ASSESSING POPULATION VARIATION USING HERITABLE NONMETRIC TRAITS: A BRONZE AGE ASSEMBLAGE FROM TELL ABRAQ, UNITED ARAB EMIRATES

by

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The following individuals read and discussed the thesis submitted by student Katie Marie Taylor, and they evaluated the student's presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

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DEDICATION

To my loving and supportive spouse, parents, and family. Thank you for the unconditional love and guidance as I navigated the ever changing waters of graduate school and completion of this work. I love you.

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ABSTRACT

This research investigates the use of heritable nonmetric traits as a means for assessing population variation and biological relatedness within an archaeological sample using the commingled human skeletal tomb assemblage from the Bronze Age site of Tell Abraq, United Arab Emirates (2100-2000 BCE). A total of 410 individuals representing all ages and both sexes were interred in the Umm an-Nar period tomb. An analysis of sixteen heritable nonmetric traits was conducted on the adult human skeletal remains for both cranial and postcranial elements. Of the eight elements analyzed, one element in particular displayed anomalies rarely described in archaeological contexts. Seven patellae were identified as emarginated, six as bipartite and one as tripartite. The frequency of traits found here are inconclusive in suggesting biological homogeneity or heterogeneity. However, the baseline data provided here may be useful in investigating biological homogeneity in other studies in the future and may allow us to look at social practices such as marriage patterns. These data may also provide an additional line of evidence to the previous hypotheses concerning consanguineous marriage for this assemblage.

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LIST OF ABBREVIATIONS

NMT(s)	Nonmetric Trait(s)
MNI	Minimum Number of Individuals

CHAPTER ONE: INTRODUCTION

The site of Tell Abraq is an important archaeological site for understanding both human health and behavior during the Bronze Age. As one of the largest prehistoric sites in the southern region of the Arabian Gulf, accompanied by a large commingled skeletal assemblage, this site provides many opportunities for studying ancient populations in the region. The goal of this study is to assess the biological variation of a Bronze Age (2100-2000 BCE) adult human skeletal sample from the Arabian Peninsula, using heritable nonmetric traits of the skeleton. In particular, these heritable nonmetric traits will be used to test hypotheses concerning potential consanguineous marriage during the Bronze Age at Tell Abraq.

Nonmetric Traits

Two primary methods used for assessing the biological relatedness of human skeletal remains in an archaeological context are metric and nonmetric traits. Metric traits are used to measure the skeletal and dental remains while nonmetric traits are observations of morphological changes to the bones and teeth. Nonmetric traits (NMTs) are recorded as present or absent with the degree of expression, and in some cases trait location. Studies have shown that NMTs can reflect the genetics within a population, even if indirectly. Both metric and NMTs can be influenced by genetic, environmental, behavioral, and activity-related factors. The onset of NMT use was to compliment metric measurements and now these traits are often used in statistical analyses to determine biodistance between archaeological populations. Metric traits in particular rely heavily on the completeness of the skeletal elements identifiable to one individual. NMTs on the other hand thrive in commingled and fragmented assemblages when the identification of individuals is not possible (Berry and Berry 1967, 1972; Buikstra 1972; Finnegan 1973, 1974, 1978; and Hauser and De Stefano 1978; Martin et al. 2013).

Based on the founding literature and the growing number of studies using NMT analysis, researchers continue to work towards determining trait etiology and categorizing them when possible. The limitations and biases of using these traits to study biological distance have been debated (Berry and Berry 1967; Hauser and De Stefano 1989; Saunders 1989; Veldman 2013). With NMTs being utilized as a quasi-genetic base for studying relatedness within archaeological populations it has been crucial to further research the effects and differences of these traits between sex, age, sidedness, and degree of sexual dimorphism (Berry and Berry 1972; Finnegan 1978; see references).

Consanguinity

From the Latin *con sanguineus*, meaning of the same blood, consanguinity refers to having the same kinship as another person in which they share one or more common ancestors. Consanguineal marriage is defined as the union between two closely related individuals, most commonly between first and second cousins, not to be confused with incestuous relationships between siblings or parent and offspring. Modern populations practicing consanguineal traditions include Southwestern Asia, North and sub-Saharan Africa, and to a lesser extent in parts of Europe and other countries (Bittles 2003, 2012; Stoltenberg 2009). More recent research in the last three decades has shown in areas that practice consanguinity more commonly, 20 to more than 50% of the populations in those given regions is part of a consanguineous marriage. Historical documentation of consanguinity has also been found among the Egyptians and in royal families (Bittles 2003, 2012; Stoltenberg 2009; Stoltenberg et al. 1999). Studies on consanguinity report that it crosses all cultural lines, religions, and beliefs, proving to have no specific preference (Stoltenberg 2009). The benefits and consequences from consanguineal unions cannot be considered mutually exclusive from cultural or religious beliefs, and for the sake of this study this will not be covered exhaustively. Taking that into consideration the benefits and costs of these unions has been discussed at length by multiple authors.

Understanding the benefits that consanguineous unions provide is important when considering the evolution of such practices. While little is known exactly when this may have occurred during the evolution of modern *Homo sapiens*, understanding how it works in modern contexts could lead us to clues of what to look for in the archaeological record. Bittles and Black (2010) refer to the accepted theory that *Homo sapiens* had such small populations to begin with that interbreeding between various kin relations would have been inevitable. And we know that breeding one way or another would have had to occur for the continuation of our species.

The benefits of consanguineous unions include but are not limited to the stability of social, political, and economic status and power. In some situations, the unions maintain wealth and property (Baustian 2010; Baustian and Anderson 2016; Bittles 2003; Bittles and Black 2010; Reilly 2013; Stoltenberg 2009). In the event that a population were to practice the passing of property such as farmland from parent to offspring, one would consider marriage to a cousin to guarantee that the land stays within the family. More so if that land is an important resource for food or economic stability. Or in the event that a daughter marrying outside of the family and moving away resulted in the loss of production and potentially political standing, one may consider marrying a cousin to keep her at home and continue aiding her family. Bittles and Black (2010) also note other positive benefits to consanguineal marriage including, "...ease of marriage arrangements, enhanced female autonomy, more stable marital relationships, greater compatibility with in-laws, lower domestic violence, lower divorce rates, and the economic benefits of reduced dowry and the maintenance of any land holdings." (p 1784). From a genetic standpoint the stacking of homogeneous genes could be advantageous in challenging environments when combating disease and illness, as well as the positive correlations between consanguinity and fertility (Bittles 2012).

On the other hand, consanguinity is more often than not looked at in a negative light specifically because of the deleterious effects on health that can occur when related individuals produce offspring. The medical literature on the effects to offspring from consanguineous unions is vast. Some of the negative effects include congenital defects, single gene disorders, behavioral and psychiatric disorders, adult-onset diseases, stillbirth, and infant/childhood death (Bittles 2012; Bittles and Black 2010; Khoury and Massad 2010). Camilla Stoltenberg and colleagues (1999) looked at the recurrence risk of stillbirth and infant death (within the first year of life) between consanguineous and non-consanguineous marriages. They found that parents related and unrelated who lost an infant to stillbirth or death within the first year of life had a higher risk of recurrence for the following child. However, in the case of related parents the increased risk for recurrence of stillbirth and infant death was even higher for the following child. They conclude that related parents increase the probability of children having homozygosity for any given chromosomal locus, this in turn relates to disease-associated genes and the potentials for increased morbidity and mortality (Stoltenberg et al. 1999).

Rittler et al. (2001) looked at the specific types of congenital anomalies associated with consanguineous unions. Their study on live and stillbirth infants showed that the congenital anomalies hydrocephalus, cephalocele, microcephaly, bilateral cleft lip +/- palate, hand postaxial polydactyly, hand + foot postaxial polydactyly, 2-3 toe syndactyly, hydrops fetalis, and Down syndrome with maternal age of 35 years or older were significantly associated with consanguinity. They also found that recurrence of these anomalies was higher in siblings of affected sibs compared to non-consanguineous offspring. They suggest that the etiology of some congenital malformations is more likely due to the genetic heterogeneity. In that same vein, early age at marriage and first pregnancy has been associated with increased morbidity and mortality of offspring (Bittles 2012).

These discussions of heritable NMTs as well as the biological consequences of consanguineous unions provide foundational information for examining potential systems of gendered inequality and structural violence which may have included consanguineous marriage at Tell Abraq. This research attempts to test hypotheses regarding consanguinity at Tell Abraq through the examination of biological homogeneity in order to contribute to these larger discussions of inequalities during the Bronze Age.

CHAPTER TWO: SOCIAL THEORY IN BIOARCHAEOLOGY: ASSESSING INEQUALITY AND STRUCTURAL VIOLENCE IN ARCHAEOLOGICAL CONTEXTS

Bioarchaeologists have used social theory to interpret indicators of stress on skeletal remains in the archaeological record using structural violence and inequality theory-driven frameworks. The use of social theory in anthropology provides a theoretical framework for understanding the interactions between social, political and economic factors and how they intersect with human biology and health. Bioarchaeological research provides direct evidence of health, through the examination of skeletal signatures of stress, activity and disease, that can then be interpreted utilizing these theoretical frameworks. Moving beyond just descriptive analyses, this approach offers opportunities to provide answers to the many questions researchers have about the human condition and past lifeways (Martin et al. 2013; Martin and Harrod 2015). Social theory, in particular, has been used in bioarchaeology as a means for uniting the gap between skeletal data and social processes (Martin et al. 2013; Martin and Harrod 2015). This discussion aims to focus on the use of social theory, specifically utilizing a structural violence perspective, as it pertains to use in bioarchaeological research.

Bioarchaeological Investigations of Inequality

Bioarchaeological investigations of inequality focus on the assessment of stress markers on skeletal remains and how this correlates to the patterns of health within an archaeological context as a means for investigating economic and political structures within past societies (Goodman 1998; Martin et al. 2013). Through this, researchers can identify the effects of inequalities by analyzing patterns and asymmetries between subgroups within a population (Martin et al. 2013). Types of inequality may include but are not limited to gender, age, ethnicity, and socioeconomic status (Martin and Harrod 2015). Bioarchaeological investigations of inequalities include reconstructions of biological signatures of stress, diet reconstruction, physical activity, traumatic injury, sex, and age at death (Klaus 2012). Instances of inequality may present as a lowered immune response to disease and illness, disruption in growth, nutritional stress and increased rates of morbidity and mortality (Baustian and Anderson 2016; Klaus 2012).

Social Theory: Structural Violence

Structural violence is defined as a form of violence that is systematically applied by everyone within a society. This may be economic, political, or religious in nature. It is violent in that it causes injury to an individual and impairs one's ability to meet fundamental needs for sustaining life. But this harm is not always as noticeable as one might expect to see, such as with examples of direct physical trauma. Researchers studying structural violence are interested in understanding how oppression and inequalities can present themselves through social structures (Farmer et al. 2004; Martin and Harrod 2015). Unequal access to resources places stress on the individual and has the potential to leave biological effects that can increase rates of morbidity and mortality within a population (Klaus 2012). Paul Farmer et al. (2004: 317) states that at the heart of structural violence are social inequalities.

