GROWING UP IN MEDIEVAL NUBIA: HEALTH, DISEASE, AND DEATH OF A MEDIEVAL JUVENILE SAMPLE FROM MIS ISLAND

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Anthropology – Doctor of Philosophy

2013

ABSTRACT

GROWING UP IN MEDIEVAL NUBIA: HEALTH, DISEASE, AND DEATH OF A MEDIEVAL JUVENILE SAMPLE

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This research investigates the lives and deaths of subadults in a medieval Nubian context. Using a sample from two medieval Christian cemeteries on the island of Mis, the mortuary treatment and skeletal health of subadults were analyzed to manifest age-related cultural practices and pathologies. The island of Mis was located in the Fourth Cataract of the Nile and was excavated prior to its inundation as part of the Merowe Dam Archaeological Salvage Project. The focus of this research was the archaeological and skeletal data of the subadult Christian burials of cemeteries 3-J-10 (n = 52) and 3-J-11 (n = 136). Within the historic and environmental context of these cemeteries, the patterns of morbidity and mortality of culturally significant age groups were utilized to understand the biological stressors and hardships that faced Mis Island inhabitants during the medieval period.

The medieval period in Nubia has been known as a time of prosperity with peace and flourishing trade relations with the Muslim rulers in Egypt. The beginning of this era, however, was a time of instability, with the rise of new kingdoms, conversion to Christianity, and attacks from Muslim armies. A peace treaty between the Egyptian rulers and the medieval Nubian kingdoms in the mid-seventh century ushered in the golden era by guaranteeing peace and stimulating trade. This period of stability lasted until the twelfth century when the Christian kingdoms began to decline and eventually disappeared and the population of Nubia converted to the Muslim faith.

In the kingdom of Makuria, despite being far removed from the capital in a seemingly inhospitable area, the island of Mis was inhabited from the pre-Christian Meroitic period through the end of Christianity. At the northeastern end of the island, cemetery 3-J-11 was used as a burial ground from AD 300 to 1400, spanning the entire Christian period, while cemetery 3-J-10 was consecrated in AD 1100 and was in use until AD 1400 when a change to Muslim burial practices occurred. Although Christian rites prescribe simple east-west graves for all individuals, the assessment of mortuary variables revealed significant differences in the burial contexts of infants and young children.

Skeletal indicators of stress, including enamel hypoplasias, cribra orbitalia, porotic hyperostosis, periostitis, scurvy and tuberculosis were used to evaluate the health experiences in each age cohort and in comparison to adult groups. The patterns of affliction indicate scurvy, megaloblastic anemia, and tuberculosis were present in these populations, suggesting there was likely limited access to nutrients such as animal protein, fruits, and vegetables that offer protection against these conditions. Furthermore, the manifestation of pathological lesions in the youngest individuals suggests the biological experience of stress began early in life and contributed to the elevated levels of infant and child mortality.

Comparisons of skeletal health within Mis Island revealed few significant differences between cemeteries except for higher levels of cribra orbitalia in the 3-J-11 sample. Significant differences were also found between Mis Island and the contemporary site of Kulubnarti. The results of this work show medieval Nubian communities had both age-related mortuary practices and biological stressors that varied across age cohorts, space, and time. This suggests that life experiences were not homogenous across Nubia and more work needs to be done to understand the variability that exists.

I dedicate this work to all those who believed in me, especially my wonderful parents, Don and Marg, my brothers, Colin and Ken, who had to put up with a nerdy sister for 28 years, and my unbelievably patient and supportive husband, Dan.

ACKNOWLEDGMENTS

A dissertation is not possible without the support and guidance of so many. It not only represents the culmination of a graduate career, but an achievement that has been a lifetime in the making. For me, it is a reflection of the amazing family, friends, teachers, and mentors that I have been so lucky to have in my life. From my parents who instilled a love of learning, to the countless teachers, coaches, and professors who taught me to see challenges as opportunities and encouraged me to be more than I thought I could be. A special thanks to Mrs. Drake, Dr. Locklear, Mr. Longstreet, and Mr. Lindquist for really believing in me in those awkward formative years.

I am also forever indebted to Dr. Bruce Anderson who gave me the opportunity to intern with him at the Pima County Office of the Medical Examiner, which ignited my love of physical anthropology. Besides helping me realize my future past college (and the important fact that I wouldn't faint at the sight of dead body), he gave me the encouragement and confidence to apply to graduate school. If it weren't for this experience, I don't know where I would be today. I also have to give a big thanks to Dr. Walt Birkby for allowing me to soak in a tiny bit of his vast experience and knowledge and for introducing me to the Ajo Café.

At Michigan State I have benefitted from the experience, wisdom, and patience of fellow graduate students who were generous in their advice, support, and sympathy. I would not have made it without Jen Vollner, Cate Bird, and Jared Beatrice and the help of Julie Fleischman, Ashley Kendell, Emily Niespodziewanski, and Nicole Geske. In addition, in the data collection process I had the help of a number of amazing undergraduate students, including Fairen Baker, Lauren Charlton, Erica Christensen, Abbie Grande, Abby Gray, Mari Isa, Valerie Leah, Shanon Leary, Florence Leah, Hannah Nelson, Orion Ryder, Kailey Shelton, Jason St. John, Holly

Vredevelt, Paige Wojcik, Dan Wright, and Maggie Zywicki. Special recognition must go out to Dr. Angela Soler, who worked tirelessly to bring this collection to Michigan State and blazed the trail for future researcher, including myself. On top of all of this, she put up with me as a roommate and proved to be a lifelong friend and great cheerleader.

Working on the Mis Island Skeletal Research Collection for my dissertation was an amazing opportunity made possible by a generous loan from The British Museum to Michigan State University and the countless hours spent by Dr. Todd Fenton and Dr. Angela Soler to see this process through. Furthermore, Derek Welsby and the Sudan Archaeological Research Society must be recognized for their hard work and dedication to the recovery and preservation of cultural material from the Fourth Cataract Region. And a huge thanks to project director Andrew Ginns and his team for the excellent excavation of the graves and human remains from the cemeteries of Mis Island.

Finally, this dissertation would not have been possible without the wisdom and guidance of my committee. Dr. Julie Anderson as an expert on ancient and medieval Nubia was integral to my background research and education on Nubia and ensured that I was abreast of the latest findings and interpretations. Without her, I would have been lost in the literature and would probably still be trying to sort things out today. Dr. Masako Fujita was the one who first introduced me to life history theory and inspired me to apply its concepts to skeletal populations. Dr. Robert Hitchcock must be thanked on numerous levels, because he was an advocate for this collection to come to Michigan State and without this early support it may not have happened. His work with local populations in Africa also provided a unique perspective on the hardships facing contemporary individuals and how it may relate to past populations. Additionally, Dr. Hitchcock was always a source of encouragement and kind words, which really kept me going when I felt like quitting. Dr. Jon Frey was the committee member who really pushed me by asking the hard questions and reminding me that my dissertation should make a unique contribution to the field of physical anthropology. Although I did not want to hear these things in the midst of writing, Dr. Frey really made a difference in this dissertation and I greatly appreciate his input. My committee would not have been complete without Dr. Norm Sauer, the man who taught me osteology and had to put up with me as his teaching assistant for three years. His influence extends far past my dissertation as he taught me invaluable lessons about teaching, the importance of balancing work and life, and how to never take yourself too seriously. And the biggest thank you has to go to my advisor, Dr. Todd Fenton, who always went far above and beyond to provide training and leadership opportunities. While the lessons I learned both in and outside of the classroom prepared me for this dissertation and entrance into the professional world, I will truly cherish all the great memories that we have shared. It is rare to find an advisor who cares and invests so much in his students, and I am truly honored to have been his student.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1 – Introduction

Nubia, located in modern day Sudan and southern Egypt, has played a unique role in history as the corridor to sub-Saharan Africa acting as a conduit for the exchange of goods, ideas and people (Adams, 1984, pp 19–20; Davies, 2004, p 9; Edwards, 2007, p 211). As such, it has a deep and varied history beginning in the Paleolithic and extending through numerous kingdoms and empires of local origin. These kingdoms were frequent partners in trade with Egyptian rulers, as their strategic location along the Nile allowed for the control of travel and access to the much sought-after resources of sub-Saharan Africa (Anderson, 2004 a, p 14). This research focuses on the medieval period when three kingdoms emerged along the Nile and its tributaries and flourished as a Christian sovereignty for almost 1000 years.

With their prominent location along the Nile and well-known northern neighbor Egypt, it is surprising that relatively little is known about the riverine kingdoms of Nubia. There are no historical accounts or chronicles written by Nubians and indigenous texts have been primarily limited to graffiti, funerary inscriptions, or records of business transactions (Welsby, 2002, p 9). Thus, the majority of textual sources about Nubia's history comes from foreign writers and they are generally political or religious in nature (Welsby, 2002, p 9). Muslim writers, some of whom actually traveled in Nubia, recorded historic, political, and cultural details about Nubia, but many of the surviving accounts have been recast or interpreted by authors far removed in space or time potentially biasing the original descriptions (Spaulding, 1995; Welsby, 2002, p 9). Recently Giovanni Ruffini (2012) has begun to address the dearth of historical accounts of medieval Nubia with the translation and contextual interpretation of legal documents and letters from the archives of the Lower Nubian site of Qasr Ibrim. His research investigates land tenure, the legal and ceremonial features of land sale, renting practices, taxation, and the role of women in such business transactions. However, while this greatly contributes to our understanding of medieval Nubia, there is still little known about the non-elite individuals inhabiting remote locations far-removed from the political centers of Qasr Ibrim, Dongola and Soba.

Fortunately, archaeological investigations have a long and rich history in the upper Nile river valley and the arid conditions have proved favorable for the preservation of sites, artifacts, and human remains. Much of what is known about Nubia has come from these efforts and interpretations are continually refined as new sites are recorded and data analyzed. Unfortunately, the impetus for many of these excavations has been the impending inundation of sites due to the construction of large hydroelectric dams. Just as details of these past cultures come to light, the opportunity for further investigation is lost to rising waters. While the loss of these sites to reservoir lakes and other dam related destruction is devastating, without these threats such expansive and detailed archaeological surveys would not have been accomplished and many sites would still await discovery or would simply be lost to urban sprawl or other development. This would likely have been the fate of the archaeological sites of the Fourth Cataract were it not for the Merowe Dam Archaeological Salvage Project (2003-2008[1]) conducted prior to the construction of a large hydroelectric dam.

Prior to the Merowe Dam Archaeological Salvage Project, the region of the Fourth Cataract received little attention as it was considered an inhospitable area that was unable to sustain any substantial settlements of the past or contribute to Nubian history (Welsby, 2008, p 33). In this region there was no floodplain on the banks of the Nile to provide the types of seasonal agricultural opportunities that populations elsewhere relied upon. Furthermore, access

[1] These dates represent the time period from the official launch of the Merowe Dam Archaeological Salvage Project and the flooding of the reservoir. Some projects were initiated before this date and some fieldwork was able to continue after the reservoir was filled.

to this region by land was encumbered by difficult rocky terrain, while the numerous cataracts and prevailing winds that followed the current made river travel nearly impossible (Welsby, 2008, p 33). Thus, it seemed that if ancient populations could even make it to the Fourth Cataract, the limited agricultural potential would require them to move quickly through to more hospitable lands.

Answering the call from the Sudanese government, researchers from across the world joined together in the area of the Fourth Cataract to survey, locate, and excavate those sites that would be lost with the construction of the Merowe Dam. As projects ensued, the preconceived notions of the Fourth Cataract as a barren and desolate region of ancient Nubia were quickly dispelled. In fact, archaeological evidence indicated the region contained prosperous settlements with high status individuals able to build medieval fortresses and other substantial architecture, procure prestige artifacts, and import goods from as far away as Egypt (Welsby, 2008, p 44). This new data prompted a reevaluation of the region and its cultural history. It is now thought that a significant amount of agricultural land was available when the river channels that separated the numerous islands dried after seasonal flooding (Welsby, 2008, p 44). Furthermore, the difficult access to the Fourth Cataract region, previously interpreted as a hindrance to habitation, may instead have been beneficial as a place of refuge during times of political insecurity (Welsby, 2008, p 44). Although this relative isolation was certainly one of the benefits of the Fourth Cataract, the large number of sites discovered suggest it was an area that was extensively occupied over long periods of time, not only during times of instability (Welsby, 2003, p 124).

