subadults were measured and aged using Maresh (1970), Anderson et al. (1964), and Scheur and Black (2000). Incomplete femora were unable to be measured and age was estimated through seriation by size and comparable physiological development. Table 1 lists the measurements used for each age category and the published methods. From these, the cut-off measurements used for the Tell Abraq remains are provided in Table 2.

Ranges for lengths measured were determined through careful comparison of available published studies featuring samples of known ages. In an effort to minimize error, length ranges for corresponding age groups used an approximate midpoint between conflicting or overlapping lengths. When no measurements were available for a particular age group (for example, as in the case of neonates), an estimate was made using the same 'midpoint of the range' technique. The corresponding age groups were chosen to allow some specificity in population subgroups while also preventing too much error in interpretation of these age categories. The younger groups have more precise age limits while the older groups have much more broad age limits. In the case of the oldest

group (6 years to 18 years), the broad age category was used because of the very few individuals of those ages in the tomb. A portion of the right femora are shown seriated by size and morphology in Figure 5.

Age Group	Age	Mean Length of Femur	Publication
Pre-term	<38 weeks gestation	<69.0mm	Fazekas & Kosa 1978
	<38 weeks gestation	<72.0mm	Jeanty 1983
Full term	38-40 weeks gestation	69.0-74.4mm	Fazekas & Kosa 1978
	38-40 weeks gestation	72.0-75.0mm	Jeanty 1983
	40 weeks gestation	72.9mm	Trotter & Peterson 1969
Neonate	0-1 month	N/A	N/A
Neonate - <2 years	2 months	86.0-87.2mm	Maresh 1970
	1 year	134.6-136.6mm	Maresh 1970
	1 year	144.8-148.1mm	Anderson et al. 1964
2 years - <6 years	2 years	170.8-172.4mm	Maresh 1970
	2 years	181.5-182.3mm	Anderson et al. 1964
6 years +	6 years	268.9-269.7mm	Maresh 1970
	6 years	280.0-285.2mm	Anderson et al. 1964

Table 1. Age groups and corresponding mean femoral lengths used to support measurements and ages in this research.

Age Group	Length of Femur Minimum	Length of Femur Range	N	Percent (%) of Subadult Sample
Pre-term	<72mm	<72mm	28	22.0%
Neonate	72mm	72-80mm	12	9.4%
1 month - 1 year	80mm	80-171mm	46	36.2%
2 years - 5 years	171mm	171-269mm	32	25.2%
6 years - 18 years	269mm	>269mm	9	7.1%

Table 2. Demographics of Tell Abraq subadult population with age groups and corresponding femoral length ranges (NA= none available).

Sexing of subadult remains was not possible due to the timing of development of sexually-specific characteristics in human long bones. The most obvious differences between male and female bones do not take shape until the onset of puberty during adolescence (Tanner 1962; White and Folkens 2003). Although there are new techniques for sexing subadults, many of them rely on dentition and the pelvis. Thus, no attempt was made to determine sex of any remains in the subadult collection.



Figure 5. Right femora seriated by size (and thus age) during initial sorting of the remains.

Analysis of infectious disease was carried out using macroscopic techniques (see Buikstra and Ubelaker 1994). Femora were examined with careful observation for any sign of pathology or trauma. Gross visual observations were made and additional light and magnification were utilized to verify status and activity levels of periosteal reactions on the bones. Periosteal reactions are the single most common pathology on subadult long bones and are related to systemic or localized infections (Ortner and Putschar 1981).

Changes in the periosteal surface (outer most layer of bone) were assessed with regard to presence, location, severity, and state of healing. Documentation of pathological conditions was recorded in an electronic database (see Document 1 in Appendix). Unusual as well as normal samples were photographed for further documentation and used in determining degree of severity categories.

In order to examine growth disruption, cortical thickness of the femora was assessed to identify potential stress in growth among the subadults at Tell Abraq. This process requires examination of the inner cortical area of each bone shaft. Radiographs of bones can be used to take these internal measurements of cortical thickness, medullary width, and bone diameter (Armstrong et al. 1981; Garn 1970; Owsley 1988). Radiographic techniques have limitations in reliability of measurements since the internal bone borders are often unclear (Garn 1970).

In light of the problems in attempting noninvasive analyses of cortical area, the decision was made to cut bones at the midpoint to measure cortical bone directly. All femora with at least half of their shaft were selected for analysis of cortical thickness and shaft diameter. Analysis within the middle two thirds of the shaft is optimal; therefore every attempt was made to cut bones at the midpoint. Complete bones were marked at the midpoint and cut. Incomplete shaft midpoint locations were approximated. Bone shafts were cut using a Mopec autopsy saw (Product Number BD040:115V). This tool allows precision in blade placement and quick cutting.

Measurements of medial and lateral cortical thickness, medullary cavity width, and diameter at the midpoint were made using digital sliding calipers. Length of complete bones was also recorded with the digital sliding calipers. Measurements were

to the nearest 1/100th of a millimeter. Figure 6 shows each measurement made. Percent cortical area (PCA) is calculated using linear measurements of the cortex (C), medullary cavity (M), and total subperiosteal diameter (T) and converting them to areas (Garn 1970). Cortical thickness and the medullary cavity together make up the total diameter. Formulae for calculation of respective areas and PCA are as follows:

$$\text{Area of T} = 0.785(T^2) \quad \text{Area of M} = 0.785(M^2) \quad \text{Area of C} = 0.785(T^2 - M^2)$$

$$\text{PCA} = 0.785(T^2 - M^2) \div 0.785(T^2)$$

which is simplified to

$$\text{PCA} = [(T^2 - M^2) \div (T^2)] \times 100\%$$

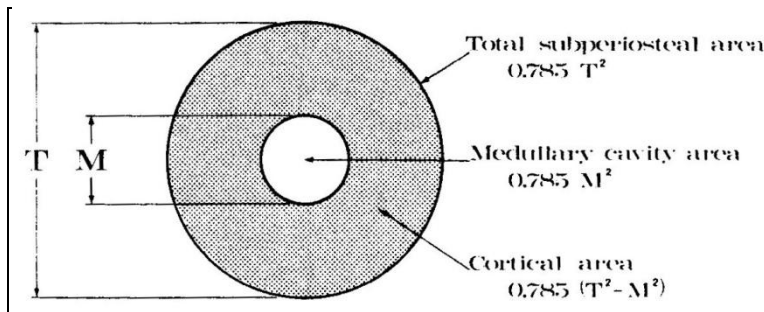


Figure 6. Cortex, medullary cavity, and shaft diameter measurements for calculation of PCA. (From Garn 1970 pg 11.)

An analysis of length and PCA can offer insight into the growth patterns of the subadults at Tell Abraq. While this is important to the current research and its goal to better understand health of this population, it also is significant to the broader field of bioarchaeology. At this time, there are no studies on ancient populations using percent cortical area data for such a young population (i.e., infants under 6 months and preterm

infants). Several publications have demonstrated the utility of PCA analysis in growth and health of past communities but most were of populations with older age representations (Armelagos et al. 1981; Garn 1970). Few publications have included subadult PCA analysis (Ruff et al. 1994). This research, therefore, represents one of few to incorporate percent cortical area in the youngest individuals of a community.

CHAPTER 4

RESULTS

Presented here are the results of analysis of the Tell Abraq subadult femora. Data include demographic findings, rates and severity of infectious activity, and evidence of growth disruption. Particular attention is given to the age structure of the subadult population and the results of the analyses are presented within age categories. First, the unique demographic findings are illustrated and discussed. Following this is a discussion of the frequencies of infectious disease affecting the femora. Lastly, growth rates of the subadults are addressed through results of the examination of the internal structure of the femora.

Age Structure

Aging all individuals in the subadult collection resulted in an unusual (and skewed) distribution among age groups. Table 3 and Figure 7 show the distribution of the subadult demography. Twenty-eight preterm infants, 12 neonates (near birth), and 46 infants under the age of two present a unique pattern not discussed in any skeletal report from the region. Even for New World collections, these frequencies are quite high (see for example, Lovejoy et al. who designed a study to specifically locate young infants). Additionally, a lack of older children buried in the tomb was surprising (32 children in the 2-6 years category and only 9 children aged 6 to 18 years).

<u>Age Group</u>	<u>N</u>	<u>% of Subadult Population</u>	<u>% of Total Population</u>
Pre-term	28	22%	7%
Neonate	12	9%	3%
1 mo to <2 yrs	46	36%	11%
2 to <6 yrs	32	25%	8%
6+ yrs	9	7%	2%
Total	127	100%	31%

Table 3. The distribution of age groups shows more subadults in the 1 month to 2 years category which comprises 36% of the subadults and 11% of the whole collection.

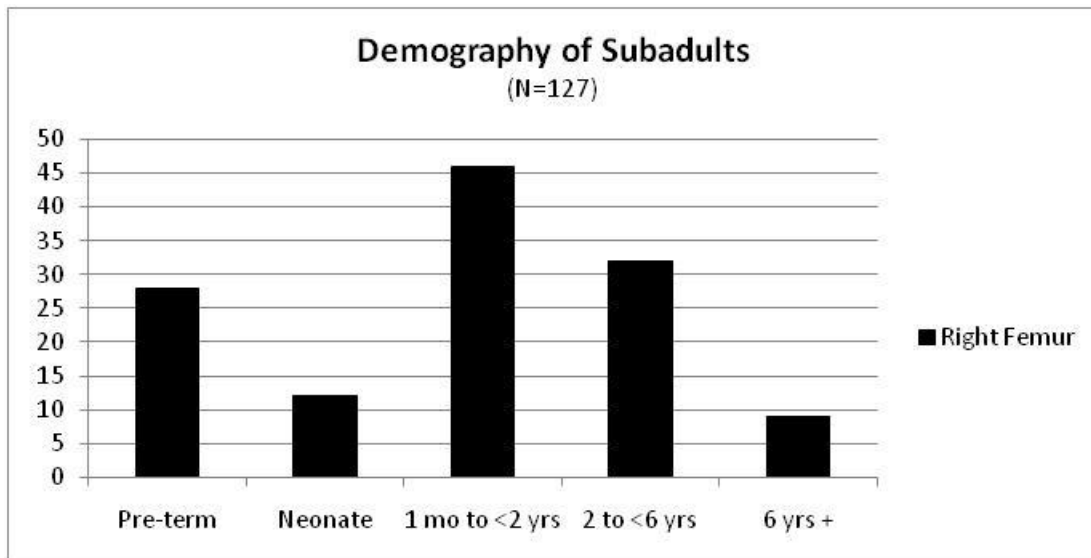


Figure 7. Age distribution of subadults shows that the largest age group is children aged 1 month to 2 years.