The use of the structural violence theory attempts to better understand the mechanisms by which social entities within a society become marginalized and the subsequent effects on the marginalized group (Klaus 2012). This theoretical framework may be used as a way of conceptualizing inequalities and their effects on health as embodied by the individuals (Baustian and Anderson 2016; Farmer 2003). Approaches for studying inequalities and structural violence can be difficult, as they often require an understanding of the interrelatedness of biological, cultural, and social processes, and the environment in which past populations live. Contemporary societies experience many forms of structural violence, and it is often through the study of modern societies that bioarchaeologists can understand that these include psychological, cognitive, and health-related consequences to the individuals (Martin and Harrod 2015).

Applications of social theory in bioarchaeology investigating structural violence and inequality continues to produce vital knowledge for understanding social complexities of the past. For example, Goodman's (1998) work using this theoretical framework was able to investigate social status and health among burials spanning from Late Woodland (ca. A.D. 900-1000) to Middle Mississippian (ca. A.D. 1150-1300) at Dickson Mounds, Illinois. He used skeletal indicators of stress and mortuary analysis of grave goods to look at differences in social status and health among individuals to analyze differences in social stratification through time. Differences of health and treatment in death among individuals suggests increases in social stratification and increases in inequality among the population through time. Additionally, Klaus's (2012) work in Peru with late pre-Hispanic Lambayeque Valley and the colonial-era Muchik from Mórrope looked to investigate structural violence based on ethnohistoric documentation that reported a socioeconomic decline following colonization of Lambayeque Valley. He analyzed the human skeletal remains from both series creating a biological profile of health, diet, disease, physical activity and trauma. This would allow him to assess if the archaeological record reflected the changes in socioeconomic stress associated with the reported changes in the ethnohistoric documentation. His results found evidence to suggest that the population of Muchik at Mórrope did experience structural violence as a result of Hispanic contact and subsequent colonization.

CHAPTER THREE: REGION AND CHRONOLOGY

Ancient Magan

The ancient land of Magan has been documented on Mesopotamian clay tablets written during the late third millennium BC. The Magan region is now known to have encompassed the southeastern reaches of the Arabian Peninsula. Today this includes the area of southwest Asia found in the modern countries of the United Arab Emirates and Oman (Potts 2000b). Mesopotamian clay tablets also documented trades with Magan consisting of textiles, hides, oils, and fish in exchange for copper, ivory, semi-precious stones, and ochre. Other artifacts include ivory from Bactria and/or the Indus Valley, tin from Afghanistan, and pottery from Iran and Mesopotamia (Potts 2000a). Magan is located near the regions of Mesopotamia, Dilmun, and Bactria as seen in Figure 3.1. Metallurgy has been documented at a handful of Umm an-Nar sites. While copper is plentiful in the Oman peninsula other metals such as tin are not and this is important since tin is required to make bronze. The presence of copper and bronze objects at these sites further suggests the extent of the trade network with Magan and the surrounding cultures (Potts 2000b; Weeks 1997).

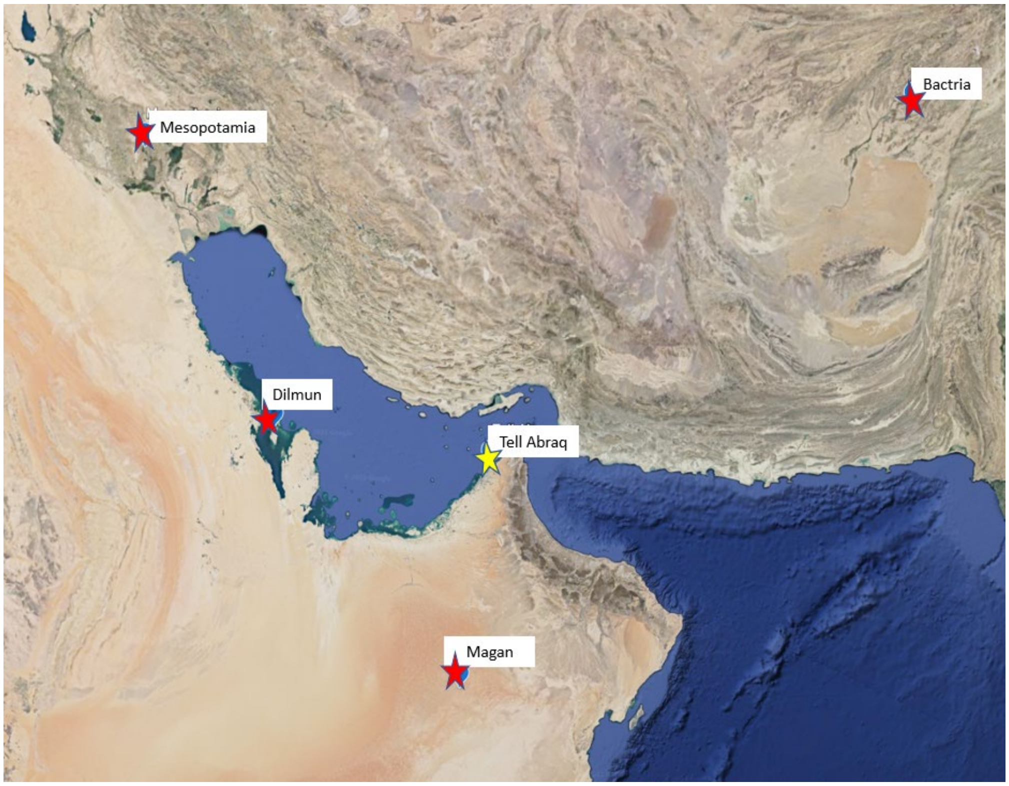


Figure 3.1 Satellite map of southwest Asia and the Arabian Peninsula. Red stars indicate the regions of Magan, Dilmun, Mesopotamia, and Bactria. A yellow star indicates where Tell Abraq is located (Google Earth).

Umm an-Nar Period

The Umm an-Nar period dates to approximately ~2700-2000 BCE during the Bronze Age (3100-1300 BCE). This period is marked by the transition from semi-nomadic herding to a more sedentary farming society with increased socioeconomic complexity and interregional exchange (Gregoricka 2013). Umm an-Nar period settlements consisted of fortification towers as large as 40 meters in diameter that acted as both protection and controlled access to freshwater sources. These freshwater sources would support increasing agriculture, including crops such as date palms and provide the inhabitants of these settlements the ability to remain sedentary for longer periods of time if not year round (Potts 1997, 2000a; Gregoricka 2014). Tombs from this period are a communal multi-chambered, circular style and range in size from as small as 4 meters to as large as 14 meters in diameter situated near the fortifications (Osterholtz et al. 2014; Gregoricka 2014).

Previous Research at the Tell Abraq Settlement

The site of Tell Abraq, United Arab Emirates (UAE) is located near the Arabian Gulf coast (see Figure 3.2) and includes a stratified mound of multiple occupations from the Bronze Age to the Iron Age (approximately 2200BC-400 BC) containing a fortification tower and a nearby tomb (Potts 1989, 2000a, 2000b). The size of Tell Abraq's fortifications in comparison to other Umm an-Nar sites and its coastal locality suggests that Tell Abraq may have been a major settlement that attracted visitors and traders from nearby villages and neighboring states. The Tell Abraq excavation originally began in 1989 led by D. T. Potts and an international team from the University of Copenhagen (Potts 1989). From there, further excavations continued at the site for several seasons (1989-1998) through the University of Sydney (Osterholtz et al. 2014; Potts 2000a, 2000b). The tomb itself is a circular, above-ground structure made up of limestone ashlar blocks and beach stone spanning 6 meters in diameter and divided into two chambers by a central stone wall (see Figure 3.3). This type of tomb is consistent with the Umm an-Nar style that was prominent during the later portion of the third millennium BC (Potts 1997, 2000a). Most importantly, besides some disturbance in the northeast section of the tomb, it remained intact and had not appeared to have been looted prior to its discovery (Potts 2000a).

Figure 3.2 Satellite map of the coastal site of Tell Abraq located in the United Arab Emirates (UAE) (Google Earth).

Figure 3.3 Umm an-Nar style tomb at Tell Abraq after excavation. Photo adopted from Baustian (2010, pg. 3).

The Tell Abraq Tomb Assemblage

Upon discovery, further investigations of the tomb were conducted and during this investigation, researchers discovered an undisturbed, commingled assemblage of human skeletal remains dating from approximately 2100-2000 BCE. This suggests continuous use of the tomb for 100 years or more by the local population (Osterholtz et al. 2014; Potts 2000a, 2000b). Figure 3.4 shows the human skeletal assemblage in its commingled state. Due to the commingled nature of the remains and the complex mortuary process that took place at the tomb, baseline data for this assemblage was collected using several analytical techniques that are appropriate for commingled samples (see Baustian 2010; Osterholtz et al. 2014). Research conducted by Osterholtz and colleagues (2014) estimated the minimum number of individuals (MNI) of the assemblage to be 276 adult individuals. This MNI estimate was based on the right talus, which is the most represented element in the sample (Osterholtz et al. 2014). Recent data suggest asymmetry in the adult sex ratio within the tomb with more males than females, not including elements for which sex could not be assigned (Martin et al. 2019). Baustian (2010) completed a preliminary MNI of subadults and has an estimated 134 individuals represented at Tell Abraq using the proximal right femora. After the more recent completion of fine sorting of the subadult remains conducted by researchers at Skidmore College, provided an updated estimate of a minimum of 410 individuals present in the tomb (Barrett et al. 2021). The results of the MNI and paleodemographic studies of this assemblage suggest that both sexes and all age ranges are represented, suggesting this tomb was likely a community cemetery consistent with other Umm an-Nar sites (Potts 1997; Osterholtz et al. 2014; Baustian 2010; Baustian and Anderson 2016).

Population Studies

Geographic Origin

Research regarding the geographic origin of the individuals buried in the tomb has also been conducted. For example, strontium isotope analysis from dentition was examined by Gregoricka (2013) who found the majority of individuals tested from the assemblage lived within the geographical area around the tomb and had lived there since dental development. However, two individuals present in this sample were not local to the geographical area surrounding Tell Abraq suggesting the accepted addition of non-locals into the community structure (Gregoricka 2013).

Archaeological evidence from grave goods provides additional information regarding geographic origin (Potts 2000a). Grave goods found within the tomb include ceramics of local origin, stone, jewelry, ivory combs, and bronze objects (Osterholtz et al. 2014). Nonlocal grave goods within the tomb may suggest an importance of fishing and trading as crucial socioeconomic activities for the settlement community and provides evidence for the extent of the interregional exchange network documented for the Magan region. The range of grave goods varies in a manner suggesting individuals within the tomb represent all social and economic groups (Osterholtz et al. 2014; Potts 2000a, 2000b).