The island of Mis was one of the many sites excavated as part of the Sudan Archaeological Research Society's concession during the Merowe Dam Archaeological Salvage

Project. An initial survey of the island in 1999 identified numerous sites, including cemeteries, a church, and settlement areas with potential for archaeological investigation (Welsby, 2003, pp 8–14). Excavations on the island occurred in two field seasons from 2005 to 2007 (Ginns, 2006, p 13, 2007, p 20). The salvage archaeological nature of the project precluded a complete excavation of identified sites, but efforts were made to collect representative samples from each area of interest (Ginns, 2010 a, p I, b, p I). Out of many areas on the island that were investigated, this dissertation focuses on the Christian burials in two neighboring cemeteries located on the northeastern end of the island. Cemetery 3-J-10 was located in an alluvial plain that was naturally enclosed by low rocky outcrops (Welsby, 2003, p 8). This cemetery contained 262 grave monuments and was thought to have been in use late in the Christian period from approximately AD 1100 to 1400, an assertion supported by the Muslim cemetery that abuts its eastern border. This evidence suggests that the graves at 3-J-10 may represent the last Christian burials on the island before conversion to Islam.

Cemetery 3-J-11 was located 55 m northwest of 3-J-10 in a flat alluvial plain stretching to the down-sloping bank of the Nile (Welsby, 2003, p 9). With at least 500 recognizable grave monuments, cemetery 3-J-11 was the largest cemetery on the island and had been in use for more than 1000 years from AD 300 to 1400, much longer and potentially overlapping cemetery 3-J-10's history. (Ginns, 2010b, p I). Although relatively near cemetery 3-J-10, there was no indication of continuity between the cemeteries and there were no graves found between the two sites (Welsby, 2003, p 9). Unfortunately, 3-J-11 had been extensively disturbed by agricultural activities, greatly reducing its original size and potentially limiting interpretations that can be made from mortuary and skeletal analyses.

This study utilizes a bioarchaeological approach within a human ecology framework to investigate the skeletal evidence of Mis Island children and the implications for health experiences in the Fourth Cataract. Infants and children represent vulnerable segments of a population who often first fall victim to disease because of high energy demands of growth and an immature immune system that lacks antibodies against common diseases (Goodman and Armelagos, 1989; McDade, 2003; Buzon, 2011). As such, these groups can be used as a measure of overall community health. The infant mortality rate, which is measured as the number of deaths of infants less than one year of age for every 1,000 live births, is a familiar example of this approach. This figure is commonly used to compare the health and well-being of populations both within and between countries (Center for Disease Control and Prevention, 2012). In such a manner, infants and young children act as the proverbial canary in the coalmine, as health factors contributing to the death of the youngest members of a society likely have significant impacts on the greater population as well (Littleton, 2011; Center for Disease Control and Prevention, 2012).

While children have long been an important focus of public health initiatives, they have essentially been ignored in the study of past cultures. Until relatively recently, subadults were relegated to the sphere of unknowable and unpredictable variables. Reasons for excluding subadults from archaeological reports and interpretations included small sample sizes, poor preservation, or absence from traditional cemetery spaces. The antiquated perspective on the utility of subadult analyses was perhaps best summarized by Hooton (1930, p 15):

> In the case of infants and immature individuals, the cartilaginous state of epiphyses and the incomplete ossification of sutures, as well as the fragility of the bones themselves usually results in crushing and disarticulation. In any event, the skeletons of young subjects are of comparatively little anthropological value.

It is now recognized that the study of subadults from archaeological excavations is a valuable and necessary endeavor. While Hooton's critique of the fragility and complexity introduced by disarticulation in subadult skeletons are founded, this does not discount the utility of these bones and their ability to provide information on past health not apparent from adult skeletal remains.

The developing skeletal systems of these young individuals are readily impacted by physiological disruptions caused by nutritional stress or disease. Skeletal lesions manifest relatively quickly and increased infectious disease mortality in these age groups mean they often perish before healing can occur (McDade, 2003). While adults often face the same biological insults as infants and young children, they are not sensitive indicators of such stressors since they have acquired immune responses over a lifetime and have a fully developed skeleton that requires long-term chronic or severe pathology to be affected. Furthermore, adult skeletons may retain evidence of healed lesions from physiological perturbations from an earlier time and possibly another place, potentially confounding interpretations of skeletal health at a particular site.

While subadult health can be a useful indicator of the biological stressors facing a community, skeletal lesions need to be contextualized biologically, ecologically, culturally, and historically. Without the appropriate contextualization of skeletal data it is impossible to understand the degree of health or illness of an individual, the sources of disease or malnutrition, and the greater implications for overall community health. First, a life history theory framework was used to understand the changing biological demands at different life stages as limited resources are allocated between the competing needs of growth, maintenance, and reproduction (Bogin, 2003; McDade, 2003). It is necessary to be cognizant of these rival biological processes as they are prioritized at different stages in life, which can impact the expression of skeletal lesions in different age groups.

Apart from the varying biological demands throughout life, the amount of energy available to allocate to growth, maintenance, and reproduction is highly dependent on an individual's ecological and cultural context. The physical environment determines the resources available to provide energy as well as the environmental features that impose stress on the body, including temperature, altitude, ultraviolet radiation, and pathogen load (Goodman et al., 1984; Goodman and Armelagos, 1989; McDade, 2003; McDade et al., 2008). These characteristics of the environment either provide or deplete energy resources in the human body and thus may contribute to the expression of malnutrition or disease. In addition, the cultural treatment of subadults may be a contributing factor to health, disease, or malnutrition. It should be realized that the concept of childhood is socially constructed and has varied across space and through time (Baxter, 2005, p 1; Perry, 2005; Lewis, 2007, p 4). Cultural expectations of roles and responsibilities at certain ages will differ, influencing exposure to pathogens and other stressors. By understanding socially relevant age categories, such as the age of transition to adulthood, patterns of mortality and morbidity can be contextualized within cultural practices. Finally, the historic context in which past communities lived need to be considered as it provides the political, economic, and religious setting of an archaeological site. Such information can provide meaningful information about burial practices, cultural features, and sources of biological stress, like famine or war.

Each of these pieces contributes to the overall picture of life in the past and must be considered to understand the skeletal data. In order to do this, this study employs a biocultural approach that incorporates skeletal biology and mortuary analysis to understand the lives and deaths of subadults in a medieval Nubian context. Patterns of morbidity and mortality in conjunction with mortuary variables were investigated to understand the biological stressors facing these communities. Specifically, the research questions investigated in this dissertation are as follows:

1) Did the mortuary treatment of subadults suggest the existence of socially meaningful age classes?
2) Which subadult age cohorts were most vulnerable to morbidity and mortality?
3) Are there detectable differences in subadult morbidity and mortality between cemeteries 3-J-10 and 3-J-11?
4) Did stressors impact the skeletal health of adults of Mis Island to the same extent and in the same manner as the subadults?
5) How did the health of Mis Islanders compare to inhabitants of other medieval Nubian sites?

Research Hypotheses and Expectations

Hypothesis 1: *Mortuary treatment of subadult cohorts will differ significantly from adult burial rites, especially marking a transition to adulthood.*

The introduction of Christianity into Nubia served to homogenize burial practices and treatment in death became a social equalizer (Anderson, 2004 b, p 205). However, despite general adherence to simple east-west extended burials without grave goods, subadult burials continue to receive differential treatment. The custom of burying infants outside of the cemetery, often under the floors of houses in cooking pots or water jars continued into the Christian era (Shinnie and Shinnie, 1978, p 107; Adams, 1999 a, p 23; Welsby, 2002, p 63). At the medieval

Christian site of Kulubnarti, infants were placed in typical graves within the cemetery but were differentiated through interment in pottery vessels (Adams, 1999 a, p 23) while infants at Debeira West and Arminna West were buried in cooking pots under house floors (Shinnie and Shinnie, 1978, p 107; Welsby, 2002, p 63). Furthermore, personal adornment is generally not found in the graves of medieval Nubian adults, but do occur in infants or adolescent burials (Adams, 1998, p 34). Thus, age specific patterns in mortuary treatment were not uncommon in medieval Nubia. Furthermore, isotopic research by Turner and colleagues (2007) identified age-related dietary patterns in which infants, post-weaning subadults, and adults were differentiated. This suggests that an important distinction between childhood and adulthood was recognized in Nubian culture. Given the fact that Soler (2012, p 245) found significant differences between adults and subadults in the expression of mortuary variables at Mis Island, it is anticipated that mortuary treatment, including burial location, grave monument, body covering, body orientation, leg position, head direction, grave inclusions, and personal adornment, will differ significantly for adults, those individuals who have reached skeletal maturity, and children. Furthermore, it is expected that these culturally meaningful differences will coincide with the age groupings found by Turner and colleagues (2007) in their analysis of dietary isotopes, with a transition to adult practices occurring at approximately seventeen years of age.

Hypothesis 2: *Subadults of weaning age will have a statistically higher representation in the mortuary sample and will exhibit significantly higher prevalence of skeletal indicators of stress.*

The ages at which children are most vulnerable to morbidity and mortality often correspond to biologically and culturally meaningful events. Traditionally, weaning was a very dangerous time for subadults who must transition from mother's milk to an often nutrient-poor weanling diet. Additionally, bacteria could be introduced through unsanitary feeding vessels, testing the infant's developing immune system. The synergistic effects of inadequate nutrition and infection can result in a detrimental feedback loop (Shell-Duncan, 1997). In this scenario, malnutrition causes suppression of the immune system, allowing for infection, which results in intestinal malabsorption, vomiting, and metabolic changes that contribute to a greater degree of malnutrition. If such a course persists, a child's health will continue to decline and may eventually lead to death. While the detrimental effects of severe malnutrition have long been recognized, epidemiological studies have found that even mild to moderate malnutrition causes suppression of cell-mediated immunity (Shell-Duncan 1997). Isotopic studies of a Roman Egyptian sample by Dupras and colleagues (2001; 2007) demonstrated that the introduction of supplementary foods began as early as six months and weaning was completed by the age of three. A similar age of weaning was found at Kulubnarti with evidence of a transition from breast milk to a diet lacking animal protein which may indicate the use of primarily cereal based foods for weaning (Sandberg, 2006; Turner et al., 2007). Thus, it is expected that subadults around the age of three will demonstrate a greater prevalence of cribra orbitalia, porotic hyperostosis, periostitis, scurvy, and tuberculosis infection.

Hypothesis 3: *The cemeteries of 3-J-10 and 3-J-11 will not differ significantly in subadult mortality or morbidity.*

The cemeteries of 3-J-10 and 3-J-11 represent two distinct burial grounds, but separated by only 55 meters, it is likely that the communities they represent were similar in may respects. Archaeological investigations of grave types and stratigraphy indicate that the much larger cemetery of 3-J-11 had a longer history of use spanning from the pre-medieval era to the late medieval period (AD 300 – 1400). The cemetery of 3-J-10 contained only grave types consistent with the late medieval period (AD 1100 – 1400) and extended to the border of a Muslim cemetery suggesting it was in use until the population converted. Since Christian burial practices typically result in a uniform mortuary treatment for all members, it is difficult to determine status differences at either the individual or community level. While any status or community differences may play a role in health disparities, these two cemetery populations had access to the same resources with a similar set of abiotic and biotic stressors acting upon them. A similar scenario was found at the site at Kulubnarti with two Christian cemeteries in close proximity. Isotope analysis by Turner and colleagues (1997) found no significant differences in diet between the two cemeteries, suggesting both communities in this region were exploiting the same resources. It is expected that the environmental and climatic conditions of Mis Island would act as an equalizing factor resulting in no significant differences in subadult mortality rates or prevalence of enamel hypoplasias, cribra orbitalia, porotic hyperostosis, periostitis, scurvy, or tuberculosis infection between the two cemetery samples.

Hypothesis 4: *Skeletal stress markers will be more prevalent in subadult individuals than adult individuals.*

Significant life events such as birth and weaning test the rapidly developing systems of subadults. The transition from the relatively stable fetal environment to the postnatal environment is the first challenge in a baby's life and suboptimal nutrition can quickly deplete any essential vitamin stores the infant may have had. Weaning, as outlined above, is an extremely vulnerable period with a transition to often nutritionally poor foods when their energy demands are still high to support proper growth. Furthermore, maternal immunity that had protected the subadult begins to decline during this time, leaving the developing immune system vulnerable to infection and disease. With growth spurts and the development of secondary sexual characteristics, adolescence is another period of significant change and high energy demands. This may also be a period of cultural transition to adulthood, placing new demands on the teenager and exposing them to new environmental or psychosocial stressors. Adolescence may also mark the age of first pregnancy for females. The physical and nutritional demands of pregnancy and the risk of childbirth are all contributing factors to morbidity and mortality. Furthermore, the subadults represented in the cemetery samples are those that did not survive. Reasons for the premature death of these subadults likely included infections, diseases, or nutritional deficiencies. Thus it is expected that the subadult cohorts from Mis Island will have higher prevalence in the mortality profiles, in conjunction with higher percentages of skeletal indicators of stress, and higher amounts of active lesions than the adult cohorts.