The age structure of the Tell Abraq population presents a surprising paleodemographic profile. The Tell Abraq population is compared with burial populations with good representation from a series of New World archaeological sites, all dated between 800 and 1300AD (see Table 4). Comparable Old World populations could not be found to construct these kinds of cohort comparisons. At Tell Abraq, older

children are highly underrepresented and children under 1 year are somewhat overrepresented. What this table does not illustrate well is the high number of pre-term infants in the Tell Abraq subadult collection.

Population (N)	Age			
	< 1 year	1 - 9 years	10 - 18 years	> 18 years
Tell Abraq (413)	17.9	12.8	1.2	69.2
La Plata (67)	6.0	29.8	7.5	56.7
Mesa Verde Early (150)	10.6	18.0	14.0	57.3
Mesa Verde Late (178)	16.8	18.5	23.5	48.6
Pueblo Bonito (93)	1.0	16.1	17.2	40.4
Black Mesa (165)	10.4	24.2	14.5	50.9
Casas Grandes (612)	10.0	22.0	14.0	54.0
Pecos Pueblo (1722)	18.7	14.0	8.0	59.0
Tlajinga, Mexico (166)	41.3	10.3	10.6	38.6
Arikara Villages (1487)	31.5	24.0	9.5	45.5
Libben, Ohio (1239)	18.0	22.0	14.0	46.0

Table 4. Demographic chart of Tell Abraq and New World prehistoric sites. Percentages of age groups comprising each population are shown. Adapted from Martin et al. (2001), Martin et al. (1991), Storey (1988), and Nelson et al. (1994).

Comparable skeletal collections that do have subadults have shown that infant mortality is present in high frequencies: 11 newborn to 6 months, 25 6 months to 1 year, 73 2 years to 5 years, 64 6 years and older (Hummert and VanGerven 1985). Infants are always at risk for higher mortality and morbidity than teenagers and adults in early agricultural communities (Saunders and Hoppa 1993).

The Tell Abraq collection therefore raises several questions regarding how it came to have this particular demography. First, why are there so many preterm and term

infants and so few older subadults in the collection? Secondly, why are there so many preterm individuals and neonates? What environmental or cultural patterns may help explain this? Rates of infectious disease and bone growth among the Tell Abra q subadults provided in the following section aid in clarifying some of the underlying factors. This information, combined with the model in Chapter 2, will address these questions.

Infectious Disease

As discussed in Chapter 2, evidence of infectious disease on bone can be used as an indicator of overall health. Observations of this infectious disease activity among the Tell Abra q subadult femora are documented here with particular attention given to frequencies of infection among age categories and status of remodeling.

Periosteal reactions observed on the Tell Abra q subadult collection were measured on an incremental scale. Each bone was scored with this scale to make an assessment as to whether the individual suffered from an infectious disease or was free of infection at the time of death. Of the 127 subadults, 40 were not able to be scored due to postmortem damage of the femora. The majority of these individuals were represented only by the femoral head and very little of the shaft. Without an intact bone shaft, the bones could not be used in this analysis. Age was still approximated based on size and features of the incomplete bones. Of the 40 bones not scored, all were over 1 month of age. All preterm and neonate bones were complete enough to be scored. The 87 individuals able to be scored comprise the sample described in the following results.

	n With Infection	% With Infection	n Without Infection	% Without Infection
All Scorable (n=87)	36	41.4%	51	58.6%

Table 5. Samples with and without infection.

Pathology Score	1 (None)	% None	2 (Slight)	% Slight	3 (Moderate)	% Moderate	4 (Severe)	% Severe
Total Count	51	58.6%	24	27.6%	6	6.9%	6	6.9%

Table 6. Infection frequencies by severity.

Scorable subadults (n=87) were assessed for presence or absence of pathologies. 41.4% (36) of individuals showed pathologies while 58.6% (51) showed no pathological activity on the right femur (see Table 5).

A total of 87 individuals were able to be rank-scored for periosteal reactions (indicators of nonspecific infection at the time of death). Ranking was as follows: none (1), slight (2), moderate (3), and severe (4). Analysis resulted in 58.6% (51) of individuals showing no pathology (see Table 6). Slight pathological activity was observed on 27.6% (24) of the scored subadults, 6.9% (6) had moderate pathological activity, and 6.9% (6) had severe pathology.

	% With Infection	% Without Infection
PT	23.0%	9.2%
Neonate	5.7%	4.6%
1 mo. to < 2yrs	9.2%	21.8%
2yrs to < 6yrs	0.0%	18.4%
6yrs to Adult	0.0%	4.6%

Table 7. Infection frequencies by age group (PT = preterm, Neonate = around the time of birth).

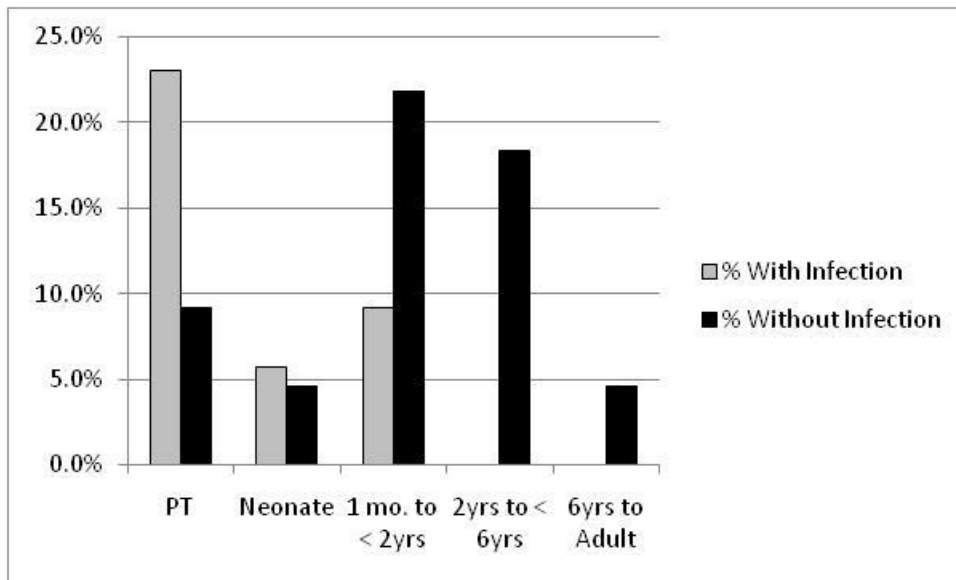


Figure 8. Distribution of infection frequencies among age groups. (n=87)

Distribution of infection presence and absence frequencies are shown for each age group in Table 7 and Figure 8 (n=87). For subadults under the age of 2 years, there is nearly an equal overall rate of those with and without infection. More preterm subadults have pathologies (23.0%). Neonates have approximately equal rates (5.7% with and 4.6% without). More subadults in the 1 month to 2 years age group show no infection

(21.8%). Those with infection in this age group make up 9.2% of the scorable individuals.

In summary, over half (n=51) of the femora in the sample showed no evidence of periosteal reaction on the bone shaft. For those femora exhibiting periosteal reactions, all were in children under 2 years of age. Within this subsample, 24 were scored as having slight reactions, 6 were moderate, and 6 were severe.

Inflammation present on the shafts of the femora were described in terms of their activity status (no activity, slight activity, moderate activity, severe activity, healing/totally healed), medial and/or lateral location, proximal and/or distal location, and the extent to which the shaft was affected ($\frac{1}{4}$ shaft, $\frac{1}{2}$ shaft, $\frac{3}{4}$ shaft, whole shaft). The majority of periosteal activity was slight, or in the process of healing. Healing was often seen as smooth, striated bone deposition. No bones showed total remodeling or completely healed periosteal reactions. This perhaps suggests that the root cause of the inflammation was too intense for children to survive long enough for their bones to completely heal.

The location of periosteal reactions was fairly consistent among the sample. Nearly all femora exhibited inflammation laterally or both laterally and medially (see Figures 9, 11, and 13). Proximal and distal positions of periosteal reactions were more difficult to ascertain due to postmortem breakage of some femora (like Figure 9 below). Only 26 femora could be given this score with the results as follows: 7 proximal, 2 distal, 17 both proximal and distal. The extent of inflammation was also comparatively recurrent with nearly all periosteal reactions covering at least half of the bone shaft.

These were not localized to any specific landmark on the femur and instead more closely resembled nonspecific periosteal reactions.



Figure 9. Femur 22515 shows periosteal reaction scored as severe (4) and active (1). Multiple layers of bone are visible, showing several periods of bone deposition.

Radiographs of femora 22515 and 26188 are shown in Figures 10 and 12. These figures demonstrate that other observation methods are available to verify the diagnosis of infection in these individuals. The layers of bone cells deposited during the remodeling process are clearly visible.

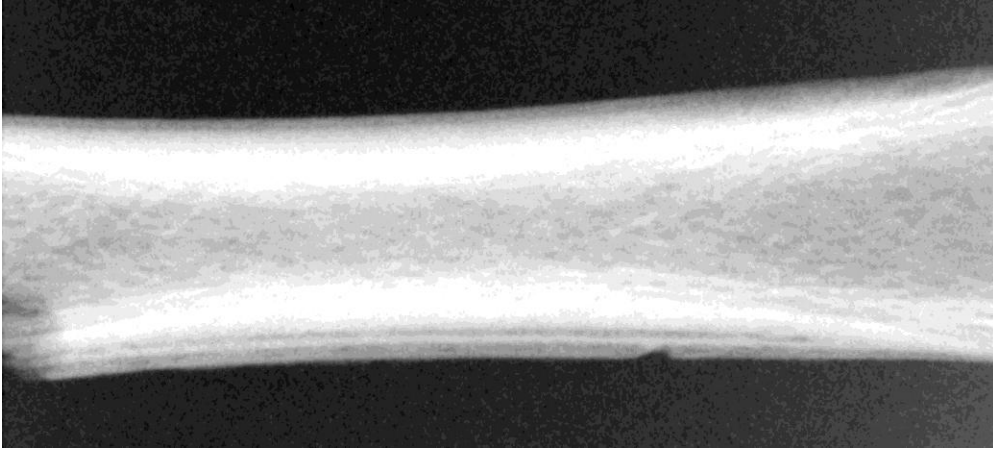


Figure 10. An x-ray of femur 22515 also shows the multiple layers of bone throughout its length.