Current Interpretations

Recent research examining the subadult sample from Tell Abraq tells has provided information about health in this Bronze Age settlement. Preliminary demographic data from Baustian and Martin (2010) showed high rates of infant morbidity and mortality within the Tell Abraq sample. High frequencies of premature (28%, n=28) and newborn (9%, n=12) infants were present within the tomb. Upon further investigation, Baustian (2010) conducted a study of the subadult population focusing on health. She used a biocultural framework and paleopathological methods to better understand the patterns of disease and assess the possible contributing factors that led to the increased risk for morbidity and mortality of these children. Her findings suggest that disease, illness, and other factors such as consanguineous unions, early age of marriage, and first pregnancy could account for these high rates (Baustian 2010).

In addition to these data, Baustian and Anderson (2016) found an anomaly on the second cervical vertebra (C2), nonunion or agenesis of the dens. This was found on 7 of 175 (4%) vertebrae that were preserved well enough for analysis. Modern medical and bioarchaeological literature indicates that this type of skeletal anomaly is rare, even in modern populations, and is likely a developmental disorder with genetic origins (Bajaj et al. 2010; Barnes 2012; Zhang et al. 2010). The high frequency of this rare congenital skeletal anomaly within the assemblage suggests population homogeneity (Baustian and Anderson 2016). And when combined with Baustian's (2010) findings and her interpretations of consanguineous practices this now provides multiple lines of evidence for consanguinity.

As part of the interpretations of the skeletal data suggesting consanguinity, Baustian (2010) and Baustian and Anderson (2016) have suggested a system of gendered inequality may have been present at Tell Abraq. For example, Baustian (2010) linked the high prevalence of infant morbidity and mortality to consanguineous unions, early age of marriage, and pregnancy. Baustian and Anderson (2016) argue that the high prevalence of agenesis or nonunion of the dens provides evidence for consanguineous marriage practices, which have a long history in the region.

In addition to the skeletal evidence, the discovery of two pendants within the tomb potentially depicting the demon-goddess Lamashtu provides further evidence of gendered inequality linked to the ideology at Tell Abraq. As seen in Mesopotamian culture, these pendants represent items that would be used for protection against Lamashtu's powers. More specifically those associated with illness and death in unborn and newborn children (Potts et al. 2013).

With the political-economic structure and the possibility of consanguineous marriage patterns linked to the stability of male wealth and land tenure (Baustian and Anderson 2016), this creates an atmosphere of gendered inequality and is a form of structural violence. Lamashtu's influences are used as a means to explain why disease and death affected the children of Tell Abraq so greatly. This could assign blame to the mothers and children as not having the ability to resist Lamashtu's corruptive influences. This lends further empowerment to males that could suggest a patriarchal society with gendered systems of inequality that may be considered a form of structural violence.

This research attempts to test a portion of this interpretation by examining biological homogeneity and marriage practices through the examination of NMTs. The goal of this study is to continue investigating these lines of skeletal evidence as well as contribute to ongoing discussions of potential gendered inequality as a form of structural violence at Tell Abraq.

Figure 3.4 The commingled human skeletal remains from the Tell Abraq tomb before excavation. Photo adopted from Potts (2000a, pg. 91).

Research Questions

This study's theoretical framework is built upon Baustian's (2010) work and seeks to further investigate the hypothesis about the potential for consanguineous marriage practices at Tell Abraq. Given the commingled and heavily fragmented nature of the assemblage and the findings of the previous studies, an assessment of the population's biological variation was conducted by utilizing heritable nonmetric traits of the skeleton. Specifically, the research questions addressed are:

1. What traits and frequencies of these traits may provide insight into biological homogeneity?
2. Is the sample within the tomb biologically homogeneous or heterogeneous?
3. Are the patterns of variation potentially influenced by cultural practices?

Based on these questions and the interpretations previously put forth, if the hypothesis about consanguineous marriage is correct then one would expect to see a more biologically homogeneous sample. More specifically, in a biologically homogeneous sample high frequencies of heritable traits that would be considered rare or absent in other populations or inversely traits common among other populations that are rare or absent in this population might be expected. If this hypothesis is not correct then one would expect to see a more heterogeneous sample, or frequencies that fall within similar ranges to other populations. However, considerations for genetic drift, community endogamy and polygamy, and consanguinity occurring simultaneously cannot be ignored as contributing factors (Bittles 2012; Martin et al. 2013). As well as all of the other cultural and environmental factors laid out by Baustian's biocultural model.

CHAPTER FOUR: MATERIALS AND METHODS

The goal of this study is to provide data for investigating the presence and frequency of heritable cranial and postcranial NMTs, in order to assess population variation and biological relatedness within the Bronze Age tomb assemblage of Tell Abraq. This skeletal collection provides a unique opportunity to apply the examination of heritable NMTs for assessing population variation given the heavily fragmented and commingled nature of this skeletal assemblage. These data were then combined with the previous archaeological and skeletal studies to better understand the potential influential effects of cultural practices, such as consanguineous unions, on the variation present within this sample.

Materials

The Tell Abraq excavation originally began in 1989 by D. T. Potts and the University of Copenhagen (Potts 1989). Further excavations continued at the site for several seasons through the University of Sydney (Osterholtz et al. 2014; Potts 2000a, 2000b). The collection is now curated by the Department of Anthropology at the University of Nevada Las Vegas. The skeletal remains have since been finely sorted by element, age, and side categories due to their heavily fragmented and commingled state (Osterholtz et al. 2014). Previous analysis of this collection has estimated a minimum number of individuals (MNI) to be 410, including adult (n=276, 67%) and subadult (n=134, 33%) remains (Barrett et al. 2021).

For this thesis, only the adult remains (18 years or older) were analyzed. The number of specimens available to assess varied by element, the lowest was the frontal bone (14) and the highest was the patella (157). Juvenile remains were excluded from this study due to the lack of trait maturity and available literature. Adults of both sexes were examined and sexes pooled since the remains are commingled and some studies have shown the nonmetric traits chosen for this study do not correlate to a specific sex or age (Veldman 2013). Only elements with adequate preservation and presence of the feature areas were analyzed. To avoid sample bias and possible duplication of individuals only the left side was assessed for paired NMTs in this study.

Methods

Biological relatedness was examined by means of cranial and postcranial skeletal elements using NMTs. The 16 NMTs employed by this study are from Berry and Berry (1967), Finnegan (1978), Hauser and De Stefano (1989), Buikstra and Ubelaker (1994), Mann, Hunt, and Lozanoff (2016) and chosen specifically for their reported heritability (Veldman 2013, Burrell 2018). NMTs that have been reported in the literature as genetically inherited include the acetabular crease, bipartite zygomatic, lateral bridging, mandibular torus, metopism, mylohyoid bridge, parietal foramen, posterior bridging, sternal foramen, supraorbital foramen, supraorbital notch, vastus notch, and zygomaticofacial foramen. The specific cause of variation in the remaining NMTs, retrotransverse foramen, frontal foramen, and mental foramen seems to be less clear and researchers in the literature are divided as to whether they are heritable or not.

Cranial elements can possess numerous NMTs in a given area, while some postcranial elements may possess only one. The commingled nature and level of preservation of this collection meant the use of both cranial and postcranial elements would better encompass the available material. The cranial NMT definitions in this study are derived from Berry and Berry (1967), Hauser and De Stefano (1989), and from Buikstra and Ubelaker (1994) unless otherwise indicated. The postcranial NMT definitions have been derived from Finnegan (1978) and Buikstra and Ubelaker (1994). Traits were scored as absent (A), present (P), unobservable (U), and other (O). The scoring systems for some traits were adjusted to be more simplified from those used in the literature for the purposes of this study. Varying degrees of expression were noted when relevant and kept for further consideration. See Table 4.1 for a complete list of the nonmetric traits analyzed, scoring methods, and reference materials. Figures 4.1 and 4.2 illustrate the locations of the cranial NMTs examined. And Figures 4.3 and 4.4 illustrate the postcranial NMTs examined. The NMTs, their definitions, and scoring system for this study are as follows:

Cranial Nonmetric Traits

Bipartite Zygomatic (*os zygomaticum bipartitum/os japonicum*)

The zygomatic is divided into two or more parts by the presence of a supernumerary suture. The most common variation of this being the division of the zygomatic by a horizontal suture into upper and lower portions. Scored as present (P), absent (A), or unobservable (U). If present, additional variation is noted when necessary.

Frontal Foramen (*foramen frontale*)

The frontal foramen is a well-defined foramen located along the lateral portion of the supraorbital margin in addition to a supraorbital foramen or notch. It may present as a single foramen, multiple small foramina, or be absent altogether. Scored as present (P), absent (A), or unobservable (U).

Mandibular torus (*torus mandibularis*)

The mandibular torus presents in varying degrees and sizes as a bony protuberance or set of nodules on the lingual aspect of the mandible and it is commonly positioned between the canine and molar area. This is scored as present (P), absent (A), or unobservable (U). If present, additional variation was noted.

Mental Foramen (*foramen mandibulae*)

The mental foramen can be found on the lateral surface of the body (or corpus) of the mandible, inferior to the premolar region. It commonly presents as one large foramen but has been known to present as two small foramina, one large and one small, or a small cluster of foramina. In very rare cases the mental foramen may be absent unilaterally. Scored as present (P), absent (A), unobservable (U), and the number of foramina.

Metopic Suture (*sutura frontalis*)

The metopic suture is located along the midline of the frontal bone separating it into two halves, left and right. This suture usually closes by the second year but may persist to adulthood known as persistent metopic suture or metopism. It can present as trace, partial, or complete. Scored as present (P) when visible in any degree, absent (A), or unobservable (U).

Mylohyoid Bridging (*ponticulus mylohyoideus*)

Mylohyoid bridging is located along the mylohyoid groove on the medial aspect of the mandible. It may cover the mylohyoid groove partially or completely with a bony bridge. Variations in this bridging include bridging near the mandibular foramen (superior), across the center (medial), or near the end of the groove (inferior). Other variations include complete/partial bridging along the full length of the mylohyoid groove creating a canal or in two sections with a gap in between. Scored as present (P) when visible in any degree, absent (A), or unobservable (U). Additional variation noted when necessary.

Parietal Foramen (*foramen parietale)*

The parietal foramen is located lateral to the sagittal suture and superior to the lambdoid suture. The foramen should pierce through the entire parietal to be considered present. It can present as a single or double foramen of varying expression unilaterally or bilaterally. Scored as present (P), absent (A), or unobservable (U).

Supraorbital Foramen (*foramen supraorbitale*)

The supraorbital foramen is located along the superior medial aspect of the supraorbital margin and needs to have openings on both orbital and external surfaces to be considered present. It may present as complete or incomplete when partially occluded by spicules. Scored as present (P) when complete/incomplete, absent (A), or unobservable (U).