Hypothesis 5: *Mis Island populations will have lower prevalence of mortality and prevalence and severity of cribra orbitalia than samples from Kulubnarti.*

Environmental conditions vary greatly along the Nile in different parts of Nubia. The site of Kulubnarti is located in an especially inhospitable environment south of the Second Cataract where the only arable land occurs in sporadic patches along the banks of the river (Adams, 1999 b). Extensive research on the skeletal remains from the medieval cemeteries 21-S-46 and 21-R-2 have consistently demonstrated high levels of skeletal lesions, including frequencies of cribra orbitalia from 82% to 94% and 100% prevalence of linear enamel hypoplasias (Van Gerven et al., 1981, 1990, 1995). These results suggest the Kulubnarti populations were heavily stressed by local environmental conditions. The extreme environmental stressors at Kulubnarti were not likely as severe at Mis Island, where arable land was more abundant and could support a greater number of people. Thus, it is expected that Mis Island samples will have a significantly lower prevalence of cribra orbitalia affliction and significantly more healed lesions than the cemeteries from Kulubnarti.

Materials

Although these cemeteries represented typical mortuary contexts with adult males, females, and children, the focus of this dissertation was on subadults from fetal to just under 20 years of age. Thus, this research sample included 188 subadults excavated from cemeteries 3-J-10 (*n* = 52) and 3-J-11 (*n* = 136) on Mis Island. This demarcation between adults and subadults has been chosen to represent a developmental age at which skeletal growth is complete and all long bone epiphyses are fused. In addition, for comparative analyses, this study relies upon data from skeletal analyses of the adult samples from Mis Island (*n* = 213) conducted by Dr. Angela Soler (2012) and data for cribra orbitalia from Kulubnarti (*n* = 407) collected by Dr. Britney McIlvaine (personal communication, July 5, 2012). The mortuary data has been compiled from archaeological records from 3-J-10 and 3-J-11 and has been combined with skeletal data to assess age related differences. Each chapter provides detailed accounts of the materials utilized for that portion of the research.

Methods

Chronological age estimates were completed for each subadult individual when possible. If the appropriate skeletal and dental elements were available, the individual was assessed independently for stage of dental development, dental eruption, epiphyseal union, and long bone length. Age has been estimated based on dental development followed the method of Moorrees and colleagues (1963) for the deciduous mandibular canine, first molar or second molar while the revisions of Smith (1991) have been used to assess permanent mandibular teeth. Stage of dental eruption has been estimated utilizing the chart of Ubelaker (1989). The degree of epiphyseal union has been assessed at 47 skeletal sites following the scoring method of Buikstra and Ubelaker (1994, p 41), and includes assessments for both the left and right sides of bilateral bones. Age estimates have been based on the degree of epiphyseal union as reported in the summaries of Schaefer and colleagues (2009). Metric evaluations include 24 postcranial measurements and an additional 18 cranial measurements for fetal to 1 year olds. These measurements have been taken bilaterally when appropriate and age estimates were produced from the numerous skeletal studies summarized in Schaefer and colleagues (2009). Omnibus age estimates have been determined based on available data, but rely on dental estimates when possible as dental development and eruption are more buffered from the effects of environmental stressors than skeletal development.

The majority of individuals have not been assessed for biological sex, since reliable methods for determining the sex of pre-pubescent individuals do not yet exist. If an adolescent showed skeletal development of secondary sex characteristics, methods of Buikstra and Ubelaker (1994), Phenice (1969) and William and Rogers (2006) have been followed.

Structure of Dissertation

This dissertation has been organized as a collection of independent research papers. As such, each chapter contains its own introduction, materials, methods, results, discussion, conclusion, and literature cited sections. The primary goal of this research has been to utilize a biocultural perspective to better understand the life experiences of subadults at Mis Island within the context of a small farming community in medieval Christian Nubia. Chapter Two introduces the concept of a bioarchaeological approach and describes the contributions that a bioarchaeology of children can make towards understanding the past. A historic overview of medieval Nubia and a review of the archaeological developments of the Nile Valley are presented to provide background and contextualize the island of Mis and its inhabitants. Chapter Three delves into the mortuary practices of medieval Nubia and those expressed at Mis Island. Hypotheses of age related differences in mortuary variables are tested and spatial relationships of age, mortuary variables, and pathological lesion activity are explored. Chapter Four focuses on the paleopathological analysis of the Mis Island subadults, including comparisons of age cohort and cemetery for prevalence, activity, and severity of skeletal indicators of stress and disease. Chapter Five takes a more holistic approach and integrates the analysis of subadult health within the complete samples from 3-J-10 and 3-J-11. Pathological variables are tested for significant differences by age and cemetery in attempt to gain a better understanding of life and the impact of biological stressors at Mis Island. Chapter Six presents a regional comparison between Mis Island and Kulubnarti with a focus on the prevalence and severity of cribra orbitalia and its association to age, sex, cemetery, and site. Finally, Chapter Seven presents the overall conclusions from this research and provides an interpretation of the cultural and biological factors that influence each age cohort at Mis Island.

LITERATURE CITED

LITERATURE CITED

Adams WY. 1984. Nubia: Corridor to Africa. Princeton: Allen Lane Princeton University Press.

Adams WY. 1998. Toward a Comparative Study of Christian Nubian Burial Practice. Archéologie Nil Moyen 8:13–41.

Adams WY. 1999a. Part I. The Graves. In: Kulubnarti III: The Cemeteries. Sudan Archaeological Research Society Publication Number 4. London: SARS. p 7–50.

Adams WY. 1999b. Introduction. In: Kulubnarti III: The Cemeteries. Sudan Archaeological Research Society Publication Number 4. London: SARS.

Anderson JR. 2004a. Treasures from Sudan. London: British Museum Press.

Anderson JR. 2004b. The Medieval Kingdoms of Nubia. In: Welsby DA, Anderson JR, editors. Sudan: Ancient Treasures. London: British Museum Press.

Baxter JE. 2005. The Archaeology of Childhood: Children, Gender, and Material Culture. (Nelson SM, editor.). Walnut Creek, CA: AltaMira Press.

Bogin B. 2003. The Human Pattern of Growth and Developmental in Paleontological Perspective. In: Patterns of Growth and Development in the Genus Homo. Cambridge: Cambridge University Press. p 15–44.

Buikstra JE, and Ubelaker DH. 1994. Standards for Data Collection from Human Skeletal Remains. Fayetteville: Arkansas Archeological Survey.

Buzon MR. 2012. The Bioarchaeological Approach to Paleopathology. In: Grauer AL, editor. A Companion to Paleopathology. Chichester, West Sussex: Wiley-Blackwell. p 58-75.

Center for Disease Control and Prevention. 2012. Infant Mortality. Cent. Dis. Control Prev. [Internet]. Available from: http://www.cdc.gov/reproductivehealth/MaternalInfantHealth/InfantMortality.htm

Davies WV. 2004. Foreword. In: Welsby DA, Anderson JR, editors. Sudan: Ancient Treasures. London: British Museum Press.

Dupras TL, Schwarcz HP, and Fairgrieve SI. 2001. Infant Feeding and Weaning Practices in Roman Egypt. Am. J. Phys. Anthropol. 115:204–212.

Dupras TL, and Tocheri MW. 2007. Reconstructing Infant Weaning Histories at Roman Period Kellis, Egypt Using Stable Isotope Analysis of Dentition. Am. J. Phys. Anthropol. 134:63–74.

Edwards DN. 2007. The Archaeology of Sudan and Nubia. Annu. Rev. Anthr. 36:211–228.

Ginns A. 2006. Preliminary Report on the Excavations Conducted on Mis Island (AKSC), 2005-2006. Sudan Nubia 10:13–19.

Ginns A. 2007. Preliminary Report on the Second Season of Excavations Conducted on Mis Island (AKSC). Sudan Nubia 11:20–25.

Ginns A. 2010a. Medieval Cemetery 3-J-10. Draft Site Report. Available from: http://www.sudarchrs.org.uk/AKS_draft_publications.htm

Ginns A. 2010b. Medieval Cemetery 3-J-11. Draft Site Report. Available from: http://www.sudarchrs.org.uk/AKS_draft_publications.htm

Goodman AH, and Armelagos GJ. 1989. Infant and Childhood Morbidity and Mortality Risks in Archaeological Populations. World Archaeol. 21:225–243.

Goodman AH, Martin DL, Armelagos GJ, and Clark G. 1984. Indications of Stress from Bone and Teeth. In: Cohen M, Armelagos G, editors. Paleopathology at the Origins of Agriculture. New York: Academic Press. p 13–49.

Hooton EA. 1930. The Indians of Pecos Pueblo: A Study of Their Skeletal Remains. New Haven: Yale University Press.

Lewis ME. 2007. The Bioarchaeology of Children: Perspectives from Biological and Forensic Anthropology. (Mascie-Taylor CGN, Little MA, Weiss KM, Foley RA, Jablonski NG, Strier KB, editors.). Cambridge: Cambridge University Press.

Littleton J. 2011. Moving from the Canary in the Coalmine. In: Ph.D SCABA, M. Sc, Ph.D BAGBS, M. A., editors. Social Bioarchaeology. Chichester, West Sussex: Wiley-Blackwell. p 361–389.

McDade TW, Reyes-Garcia V, Tanner S, Huanca T, and Leonard WR. 2008. Maintenance versus Growth: Investigating the Costs of Immune Activation Among Children in Lowland Bolivia. Am. J. Phys. Anthropol. 136:478–484.

McDade TW. 2003. Life History Theory and the Immune System: Steps Toward a Human Ecological Immunology. Am. J. Phys. Anthropol. 122:100–125.

Moorrees CF, Fanning EA, and Hunt EE. 1963. Formation and Resorption of Three Deciduous Teeth in Children. Am. J. Phys. Anthropol. 21:205–213.

Perry MA. 2005. Redefining Childhood through Bioarchaeology: Toward an Archaeological and Biological Understanding of Children in Antiquity. Archeol. Pap. Am. Anthr. Assoc. 15:89–111.

Phenice TW. 1969. A Newly Developed Visual Method of Sexing the Os Pubis. Am. J. Phys. Anthropol. 30:297–302.

Ruffini GR. 2012. Medieval Nubia: A Social and Economic History. Oxford University Press.

Sandberg PA. 2006. An Isotopic Investigation of Health and Illness in Two Skeletal Populations from Kulubnarti, Sudanese Nubia [thesis]. [Boulder, (CO)]: University of Colorado.

Schaefer M, Black S, and Scheuer L. 2009. Juvenile Osteology: A Laboratory and Field Manual. San Diego: Academic Press.

Shell-Duncan B. 1997. Evaluation of Infection and Nutritional Status as Determinants of Cellular Immunosuppression. Am. J. Hum. Biol. 9:381–390.

Shinnie PL, and Shinnie M. 1978. Debeira West, a Medieval Nubian Town: University of Ghana Expedition to Nubia. Warminster: Aris and Phillips.

Smith BH. 1991. Standards of Human Tooth Formation and Dental Age Assessment. In: Kelley M, Larsen C, editors. Advances in Dental Anthropology. New York: Wiley-Liss. p 143–168.

Soler A. 2012. Life and Death in a Medieval Nubian Farming Community: The Experience at Mis Island [dissertation]. [East Lansing, (MI)]: Michigan State University.

Spaulding J. 1995. Medieval Christian Nubia and the Islamic World: A Reconsideration of the Baqt Treaty. Int. J. Afr. Hist. Stud. 28:577–594.

Turner BL, Edwards JL, Quinn EA, Kingston JD, and Van Gerven DP. 2007. Age-Related Variation in Isotopic Indicators of Diet at Medieval Kulubnarti, Sudanese Nubia. Int. J. Osteoarchaeol. 17:1–25.

Ubelaker DH. 1989. Human Skeletal Remains: Excavation, Analysis, Interpretation. Washington D.C.: Smithsonian Institute.

Van Gerven DP, Beck R, and Hummert JR. 1990. Patterns of Enamel Hypoplasia in Two Medieval Populations From Nubia's Batn El Hajar. Am. J. Phys. Anthropol. 82:413–420.

Van Gerven DP, Sandford MK, and Hummert JR. 1981. Mortality and Culture Change in Nubia's Batn el Hajar. J. Hum. Evol. 10:395–408.

Van Gerven DP, Sheridan SG, and Adams WY. 1995. The Health and Nutrition of a Medieval Nubian Population: The Impact of Political and Economic Change. Am. Anthr. 97:468–480.

Welsby DA. 2002. The Medieval Kingdoms of Nubia. London: The British Museum Press.