Figure 11. Femur 26188 shows periosteal reaction scored as severe (4) and active (1).

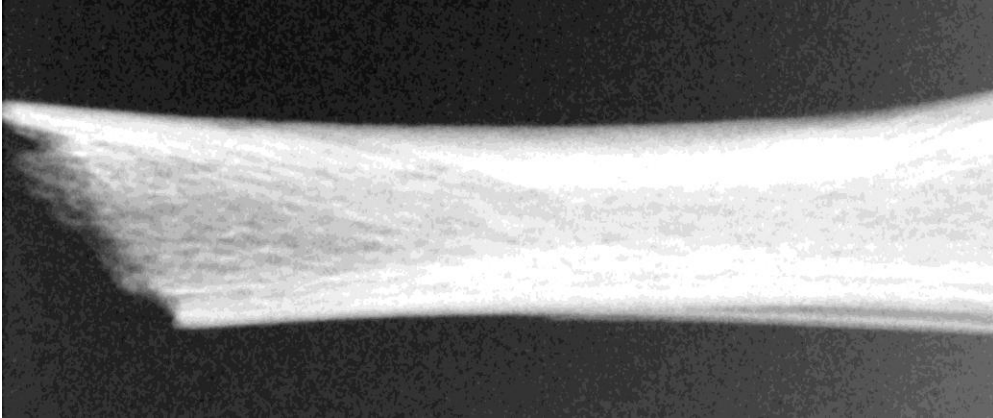


Figure 12. An x-ray of femur 26188 shows layers of deposited bone.



Figure 13. Femur 4352 shows periosteal reaction scored as moderate (3) and moderately active (3).

Subadults showing pathological activity (n=36) were assessed for level of pathology severity within each age group (Figure 14). Preterm individuals comprise the majority of infected subadults. Slight pathology was observed among 14 (38.9%) preterm femora, 3 (8.3%) femora showed moderate pathologies, and 3 (8.3%) had severe pathologies. The next age group, neonates, revealed 5 (13.9%) with slight pathologies, 2

(5.6%) with moderate pathological activity, and 1 (2.8%) with severe pathology. The 1 month to 2 year old age group was nearly identical in pathology distribution: 5 (13.9%) slight, 1 (2.8%) moderate, and 2 (5.6%) severe. Both the 2 to 6 years and 6 years to adult age groups had no individuals with pathological activity.

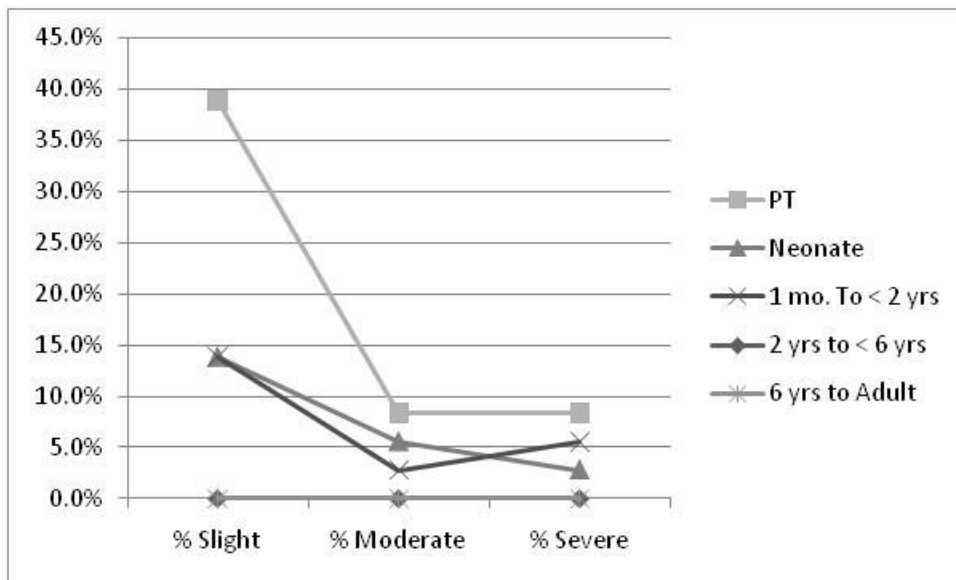


Figure 14. Distribution of age groups for each infection severity. (n=36)

Subadults with periosteal reactions (n=36) are shown in Table 8 and Figure 15 and are categorized by severity and age group. Scores were as follows: slight (2), moderate (3), and severe (4). The majority of subadults were preterm individuals with slight periosteal reactions (38.9%, n=14). All individuals with periosteal reactions were under the age of 2 years.

	2 (Slight)	% Slight	3 (Moderate)	% Moderate	4 (Severe)	% Severe
PT	14	38.9%	3	8.3%	3	8.3%
Neonate	5	13.9%	2	5.6%	1	2.8%
1 mo. to < 2yrs	5	13.9%	1	2.8%	2	5.6%
2yrs to < 6yrs	0	0.0%	0	0.0%	0	0.0%
6yrs to Adult	0	0.0%	0	0.0%	0	0.0%

Table 8. Infection frequencies by age and severity.

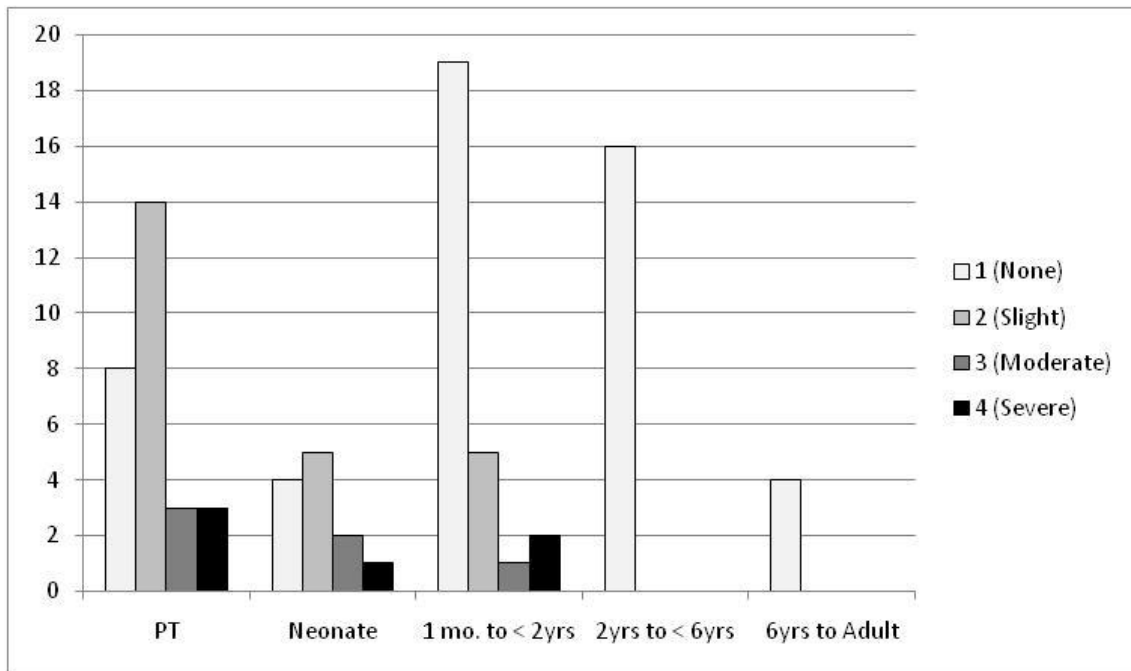


Figure 15. Distribution of infection rates among age groups. (n=87)

During the course of analyzing femoral pathologies, an unusual observation was made. Approximately 20% (n=25) of all subadult right femora exhibited an inflamed linea aspera (see Figures 16 and 17). Typically limited to the proximal inferior side of the bone, this inflammation did not spread to the surrounding surface of the bone shaft. It seems to follow the *linea aspera* which is a major muscle attachment site for the upper

leg. The presence of this pathological reaction poses two primary questions. First, are these simply inflamed muscle attachments related to rapid growth rates during infancy and young childhood? Or alternatively, do these reactions indicate a different or unknown pathological origin? The posterior proximal femur facilitates insertion of the *gluteus maximus*, *vastus medialis*, and *adductor magnus* muscles which serve to allow locomotion of the lower limbs.



Figures 16 & 17. Femora 20846 and 15661 each show inflamed *linea aspera* muscle attachment sites. 20846 is active and 15661 is healing.

Examination of 102 of the 127 subadult right femora resulted in 25 exhibiting inflamed *linea aspera* muscle attachment sites. The most frequently inflamed age group was the 1 month to 2 years category with 14 (13.7%) of the 102 femora being affected (see Table 9 and Figure 18). This is more than twice as many preterm or neonate

individuals with inflammation. Inflammation was observed on both femora with and without periosteal reactions on the shaft of the bone. This may indicate that the inflammatory processes are independent of one another.

Inflamed <i>Linea Aspera</i>	N	% of ALL (102)
PT	6	5.9%
Neonate	4	3.9%
1 mo. to < 2yrs	14	13.7%
2yrs to < 6yrs	1	1.0%
6yrs to Adult	0	0.0%
Total	25	24.5%

Table 9. Frequencies of inflammation among age groups.