Supraorbital Notch (*incisura supraorbitalis*)

The supraorbital notch is located along the superior medial aspect of the supraorbital margin. It is characterized by an open smooth border and should not be occluded by spicules by more than half. Scored as present (P), absent (A), or unobservable (U).

Zygomaticofacial Foramen (*foramen zygomaticofaciale*)

The zygomaticofacial foramen is located on the convex lateral border of the zygomatic and inferior to the orbital margin and frontal process. This commonly presents as singular or multiple foramina. Scored as present (P), absent (A), unobservable (U), and the number of foramen present.

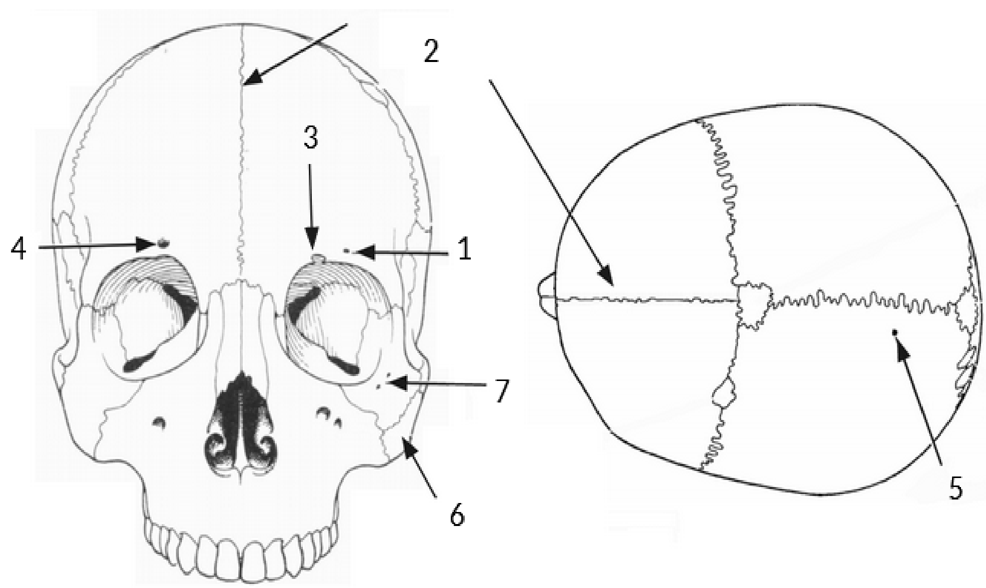


Figure 4.1 Cranial nonmetric traits. 1) Frontal foramen, 2) Metopic suture, 3) Supraorbital notch, 4) Supraorbital foramen, 5) Parietal foramen, 6) Bipartite zygomatic, 7) Zygomaticofacial foramen. Adopted and modified from Berry & Berry (1967, 365-367).

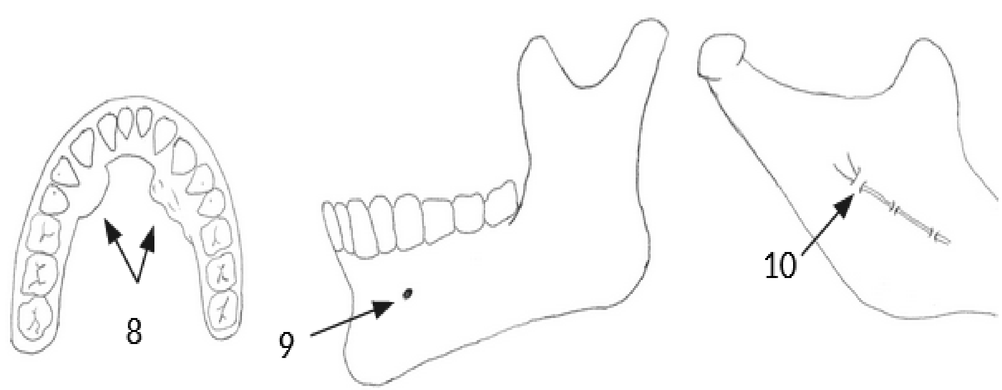


Figure 4.2 Cranial nonmetric traits of the mandible. 8) Mandibular torus, 9) Mental foramen, 10) Mylohyoid bridge.

Postcranial Nonmetric Traits

Acetabular Crease (*rimula acetabula*)

The acetabular crease is located on the articular surface (lunate surface) of the acetabulum of the os coxae. It can present as a crease, fold, pit, or pleat, occurring along a line from the superior aspect of the acetabular fossa to the border of the articular surface. Scored as present (P) in any degree, absent (A), or unobservable (U).

Lateral Bridging (*ponticulus lateralis*)

Lateral bridging of the first cervical vertebrae or atlas is the presence of bony spicules that join the lateral border of the superior articular facet with the lateral process. Variation of this trait includes trace, partial, or complete bridging. Scored as present (P) in any degree, absent (A), or unobservable (U).

Posterior Bridging (*ponticulus posticus*)

Posterior bridging of the first cervical vertebrae or atlas is the presence of bony spicules that join the posterior border of the superior articular facet with the posterior arch. Variation of this trait includes trace, partial, or complete bridging. Scored as present (P) in any degree, absent (A), or unobservable (U).

Retrotransverse Foramen

The retrotransverse foramen is located posteriorly to the posterior root of the transverse process where it meets the posterior arch of the atlas. This can vary from a defined groove, incomplete foramen with spicules, and a complete foramen as well as varying in sizes. Scored as present (P) in any degree, absent (A), or unobservable (U). If present, additional variation is noted when necessary. (Agrawal et al. 2012; Sanchis-Gimeno et al. 2018; Travan et al. 2015; Le Minor 1997).

<u>Sternal Foramen (*foramen sternale*)</u>

A sternal foramen is present on the corpus sterni or body of the sternum. Variation of the foramen ranges from a pinhole size to a large perforation, round or oval, and must fully penetrate the sternum. Scored as present (P), absent (A), or unobservable (U).

<u>Vastus Notch (*incisura vastus*)</u>

The vastus notch is a concavity on the superolateral aspect of the patella. It is characterized as having smooth borders with a possible sharp point on the most lateral edge and can range in size. Not to be confused with a bipartite patella that has a rough border with one or more separate bone segments, or possible trauma and pathology. Scored as present (P), absent (A), or unobservable (U).

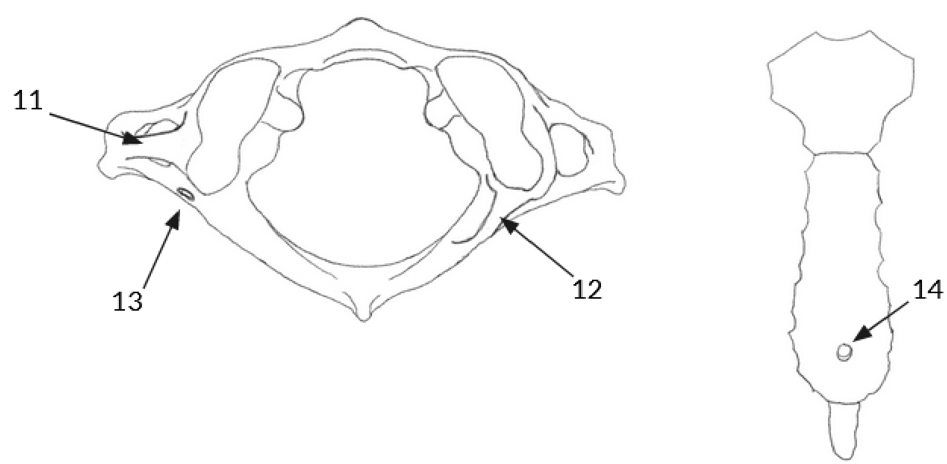


Figure 4.3 Postcranial nonmetric traits. 11) Lateral bridging, 12) Posterior bridging, 13) Retrotransverse foramen, 14) Sternal foramen.

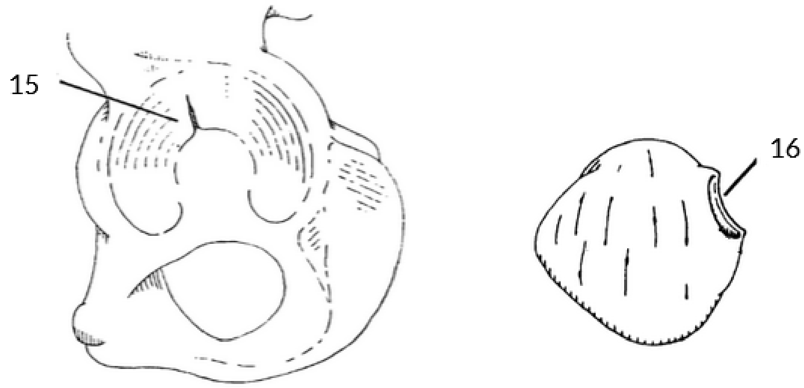


Figure 4.4 Postcranial nonmetric traits. 15) Acetabular crease and 16) Vastus notch. Adopted and modified from Finnegan (1978, 29).

All data were recorded using modified standard recording from *The Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker 1994). This study maintained all lab-assigned accession numbers present on the remains to promote data accessibility and integration into the current research database. Once data collection and analysis were completed it was then compared to the current body of research that has been published for the site of Tell Abraq. The frequency for each trait was calculated and prevalence was compared to other studies when applicable. The comparison was limited based on the inability to sex and age each specimen, the commingled and fragmentary nature of the assemblage, and the lack of comparative samples for this period and region.

The methods represented in this research are the currently available techniques used for assessing NMTs concerning biological relatedness. Another method of NMT analysis implemented to study relatedness and biodistance is dental NMTs but those were excluded for this current study due to lack of training in these methods and time restrictions.