Welsby DA. 2003. Survey Above the Fourth Nile Cataract. London: Sudan Archaeological Research Society Publication No. 10.

Welsby DA. 2008. Merowe Dam Archaeological Salvage Project 1996-2006. In: Godlewski W, Łajtar A, editors. Between the Cataracts. Proceedings of the 11th Conference for Nubian Studies Warsaw University, 27 August – 2 September 2006. Part One. Main Papers. Vol.

2.1. Polish Archaeology in the Mediterranean Supplement Series. Warsaw: Polish Centre of Mediterranean Archaeology and Warsaw University Press. p 33–48.

Williams BA, and Rogers TL. 2006. Evaluating the Accuracy and Precision of Cranial Morphological Traits for Sex Determination. J. Forensic Sci. 51:729–736.

Introduction

Skeletal remains are as much part of the archaeological record as artifacts, but their contributions to investigating anthropological questions has not always been recognized. The investigation of historic or prehistoric human remains traditionally fell to medical practitioners who were concerned with diagnosing skeletal lesions and documenting the rise and spread of diseases (Larsen, 1997, p 3; Armelagos, 2003, p 29; Ortner, 2003, p 8). Thus, early studies were largely descriptive in nature and focused on individual case studies of abnormalities (Ortner, 2003, p 8). Such analyses failed to contextualize these skeletal lesions within a population perspective and no attempt was made to use skeletal data to address questions about health and human adaptation in the past (Larsen, 1997, p 3; Ortner, 2003, p 9). Conversely, archaeological science has a history of ignoring or intentionally discarding skeletal remains, failing to embrace their utility as a source of information on behavior, health, disease, and biocultural adaptation (Owsley et al., 1989; Larsen, 1997, pp 1–2). Bioarchaeology has emerged from the confluence of human osteology and archaeology to provide a unique line of evidence to illuminate the lives, deaths, and culture of the people of past societies.

Skeletal material from an archaeological context has been used to measure health consequences of social, political, and economic transformations, understand patterns of disease, and the evolution and adaptation of human populations with respect to their environment. Jane Buikstra was the first academic in the United States to use the term bioarchaeology to describe a multidisciplinary research program that included the work of archaeologists, osteologists, and other specialists, to address anthropological questions about past cultures. Such research agendas may investigate the demographics of a community, evidence of migration, dietary staples and subsistence practices, prevalence of disease, divisions of labor, and social organization and its reflection in cemeteries (Buikstra, 1977, pp 67–68). Influenced by the emergence of processual archaeology, physical anthropology transitioned from description and typological classifications to interpretation, aligning with anthropological goals that strive to answer questions about humans and human society (Buikstra, 2006, p xviii; Agarwal and Glencross, 2011, pp 1–2). According to Agarwal and Glencross (2011, pp 1–3), this theoretical engagement in bioarchaeology occurred in three waves. The first occurred when physical anthropology adopted a population-based approach where clues to environmental stressors facing a community could be manifested in the adaptive responses chronicled in the skeleton. The second era of theoretical engagement was ushered in by the application of new technologies in bioarchaeology to elucidate aspects of health and life experiences in past populations as well as the critical evaluation of the nature of skeletal samples. Bioarchaeologists grappled with questions about who is actually represented in a burial ground, the limitations of skeletal analysis, and how these factors may influence an osteologist's interpretation (e.g. Wood et al., 1992). The third wave of engagement in bioarchaeology was marked by greater incorporation of contextual data to inform and help guide skeletal analyses. The multidimensional research projects that are part of this most recent trend integrate archaeological, historical, and ethnographic data to ground skeletal analyses in the appropriate cultural and historic framework (Agarwal and Glencross, 2011, p 3).

Bioarchaeology of Children

Traditionally, children have not been included in bioarchaeological investigations of past cultures. Notions of childhood as a period of play, devoid of significant social or economic contributions have rendered this line of investigation meaningless in the study of past populations. Similar to the archaeological view of women, who were largely ignored before the emergence of feminist archaeology, children have been relegated to the seemingly unknowable sphere of the home, their contributions ignored, their agency devalued, and their societal impact diminished (Kamp, 2001, p 24; Lewis, 2007, p 1). The bioarchaeology of children is a relatively new area of study where the subadults of a population become the focus of study and are used to bring to light the life experience of children within a population (Baxter, 2005, p 2; Lewis, 2007, p 1).

A common misconception is that the bioarchaeological study of children has limited potential because of the poor preservation of these skeletal remains (Lewis, 2007, p 20). This has led to a general ambivalence towards the excavation and analysis of subadult remains as researchers believed that too few would be recovered to contribute to a statistically robust analysis (Lewis, 2007, p 20). In reality, however, juvenile bones may be better preserved at some sites since they contain less fragile trabecular bone than adults (Trotter, 1971; Lewis, 2007, p 25). Taphonomic literature suggests that children's bones have the potential to preserve well, but the fact that soft tissue decomposes more quickly may leave them susceptible to scavenging and dispersal (Morton and Lord, 2002; Lewis, 2007, pp 23, 37). Other factors that may contribute to the poor representation of subadults in skeletal collections are methodological or cultural in nature. The skeleton of an infant is comprised of over 400 small bones that have not yet assumed adult morphology and an excavator inexperienced in juvenile osteology may fail to recognize these osseous pieces as human bone. Alternatively, the youngest members of a community may be afforded a different burial treatment than the general populace. It is a relatively common occurrence throughout the world that young children are not interred in communal burial grounds but are found under the floors of homes or in a special children's cemetery (Lewis, 2007, pp 30–33). Thus, if entire cemeteries and habitation sites are not excavated, these remains may simply be overlooked. When subadults are incorporated into bioarchaeological analyses, a richer understanding of a past society can be achieved.

The human species has evolved to have completely dependent offspring who require physical, mental, and social development outside the womb. This means that childhood is a dynamic period where important developmental milestones occur and a society's values are inculcated (Kamp, 2001, p 2). Thus, the study of children has the potential to reveal numerous aspects about the social, cultural, and economic systems of a community. Studies of growth, diet, and mortuary features may elucidate information about physical and social development. These analyses may also reveal important cultural milestones such as the adoption of specific gender roles or the social transition to adulthood (Lewis, 2007, p 1). These new roles in a community signify important life stages that often come with additional responsibilities, which may expose subadults to different cultural and biological stressors, placing new burdens on a developing body. Understanding both the biological and cultural demands of childhood at different life stages allows for thoughtful and informed bioarchaeological analyses. Children are also the most vulnerable segment of the population because of their dependency on others for care and susceptibility to many diseases as their immune systems develop. Thus, the health and well-being of children serve as a measure of a population's cultural and biological adaptations to the local physical and social environment (Lewis, 2007, p 19).

One of the initial steps in skeletal analysis of subadults is the estimation of age to place an individual into a pre-defined age category readily allowing for comparisons between bioarchaeological studies. These age categories are based on biological milestones that are equated with chronological age. For instance, the most commonly used age cohorts in the

United States are from *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker, 1994, p 9). In this system, children are divided into age categories that correlate with important biological events. “Fetus” is defined as the period before birth; “Infant” spans from birth to age three, the age of weaning in traditional human societies around the world (Dettwyler, 1995, p 39); “Child” incorporates the ages from three to twelve, or approximately the age of puberty; and “Adolescent” begins at twelve and ends at twenty years, an average age at which skeletal maturation completes. The problem with such a practice is that biological age does not necessarily correlate with culturally meaningful age categories.

Age categories, like gender roles, are cultural constructs prescribed by the principles of social organization that structured past societies and are influenced by adult perceptions of the abilities, maturity, and responsibilities that characterize each stage of development (Kamp, 2001, pp 2–3; Baxter, 2005, pp 97–98; Lewis, 2007, pp 5–7). As researchers attempt to understand the role of children in past societies, it is important to be cognizant of personal bias in the definition and expectations of childhood. As Ariès (1962) points out in his book *Centuries of Childhood: A Social History of Family Life*, the western notion of childhood as a time of play and learning did not exist until the modern period. For many cultures across space and time, subadults were considered integral in the overall function and success of the family and had important responsibilities beginning at a young age. This highlights the importance of understanding childhood within the context of the culture that is being studied.

The interdisciplinary approach of bioarchaeology provides tools for addressing the cultural context of such skeletal remains. Mortuary analysis, the archaeological study of funerary practices, can be an avenue towards understanding a past society’s view on childhood (Kamp, 2001; Pearson, 2001, p 3; Perry, 2005; Lewis, 2007, p 1; Halcrow and Tayles, 2011). Mortuary practices are one form of social activity that is typically accessible to archaeologists and is often studied as a reflection of a community's social system. Thus, a burial's location, body positioning, orientation, grave markers, and grave goods may all serve as indicators of the subadult's position within the social hierarchy (Kamp, 2001, p 6; Baxter, 2005, pp 97–99). Differential burial rites may serve as an indicator of important social demarcations within a culture and can provide clues to socially meaningful age categories. Mortuary data may also serve to reveal information about social status and gender roles. For instance, the inclusion of adult status objects within a subadult's grave may suggest the practice of ascribed status, where the child's status is based on that of his or her family. Alternatively, gendered artifacts, such as tools or weapons associated with a particular sex may indicate the societal expectations of young boys or girls. Such interpretations must be made with caution, however, since alternative explanations are also tenable, such as the juvenile is already considered a contributing adult member of society and have assumed their gender role (Kamp, 2001, p 7; Baxter, 2005, pp 103–104).

A bioarchaeological approach emphasizes the integration of diverse data sets in multidisciplinary research to converge on a more comprehensive representation of life in the past. This methodology is utilized in this dissertation to study the lives and deaths of subadults from the Island of Mis in the Fourth Cataract of the medieval Kingdom of Makuria. As outlined above, the study of children has significant potential to contribute to our understanding of health and disease in the past, as well as culturally relevant stages of development and perspectives on childhood. To accomplish such an analysis, the historical context of the subadults from Mis Island must be understood.

The Medieval Kingdoms of Nubia: Historic Background

The medieval period began in the sixth century AD when three kingdoms emerged from the polities of the preceding Post-Meroitic period. The Kingdom of Nobadia was located in the north from the 1st to 3rd Cataracts, Makuria between the 3rd and the 5th Cataracts, and Alwa in the south, extending upstream of the 5th Cataract to at least the Sennar region on the Blue Nile (Welsby, 2002, pp 8, 24, 2006, p 21). Shortly after their inception, these kingdoms independently underwent state-level conversions to Christianity in the mid-sixth century AD.

Much of what we know about the Christianization of the three medieval Nubian kingdoms was compiled and translated from primary sources, including descriptions and reports of Arab writers, travelers, and historians (e.g. Vantini, 1975). In addition, the accounts of John of Ephesus and John of Biclar, two ecclesiastical historians, document the official Christian conversions of the three Nubian kingdoms. At the time of their conversion, there were two major Christian denominations in Byzantine Empire, each centered on a different understanding of the nature of Christ. The Monophysite doctrine, endorsed by Empress Theodora, held that Christ was a single divine being. Conversely, Emperor Justinian favored the Dyophysite, or Melkite, doctrine, which adhered to the belief in the dual nature of Christ as both human and divine (Welsby, 2002, p 32).