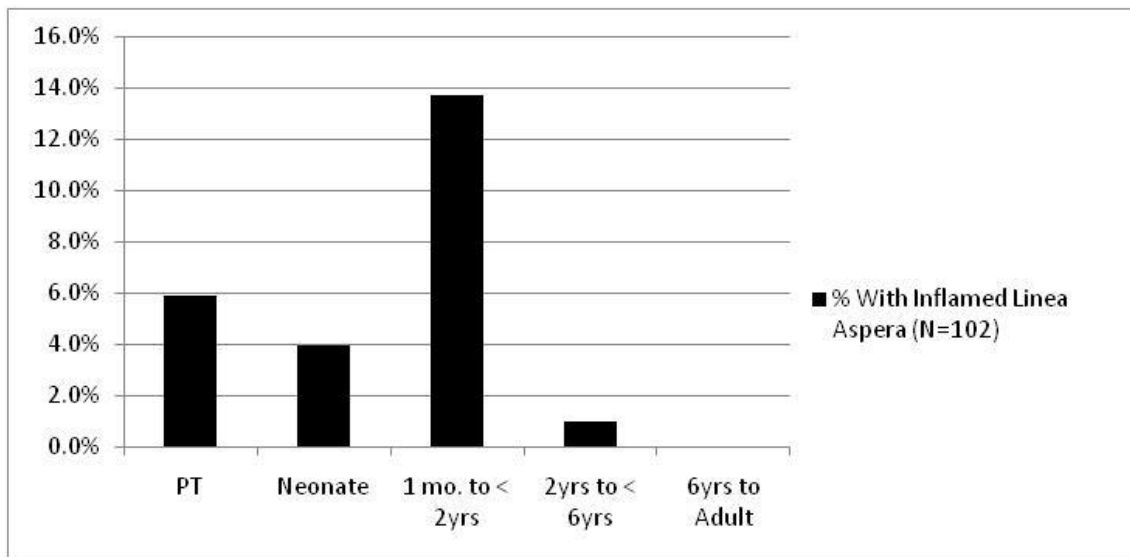


Figure 18. Distribution of inflammation on the *linea aspera* among 102 right femora.

Growth Disruption

In an effort to further explore subadult patterns of morbidity and mortality at Tell Abraq, percent cortical area (PCA) was also considered. PCA is useful for this research because the sample being analyzed represents a population in the midst of rapid and extensive growth and any patterns observed that indicate a growth disruption are helpful for understanding overall health status. PCA is calculated using linear measurements of the cortex (C), medullary cavity (M), and total subperiosteal diameter (T) and converting them to areas (Garn 1970).

PCA is higher in individuals who are growing normally and lower in individuals who are physically stressed to the point that there is a decrease or cessation in growth (Garn 1970). Cortical growth and maintenance is sacrificed during stressful times. That is, growth of brain and other soft tissues continue while hard tissue growth slows (Garn 1970). Garn (1970:65-76) suggests a PCA score of approximately 85% is optimal. Throughout childhood, PCA scores generally increase as bone development increases. Children's scores will therefore range from approximately 60-85%. Higher scores indicate better growth and the likelihood of better overall health.

The growth of bone in young infants can be variable even under normal conditions. Garn (1970:46) reports that there is initial growth of the cortex in the neonatal period and that this is followed by approximately six months of an increase in cortical width (but not cortical thickness). This was also corroborated by research done by VanGerven and colleagues (1985). As infants grow older, their bones begin a more orderly development pattern and cortical width also increases in pace with cortical thickness. If infants are healthy, their PCA scores should still be in the range of 60-85%,

even with these fluctuations in growth and development. Although bones are under some genetic and hormonal control in terms of growth, there are well-known environmental factors that can influence growth. For example, protein-calorie malnutrition has been linked with loss of bone at the endosteal surface, thereby decreasing percent cortical area to below 50% (Garn 1970:36, 71). Finally, PCA is more sensitive to physiological disruption than is overall length so sick infants may still grow in bone length but not maintain growth in bone (Armstrong et al. 1981).

The results of the analysis of percent cortical area of Tell Abraq subadults are shown in Figures 19 and 20. A subsample of 66 subadults was available for analysis of percent cortical area. For the majority of individuals under 2 years of age, PCA scores were above 70%. A few individuals between 2 and 6 years of age had lower than 70% PCA. Only one individual aged over 6 years was able to be scored for PCA and resulted in a score higher than 70%.

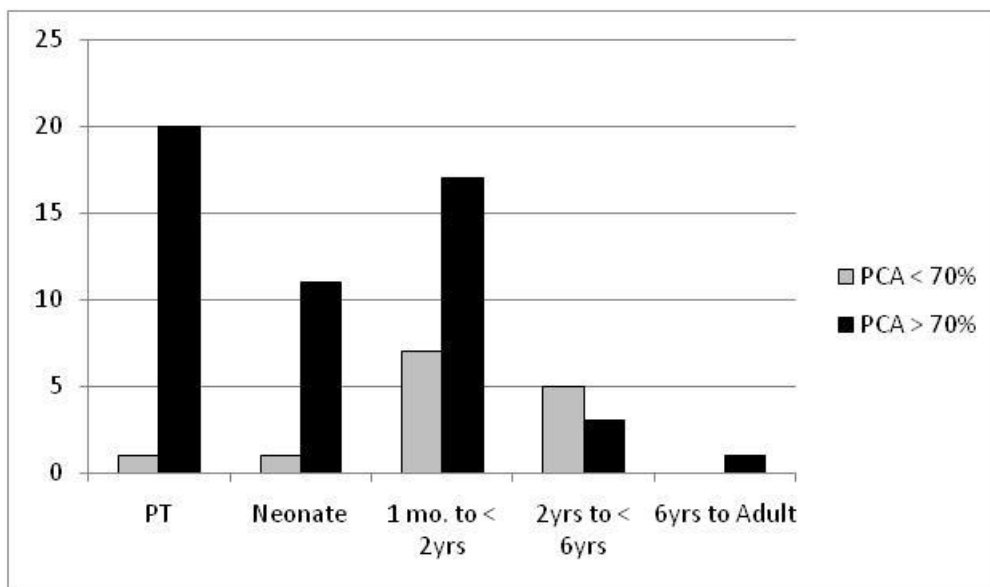


Figure 19. Distribution of individuals with PCA above 70% and below 70% among age groups. (n=66)

Sixty-six subadults were analyzed for percent cortical area (PCA). Figure 19 shows the distribution of PCA scores above and below 70% for each age group. Low PCA was more frequent for subadults between 1 month and 6 years of age however the majority of subadults in all age groups had PCA scores above 70%.

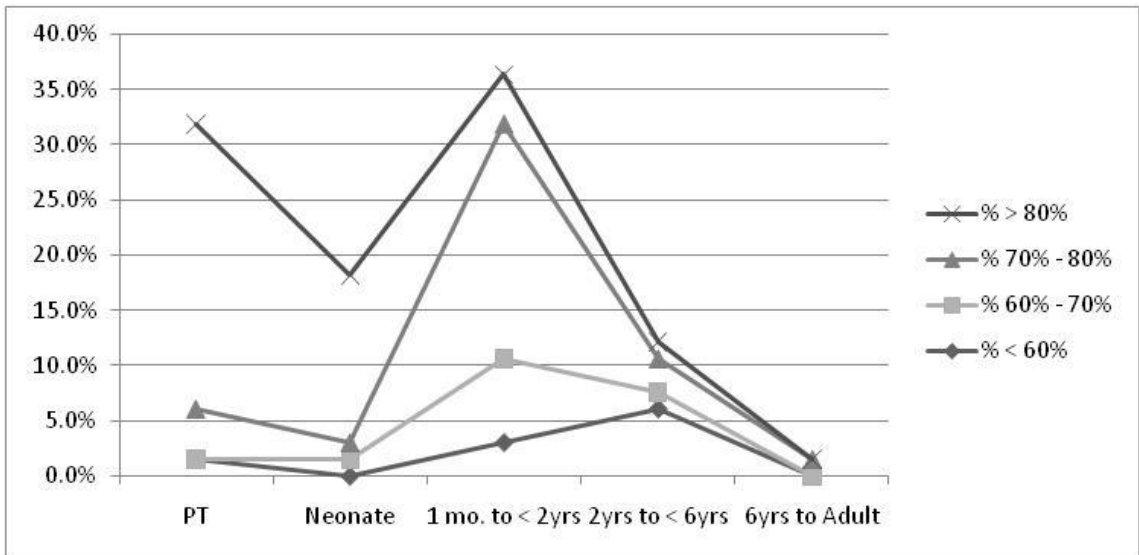


Figure 20. Distribution of PCA scores among age groups. (n=66)

Looking at the distribution of the range of PCA scores among the age groups in Figures 19 and 20, a higher percentage of individuals across all age groups had good scores. Fewer individuals had scores in the 60-70% and below 60% ranges. Lower PCA scores were more frequent among individuals aged 1 month to 6 years than among those aged less than 1 month.

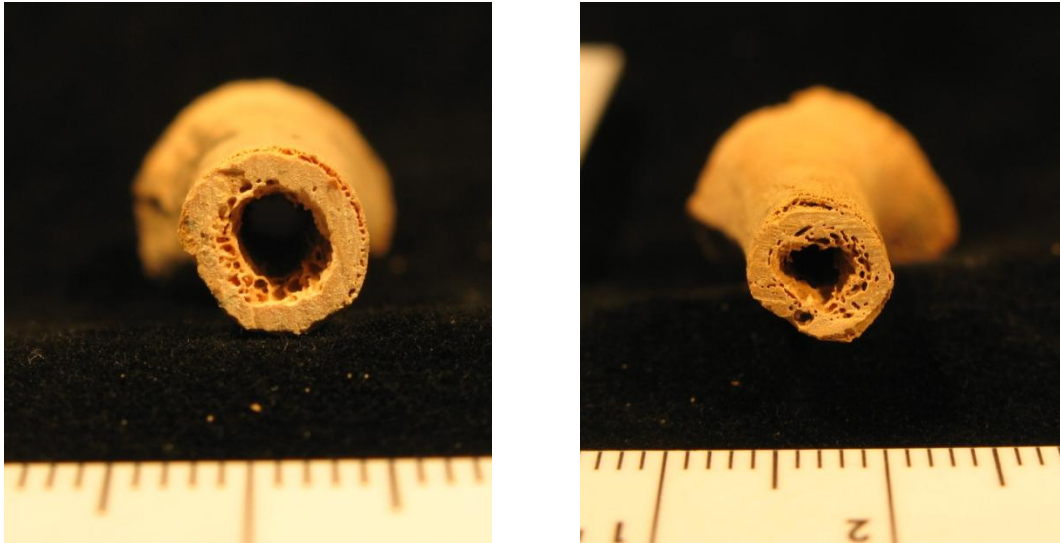


Figure 21. Femur 4352 (left). PCA was calculated to be 68.04%. Also visible is a layer of bone deposited on the outer periosteum (infectious disease observed in Figure 13).