Table 4.1 A complete list of the nonmetric traits analyzed, scoring methods, and references

Element	Nonmetric Trait	Scoring System	Additional Info	References
Cranial NMTs				
Frontal	Supraorbital Foramen	(P), (A), (U)	Singular/Multiple	Berry & Berry (1967), Hauser and De Stefano (1989), Buikstra and Ubelaker (1994)
	Supraorbital Notch	(P), (A), (U)	Singular/Multiple	Berry & Berry (1967), Hauser and De Stefano (1989), Buikstra and Ubelaker (1994)
	Frontal Foramen	(P), (A), (U)	Singular/Multiple	Berry & Berry (1967), Hauser and De Stefano (1989), Buikstra and Ubelaker (1994)
	Metopic Suture	(P), (A), (U)	Trace/Partial/Full	Berry & Berry (1967), Hauser and De Stefano (1989), Buikstra and Ubelaker (1994)
Parietal	Parietal Foramen	(P), (A), (U)	Singular/Multiple	Berry & Berry (1967), Hauser and De Stefano (1989), Buikstra and Ubelaker (1994)
Zygomatic	Zygomatico-facial Foramen	(P), (A), (U)	Singular/Multiple	Berry & Berry (1967), Hauser and De Stefano (1989), Buikstra and Ubelaker (1994)
	Bipartite Zygomatic	(P), (A), (U)	Location	Hauser and De Stefano (1989), Buikstra and Ubelaker (1994
Mandible	Mental Foramen	(P), (A), (U)	Singular/Multiple	Hauser and De Stefano (1989), Buikstra and Ubelaker (1994)

	Mandibular Torus	(P), (A), (U)	Location/Degree of Expression	Hauser and De Stefano (1989), Buikstra and Ubelaker (1994)
	Mylohyoid Bridging	(P), (A), (U)	Location/Degree of Expression	Hauser and De Stefano (1989), Buikstra and Ubelaker (1994)
Postcranial NMTs				
C1 Atlas	Posterior Bridging	(P), (A), (U)	Unilateral/Bilateral, Partial/Full	Finnegan (1978), Hauser and De Stefano (1989), Buikstra and Ubelaker (1994)
	Lateral Bridging	(P), (A), (U)	Unilateral/Bilateral, Partial/Full	Finnegan (1978), Hauser and De Stefano (1989), Buikstra and Ubelaker (1994)
	Retrotransverse Foramina	(P), (A), (U)	Singular/Multiple	Le Minor (1997), Agrawal et al. (2012), Travan et al. (2015), Sanchis-Gimeno et al. (2018)
Sternum	Sternal Foramen	(P), (A), (U)	Location/Degree of Expression	Buikstra and Ubelaker (1994)
Patella	Vastus Notch	(P), (A), (U), (O)	Other: Segmented/ Degree of Expression	Finnegan (1978)
Os Coxa	Acetabular Crease	(P), (A), (U)	Fold/Pleat/Crease/Pit	Finnegan (1978)

CHAPTER FIVE: RESULTS

The following results are the frequencies for the sixteen heritable nonmetric traits that were examined. Each element, trait, and the associated figures are detailed below. Table 5.1 illustrates the frequencies for each trait by element for the cranial remains and Table 5.2 shows the frequencies for each trait by element for the postcranial remains. The frequencies of Tell Abraq's NMTs in comparison to other NMT studies are shown in Figures 5.1 and 5.2. The comparison for these studies is detailed further in the discussion.

Table 5.1 Frequencies for each trait ordered by element for cranial nonmetric traits.

Cranial			Frequency (%)	
		N	Present	Absent
Frontal	Frontal Foramen	14	3 (21.43%)	11 (78.57%)
	Metopic Suture	19	0 (0%)	19 (100%)
	Supraorbital Foramen	48	15 (31.25%)	33 (68.75%)
	Supraorbital Notch	47	36 (76.6%)	11 (23.4%)
Parietal	Parietal Foramen	20	11 (55%)	9 (45%)
Zygomatic	Bipartite Zygomatic	40	0 (0%)	40 (100%)
	Zygomaticofacial Foramen	49	41 (83.57%)	8 (16.33%)
Mandible	Mylohyoid Bridging	32	6 (18.75%)	26 (81.25%)
	Mental Foramen	49	49 (100%)	0 (0%)
	Mandibular Torus	27	0 (0%)	27 (100%)

Table 5.2 Frequencies for each trait ordered by element for postcranial nonmetric traits.

Postcranial			Frequency (%)	
		N	Present	Absent
C1 Atlas	Posterior Bridging (Complete)	82	10 (12.2%)	61 (74.39%)
	Lateral Bridging (Complete)	82	2 (2.44%)	80 (97.56%)
	Retrotransverse Foramen	84	7 (8.33%)	77 (91.67%)
Sternum	Sternal Foramen	69	0 (0%)	69 (100%)
Os Coxa	Acetabular Crease	35	6 (17.14%)	29 (82.86%)
Patella	Vastus Notch	150	51 (34%)	99 (66%)
	Bi/Tripartite	157	7 (4.46%)	150 (95.54%)

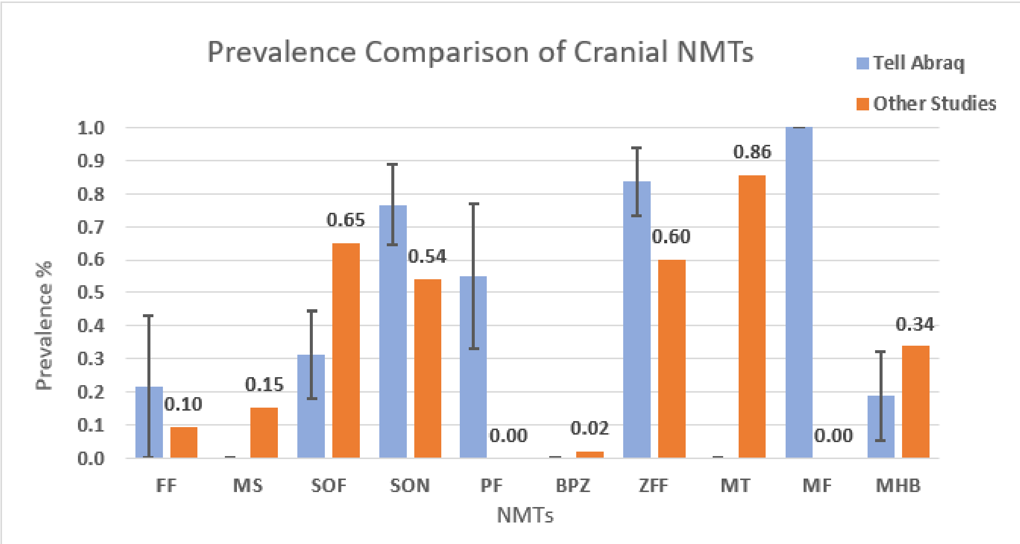


Figure 5.1 Prevalence rate comparison between Tell Abraq and other studies for cranial NMTs. Tell Abraq includes 95% confidence intervals for each trait.

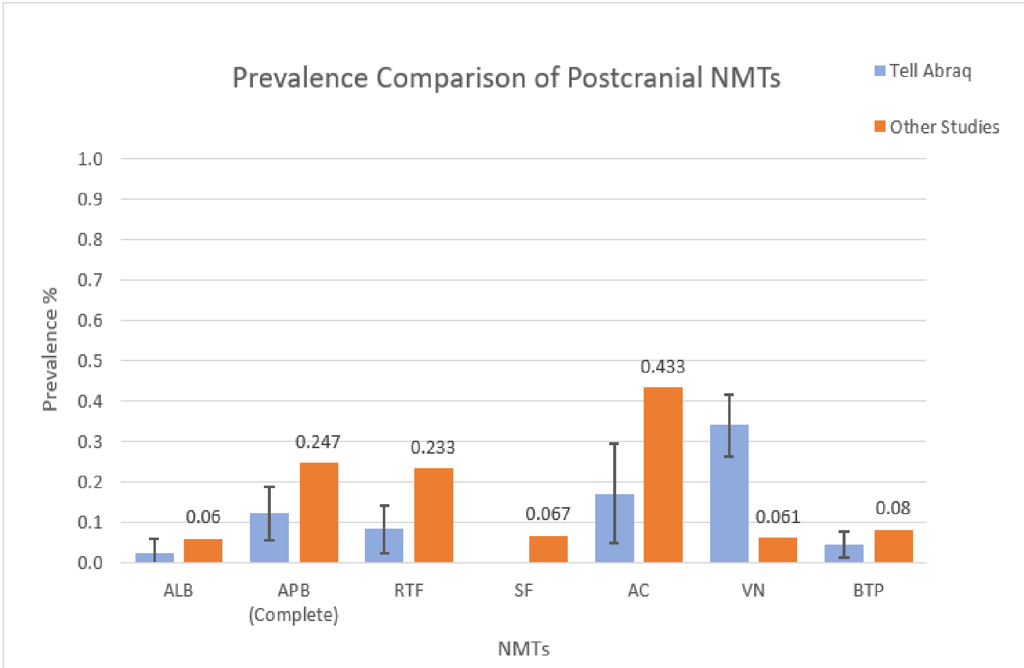


Figure 5.2 Prevalence rate comparison between Tell Abraq and other studies for postcranial NMTs. Tell Abraq includes 95% confidence intervals for each trait.

Frontal

Of forty-eight individuals that were preserved well enough to assess, 15 (31.25%) presented a supraorbital foramen while 33 (68.75%) did not. Thirty-six (76.6%) of 47 individuals had a supraorbital notch while 11 (23.4%) did not. And six (12.50%) of those 48 individuals presented both a supraorbital notch and foramen. Figure 5.3 shows both a supraorbital foramen (white arrow) and notch (grey arrow) on the left side and a foramen on the right side. Figure 5.4 shows an example of a fragmented left orbit that has a large supraorbital notch (white arrow). Nineteen (100%) of the frontals with the feature area present for metopic suture were absent of the trait. A frontal foramen was seen in 3 (21.43%) of 14 individuals while 11 (78.57%) did not display this feature. Figure 5.5 shows a small single frontal foramen (grey arrow) lateral to a supraorbital foramen (white arrow).

Figure 5.3 Frontal, anterior view of both a supraorbital notch (grey arrow) and foramen (white arrow) on the left side with a supraorbital foramen on the right. Lacking the presence of a metopic suture.

Figure 5.4 Frontal, anterior and posteroinferior views of left orbit expressing a large supraorbital notch (white arrow).

Figure 5.5 Frontal, anterior view of a supraorbital foramen (white arrow) and frontal foramen (grey arrow) on the left side.

Parietal

In the case of the parietal, 20 were preserved well enough to assess. Of those 20, 11 (55%) presented with a single parietal foramen while 9 (45%) did not display this trait. Element completeness ranged from whole parietals to fragments measuring as small as 3 cm in width, only identifiable by the sagittal sulcus, occipital angle, and trace presence of meningeal grooves. Figure 5.6 image A shows mostly complete left and right parietals with a singular parietal foramen on each side indicated by the black arrows. Image B shows a more fragmented example of left and right parietals with a single parietal foramen (white arrows) on each side.