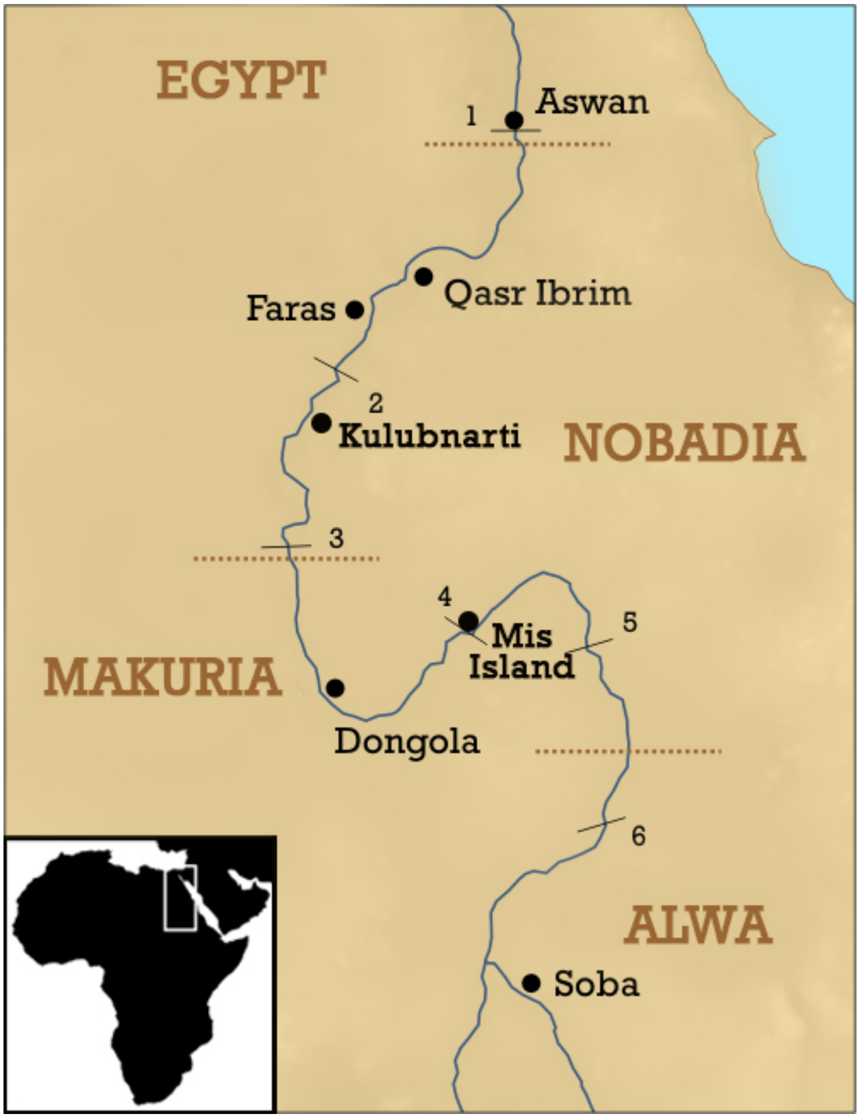

Figure 2.1: Map of the medieval kingdoms of Nubia. For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this dissertation.

The narrative of John of Ephesus chronicles the competing missions of the Monophysites sent by Byzantine Empress Theodora and the Melkites sent by the Emperor Justinian (Vantini, 1975, pp 7–11; Welsby, 2002, pp 32–33). Using subversive tactics, Theodora's mission reached the Kingdom of Nobadia first and converted the royal court to the Monophysite doctrine. The ruler of the most southern kingdom, Alwa, followed suit by requesting the bishop who had baptized the Nobades be sent to Alwa to do the same (Vantini, 1975, pp 14–15). Thus the

Kingdom of Alwa also became followers of Monophysite faith. Despite being bordered by its followers, the Kingdom of Makuria was not converted to Monophysitism. According to John of Biclar, the Makurian king sent delegates to Constantinople bearing gifts and adopting the Melkite doctrine of Emperor Justinian to demonstrate their friendship and loyalty (Vantini, 1975, pp 27–28).

Beyond religious differences textual evidence suggests that the central Kingdom of Makuria and the northern Kingdom of Nobadia were antagonistic during the fifth and sixth centuries AD. This is further confirmed by the victory stela of Nobadian King Silko that boasts of ravaging the Makurian lands and signs of fortification at the Makurian capital of Old Dongola (Eide et al., 1996, pp 1150–1151; Godlewski, 1999, pp 556–557). Furthermore, relatively few Egyptian artifacts travelled beyond Nobadia, indicating that Makuria's trade relations with Egypt had been disrupted (Anderson, 2004 a, p 203).

Despite these hostilities in the early period, by the mid-seventh century, these two kingdoms were united under the Makurian king, but were practicing Monophysitism, the religious doctrine of Nobadia (Adams, 1991, p 257; Anderson, 2004 a, p 203). Exactly how this political unification occurred between these two previously hostile kingdoms is unknown, especially since there is no evidence of a hostile or bloody takeover and peace was maintained for over 600 years (Adams, 1991, p 257). According to Adams (2001, p 48), a period of impoverishment in Lower Nubia caused by recurring destructive floods and diminished trade with the politically unstable Egypt may have caused the desperate Nobadians to accept the rule of the flourishing Kingdom of Makuria. Although politically unified, the two former kingdoms maintained linguistic, ethnic, and economic distinctions (Adams, 1991, p 261). Adams (1991, p

261) concludes that despite being subsumed under one king, these neighboring lands had two different administrations over two different peoples with little to no integration.

In the seventh century AD, the death of Mohammed incited the rapid spread of Islam beyond the Arabian Peninsula. This expansion began with the conquest of Syria in AD 636 and by 639, Muslim armies had captured Egypt and were targeting other Byzantine lands in Libya, Tunisia, and Algeria (Welsby, 2002, p 68; Anderson, 2004 a, p 204). A Muslim army of 20,000 troops moved south in 641 to invade Nubia, but were halted by an army rumored to contain 100,000 Nubian men who forced the Muslim army to retreat (Vantini, 1975, p 95). The tense peace was not long-lived. A Nubian raid of Upper Egypt in 652 prompted a second Muslim campaign on the Makurian capital at Old Dongola, but the Nubians were again able to fend off the invaders with their skilled archers. The result of this conflict was the *Baqt*, a bilateral peace agreement between Muslim Egypt and the Christian Nubia, making Nubia one of the last strongholds of Christianity in the region (Welsby, 2002, p 70; Anderson, 2004 a, p 204). This guaranteed peace between the two powers with a regular exchange of commodities led to a period of amicable trade relations and prosperity in which the medieval kingdoms flourished. Since no textual sources from Nubia have survived and most Arab accounts were written by historians centuries later, the details and provisions of the *Baqt* remain unclear (Spaulding, 1995). Most accounts suggest that the Makurians would supply slaves in exchange for Muslim grains, pottery, cloth, wine, and horses and allowed free travel for Muslims and Nubians between the two lands.

The Eparch of Nobadia, an administrative position in the Nubian political sphere, was responsible for ensuring the provisions of the *Baqt*, including supervising trade, protecting Muslims who were trading or residing in Lower Nubia, providing the annual quota of slaves, and returning any runaway slaves (Adams, 1991, p 258). The Eparch also conducted trade with Muslim merchants at Cairo and on the Red Sea coast on behalf of the Makurian, and possibly Alwan kings (Adams, 1991, p 259). Until recently, it was believed that this free trade zone only extended to the Second Cataract, the northern boundary of the Makurian heartland, and any travel beyond this point required royal permission (Adams, 1991, p 258). This was thought to allow strict control of trade in Upper Nubia by the king, while Lower Nubia utilized currency in market exchange. Giovanni Ruffini (2012) challenges this interpretation, however, based on recent analysis of texts from Qasr Ibrim that provide evidence of private land ownership and a monetized economy throughout Christian Nubia.

The golden era of the medieval Nubian kingdoms began to decline in the 12th century AD due to the rise of internal political strife and increasingly antagonistic relations with Muslim rulers to the north and south (Anderson, 2004 b, p 17). During this time, castle houses and watchtowers were built in Lower Nubia and the populace abandoned their homes for refuge in fortified settlements. The increasing presence of such architecture on the landscape serves as a potential indicator of the weakening power of the Makurian king (Adams, 1994; Anderson, 2004 a, p 207). The strength of the clergy also waned and churches shrank in size as political relations with the Muslim rulers of Egypt deteriorated, effectively isolating Christian Nubia from the religious guidance of the patriarchs of Alexandria (Welsby, 2002, p 256; Anderson, 2004 a, p 207; Żurawski, 2006, p 184). In its weakened state, Makuria was plagued by internal political rivalries and the rise of secular feudalism. Such internal struggles provided ample opportunities for Egypt's Muslim leaders to engage in political intrigue for their own benefit (Welsby, 2002, pp 242–43; Anderson, 2004 a, p 207).

In the face of power struggles, raids by nomadic desert tribes, and invasions from Egypt, the Christian sovereignty in Makuria was unable to endure. Eventually, the throne room was converted to a mosque in 1317 and a Muslim was crowned king in 1323 (Welsby, 2002, p 247; Anderson, 2004). Even under Muslim rule, the Makurian kingdom was unable to endure and eventually collapsed in AD 1365 (Welsby, 2002, p 243; Anderson, 2004 a, p 207). Unfortunately, the fate of the Kingdom of Alwa to the south during this tumultuous time period is generally unknown. Buffered by distance, Alwa did not have to endure dynastic meddling by Egyptian rulers and remained a Christian kingdom until the early sixteenth century. The Funj Chronicle, the record kept by the first powerful Islamic state in the Middle Nile Valley, claims Alwa was conquered in 1504, but archaeological evidence suggests that this was a victory over an already dilapidated city (Welsby and Daniels, 1991, p 34; Welsby, 2002, p 255; Anderson, 2004 a, p 208). The history of Alwa in its terminal phase is largely unknown, but its decline has been attributed to a long history of raids and incursions by desert Arabs and the Funj (Welsby, 2002, p 255). Whatever the details may be, Alwa's reputed conquest by the Funj in 1504 marked the end of the era of the medieval Christian kingdoms of Nubia.

Archaeology in the Nile Valley

While the general chronology of the medieval kingdoms of Nubia is known, there is a dearth of historical texts concerning the inhabitants of these kingdoms and the human experiences of day-to-day life. Fortunately, the dry desert sands of the Nile Valley have served to preserve archaeological sites, artifacts, and human remains. Archaeological investigations have discovered past towns and villages along the Nile, and data from these excavations is being used to gaze into the past and contribute to our understanding of Nubia.

Unlike many other parts of the world, where human remains were discarded in favor of grave goods and other artifacts, there is a long history and appreciation for the long deceased in the Nile Valley. The excellent preservation of remains, due to intentional mortuary practices and favorable climatic conditions, piqued the interest of archaeologists investigating the pyramids and their magnificent tombs. Unable to accept that such an advanced culture could have African origins, scholars worked to understand the population history of these ancient people. As Batrawi (1946) noted, "It is a remarkable feature of the literature on the present subject that most investigators can think of a homeland for the Ancient Egyptians and their civilization in every corner of the world except Egypt" (p 136). Often, the evidence to support such claims came from the skeletons themselves. Crania were analyzed, measured, and indexed into typological categories to support archaeological interpretations.

Over time, interest in the extent of Egyptian influence into Africa prompted investigation to extend up the Nile Valley to focus on the land of the Nubians. One of the first bioarchaeological investigations was prompted by the imminent widespread flooding of the Nile Valley that would result from an increase in the water level of the Aswan Dam. Conducted and led by George Reisner, the First Archaeological Survey of Nubia was one of many salvage projects that would take place along the Nile. These early surveys and excavations laid the foundation for Nubian archaeology and Reisner's early interpretations provided structure for the investigation of Nubia's past and a cultural chronology that is still utilized today. In accordance with research standards of the time, however, a typological approach was used to classify the architecture, artifacts, and the human remains. This forced all classifications into restricted archetypal categories, ignoring the range of diversity that was present. Unfortunately, preconceived notions also shaped Reisner's work. Although he proposed the investigation of a number of anthropological questions during this expedition, he also exhibited the type of Egyptocentric and racist perspective that was prevalent among many early Nubian researchers. Demonstrated in *The Archaeological Survey of Nubia, Bulletin No. 1* (1908), Reisner's stated goals were as follows:

> The archaeological survey of Lower Nubia has been undertaken (1) for the purpose of ascertaining the value and extent of the historical material buried under the soil, and (2) for the purpose of making this material available for the construction of the history of Nubia and *its relations to Egypt*. The questions on which it is hoped to throw light concern the *successive races and racial mixtures*, the extent of the population in different periods, the economical basis of the existence of these populations, the character of their industrial products, and the *source and degree of their civilization* (p 9, emphasis added).

Biased by his perspective, Reisner proceeded to interpret Nubia's history in the context of its relation to known Egyptian civilizations. Any cultural advancement in Nubia was attributed to interactions with Egypt and racial immigrations and admixtures explained the ebb and flow of "civilization". A prime example is Reisner's interpretation of the historical chronology of the Middle Nile region. Following the fall of the great Kingdom of Kush, a dark age ensued when mass migrations of nomadic groups diluted the previously civilized culture (Hägg et al., 2002, p xiv).

Elliot Smith, Douglas Derry, and F. Wood Jones followed the same typological methods in the analyses of the human remains recovered in the First Archaeological Survey. They identified Egyptian, Nubian, Syrian, Negro, and hybrid races among the recovered skeletal remains. These classifications were used to corroborate the preconceived notions of Reisner and to correlate racial migrations with significant cultural changes (Elliot Smith and Wood Jones, 1908; Van Gerven et al., 1973, p 555). Overall, these early Nubian researchers believed that cultural advancements in Nubia were associated with Egyptian influences and cultural stagnation was caused by African admixture (Elliot Smith, 1909, pp 22–25; Van Gerven et al., 1973, p 555).