Figure 22. Femur 26188 (right). PCA was calculated to be 77.67%. Again, a layer of bone deposited on the outer periosteum is visible (infectious disease observed in Figures 11 and 12).

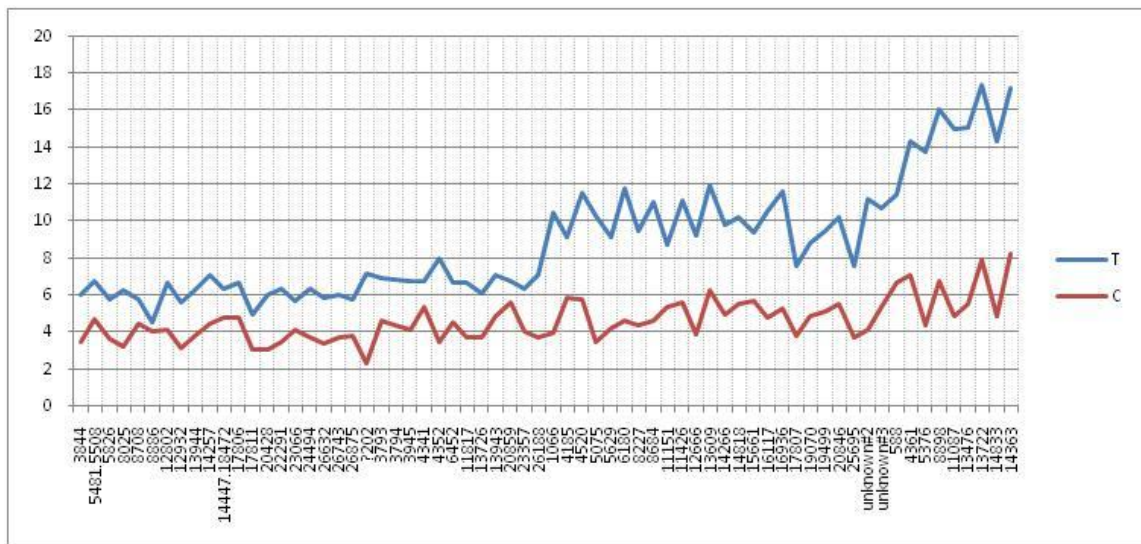


Figure 23. Measurements of cortical thickness (C) and diameter (T) are shown for all available right femora (n=66). Samples are seriated by age groups with the youngest at the left and oldest at the right. Diameter increases at a greater rate than cortical thickness as individuals age.

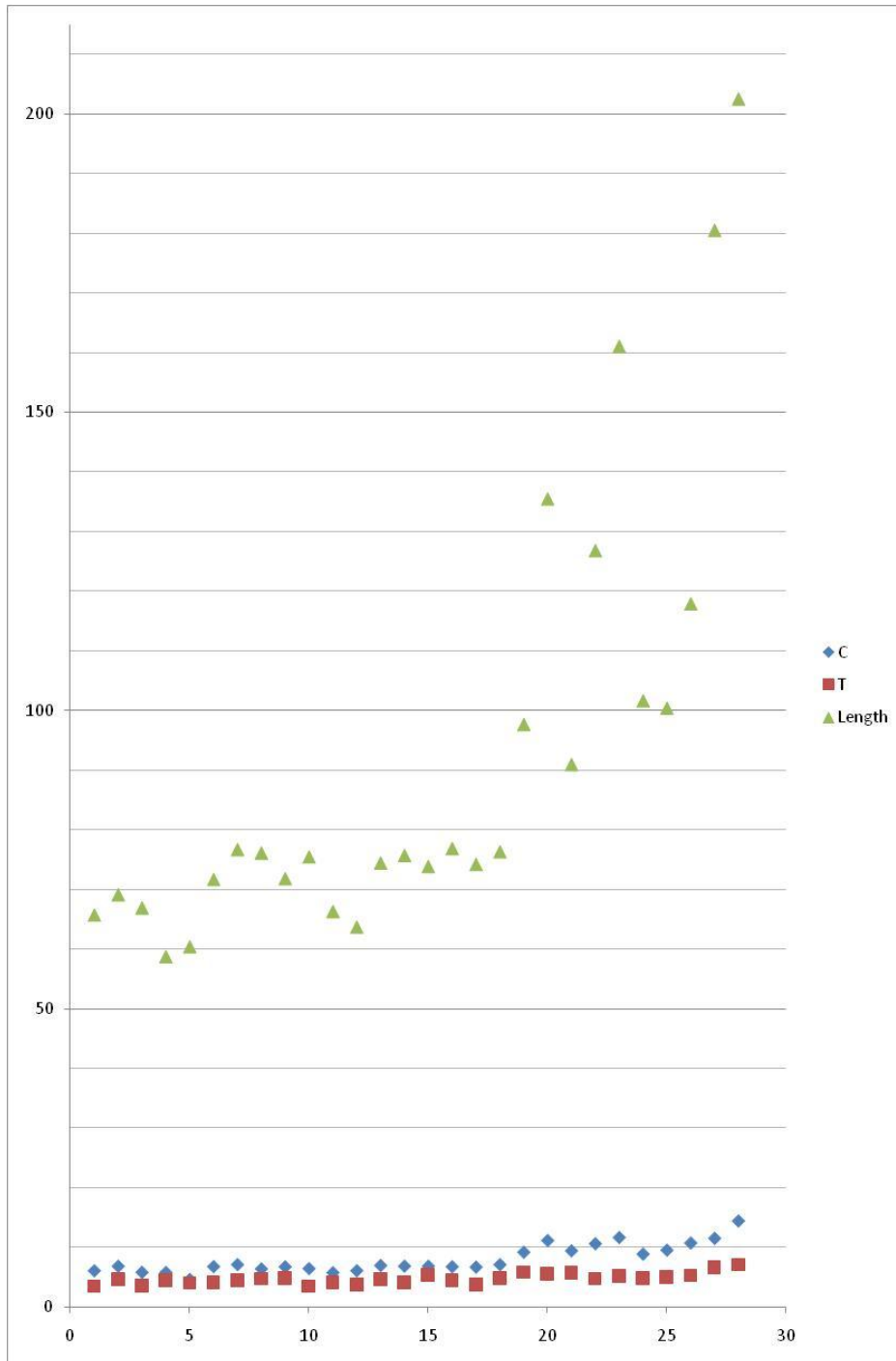


Figure 24. Cortical thickness (C), diameter (T), and length is shown for all femora available for all three measurements (n=28). Samples are seriated by age groups with the youngest at the left and oldest at the right. T and C experience larger increases at the same time length increases.

Figures 23 and 24 illustrate general growth patterns by length, thickness, and diameter. As is expected, increases in length are accompanied by growth in cortical thickness and femoral diameter. Figure 24 shows that the rate of increase is larger for diameter than that of cortical thickness. The difference in these rates results in decreasing PCA for the older subadults, particularly the oldest.

Considering PCA scores and infection together, some correlations were observed. For 31 individuals with periosteal reactions, PCA was able to be calculated. Correlation analysis of specimens with pathology and PCA scores (n=31) showed that PCA and pathology are significantly negatively correlated at the $p < .05$ level (Correlation Coefficient= $-.410$; $df=29$; $p=.022$). There is a moderate effect between PCA scores and severity of periosteal reactions observed on the subadult bones. That is, for individuals who died with infection, it appears that growth faltering occurred as well, as seen in the lower PCA scores. Infants with infection likely were feverish and not eating. This would negatively impact normal growth and development.

Correlation analysis was also performed to test the relationship between severity of pathology and age. All individuals that were scorable for pathology (n=87) were included. A statistically significant negative correlation exists between severity of pathology and age at the $p < .01$ level (Correlation Coefficient= $-.538$; $df=85$; $p < .0005$). There is a strong effect between age and severity of periosteal reactions observed, meaning that younger ages had more severe infectious disease.

Results Summary

These data, taken collectively, suggest that some preterm and infant deaths were due to everyday encounters with communicable infections, such as *Staphylococcus* and *Streptococcus*, to which infants are so susceptible. Other preterm and newborn infants show no infectious diseases and likely died a very quick death due to other factors such as premature birth, genetic problems, or other biocultural variables which will be discussed in the next chapter.

CHAPTER 5

DISCUSSION

The analysis carried out in this project focused on the infants and children in the tomb at Tell Abraq by focusing on demography and pathology. Given the relatively large presence of preterm and term infants and infants up to the age of 2 years, the research questions became the following:

- Were children failing to thrive due to disease and/or diet?
- What economic and cultural factors played a role in infant mortality?

Mortality and morbidity profiles of the subadults revealed some strong patterns that include the high frequency of individuals in the preterm and neonate age groups that show infections at the time of death. These findings are discussed with reference to the biocultural research model (discussed in Chapter 2 of this thesis). Several cultural factors are discussed that may have contributed to the paleodemography and paleopathology observed in the youngest individuals living at the site of Tell Abraq.

General Patterns in Health

Rates of infection among the subadult right femora were assessed to provide information on the youngest members of the population buried in the tomb at Tell Abraq. Periosteal reactions present on the shafts of femora occurred in almost half of all bones available for observation. These reactions indicate infectious disease processes at work in these individuals. The extent of most pathological activity was more often slight but moderate and severe activity levels were also observed, just at lower frequencies. The most notable finding was that the youngest individuals (i.e., preterm, neonate) more

commonly exhibited infectious periosteal reactions. No individuals over the age of 2 years were observed with periosteal reactions.

Calculation of percent cortical area (PCA) was completed for 66 right femora. Of these specimens, 14 scored less than 70% and 52 scored more than 70%. For the purposes of this study, 70% (a conservative estimate) was used as the cutoff point between “good” and “bad” PCA. Garn (1970) has suggested that 85% is optimal for older individuals. The selection of 70% was made because infants and children naturally have less dense bone as part of the growing process.

The results of the PCA analysis demonstrated that children at Tell Abraq did not experience growth disruption in terms of cortical thickness. Most infants (52) can be considered to have had normal growth rates based on their PCA scores. Seven individuals (10.6%) had scores below 60% which indicates difficulty for some infants to maintain adequate levels of cortical thickness during bone growth.

Mortality and Morbidity Profiles

Preterm Infant Health

The Tell Abraq subadult collection had a relatively large number of individuals aged as young as 7 or 8 lunar months gestation. This age is within the third trimester of pregnancy. For subadults, 22% (n=28) were preterm. These preterm infants were experiencing health problems at the time of death. For these youngest infants, 20 of the 28 bones had periosteal reactions or evidence of inflammation and infection at the time of death. Although the infections were slight in expression, some individuals survived long enough for moderate and severe pathological activity to occur.