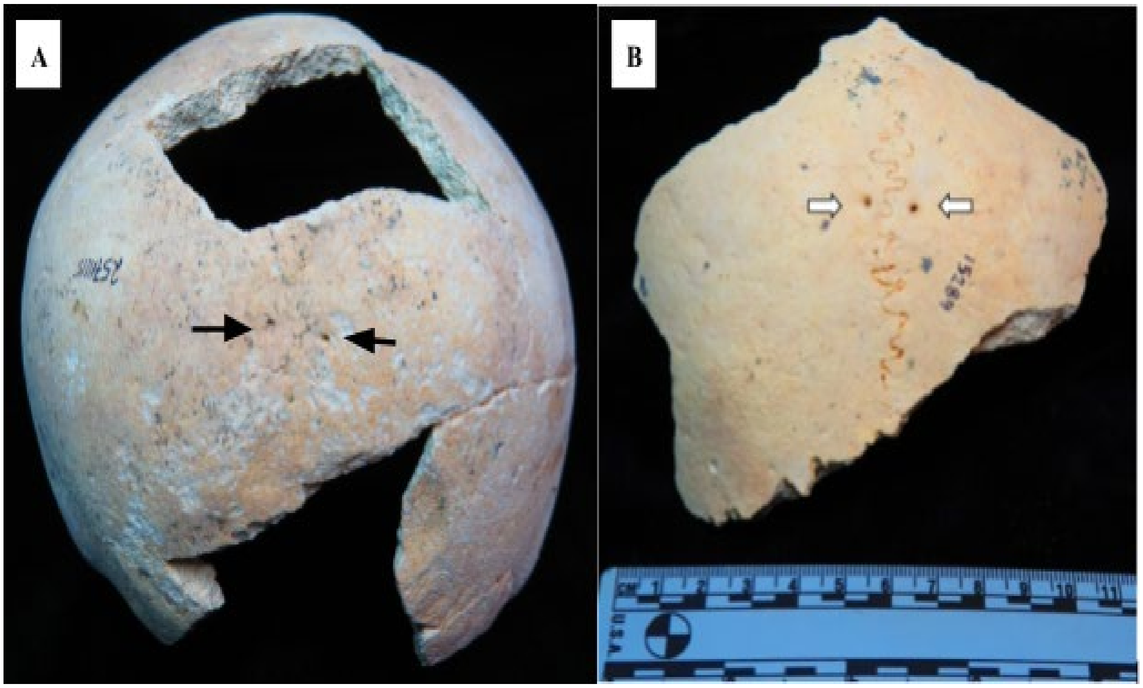


Figure 5.6 Parietal (A) posterosuperior view of the left and right parietals with a singular parietal foramen (black arrows) on each side. (B) posterosuperior view, singular parietal foramen (white arrows).

Zygomatic

Forty-one (83.57%) of the 49 zygomatics presented with a zygomaticofacial foramen and eight (16.33%) did not. Of those 41 zygomatics with a zygomaticofacial foramen present, 11 (26.83%) presented as a double foramen and 30 (73.17%) as a single foramen. Figure 5.7 image A shows a left zygomatic with an absent zygomaticofacial foramen and image B shows an example of a zygomatic with two zygomaticofacial foramina present. None of the zygomatics were bipartite.

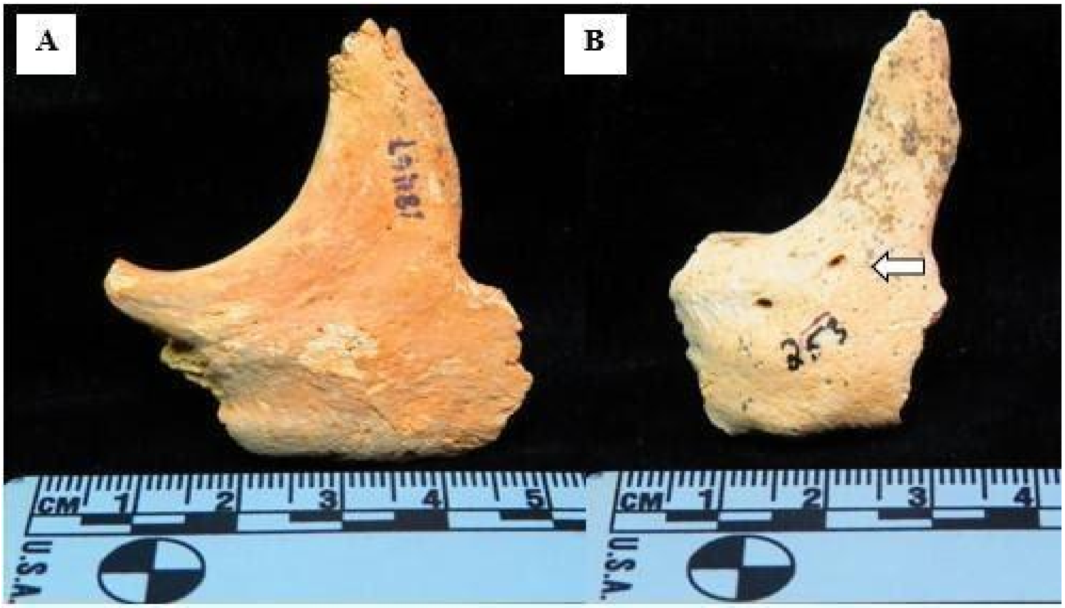


Figure 5.7 Zygomatic, anterior view of the left zygomatic. (A) No zygomatico-facial foramen present. (B) Two zygomaticofacial foramen present (white arrow).

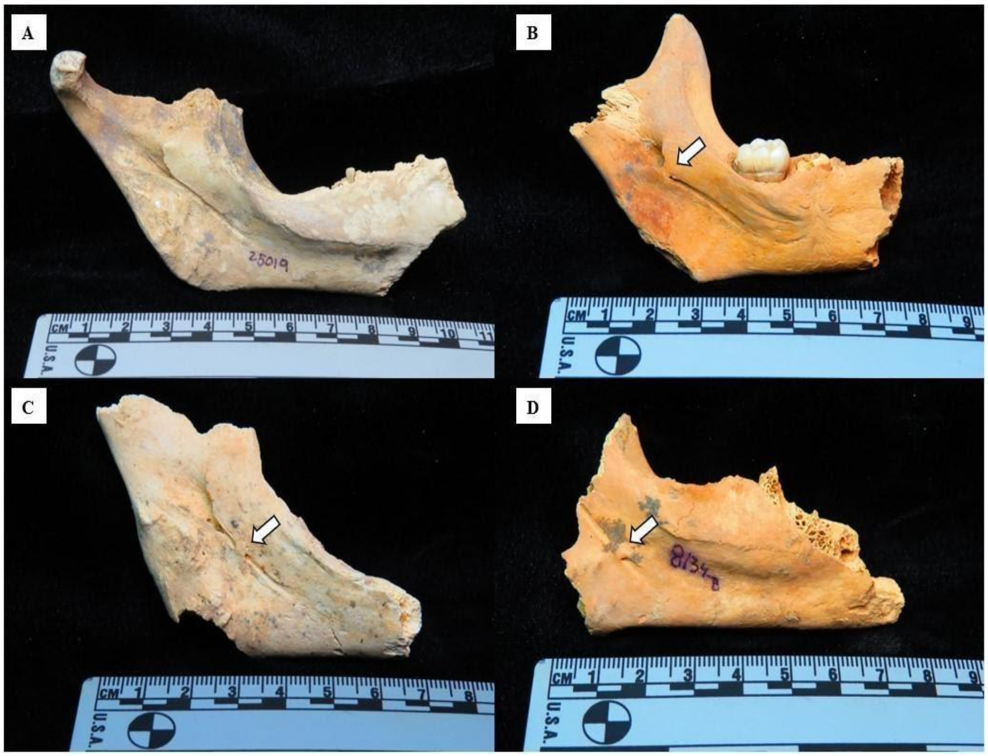
Mandible

Results from the mandible showed that mental foramina were present on 49 (100%), 48 (97.96%) presented as a single foramen of varying sizes, and 1 (2.04%) presented with a double foramen (one main mental foramen with a small single accessory foramen). Figure 5.8 shows a fragmentary mandible with one large mental foramen present. The mandibular torus was absent on the 27 (100%) mandibles that retained the feature area.

And lastly, a mylohyoid bridge was observed on 6 (18.75%) of 32 mandibles, 26 (81.25%) did not have this trait. The mylohyoid bridges present were expressed as a complete bridge over the mylohyoid groove but varied in the location from superior to inferior with none of the bridges spanning the full length of the groove. Three (9.37%) were superior, one (3.13%) was medial, and two (6.25%) were inferior. Figure 5.9 shows four mandibles from the medial view, image A is absent of a mylohyoid bridge. Images

B-D show bridges, as indicated by white arrows, located in the superior, medial, and inferior locations along the groove in their respective order.

Figure 5.8 Mandible, anterolateral view of a singular, large mental foramen.



Picture 5.9 Mandible, medial view. (A) Mylohyoid bridge absent. (B) Complete superior mylohyoid bridge (C) Complete medial bridge (D) Complete inferior bridge.

First Cervical Vertebra/Atlas

Eighty-four first cervical vertebrae were examined for posterior and lateral bridging and retrotransverse foramen. Of 82 individuals, 21 (25.6%) presented posterior bridging of varying degrees from partial to complete bridging. Ten (12.19%) had complete posterior bridging and the remaining 61 (74.39%) did not. Lateral bridging was present in 2 (2.44%) individuals, both complete bridges, and the remaining 80 (97.56%) did not display bridging. Figure 5.10 shows four mostly complete first cervical vertebra. Images B-D show examples of complete posterior bridging, partial posterior bridging, and complete lateral bridging. Figure 5.11 shows three vertebrae, two fragmentary and one complete. Images A and B show posterior and lateral views of a complete lateral bridge and trace partial posterior bridging of the left side. Image C is a fragmentary left side that shows a complete posterior bridge while image D shows a complete vertebra with bilateral complete posterior bridging.

Retrotransverse foramina were present in 7 (8.33%) of 84 individuals, and absent in the remaining 77 (91.67%). Of the 7 individuals that presented with retrotransverse foramen, 3 (3.57%) were accompanied by posterior bridging. Figure 5.10 image A shows a normal, mostly complete first cervical vertebra with two retrotransverse foramina on the left side indicated by the grey arrow. And in Figure 5.11 image C is a fragmentary vertebra with a single retrotransverse foramen (grey arrow) and complete posterior bridge (white arrow) while image D is a complete vertebra with a singular retrotransverse foramen (grey arrow) and bilateral complete posterior bridging (white arrow).

Figure 5.10 C1/Atlas, superior view with posterior down. (A) Atlas with unilateral double retrotransverse foramina. (B) Atlas with bilateral posterior bridging. (C) Atlas with unilateral partial bridging of the right side. (D) Atlas with complete lateral bridging of the left side.