Even in locations remote from the Egyptian border, an Egyptocentric perspective still prevailed in the early archaeological interpretation of past Sudanese cultures. The ancient capital of the Kushite state, Meroe, was located just north of Khartoum, the current capital of Sudan. John Garstang began excavation at Meroe in 1909. In spite of the fact that this city was far removed from the Egyptian frontier, Garstang still assessed the cultural achievements of its inhabitants based on the presence or absence of Egyptian influence. For instance, the high quality of artifacts from Meroe's early history suggested there was no 'negro blood' in its founders, and the handmade decorative pottery was thought to be made by a 'native' population, with no ties to Egypt (Hägg et al., 2002, p xiii).

Despite the prevalent racial theories used to explain the history of Nubia, there were hints of an approaching sea change. In the mid-1920s, Hermann Junker challenged the idea of a racial discontinuity between the Meroitic and the X-Group populations by demonstrating common traits between these two groups (Hägg et al., 2002, p xv). A decade later, Georg Steindorff campaigned for the replacement of the ethnically based chronology with one informed by archaeologically derived cultural divisions (Hägg et al., 2002, p xv). Unfortunately, few took notice and these suggestions did little to alter the racial ideology of the field.

Another rise in the water levels of the Aswan Dam prompted the Second Archaeological Survey of Nubia (1929-1934) directed by Walter Emery. Ahmed Batrawi was responsible for studying the skeletal collections recovered from these archaeological excavations. Despite initially agreeing with the conclusions of his predecessors (Batrawi, 1935), Batrawi eventually rejected the hypothesis of a causal link between race and cultural achievement (Batrawi, 1946, p 131; Van Gerven et al., 1973, p 556). However, his goal was still to clarify the racial history of the region by studying the physical characteristics of its inhabitants (Batrawi, 1946, p 131).

Although Batrawi presented seemingly advanced methodologies with a statistical basis, his approach still utilized a typological approach to race and racial admixture. After extensive studies of the human remains, Batrawi (1946) concluded that ancient Nubian populations varied morphologically through time, but were not sufficiently distinct to represent different racial groups (pp 154–155). While this was an important recognition of the biological and cultural continuity of Nubia, advances in scientific methods, such as analysis of blood groups, continued to utilize typological and racially based approaches (Van Gerven et al., 1973, pp 556–557).

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) Campaign to Save the Monuments of Nubia (1960-1980) finally ushered in a new interpretive paradigm for Nubian archaeology. The detailed survey uncovered more than 1,000 sites from a wide range of time periods (Edwards, 2004, p 5). The thorough investigations by teams from across the globe filled in many gaps that had plagued Nubian chronologies, revealing in the process a large degree of populational homogeneity through time. This prompted a critical re-evaluation of foreign invasion theories for cultural change and promoted comprehensive interpretations based on archaeological evidence.

One of the largest excavations during this campaign was the island site of Meinarti at the foot of the Second Cataract (Adams, 2001, p 1). This extensive excavation revealed a site with 18 occupation levels inhabited periodically from the late Meroitic to the end of the Christian period (Adams, 2001, p 1). A marked difference in the architectural and artifactual assemblages throughout the occupational history of Meinarti indicated a functional change in the site's purpose over time. Government sanctioned building projects in Meinarti's initial period of habitation suggested an administrative role for the island, possibly to facilitate trade along the Nile (Adams, 2000, p 64). However, haphazard and unorganized building in later reoccupations indicated Meinarti no longer served as an administrative center, but had become home to a population of peasant farmers (Adams, 2000, p 100). Evidence of repeated flood damage during the medieval occupation may have led to the site's eventual abandonment and may also provide clues to the potential impetus for the unification of Nobadia and Makuria (Adams, 2001, p 48).

Excavations at Debeira West between 1961 and 1964 were also undertaken during the UNESCO Save the Monuments Campaign and provide a comparative view of life in Lower Nubia during the medieval period. The recovery of pot knobs from the ceramic vessels used in a *saqia*, a waterwheel utilized in irrigation, and iron sickle blades was strong evidence of agricultural practices (Shinnie and Shinnie, 1978, p 107). Although sheep, goat, cattle, and pig bones were recovered, the overall amount was relatively small suggesting that meat was not a regular part of the diet. Despite its prime location on the bank of the Nile with its piscatorial resources, fish bones were also sparse suggesting these too were absent from the typical diet of inhabitants of Debeira West. Significant amounts of ovis/capra coprolites suggested to researchers that herds were kept and may have been a source of milk or meat (Shinnie and Shinnie, 1978, p 107). Paleobotanical and artifactual evidence indicates that dates, wine imported from Egypt, and sorghum bread were the staples of the diet at Debeira West (Shinnie and Shinnie, 1978, p 107).

The most recent dam project occurred on the island of Merowe and flooded 170 km of land upstream of the Fourth Cataract, creating a 4 km wide lake (Salah eldin Mohamed Ahmed, 2004, p 308). Since the Fourth Cataract region was one of the least archaeologically investigated areas of the Nile, the Merowe Dam Archaeological Salvage Project was initiated to recover as much information about ancient settlements as possible before the area was flooded. The salvage work that took place between 1999 and 2008 included both areas of impending flooding and sites that would be destroyed by the construction of power lines and the resettling of more than 48,000 people displaced by the project (Salah eldin Mohamed Ahmed, 2004, p 308). The efforts of several international teams have demonstrated the archaeological richness and diversity of this regions by identifying hundreds of sites, including cemeteries, tombs, rock drawings, and settlements from all phases of Nubian human occupation.

There have been a number of studies from Egyptian and Nubian sites that have focused on the health of the youngest cohorts in a population. Kulubnarti is one of the most intensely studied sites in Nubia located in the northern extent of Upper Nubia in a region known as the *Batn el Hajar*. This area is considered one of the most inhospitable Nubian environments with limited resources that can only support small villages. Extensive paleopathological studies have compared the two excavated cemeteries investigating a number of aspects of health and disease, including survivorship curves, cribra orbitalia, cortical bone growth, enamel hypoplasias, and sex differences (Van Gerven et al., 1973, 1981, 1990, 1995; Moore et al., 1986; Mittler and Van Gerven, 1994; Sheridan and Van Gerven, 1997). More recent studies have examined isotopic indicators of diet to detect any dietary differences by sex and age (Turner et al. 2007). Van Gerven et al. (1995) suggest that the early Christians were more stressed as subadults as indicated by higher rates of infant mortality, cribra orbitalia, linear enamel hypoplasias, and stunting. The late Christian population, on the other hand, had a slightly higher adult mortality and a 30% increase in fractures of the upper limbs of adults, especially males. Overall, Van Gerven et al. (1995) conclude that the late population demonstrates better adaptation to their environment, but may be plagued by interpersonal violence. The long-term and extensive study of the skeletal collection from Kulubnarti has allowed interpretations of health and disease to be refined as new technologies emerge and new research hypotheses are tested.

Further north in Egypt, Fairgrieve and Molto (2000) performed a comparative analysis of cribra orbitalia between a pre-Roman and Roman period cemetery from the Dakhleh Oasis, located in Egypt's Western Desert. They found 78% of the 153 individuals from the pre-Roman cemetery sample and 55% of the 143 individuals from the Roman period site displayed orbital lesions. This difference in prevalence was not only statistically significant, but the authors also report that the frequency of cribra orbitalia was higher in virtually all age cohorts from the pre-Roman cemetery. Most notably, the subadult cohorts (<18 years) from the pre-Roman cemetery had a prevalence of 100%. Furthermore, cribra orbitalia was found in infants younger than six months, the minimum age in which iron stores can be depleted, indicating that iron-deficiency anemia was not likely the cause. Alternatively, these authors propose megaloblastic anemia may play a role in the etiology of cribra orbitalia. Megaloblastic anemia results from a deficiency in folic acid or vitamin $B_{12.}$ Inadequate levels of these nutrients impair DNA synthesis and cause the enlargement and premature death of red blood cells. The resulting anemic condition stimulates red blood cell production and may result in marrow hypertrophy and cribra orbitalia. Support for this interpretation comes from the fact that folic acid deficiencies can occur when a child is weaned onto goat's milk at an early age – a practice consistent with traditional Roman medical advice (Fairgrieve and Molto, 2000, pp 328–329).

Weaning practices have been a popular area of investigation for bioarchaeological studies. The transition from breast milk to other foods is considered a particularly dangerous time due to the often nutritionally poor weanling diet and the bacteria that are introduced to the child's vulnerable immune system from unsanitary feeding vessels. The ability to ascertain at what age weaning takes place allows physical anthropologists to further understand how childhood nutrition impacts subadult morbidity and mortality in various age classes. Dupras and colleagues (2001, 2007) examined weaning practices in Roman Egypt at the site of Kellis 2 in the Dakhleh Oasis. Initially, the skeletal remains of 49 infants and juveniles (Dupras et al., 2001) and later an additional 102 juveniles and adults (Dupras and Tocheri, 2007) were subjected to stable isotope analysis. The results of both studies suggested that supplementary foods were introduced around the age of six months with the gradual weaning process completed by three years. Additionally, enriched $\delta^{13}C$ suggests infants were fed supplementary goat or cow milk during weaning. As previously mentioned, this is consistent with weaning practices professed by the ancient physicians and medical writers, Galen (Green, 1951) and Soranus (Temkin, 1991). They advised that at six months supplementary foods, like a mixture of goat milk and honey, should be introduced followed by a gradual weaning process until the child reached three years of age (Dupras et al., 2001, p 210; Dupras and Tocheri, 2007, pp 71–72). If such practices were employed in the Dakhleh Oasis, cribra orbitalia in this population may have been due to megaloblastic anemia.

Additional work in the Dakhleh Oasis by Wheeler (2009, 2010) investigated the effects of Roman policies during the early years of Christianization in Egypt. Non-specific indicators of stress, including cribra orbitalia, enamel hypoplasias, and periostitis were analyzed in conjunction with skeletal growth, trauma, and the seasonality of death. In a sample of 238 subadults (<15 years) there was moderate levels of stress, low prevalence of trauma, comparable skeletal growth and height to a contemporary site but significantly shorter than modern children, and a spring mortality peak indicated by grave orientation and isotopic composition of hair (Wheeler, 2009, pp 211–213, 2012, pp 226–227). These results showed a marked improvement over the skeletal health of subadults of a pre-Roman site from the same area suggesting that Egyptian Roman infrastructure benefited the populations in Dakhleh Oasis.

The exciting research that has been undertaken thus far on juveniles in the Nile Valley demonstrates the vast potential to learn about the lives of the youngest members of the community and may help contribute to the current understanding of these ancient cultures. The extremely arid conditions of the Nile Valley make it an ideal location to study the well-preserved skeletal remains of past peoples and employ a bioarchaeological approach to gain better understanding of their communities and hardships. While excellent research agendas have been executed at sites like Kulubnarti and the Dakhleh Oasis, it is clear that much more work needs to be done to gain a regional perspective of what life was like throughout the Nile Valley and across Nubia. This work on the subadults of Mis Island significantly contributes to the emerging research about the Fourth Cataract region and takes a unique perspective on the life and death experiences of juveniles in the medieval Kingdom of Makuria.

LITERATURE CITED

LITERATURE CITED

Adams WY. 1991. The United Kingdom of Makouria and Nobadia: A Medieval Nubian Anomaly. In: Davies WV, editor. Egypt and Africa: Nubia from Prehistory to Islam. London: British Museum Press.

Adams WY. 1994. Castle Houses of Late Medieval Nubia. Archéologie Nil Moyen 6:11–46.

Adams WY. 2000. Meinarti I: The Late Meroitic, Ballaña and Transitional Occupation. Oxford: Archaeopress.

Adams WY. 2001. Meinarti II: The Early and Classic Christian Phases. Oxford: Archaeopress.

Agarwal SC, and Glencross BA eds. 2011. Social Bioarchaeology. Chichester, West Sussex: Wiley-Blackwell.

Anderson JR. 2004a. The Medieval Kingdoms of Nubia. In: Welsby DA, Anderson JR, editors. Sudan: Ancient Treasures. London: British Museum Press.

Anderson JR. 2004b. Treasures from Sudan. London: British Museum Press.

Ariès P. 1962. Centuries of childhood: a social history of family life. New York: Random House.

Armelagos GJ. 2003. Chapter 3. Bioarchaeology as Anthropology. Archeol. Pap. Am. Anthr. Assoc. 13:27–40.

Batrawi A. 1946. The Racial History of Egypt and Nubia: Part II. The Racial Relationships of the Ancient and Modern Populations of Egypt and Nubia. J. R. Anthr. Inst. Gt. Br. Irel. 76:131–156.

Batrawi AM. 1935. Mission archéologique de Nubie, 1929-1934. Report on the human remains. Cairo: Government Press.

Baxter JE. 2005. The Archaeology of Childhood: Children, Gender, and Material Culture. (Nelson SM, editor.). Walnut Creek, CA: AltaMira Press.