This high frequency of infection among preterm infants is unusual because, prior to birth, a fetus is in a highly protected environment in its mother's womb. This environment is crucial for setting the stage of infant survivability. While in the mother's womb, a fetus is completely dependent upon the mother. She is the provider of nutrients, oxygen, waste removal, and protection (vonRango 2008). Unfortunately, she is also capable of passing any illness she may have to the fetus and can be engaged in activities that can harm the fetus. A poor fetal environment can result in deficient fetal growth and development, thus leading to lower rates of survivability, premature delivery, or miscarriage (Aagaard-Tilly et al. 2006; Hediger et al. 1997).

The relationship between a mother and her fetus is a symbiotic one in which both individuals are affected by the other. This relationship is known as the maternal-fetal interface (vonRango 2008). The basic elements of this relationship include the reproductive system, most importantly the placenta, and the fetus. The placenta is the organ in which the fetus grows. It functions to connect the fetus to the mother so that the fetus can receive nutrients and the mother can remove the fetus' waste via their interconnecting blood supply (Haig 1995). The fetus functions in similar ways to a semiallograft (a transplant) because it shares half the genetic makeup with the mother and half with the father (vonRango 2008; Wadhwa et al. 2001) and the maternal environment will react to it in such a way that it is recognized as foreign to the body. Since this is not desirable, certain processes have developed to protect the fetus from being destroyed. Aagaard-Tilly and colleagues (2006) suggest that the maternal immune system features mechanisms which prevent attack of the fetus. If this is the case, it provides evidence for the evolution of a complementary system within reproductive organs so that the fetus can

thrive and persist to full term gestation. For the Tell Abraq preterm individuals, this protective system seems to have been faulty since so many of the subadults in this age group show premature delivery and infectious activity. It can be hypothesized that the mothers of these individuals were physiologically stressed and possibly suffering from an infectious disease as well.

If the placenta functions properly, a fetus has the potential to develop normally. Even with this protection, however, maternal factors can negatively affect optimal growth of the baby. Often times, these factors result in premature birth (birth occurring prior to full term gestation / 37-40+ weeks) and/or low birth weight (less than 2500g) of a baby (Hediger et al. 1997; Kirchengast and Hartmann 2003; Nkwabong and Fomulu 2009; Scholl et al. 1992). Low birth weight can lead to higher rates of infant and childhood morbidity and mortality (Aagaard-Tilly et al. 2006; Barker 2001; Brooks et al. 2001; Cook 1961; Kramer et al. 2000; Lindsay et al. 2000; McCormick 1999).

Neonate Health

There are fewer neonates in the tomb than preterm infants. There are a total of 12 neonates, representing approximately 9.5% of the subadults (compared to the 28 preterm infants that represent 22% of the subadults). A majority of these individuals exhibit infectious activity on their femora (8 of the 12 specimens showed slight to moderate periosteal reactions). Similar to the preterm individuals, neonates are immunologically vulnerable. They are at risk to many things due to immature physiology. Modern human infants evolved as severely dependent organisms as bipedalism and changes in brain size occurred in *Homo sapiens* (Bogin 1999). Infants rely on others to provide the means for meeting the demands of daily bodily functions. Rapid growth and development begins in

the neonate stage and continues through infancy and young childhood. This further increases the energy and nutrient requirements to achieve growth. If an infant's needs are not properly met during this crucial period in life, the child is at greater risk for developmental problems and potentially death.

This stage of life, therefore, represents a time fraught with high risks for increased morbidity and mortality. Some immunity is shared by the mother, however, and this normally allows the neonate to thrive. This maternal immune protection comes through the infant's consumption of breast milk. Breast milk contains antibodies and proteins capable of battling invading pathogens (Hamosh et al. 1999). As long as infants consume the mother's breast milk, they are better able to stave off infection and can continue to develop and strengthen their own immunity. For neonates at Tell Abraq, early death may have resulted because of preexisting infections that were too much for the maternal immune protection to defend against. The fact that numerous individuals died before reaching one month of age and many had infections at the time of death also suggests that mothers were ill prior to the birth of their babies.

Health of Infants and Young Children

The subadult collection at Tell Abraq included 46 individuals in the 1 month up to 2 years age group. These make up 36% of the subadults. Only 27 of these individuals were included in pathology analysis due to the poor condition of the bones. Within this age group, only 8 of the 27 subadults showed periosteal reactions. This decrease in the frequency of infectious disease suggests that individuals in this age group could have been immunologically stronger or more protected by cultural factors in the community.

The age group 2 years up to 6 years included 32 individuals which comprised 25% of the subadults at Tell Abraq. Again, poor preservation excluded 16 femora from pathology analysis so only 16 were assessed. None of the subadults in this age group had periosteal reactions, thus infection may not have contributed to the deaths of these individuals.

Health of Children Aged 6 Years and Older

The subadult collection at Tell Abraq had only 9 individuals in the 6 years and older age group. These make up 7% of the subadult population. This small sample of children limits the amount of information that can be gleaned from this age group and is further constrained by allowing pathological assessment of only 4 femora. No periosteal reactions were observed on these individuals so, again, infection may not have been involved in the deaths of these children.

An Additional Explanation for Morbidity and Mortality

For the infants and children without infections, their early death suggests there were other risks involved. One way to think about children with infection is that they survived long enough for their bodies to resist the illness. According to the “osteological paradox” proposed by Wood and colleagues (1992), the human skeletal remains that do not show evidence of infection may have been less healthy than others and died prior to the onset of periosteal reactions on their skeletons. Since it takes time for infection to reach the skeletal system, the individuals affected would have to survive long enough for the reaction to present itself. Other explanations, therefore, need to be examined to explain why infants without infections died so young.

An Abundance of Preterm and Neonate Infants

There are two major questions that the data raise: What can explain the presence of preterm and term infants in the tomb? Also, why are there so few 6-18 year olds? This unusual paleodemographic finding could be the result of countless factors but use of the biocultural model presented in Chapter 2 can assist in narrowing the primary reasons for infant illness and death. Using the model, potential causes of high preterm and term infant morbidity and mortality are discussed using environmental, cultural, and biological lenses. Doing so permits the focus to shift to young maternal age and consanguinity, maternal physiological immaturity, and placental malaria, all of which can account for high preterm and term infant death. Infectious disease in approximately half of these infants can be explained by *Staphylococcus* and *Streptococcus*, common ailments in ancient agricultural communities (Goodman and Armelagos 1980). Cultural factors operating at Tell Abraq reveal other variables that likely contributed to infant death.

Young Maternal Age and Consanguinity

Preterm and neonate death rates at Tell Abraq may have occurred because of cultural practices relating to marriage and reproduction. The region of the Arabian Peninsula, where Tell Abraq is located, has a long tradition of marriage of young adolescents and marriage between first cousins (Al-Gazali et al. 1997; Al Khabori and Patton 2008; Bristol-Rhys 2007). These practices are still common among modern populations in the region and very likely could have been prevalent during the Bronze Age (Al-Gazali et al. 2005; Bener et al. 1996; Rajab and Patton 2000). These traditions are relevant because they both contribute to higher incidences of preterm birth and infant

morbidity and mortality (Al-Gazali et al. 2005; Joseph 2007; Al Khabori and Patton 2008; Magnus et al. 1985; Stoltenberg et al. 1999).

Traditionally, following their first menses, ‘girls’ become ‘women’ and are considered eligible for marriage (Bener et al. 1996). Girls are married at young ages so that their families can receive the traditional dowry payment (called a “mahr”) from the groom’s family (Bristol-Rhys 2007). Following marriage, sexually active females would likely become pregnant quickly and, as the coming paragraphs will describe, adolescent mothers can contribute significantly to poor development and health of their offspring which, in turn, affects infant mortality and morbidity.

Another component to marriage ritual in the Near East is the practice of marriage between related individuals. Typically unions between first cousins, consanguineous marriages are often arranged between families so that wealth and power remains within the same family and/or tribe, thus a tool of economic stabilization (Al-Gazali et al. 2005; Rajab and Patton 2000). While this unified family may have positive effects on the lives of children, there are consequences to consanguinity that are relevant to this research. Research has demonstrated high rates of diseases and defects such as cystic fibrosis, thalassemia, sickle-cell anemia, osteochondrodysplasias, and deafness among offspring from consanguineous unions (Al-Gazali et al. 2005; Al Khabori and Patton 2008). Additionally, studies have shown increased risks of infantile death and low birth weight for children with genetically-related parents (Magnus et al. 1985; Stoltenberg et al. 1999).

Maternal Physiological Immaturity

In researching preterm birth, gynecological age is also considered. Gynecological age is a measure of the maturity level of the reproductive system. It is calculated by

subtracting the age at the onset of menarche from the female's chronological age at the time of conception (Frisancho et al. 1984; Hediger et al. 1997; Scholl et al. 1992; Zlatnik and Burmeister 1977). It is important to note gynecological age of a young mother because it is indicative of the likelihood that she is able to carry a viable conceptus. A female has a low gynecological age if the value is under 2 years (Frisancho et al. 1984; Hediger et al. 1997; Zlatnik and Burmeister 1977). For example, a female would have a gynecological age of 1.5 years if she had her first menses at 13 years and became pregnant at 14.5 years of age. Even though the onset of menarche may culturally reflect that she is a fully-developed woman, this adolescent girl is still physiologically immature and her reproductive system is not fully mature. Her fetus is therefore at risk (Frisancho et al. 1985; Hediger 1997; Scholl et al. 1992, 1994; Zlatnik and Burmeister 1977).

Low gynecological age has been linked to preterm labor. Hediger (1997), Scholl (1992, 1994), and colleagues have demonstrated that preterm neonates are frequently born to mothers of low gynecological age, regardless of chronological age. For example, Scholl et al. (1992) found that 34.3% of mothers with a gynecological age of 1 (mean chronological age of 13.9 years) and 21.2% of mothers with a gynecological age of 2 (mean chronological age of 14.3 years) delivered a preterm neonate. These findings are consistent with the other research referenced.