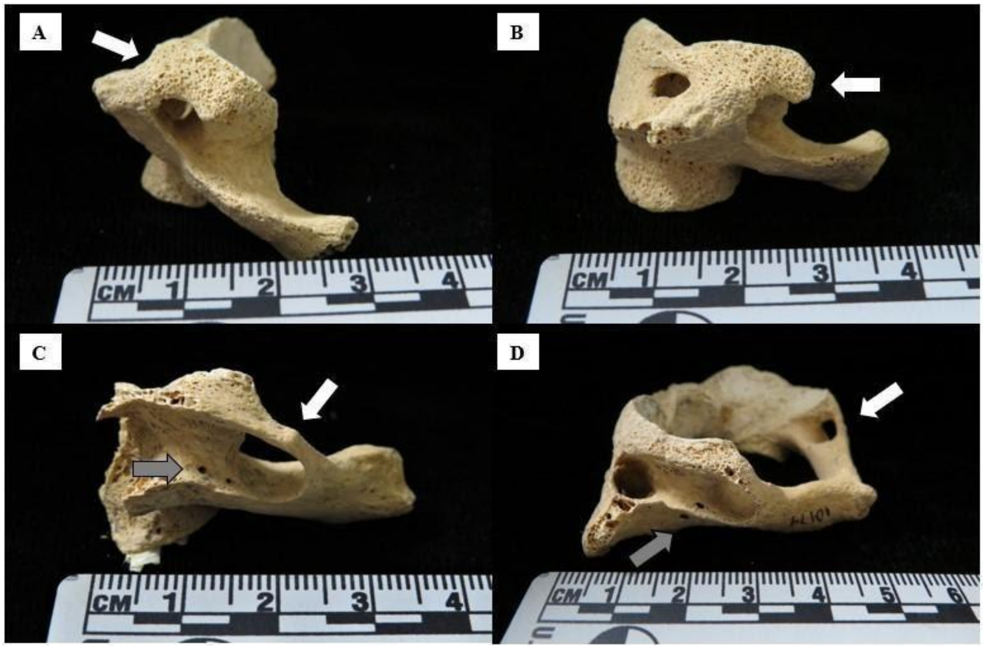


Figure 5.11 C1/Atlas (A) Posterior view, left side with complete lateral bridging (white arrow) present. (B) Lateral view, trace posterior bridging (white arrow). (C) Lateral view, complete posterior bridging (white arrow) and double retrotransverse foramina (grey arrow). (D) Posterolateral view, bilateral complete posterior bridging (white arrow) with singular retrotransverse foramen (grey arrow).

Sternum

Sixty-nine sterna were examined for the presence or absence of a sternal foramen. All 69 (100%) did not display a sternal foramen as shown in Figure 5.12. The sternum was the second most preserved element in the sample ranked according to completeness.

Figure 5.12 Corpus sterni, anterior view. Sternal foramen is absent.

Patella

The patellae in this assemblage predominately presented as normal, absent of a vastus notch (69/150, 66%). Fifty-one (34%) of the patellae did have a vastus notch present, this included the presence of a vastus notch in all degrees of expression from small to large. The vastus notch is identified by the smooth bordered notch along the superolateral margin. Figure 5.13 shows four images, A and B are the anterior and posterior views of a normal patella. Images C and D show a patella with a vastus notch.

During the examination, seven (4.46%) of 157 patellae presented with features that were not consistent with the characteristics of a vastus notch. Closer examination suggested that these abnormal features were also not trauma or pathology related. Six (3.82%) were identified as bipartite and one (0.64%) as tripartite. Also known as segmented patella, these are identified when one or more individual segments are present. This happens when one or more ossification centers develop, are held in place by fibrocartilage, and may or may not merge with the main body during growth and development (Barnes 2012). In this case, they had rough superolateral borders compared to the smooth border of the vastus notch as seen in Figure 5.14. Images A and B show the anterior and posterior views of what was identified as a bipartite patella and images C and D show a tripartite patella. The tripartite patella was identified by the slight W-shaped border that suggests two segments in addition to the main body. It should be noted that due to the commingled and fragmented nature of the assemblage the segments associated with these patellae could not be individually identified. The patella was the most well preserved element in the sample and had the largest sample size.

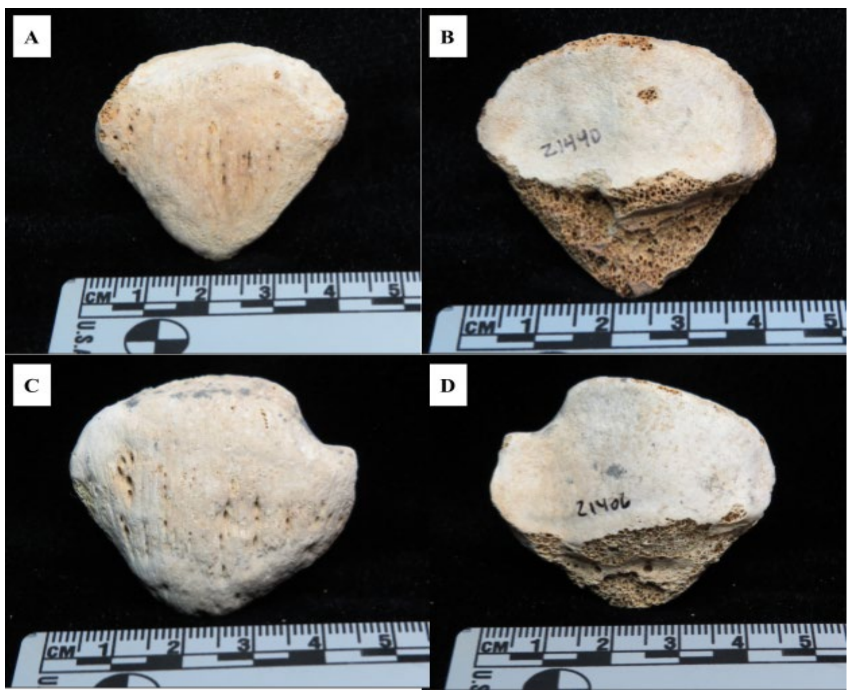


Figure 5.13 Patella. (A) anterior view of patella (B) posterior view. (C) anterior view of a patella with vastus notch present, note the smooth superolateral border (D) posterior view.

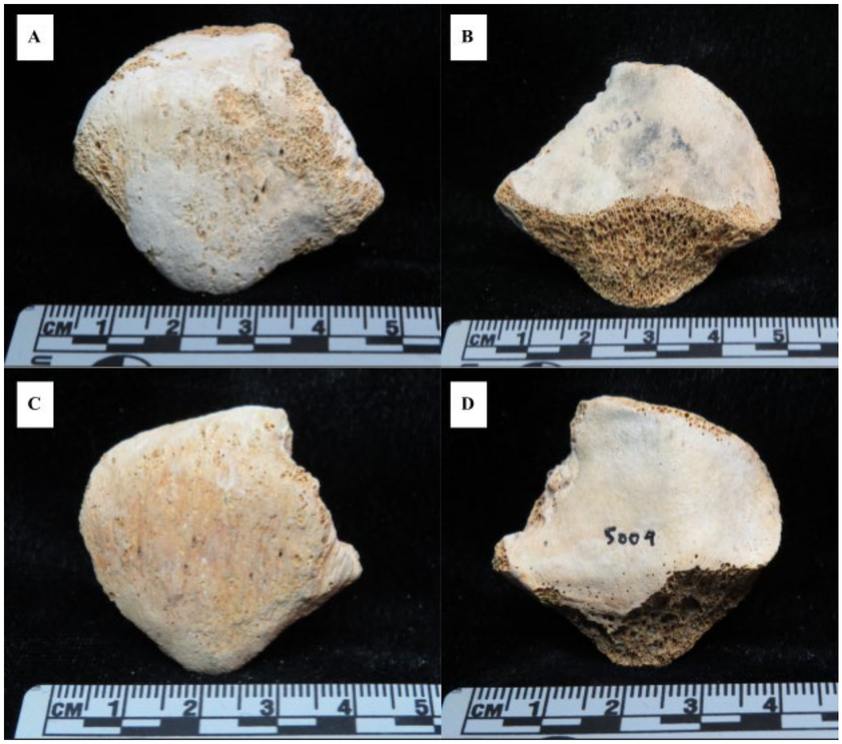


Figure 5.14 Emarginated patellae (A) anterior view of bipartite patella (B) posterior view. (C) anterior view of tripartite patella with a slight w-shape (D) posterior view. Note the rough superolateral borders.

Os Coxa

Thirty-five ossa coxae were examined for the presence or absence of an acetabular crease. Six (17.14%) displayed an acetabular crease as either a pit, crease, or fold while 29 (82.86%) did not. Figure 5.15 image A shows a left os coxa with an acetabular crease presented as a fold (black arrow) with image B being an enhanced view of the same os coxa. Image C is an example of an os coxa without an acetabular crease.

Figure 5.15 Ossa coxae (A) lateral view of a left os coxa with acetabular crease presented as a fold (black arrow) on the articular surface of the acetabulum (B) close up view of acetabular crease (C) lateral view of a left os coxa absent of an acetabular crease.

CHAPTER SIX: DISCUSSION

The frequencies of the heritable nonmetric traits present in this study are subject to limitations, which in turn makes the comparison to contemporary populations difficult especially when there is a lack of published work. It should be noted that there are major differences between the available studies and the Tell Abraq assemblage. This includes differences in trait terminology, sample size, available materials, degree of preservation, recorded side preference, commingling, and time restrictions. Because of these limitations, population comparisons of prehistoric, historic, and modern reported prevalence rates for varying populations across the world and around the Arabian Peninsula region have been included. The archaeological and modern prevalence rates were only available for some of the traits examined here.

Frontal

The supraorbital notch had shown the highest incidence (76.6%), followed by supraorbital foramen (31.25%) in the present sample. The supraorbital notch being a higher incidence and the supraorbital foramen being a lower incidence than those found in a Northern India sample, 54%, and 44.5%. Kaur et al. (2012) reports both traits showed no sexual or side dimorphism and they suggest these traits to be predominantly under genetic control and effective when used in population studies. Other studies show incidence rates of supraorbital foramen to be 9.5-65.1% across multiple populations (See Dodo 1987), the highest rates being from prehistoric North American populations (33.3-65.1%), followed by Asian (13.7-49.8%).

In the present study, the prevalence of frontal foramen was recorded as 21.43% in 3 of 14 individuals, separating supraorbital foramen and frontal foramen into two traits as proposed by Berry and Berry (1967). Dodo (1987) reports prevalence rates to be 3-9.5% in Asian and North American populations from various other publications. However, Dodo (1987) argues that frontal foramen, as defined by Berry and Berry (1967), when included in the category of the supraorbital foramen, does not distort the number of incidence due to its already low frequencies. And therefore, recording the trait may be easier if all foramen opening to the orbital cavity present along the supraorbital margin are included in this category (Dodo 1974, Korey 1980).

The prevalence rates of persistent metopism in adult cranial from diverse populations have been reported to be 0-15.38%, with higher incidence rates in East Asia populations (Zdilla et al. 2018). And other studies have found similar rates across populations at 1.1-11.46%, the lower rates being from North and South Indian populations (Makander et al. 2015). There were no instances of metopism at Tell Abraq.

Zygomatic

The presence of zygomaticofacial foramen at Tell Abraq was 83.57%. Prevalence rates of 60% for zygomaticofacial foramen are seen in some studies (Kaur et al. 2012). Hanihara, Ishida, and Dodo (1998) found a range of 0-2.79% from various populations and periods. Specifically, they found that populations from East/Northeast Asia had the highest prevalence rates, and American Indian samples had the lowest (Hanihara, Ishida, and Dodo 1998). Their study also supports a lack of sexual dimorphism and side differences in the zygomatics as previously suggested by Hauser and De Stefano (1989). The bipartite zygomatic was completely absent from the present study but this trait in particular is seen most prevalently in East Asian populations (Hauser and De Stefano 1989; Zhang et al. 2019).