Buikstra JE, and Ubelaker DH. 1994. Standards for Data Collection from Human Skeletal Remains. Fayetteville: Arkansas Archeological Survey.

Buikstra JE. 1977. Biocultural Dimensions of Archeological Study: A Regional Perspective. In: Blakely RL, editor. Biocultural Adaptation in Prehistoric America. Athens: University of Georgia Press. p 67–84.

Buikstra JE. 2006. Preface. In: Bioarchaeology: The Contextual Analysis of Human Remains. Amsterdam: Academic Press.

Dettwyler KA. 1995. A Time to Wean: The Hominid Blueprint for Natural Age of Weaning in Modern Human Populations. In: Breastfeeding: Biocultural Perspectives. Evolutionary Foundations of Human Behavior. New York: Transaction Publishers. p 39–73.

Dupras TL, Schwarcz HP, and Fairgrieve SI. 2001. Infant Feeding and Weaning Practices in Roman Egypt. Am. J. Phys. Anthropol. 115:204–212.

Dupras TL, and Tocheri MW. 2007. Reconstructing Infant Weaning Histories at Roman Period Kellis, Egypt Using Stable Isotope Analysis of Dentition. Am. J. Phys. Anthropol. 134:63–74.

Edwards DN. 2004. The Nubian Past: An Archaeology of the Sudan. London: Routledge.

Eide T, Hägg T, Pierce RH, and Török L eds. 1996. Fontes Historiae Nubiorum. Textual Sources for the History of the Middle Nile Region Between the Eighth Century BC and the Sixth Century AD: From the First tot he Sixth Century AD. Bergen: University of Bergen, Dept. of Classics.

Elliot Smith G, and Wood Jones F. 1908. The Anatomical Report. In: The Archaeological Survey of Nubia Bulletin No. I. Cairo: National Printing Department.

Elliot Smith G. 1909. Anatomical Report (A). In: The Archaeological Survey of Nubia no. 3. Cairo: National Printing Department. p 21–27.

Fairgrieve SI, and Molto JE. 2000. Cribra Orbitalia in Two Temporally Disjunct Population Samples From the Dakhleh Oasis, Egypt. Am. J. Phys. Anthropol. 111:319–331.

Godlewski W. 1999. The Earliest Evidence of the Settlement at Old Dongola. Meroitica:554–559.

Green RM. 1951. A translation of Galen's Hygiene: (De sanitate tuenda). Springfield: Charles C. Thomas.

Hägg T, Török L, and Welsby DA. 2002. Preface. In: Hägg T, Török L, Welsby DA, editors. Studies on the History of Late Antique and Christian Nubia. Aldershot: Ashgate Publishing Limited.

Halcrow SE, and Tayles N. 2011. The Bioarchaeological Investigation of Children and Childhood. In: Ph.D SCABA, M. Sc, Ph.D BAGBS, M. A., editors. Social Bioarchaeology. Chichester, West Sussex: Wiley-Blackwell. p 333–360.

Kamp KA. 2001. Where Have All the Children Gone?: The Archaeology of Childhood. J. Archaeol. Method Theory 8:1–34.

Larsen CS. 1997. Bioarchaeology: Interpreting behavior from the human skeleton. (Lasker GW, Mascie-Taylor CGN, Roberts DF, Foley RA, editors.). Cambridge: Cambridge University Press.

Lewis ME. 2007. The Bioarchaeology of Children: Perspectives from Biological and Forensic Anthropology. (Mascie-Taylor CGN, Little MA, Weiss KM, Foley RA, Jablonski NG, Strier KB, editors.). Cambridge: Cambridge University Press.

Mittler DM, and Van Gerven DP. 1994. Developmental, Diachronic, and Demographic Analysis of Cribra Orbitalia in the Medieval Christian Populations of Kulubnarti. Am. J. Phys. Anthropol. 93:287–297.

Moore K, Thorp S, and Van Gerven D. 1986. Pattern of dental eruption, skeletal maturation and stress in a Medieval Population from Sudanese Nubia. Hum. Evol. 1:325–330.

Morton RJ, and Lord W. 2002. Detection and recovery of abducted and murdered children: behavioral and taphonomic influences. In: Haglund W, Sorg M, editors. Advances in Forensic Taphonomy: Method, Theory and Archaeological Perspectives. New York: CRC Press. p 151–171.

Ortner DJ. 2003. Identification of Pathological Conditions in Human Skeletal Remains. 2nd ed. San Diego, CA: Academic Press.

Owsley DW, Marks MK, and Manheim MH. 1989. Human skeletal samples in the southern Great Plains. In: Hofman JL, Brooks RL, Hays JS, Owsley DW, Jantz RL, Marks MK, Manhein MH, editors. From Clovis to Comanchero: Archeological Overview of the Southern Great Plains. Fayetteville: Arkansas Archeological Survey.

Pearson MP. 2001. The Archaeology of Death and Burial. College Station: Texas A&M University Press.

Perry MA. 2005. Redefining Childhood through Bioarchaeology: Toward an Archaeological and Biological Understanding of Children in Antiquity. Archeol. Pap. Am. Anthr. Assoc. 15:89–111.

Salah eldin Mohamed Ahmed. 2004. The Merowe Dam Archaeological Salvage Project. In: Welsby DA, Anderson JR, editors. Sudan: Ancient Treasures. London: British Museum Press.

Sheridan SG, and Van Gerven DP. 1997. Female Biological Resiliency: Differential Stress Response by Sex in Human Remains from Ancient Nubia. Hum. Evol. 12:241–252.

Shinnie PL, and Shinnie M. 1978. Debeira West, a Medieval Nubian Town: University of Ghana Expedition to Nubia. Warminster: Aris and Phillips.

Spaulding J. 1995. Medieval Christian Nubia and the Islamic World: A Reconsideration of the Baqt Treaty. Int. J. Afr. Hist. Stud. 28:577–594.

Temkin O. 1991. Soranus' Gynecology. Baltimore: Baltimore: The Johns Hopkins University Press.

Trotter M. 1971. The density of bones in the young skeleton. Growth:221–231.

Van Gerven DP, Beck R, and Hummert JR. 1990. Patterns of Enamel Hypoplasia in Two Medieval Populations From Nubia's Batn El Hajar. Am. J. Phys. Anthropol. 82:413–420.

Van Gerven DP, Carlson DS, and Armelagos GJ. 1973. Racial History and Bio-Cultural Adaptation of Nubian Archaeological Populations. J. Afr. Hist. XIV:555–564.

Van Gerven DP, Sandford MK, and Hummert JR. 1981. Mortality and Culture Change in Nubia's Batn el Hajar. J. Hum. Evol. 10:395–408.

Van Gerven DP, Sheridan SG, and Adams WY. 1995. The Health and Nutrition of a Medieval Nubian Population: The Impact of Political and Economic Change. Am. Anthr. 97:468–480.

Vantini G. 1975. Oriental Sources Concerning Nubia. Heidelberg: Akademie der Wissenschaften.

Welsby DA, and Daniels CM. 1991. Soba: Archaeological Research at a Medieval Capital on the Blue Nile. London: The British Institute in Eastern Africa.

Welsby DA. 2002. The Medieval Kingdoms of Nubia. London: The British Museum Press.

Welsby DA. 2006. Settlement in Nubia in the Medieval Period. In: Caneva I, Roccati A, editors. Acta Nubica: proceedings of the X International Conference of Nubian studies, Rome, 9-14 September 2002. Rome: Istituto Poligrafico e Zecca dello Stato, Libreria dello Stato. p 21–43.

Wheeler SM. 2009. Bioarchaeology of Infancy and Childhood at the Kellis 2 Cemetery, Dakhleh Oasis, Egypt [dissertation]. [London, (ON)]: The University of Western Ontario.

Wheeler SM. 2012. Nutritional and Disease Stress of Juveniles from the Dakhleh Oasis, Egypt. Int. J. Osteoarchaeol. 22:219–234.

Wood JW, Milner GR, Harpending HC, and Weiss KM. 1992. The osteological paradox: Problems of inferring prehistoric health from skeletal samples. Curr. Anthr. 33:343–370.

Żurawski B. 2006. Nubian mortuary complex of the Christian Period. In: Caneva I, Roccati A, editors. Acta Nubica: proceedings of the X International Conference of Nubian studies, Rome, 9-14 September 2002. Rome: Istituto Poligrafico e Zecca dello Stato, Libreria dello Stato. p 171–187.

Introduction

Death is a transformative event, not just for individual but also for the society in which they live. The deceased has moved from the living to the dead, from an individual with agency to a memory that can be altered in the minds of those who remain. Thus the portrayal of the deceased is contingent on decisions made by the living, including if and how the person should be commemorated. While it may be impossible to know the exact rationale behind certain details, many clues from the grave can help to elucidate a society's cultural beliefs and practices. Religious rituals, status, funerary rites, social systems, and cultural beliefs may all influence the treatment of the deceased and various mortuary variables still evident long after the burial event.

Medieval Nubian Mortuary Practices

The medieval period in Nubia brought substantial changes to mortuary practices of the region related to conversion to Christianity. Prior to this, Nubian burial practices included the creation of elaborate subterranean and aboveground structures with extensive grave provisions. The conversion to Christianity ushered in a new mortuary tradition with simple internments lacking grave inclusions and marked by small monuments. Accompanying these material changes was also a new perspective on the afterlife. In the deeply rooted pagan eschatology, the corporeal human body traveled to the afterworld and thus needed preservation and provisions for the long journey (Adams, 1998, p 27). In Christian faith, however, it was the soul, rather than the body, that traversed to the afterlife (Adams, 1998, p 27; Żurawski, 2006, p 171). Furthermore, in the Christian view, everyone became equal at death and rewards in the afterlife were attainable for all individuals who followed the faith (Anderson, 2004, p 205; Żurawski, 2006, pp 171–172).

As a result, grave goods and monumental tombs for high status individuals disappeared as Christian rites came to be characterized by simple graves without inclusions (Anderson, 2004, p 205; Żurawski, 2006, p 172). These burial customs brought a greater degree of homogeneity to grave types in Nubia that had previously displayed significant status-based and regional variation (Welsby, 2002, p 48). The standard grave type across medieval Nubia became an east-west oriented, long and narrow grave containing a shrouded supine burial with head placed toward the west, marked by a small rectangular superstructure (Welsby, 1998, p 278; Anderson, 2004, p 205).

Despite canonical traditions, medieval Nubian cemeteries demonstrated a wide range of practices at the regional, site, and cemetery levels of analysis. These differences have been attributed to local and personal preferences as no systematic or consistent association has been observed between superstructures, substructures, body coverings or burial positions (Adams, 1998, p 36). Making sense of these differences is further complicated by the difficulty of establishing a chronology both within and between Christian cemeteries. The lack of grave inclusions, which are often used to establish chronology within and between cemeteries, contributes to the challenging nature of understanding medieval Nubian burial traditions.

A survey by Adams (1998) of 117 excavated Christian cemetery sites highlighted both the similarities and differences in mortuary practices across space and time in medieval Nubia. It was found that although Christian doctrines represented a drastic departure from past ideologies, this did not preclude the continued use of past burial grounds (Adams, 1998, p 19; Żurawski, 2006, p 174). The most uniform feature of Christian burials was the east-west orientation, however the actual orientation of graves varied considerably as the Nile was often used to indicate north (Adams, 1998, p 25). In Lower Nubia, graves were marked by mastabas, rectangular stone or brick constructions roughly the size of the grave and approximately 50 cm or higher (Adams, 1998, p 19). There was a large variety of mastaba forms including round-topped, flat-topped, cross-topped, and cruciform-topped (Adams, 1998, pp 20–21). At the Lower Nubian site of Meinarti, more than twenty different types were found during investigation of the cemetery (Adams 2001, p. 74). Pavements, flat arrangements of stone or mud-brick, were the preferred grave marker further south (Adams, 1998, p 20). A common feature associated with mastabas and some brick pavements were lamp boxes, two vertical bricks supporting a third horizontal brick.

The substructure of graves also displayed variation with three general types of grave shafts (Fig. 3.1). The most common form was the slot grave, a simple rectangular pit to inter the body (Adams, 1998, p 26). Also common in some regions were side-niche and bottom-niche graves. Both of these forms allowed for the covering of bodies with slabs of rock or bricks. Side-niche graves included an undercut area on one side into which half of the deceased's body was inserted while the remainder was in the main shaft (Adams, 1998, pp 26–27). In many cases, bodies in this type of grave were covered with a diagonal slab, while horizontally placed slabs covered graves with bottom niches (Adams, 1998, pp 26–27). These methods of body covering are thought to be a continuation of the pagan belief that the corporeal body should be protected (Adams, 1998, p 27; Żurawski, 2006, p 172). In its most rudimentary form, only an individual's head was protected, typically with three stones or bricks—two vertically placed on either side of the head with a third across the face (Adams, 1998, p 28). Even fetuses and newborns were afforded bodily protection as they were typically buried in pottery vessels or cooking pots (Shinnie and Shinnie, 1978, p 107; Adams, 1998, p 28; Welsby, 2002, p 63).