There is some contention, however, regarding gynecological age as a significant factor in preterm labor and fetal growth. Frisancho and colleagues (1985) suggest that gynecological age may not necessarily affect growth of the neonate as their research results indicate a combination of factors. Specifically, their data shows that a competition for resources between the mother and her fetus may be taking place. This

results in poor fetal development which signals to the fetus that exiting the womb may be a better environment for survival.

Young adolescent mothers are typically still in a state of continued growth and physiological maturation (Baughn et al. 1980, Scholl et al. 1997, Scholl and Hediger 1993, Zlatnik and Burmeister 1977). For this growth process to take place, certain needs must be met by the body. Referring back to the maternal-fetal interface, this relationship exists so that a fetus can derive all the necessary nutrients and resources from the mother. These nutrients and resources facilitate growth and maturation of the fetus. They come directly from the mother's reserves of energy and nutrients and, therefore, she must be taking in more than her pre-pregnancy amounts so that the needs of both her and her fetus are fulfilled. But what if the mother is still in the process of growing herself? How does this impact fetal development? Research indicates that still-growing adolescent mothers may contribute to poor fetal development because their own bodies hinder fetal growth by competing for available nutrients (Naeye 1981, Scholl et al. 1997). Additionally, much research indicates that there is a need for further maturation of the reproductive organs, specifically the uterus and cervix (Zlatnik and Burmeister 1977), after the onset of menarche.

Not only are maternal organs maturing throughout the teenage years, but skeletal growth is also taking place. Long bones of the adolescent usually undergo a growth spurt, typically at ages 12 to 16 in females (Baughn et al. 1980), which requires higher energy intake to facilitate increased length and fusion of epiphyses. Several examinations of pregnant adolescents have shown continued skeletal growth throughout the time the fetus is gestating. Frisancho and colleagues (1984, 1985, 2006) showed that

still-growing adolescents had significantly smaller infants than adolescents who had already completed their growth. (It should be noted, however, that these results only reflect growth in stature.)

A study by Scholl and Hediger (1993) additionally showed that approximately 50% of young adolescent mothers continued growth during pregnancy. Stevens-Simon and McAnarney (1993) reported the potential for skeletal growth during and after pregnancy, however their study failed to provide significant correlation to obstetric risk. Following the adolescent growth spurt, other skeletal elements experience changes that also require additional energy. Research by Moerman (1982) has shown that maturation of the pelvic birth canal is not complete by the time adult stature is reached nor is the reproductive system mature.

All of the studies share a common finding: adolescents who continue to grow and mature physiologically throughout pregnancy are likely competing with their fetus for nutrients and energy. This competition is important to recognize because it highlights the dangerous environment for the fetus. Evolutionarily speaking, it is more crucial for the mother to survive than her fetus (Bogin et al. 2007). Even if her fetus does not survive to full term, she is still able to reproduce later in life. In the competition for nutrients, therefore, the mother will divert resources from her fetus to maintain her own growth (Frisancho et al. 1985; Scholl and Hediger 1993). The fetus would then likely be born prematurely or with a low birth weight and be more at risk to illness and death. The correlation of continued growth of the adolescent, her gynecological age, and her young chronological age to fetal risk is therefore important in studies pertaining to infant morbidity and mortality.

In summary, given the long history of arranged early (adolescent) marriages in the Near East, if this practice has deep history in this area, it could help account for those preterm and term infants in the tomb. Consanguinity combined with early marriage and adolescent pregnancy contributes to miscarriages and infant mortality today (Al-Gazali et al. 2005; Bener et al. 1996; Rajab and Patton 2000) and so it is possible that it did so in the past as well.

Placental Malaria

As pointed out in the biocultural model for the Arabian Peninsula, it is likely that malaria was a persistent health problem (Abrams and Meshnick 2009). Beyond young maternal age and continuing skeletal growth, fetal development can also be impacted by diseases such as malaria. Since malaria is associated with the circulatory system, it affects fetal development as the fetus in the placenta derives all of its resources from the mother's blood supply and can also be infected by the disease. It is important to note, however, that an infected mother will not always pass the disease on to her fetus congenitally (Abrams and Meshnick 2009). When placental malaria does occur, the fetus may react with poor development and growth. Research by Abrams and Meshnick (2009) supports this possibility with their work among areas of the world experiencing varying levels of malaria prevalence. The outcomes of this research show that pregnant women infected with malaria must find a balance between support of their fetus and maintenance of their own bodily functions, particularly immune processes that will help them survive the illness.

The possibility exists that more energy is required for maintenance of immune function during this time, which leaves lower reserves of energy to be invested in the

fetus. This can result in two things: 1) poor fetal development that leads to low birth weight, or 2) a fetal environment that can no longer support pregnancy. Ultimately, the work by Abrams and Meshnick (2009) supports the theory that resources are being negotiated in malarial pregnancies and that this can be a significant factor in the outcome of the fetus.

In conjunction with the results produced by Abrams and Meshnick (2009), Menendez and colleagues (2000) further support an impact of placental malaria on fetal development. Their large sample of 1,177 mothers and their neonates showed a prevalence of malaria among 75.5% of the placental samples. Their results showed a high number of neonates with low birth weight (18%, n=155), however maternal HIV was also a factor in this result for 61 of the mothers. For those neonates whose gestational age was able to be calculated (n=910), 8% were found to be preterm. Examination of the low birth weight infants revealed that 21% of them were preterm while the remaining 78.8% were associated with intrauterine growth retardation. These results also showed that younger mothers infected by malaria were more likely to give birth to preterm or low birth weight babies. This is also congruent with research described by Abrams and Meshnick (2009). They found more severity among younger mothers who had malaria and attributed it to maternal immune function and its altered state during pregnancy that keeps the body from attacking the fetus. This altered state may be responsible for causing poor nutrient transfer between the mother and fetus. Additionally, for areas without endemic levels of malaria, immunity against the illness is lower as people are not continually combating it and building a tolerance (Desai et al. 2007), thus leaving individuals more susceptible.

Another study by Luxemburger and colleagues (2001) further supports the correlation between maternal malaria and poor fetal development and consequences for infant life. Their findings showed that 20% of low birth weight infants were the result of maternal malaria during pregnancy. They attribute this poor fetal development to anemia resulting from the malaria. Malaria is therefore described as an “indirect” cause of higher infant mortality as these low birth weight babies had higher likelihood of dying than those not of maternal malarial pregnancies (Luxemburger et al. 2001:464).

To illustrate the culmination of recent research on this topic in reproductive health, see Figure 25. It effectively highlights the maternal, fetal, infant, and childhood outcomes of maternal malaria and its potential transmission to offspring. What is important for this study is that if there was placental malaria, the preterm infants could in fact be small-for-gestational age term infants who had growth faltering in utero.

The abundance of preterm and neonate infants may relate to fetal development and low birth weight. The aging methods used for the Tell Abraq subadult femora rely on data from normal, healthy populations. The discussion on the ways that can be poor fetal growth can result illustrates that there may have been infants who were small for their gestational age or ‘low birth weight’. What this possibility means is that many of the individuals at Tell Abraq that have been aged as preterm may actually be small for gestational age. If this is the case, more individuals would be labeled as newborns or neonates.

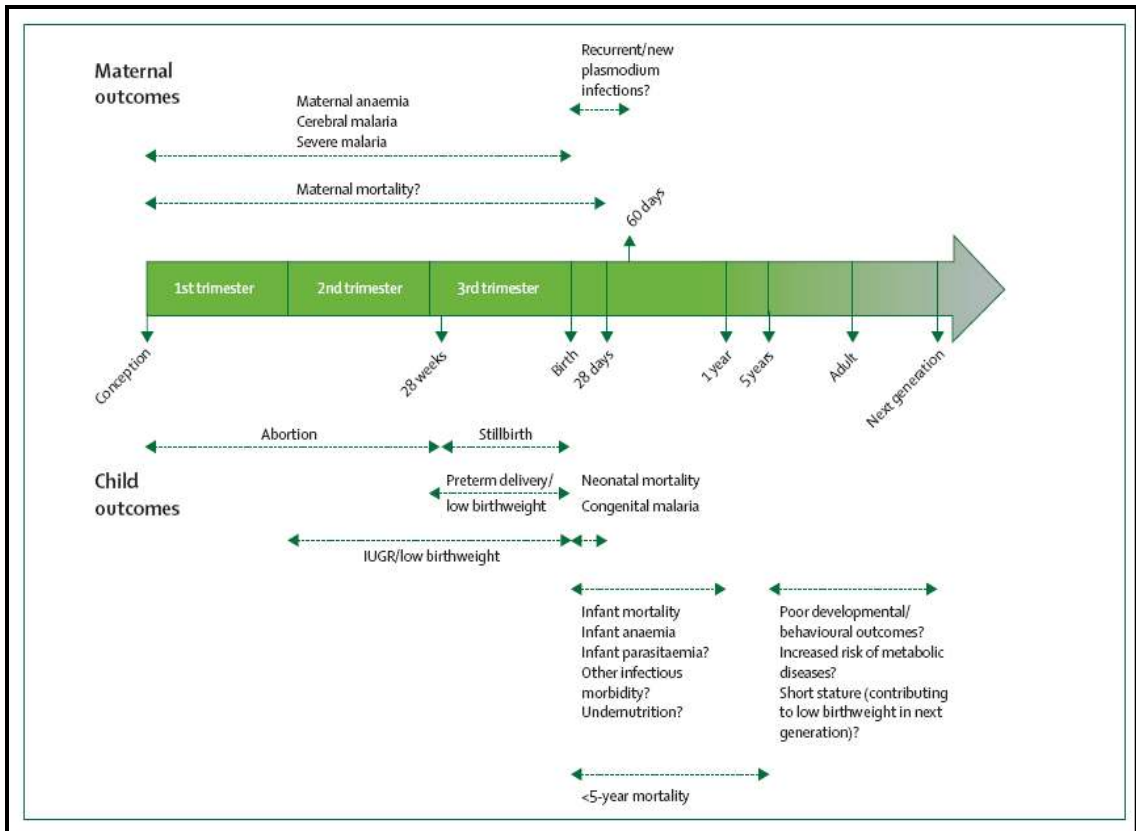


Figure 25. Outcomes for both mother and fetus/child when malaria affects pregnancy. Most notable effects for the fetus/infant are stillbirth, preterm delivery, low birthweight, and anemia. Mothers with malaria can become anemic and be susceptible to infections. (Reprinted from Desai et al. 2007 :95)

Summary of Biocultural Factors Affecting Newborn Infants

Low birth weight can result from all of the conditions described and could have been operating in ancient Arabia at the site of Tell Abraq. The complications of poor fetal development are significant to this research because they can have great consequences for further physiological development and good health. Low birth weight babies can have higher risks of disease and death. An infant determined to have low birth weight may have both immediate and long term risks for health problems. Immediate risks include neurological disorders such as cerebral palsy and delayed brain

development (McCormick 1999), as well as Sudden Infant Death Syndrome (SIDS) (Kramer et al. 2000) and asthma (Brooks et al. 2001). Because of the amount of brain growth that is taking place during the infancy stage and the large amounts of energy that are being allocated toward that function, it is clear that infants are most at risk. Older children are better equipped physiologically to survive disruptions. Long term risks linked to low birth weight include coronary heart disease (Barker 2001) and diabetes (Lindsay et al. 2000).