Mandible

Choi et al. (2012) report varying frequencies and expressions of mandibular tori across the world from 0-80% (See Choi et al. 2012 for included studies). They also report that there seems to be a significant prevalence varying by age and gender. AlZarea (2016) reports prevalence rates in diverse populations to be 0-85.7%. All mandibles examined in this present study did not present a mandibular torus.

Turan-Ozdamir and Sendamir (2006) report rates of mylohyoid bridging to be 0.47-33.8% in varying populations and periods. Mylohyoid bridging in their sample combined superior and inferior bridges as one frequency, their study sample of late Byzantine Anatolia reported 9% mylohyoid bridging. They found that mylohyoid bridging in their study and others did not have a side preference. Sawyer and Kiely (1987) and Jidoi et al. (2000) have reported no significant differences between males and females in their studies. The presence of a mylohyoid bridge in any degree was 18.75% in the present sample, approximately halfway between the reported prevalence rates.

First Cervical Vertebra

This study reported a frequency of complete posterior bridging as 9.76%, complete and incomplete as 25.6%. Le Minor (1997), Le Minor and Trost (2004), and Traven et al. (2015) report various population frequencies of complete posterior bridging to be 2-24.7%. This study’s frequency falls in the lower half of the rates reported by these authors. Le Minor and Trost (2004) also note that the frequencies for this trait are reported to be significantly lower in Japanese populations (5.3%) compared to European and American populations (13.5%). Complete lateral bridging reported here was 2.44%, Le Minor (1997), Le Minor and Trost (2004), and Traven et al. (2015) report prevalence to be 0.5-6%. This trait is higher in Japanese (4.3%) than in European and American populations (2%). While the varying forms of incomplete posterior bridging were reported in this study not all authors report their incidence of incomplete atlantal bridging based on inconsistent classifications in the literature (Traven et al. 2015) in which case many report only the incidence of complete bridging as suggested by Hauser and De Stefano (1989). The frequency of retrotransverse foramen in this study was 8.33%. Traven et al. (2015) report widely varied frequencies of 4.2-23.3% and these canals (foramina) appear to be exclusive to the first cervical vertebra. Sanchis-Gimeno et al. 's (2018) report range from 2-20% in the various literature. Geographical origins appear to be a significant factor for the wide variation of atlantal bridging between populations (Le Minor and Trost 2004).

Sternum

Sternal foramen has a reported prevalence of 4.3-6.7% according to some studies (Gossner 2013). All sterna from Tell Abraq did not display this feature.

Patella

The patellae in the present study included both the presence of the vastus notch trait as well as the presence of segmented (emarginated) patella. More specifically, bipartite, and tripartite variants. The incidence rates of vastus notch vary between populations while the incidence of segmented patellae is much lower and rarely documented in archaeological studies. Bipartite patella incidence is reported across various studies to affect 0.2-3% of the population (Anderson 2002; Oohashi 2015). The incidence at Tell Abraq for bipartite is 3.82% which is slightly higher. Though Green (1975) suggests prevalence could be as high as 6% but the highest frequency recorded for bipartite patella is 8% from an archaeological site of a Canadian Iroquois ossuary (Anderson 1964). Being that the rates for bipartite are low, tripartite is likely even lower. In this case, the present study was 0.64% in one individual. No reported prevalence rates have been found for the tripartite patella.

Os coxa

Mafart (2005) reported prevalence rates of an acetabular crease as 6-43.3% in studies from a French historic sample and prehistoric native Canadian samples, and a comparison with the series from Notre-Dame-du-Bourg. Yamaguchi's (1981) study of Hokkaido Ainu, Ontario Iroquois, and Japanese skeletal samples showed prevalence rates for an acetabular crease to be 21.1%, 42.6%, and 11.7%, respectively. The present study sample has a prevalence of 17.17%, sitting between the ranges presented.

Prevalence Comparison

Overall, the frequencies found here in comparison to other studies, as seen in Figures 1 and 2, are mixed. The majority of the traits examined have prevalence rates that fall within those reported by other studies worldwide or within the same area from varying time periods. Some of the trait frequencies that are of interest include the supraorbital notch, bipartite zygomatic, zygomaticofacial foramen, posterior bridging of the atlas, vastus notch, bipartite and tripartite patella. These traits are outside of the reported studies, they are absent, or the literature regarding the reporting as complete and/or incomplete is not clear. Though this should be taken lightly as there are many other studies that may have reported rates but those studies were not found during this initial investigation.

In revisiting the research questions and hypothesis for this study, the expectations about high incidents for certain rare traits or the absence of traits within the population to suggest biological homogeneity is inconclusive. Again, the overall NMT results are mixed, and while very informative, the majority of these frequencies cannot be used to conclusively support or refute the hypothesis. The previous findings for this assemblage surrounding hypotheses about consanguineous practices at Tell Abraq do still provide the best lines of evidence for such practices and population homogeneity. The congenital anomaly of the second cervical vertebrae in particular falls into the boundaries of being a very rare trait in all populations both archaeological and modern but having a high frequency in the Tell Abraq sample is still the best evidence for suggesting biological homogeneity. Next to that, arguments could be made that the rate of bipartite and tripartite patella present in this sample, upon further investigation, could also suggest homogeneity. Specifically, because the 8% reported from the Iroquois ossuary could be considered an extreme outlier. If excluded, the rates at Tell Abraq are slightly higher than those reported. Arguments could also be made that if the frequency for posterior bridging of the atlas was combined and other studies would report the incidents of incomplete bridging this could give us a better idea of prevalence rates to compare to. This alone illustrates some of the issues in the literature regarding NMT recordation. There are still debates about the standards for which these traits are recorded. Some follow the founding literature suggestions of only recording complete expression of various traits and some making strong arguments for including all types of expression from trace to complete. In focusing on these traits that are reported as genetic in nature one could argue that any degree of expression warrants recording and reporting. Granted this could completely change the current prevalence rates reported worldwide but it could also not affect them significantly as previously discussed with the frontal foramen.

Gendered Inequality

The frequencies of heritable nonmetric traits presented here provide a baseline for investigating biological homogeneity. While they cannot definitively suggest homogeneity, the results can be used to test hypotheses about consanguineous marriage in the future. As other studies reporting heritable nonmetric traits become available, future investigations will be possible on this topic. This may also allow for future contributions to research investigating possible gendered inequality and structural violence at Tell Abraq during the Bronze Age.

Umm an-Nar Comparisons

Tell Abraq is not the only Umm an-Nar period settlement in the Oman Peninsula. Over 65 Umm an-Nar period tombs have been recorded but only about a third have been excavated (Blau 2001). Two settlements in particular are Tomb N at Hili and Tomb A at Hili North. Tomb N is a pit grave instead of the typical Umm an-Nar period tomb, as seen at Tell Abraq and Tomb A Hili North. However, it is also in the immediate vicinity of a circular tomb that is consistent with the Umm an-Nar period. Tomb N being one of a few known pit graves for this period, another example being Tomb B at Mowaihat, Ajman, UAE. Which has led researchers to wonder what would have caused this deviation. Some interpretations suggest a secondary burial location acting as an overflow ossuary or an additional primary burial with more complex mortuary practices taking place (Méry et al. 2001).

The current biological profile from Tomb N at Hili, Al Ain, UAE shows similarities in site preservation and tomb assemblage to that of Tell Abraq. It is highly commingled, fragmentary, and contains a high proportion (43%) of subadult remains to the total estimated MNI of 700 with mortality rates of subadults <5 years of age at 58%. The highest mortality rate being between 3 months to 4 years (McSweeney et al. 2010). Tomb A Hili North contained an estimated MNI of 300. A high rate of subadult mortality has also been reported at 42%, though it should be noted that this is only accounting for the 31 articulated individuals present in the tomb. Full analysis of the disarticulated individuals has yet to be determined or may be unpublished (McSweeney et al. 2008). In comparison the proportion of subadults at Tell Abraq was 33% of the total population (MNI 410). However, 67% of the subadult population was pre-term to <2 years of age (Barrett et al. 2021). This sparks several questions. Could there be significant differences of mortality rates among certain age groups across all sites? Can this difference be accounted for by the prevalence rates for disease and pathology found at each site? Is there a general pattern of similar conditions occurring at all of these locations or are there marked differences between them suggesting dissimilarity? It could be argued that the limited comparison made here warrants further investigation and comparison across all Umm an-Nar tombs with skeletal remains where possible.

CHAPTER SEVEN: CONCLUSION

In conclusion, this study reported the frequencies of sixteen heritable nonmetric traits. The frequency of traits found here are inconclusive in suggesting biological homogeneity or heterogeneity. The comparisons made here are only a small fraction of the numerous studies that have been published on nonmetric trait analysis and the usefulness of nonmetric traits continues to grow. However, the baseline data provided here may be useful in investigating biological homogeneity in other studies in the future and may allow us to look at social practices such as marriage patterns. These data may also provide an additional line of evidence to the previous hypotheses for this assemblage. The frequencies reported for the bipartite and tripartite patella in particular should be investigated further. Given the level of preservation and commingled nature of this assemblage, heritable nonmetric traits may allow for the examination of biological and social factors such as marriage practices and gendered inequality.

Future Directions

A number of future directions could be pursued for the assemblage at Tell Abraq. Beginning with a complete nonmetric trait analysis of the remains for both adults and subadults. There are over 100+ nonmetric traits for cranial and postcranial remains. Dental nonmetric traits in particular would be incredibly beneficial as their genetic basis is the strongest. The complete assessment would place the assemblage in a better position to be compared as a whole to the larger studies that have been completed, including biodistance studies. It would also provide baseline data for nonmetric trait studies on subadults. The literature surrounding subadults, especially in the archaeological record, leaves much to be desired. Any assemblages containing subadults is worth studying to the fullest extent.

Aside from a continuation of nonmetric traits another recommendation moving forward would be DNA analysis. Having DNA profiles of the individuals from Tell Abraq could greatly extend the current working hypothesis about consanguineous unions. It could provide evidence of related individuals and overall a better understanding of the genetic makeup of this tomb population spanning its 200 years of use. This DNA could then be compared to the surrounding regions of the Arabian Peninsula as well as to address hypotheses about potential admixture between the Tell Abraq population and those it had trade networks with. Though previous research does suggest the tomb population is mostly local individuals, since there are many potential factors that could affect the genetic makeup of this population, DNA analysis would be most beneficial.

Additionally, as previously discussed, there are numerous archaeological sites near Tell Abraq that are from the same time period. An in-depth comparison of the skeletal remains between Tell Abraq and these other sites could provide useful information about similarities and/or differences resulting from biological, environmental, cultural and social factors. In the event that biological profiles have not been conducted on the other skeletal assemblage, this would be a great opportunity to begin such analyses. And in doing so, providing a wealth of information for the Umm an-Nar period, the Bronze Age, and contributing to the pool of research in bioarchaeology.

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