The combination of both low birth weight and prematurity can also lead to problems for neonates and infants. Preterm infants are more susceptible to infection as their skin is more poorly developed than that of full-term infants and it does not fully protect them from bacteria (Aagaard-Tilly et al. 2006). Additionally, since the lungs are among the final organs to mature in a fetus, typically around 37 weeks, respiratory function can also be compromised (Cook 1961). Neonates may thus be at risk to develop pneumonia or respiratory distress syndrome (Cook 1961). These illnesses are very treatable with modern technology and medicine, but populations without this advanced technology (like the Bronze Age population at Tell Abraq) would likely lose infants in these cases.

Death of infants in the neonate period might be explained by weak immune systems that could allow greater severity of infections, but there might be other explanations as well. As mentioned in Chapter 2, early weaning of infants has been recorded as a strong historical cultural behavior in the Near East (Beckerleg 1984; Forman et al. 1990). This cultural practice could jeopardize health by causing malnutrition and further weakening the infant's defense systems. Additionally, the infant

no longer receives immunity protection from the mother's breast milk once it has been weaned.

As noted in the model in Chapter 2, close proximity of the living space to animal herds could introduce bacteria to infants, especially through the water, which could have been shared by animals and people. The excavation at Tell Abraq resulted in the finding of shells described as "feeding shells" (Potts 1993a). These likely were put in the tomb as grave offerings for the infants. Useful for giving infants water and other liquids, these would have been sources of bacteria that could lead to infection.

Also related to the water is its high fluoride content. The Arabian Peninsula region features high levels of fluoride in fresh water resources and this can cause problems for the population consuming them (Littleton 1999; Littleton and Frolich 1989). Effects of high fluoride consumption include ankylosis, bone thickening, and ossification of ligaments (Littleton 1999). While children are not primarily affected by skeletal fluorosis, it is still important to identify this as a potential environmental factor in population health.

Stress and Weaning in Infants and Toddlers

Children in older age groups (2 – 6 years and 6 – 18 years) have better immune function and are more self-sufficient in terms of personal needs (i.e., feeding themselves, transporting themselves from place to place). Because of this, they are not at as much risk of developing serious health problems that could potentially lead to death and they also have lower rates of mortality (Gage 2000).

One major event that takes place during this period, however, is weaning. As a child transitions from a diet solely comprised of breast milk to one of solid foods, nutritional deficiencies might occur. A child not receiving adequate nutrition could become malnourished. This causes the child to be further susceptible to developing infections and other health problems. When the child's energy needs remain the same but incoming energy is decreased, vital body functions will use the energy first and sacrifice other functions which might lead to failing health or even death.

Mortality among this age group at Tell Abraq is puzzling and a lack of infectious activity on the femora does not indicate specific illness or health stressors. The number of individuals in this age group is comparable to the other age groups so it is apparent that something had to be causing these children to die. Unfortunately there is little evidence on the skeletal remains to suggest some specific cause of death. The alternative cultural and environmental factors described in this thesis, therefore, may be possible explanations.

Adolescents at Tell Abraq

The presence of very few older children and adolescents (6 – 18 years) among the Tell Abraq subadults suggests that infants who survived the youngest years do quite well as adolescents and teenagers. These children would have been able to survive bouts of poor health with their more mature immune systems. For those who did die at this age, none had periosteal reactions. This suggests that they did not die as the result of infection. Lovejoy and colleagues (1990) propose that adolescent deaths related to illness are more often acute conditions that do not affect maturation of dentition or the skeleton.

Some other causes, therefore, may have been responsible for adolescent deaths at Tell Abraq.

Two important questions are raised by the small sample size and the lack of periosteal reactions.

1. Were adolescents at Tell Abraq healthier than other age groups?

or

2. If adolescents were dying at similar rates of other age groups, is their absence from the tomb a consequence of differential mortuary ritual?

If adolescents were better equipped to survive the environment of Bronze Age Tell Abraq, they likely survived to adulthood. No other mortuary features have been discovered at the site so it appears that this age group was not interred elsewhere. Mortuary practices for other Bronze Age burial populations suggest that they were inclusive of all members of the community with no preferential burial of age groups (Blau 2001; Cleziou 1983; Ilan 1995). At Tell Abraq, this is supported by the inclusion of the youngest infants within the tomb. Similar styles of mortuary tombs continued in the region for many centuries with none reserved for adolescents. While not conclusive, it appears that there are so few adolescents because few in that age category died at the site.

CHAPTER 6

CONCLUSIONS

The tomb at Tell Abraq represents a unique opportunity to understand what life was like at the end of the Bronze Age (c. 2200-2000 BC) living on the edge of the Arabian Gulf in a relatively large community (approximately 500 people at any given time) (Potts personal communication). The fortress associated with the tomb was occupied for a much longer time period (having been started before the tomb was in use, and continuing into the Iron Age, long after the tomb was no longer used). Currently, there is no explanation for why the tomb was used for such a short time (200 years represents about 6 generations). The commingled nature of the human remains (the minimum number of individuals is 413) suggests a complex mortuary behavior associated with how and when the dead were put into the tomb. A preliminary analysis of the complete collection suggested early on that all ages and both sexes are well represented in the tomb (Potts 2000b).

This thesis research focused on the youngest portion of the death assemblage, which in this case ended up being 28 preterm infants, 12 neonates, and 46 aged 1 month to 2 years. Although the original research design was to study carefully all of the subadults (that is, all infants, children, adolescents, and teenagers), there was an early realization that there simply were not very many children, adolescents and teenagers. In this case, the absence of data became data itself in that, given the general lack of pathologies on the older children, it is likely that children survived childhood quite well and teenagers survived to become adults at Tell Abraq or relocated to other areas.

The preterm and term infants became the focus of the analysis because they represented a relatively large cohort upon which frequency data on infection and growth and development could be obtained and where statistical significance could be calculated.

Bioarchaeological studies demand that the human remains be analyzed within the broad context in which they are found. That means that the environmental, cultural, and biological factors that could be reconstructed for this population needed to be fairly well understood. Chapter 2 presented a model that spelled out all of the known important variables that would be necessary to contextualize data on health.

What these data suggest strongly are that cultural practices likely contributed to the deaths of many preterm and term infants. Marriage rituals in the Near East have a long history of consanguinity (marriage between first cousins) as well as adolescent females being placed in marriages that resulted in pregnancies while the girl is still growing and developing. Marriage of adolescent females and unions with first cousin males both can increase morbidity and mortality of infants (Al-Gazali et al. 2005; Al Khabori and Patton 2008; Bristol-Rhys 2007; Joseph 2007; Magnus et al. 1985; Stoltenberg et al. 1999). These highly ritualized marriage practices have a very deep history in the region (Al-Gazali et al. 1997; Al Khabori and Patton 2008; Bristol-Rhys 2007).

To be sure, some infants died from infectious disease such as those associated with *Staphylococcus* and *Streptococcus* bacteria. There are many studies of agricultural populations that show that sedentism produces high infant mortality due to sanitation and crowding issues. Yet, deaths for only about 50% of the preterm individuals and older infants can be attributed to having contracted a bacteria-based transmissible disease. The

very young ages of these infected individuals also suggests that maternal health was also problematic, which may have also contributed to infant health and survival. In addition to this, placental malaria could also produce very low birth weight infants who are frail and at risk of death.

The deaths of the other infants and children (those without infection) could be due to the full range of problems associated with consanguinity and pregnancy at an early age. Results from the analysis of percent cortical area do not support major difficulties in maintaining bone growth, therefore, the findings of this research are more indicative of a link between cultural practices and subadult death.

In summary, the patterns of infections and age-at-death suggest that both environmental factors (transmissible disease, malaria) and cultural practices (consanguinity and teen pregnancies) could easily account for the number of infants in the tomb.

Research Findings in a Broader Context

This research project has focused on childhood morbidity and mortality with the goal of understanding community health in a way that is inclusive of more than just adult health data. Children of the past faced immense odds for survival under various situations and contexts. Unfortunately, today there are still areas of the world that continue to have high rates of child mortality. The rate of death for children under the age of 5 years is still high for much of Africa, the eastern Mediterranean, and southern Asia and the infant mortality rate for these regions is even higher (World Health Organization 2009). Many factors contribute to each of these areas and it is vital that

research consider them when attempting to find solutions for better survival rates. This research has done just that and brings together a variety of information so that health in the past can be contextualized and understood in a way that can also contribute to current topics in health. The Tell Abraq skeletal collection has offered much insight into knowledge of premature birth of infants and the maternal-fetal relationship as it relates to health.

Finally, this research contributes to many areas of study. Bronze Age Arabian topics in bioarchaeology, paleopathology, and cultural practices including mortuary and marriage ritual are enhanced by the findings of this research. Paleopathology and bioarchaeology in particular benefit from the specific focus on subadults that this research presents. The biocultural model is a new approach to understanding past human behavior and health. Researchers in anthropology, particularly bioarchaeology, should consider this analytical model as a tool that encompasses multiple fields of information and can better interpret remains of the past.

Suggestions for Future Research

The outcomes of this research provide several opportunities for future studies using the Tell Abraq collection. Potential research topics include questions regarding the relationship between maternal health and subadult health, contributions of subadult dentition to understanding health of the Tell Abraq subadults, testing for relatedness within the population, and additional biocultural factors that may have impacted health in this region of the world. Each of these research areas could provide a better understanding of life at Tell Abraq during the Bronze Age.

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