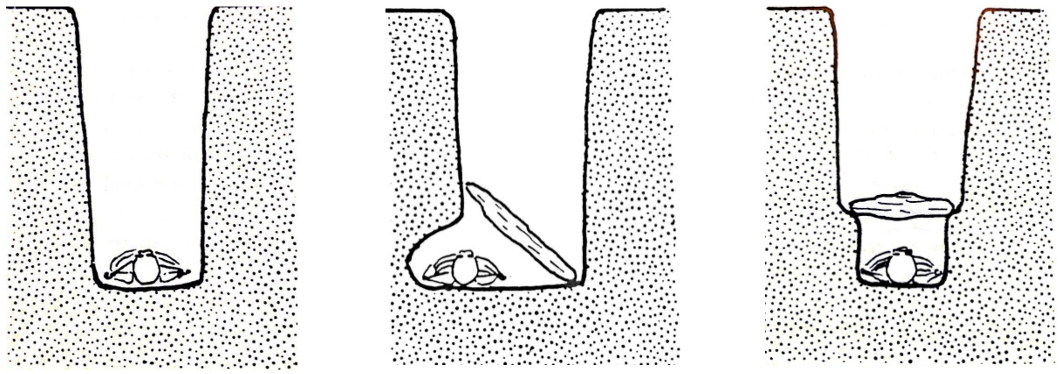

Figure 3.1: Grave shaft types from left: slot, side-niche, and bottom-niche reproduced from Adams (1998, p 26).

Bodies in medieval Nubian cemeteries were typically shrouded and placed in the grave in an extended supine position with head to the west facing upwards, hands near the hips, together on the pelvis or crossed on the chest (Adams, 1998, p 28; Welsby, 2002, p 48). Individuals were also buried with their head tilted to the left of right, with their whole body on its side, or with various hand and leg positions. Individuals were sometimes buried in reversed orientation with their head to the east or, more rarely, face down in the grave. The potential meaning of such acts is unknown, but it has been postulated that ventral burial may be a sign of condemnation, but their location within the main cemetery adjacent to graves with typical positioning complicates this interpretation (Adams, 1998, p 28; Welsby, 2002, p 49). Alternatively, it is possible that the act of shrouding obscured features of the individual and they were accidentally placed in a prone rather than dorsal position.

Mis Island Mortuary Practices

The island of Mis was located in Fourth Cataract of the Nile with evidence of inhabitation from pre-Christian through modern times. Although a number of sites were identified, this work focuses on two Christian cemeteries on the northeast end of the island. The cemeteries 3-J-10 and 3-J-11 were excavated under the direction of Andrew Ginns in two field seasons, 2005-2006 and early 2007 (Ginns, 2006, p 13, 2007, p 29). Cemetery 3-J-10 was located approximately 300 m northwest of the Christian church on the island and contained 262 recognizable medieval grave monuments (Ginns, 2006, p 17, 2010 a, p I). The perimeter of the cemetery was defined by bedrock outcrops on its northern and western extremities and was contiguous with Muslim burials on its eastern border (Ginns, 2006, p 17). All graves were aligned east-west and were believed to be from a single prolonged phase of cemetery use (Ginns, 2010 a, p I). A total of 126 individuals from across the cemetery were disinterred (Fig. 3.1), and of these 15 were unmarked due to disturbance from later burials or grave monument destruction by erosion or human disturbance (Ginns, 2010 a, p I). Ginns (2007, p 20, 2010 a, p I) reported two basic types of inhumations (Ginns, 2007, p 20, 2010 a, p I):

1. Supine individuals with rocks or mud-bricks in a post and lintel arrangement covering the head.
2. Individuals either supine, on sides, or prone with no rocks surrounding their head.

In addition, there were two main types of monuments marking graves (Ginns, 2007, p 20, 2010 a, p I):

1. FF03a: a rectangle of a single row of stone blocks filled with earth and gravel (see Fig. 3.4) (Borcowski and Welsby, 2009, p 9).

2. FF03c: a rectangle of multiple rows of stone blocks filled with earth and gravel (see Fig. 3.4) (Borcowski and Welsby, 2009, p 9).

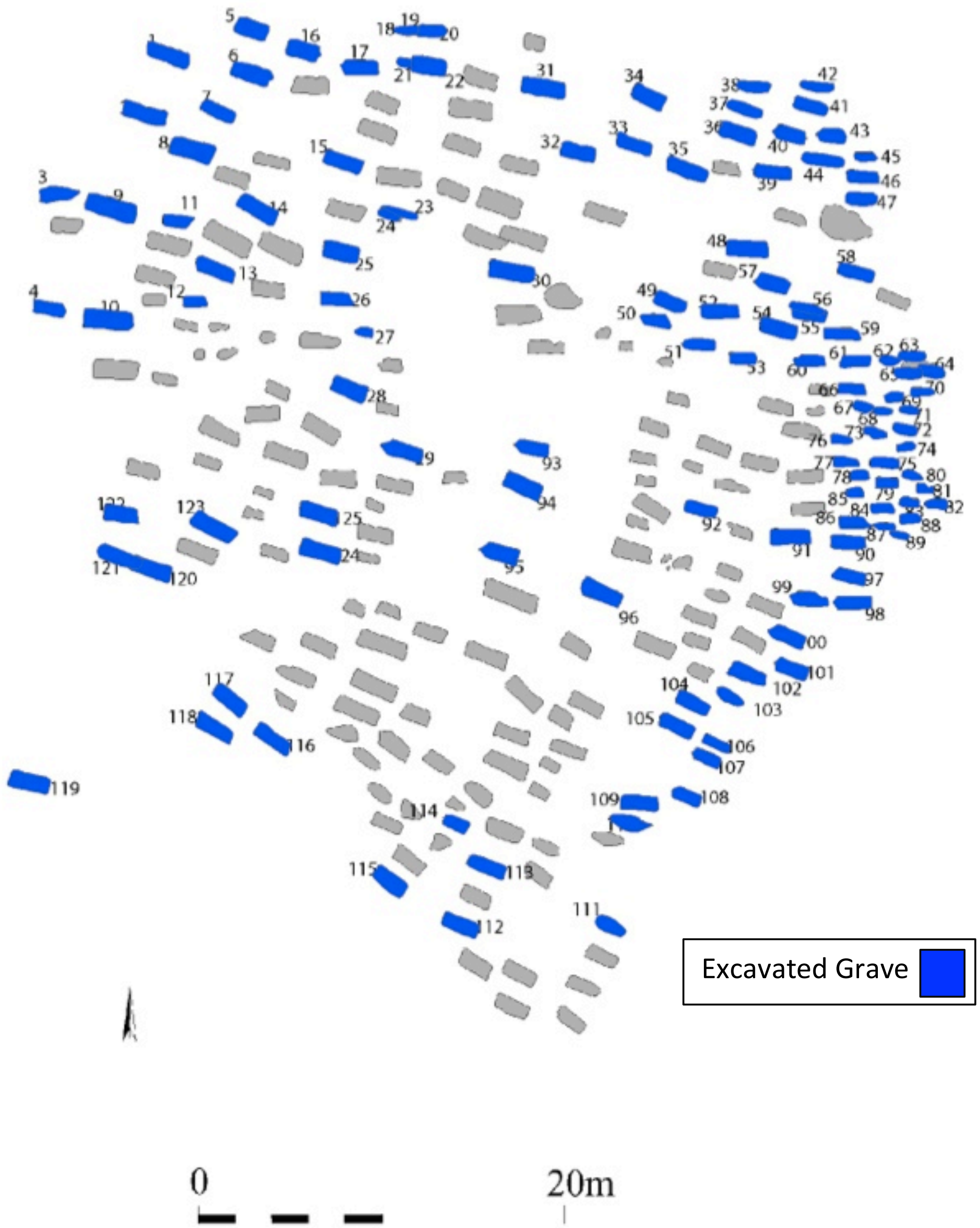

Figure 3.2: Spatial distribtuion of excavated graves at cemetery 3-J-10 (Soler 2012).

Cemetery 3-J-11 was the largest cemetery located on the island's northern extremity. Despite substantial disturbance by agricultural activity, this cemetery contained more than 500 grave monuments of various types aligned approximately east-west (Ginns, 2006, p 17, 2010 b, p I). A total of 259 complete individuals were excavated (Fig. 3.2) with an additional 29 individuals represented by partial remains from disturbed graves (Ginns, 2010 b, p I).

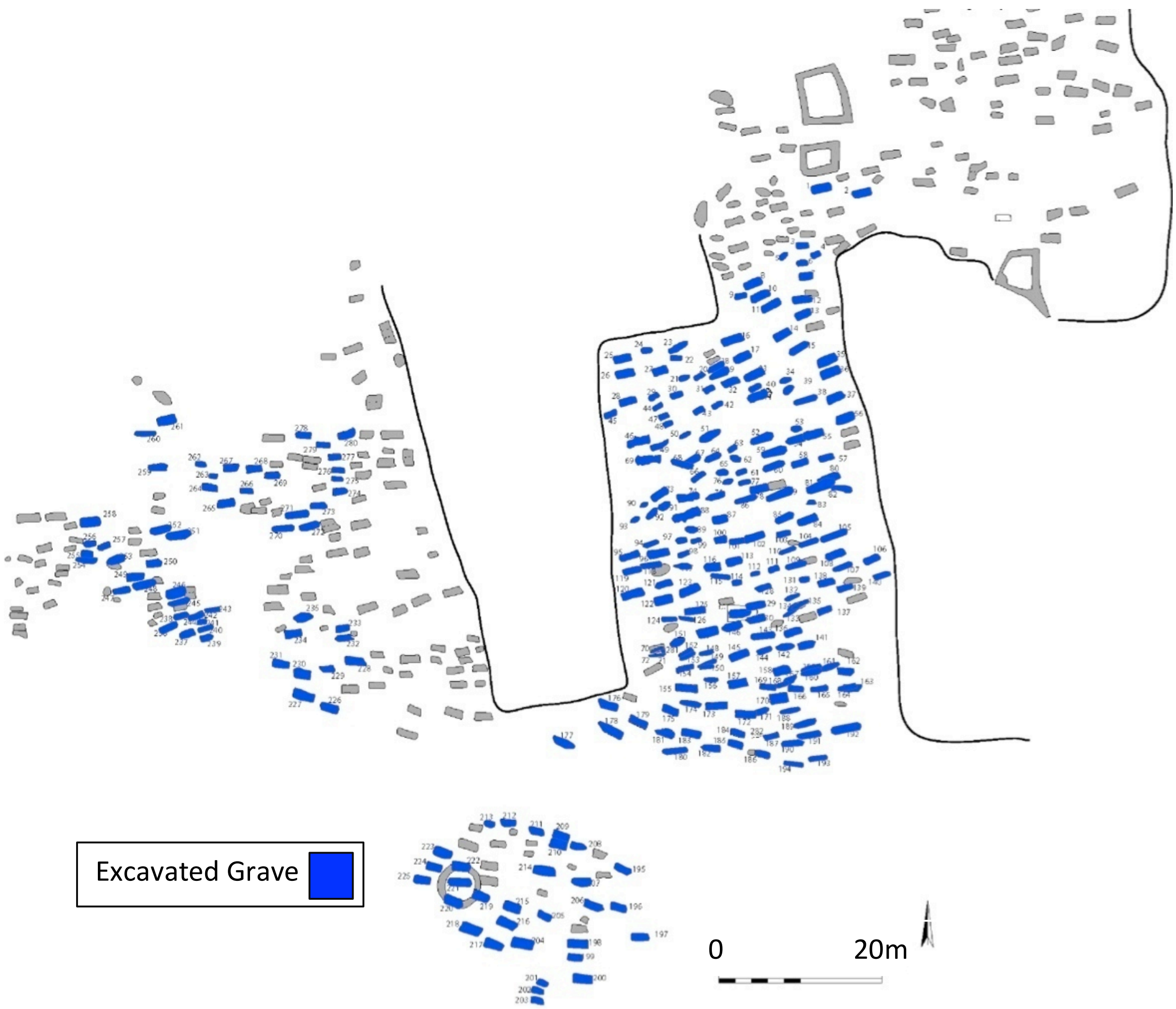

Figure 3.3: Spatial distribution of excavated graves at cemetery 3-J-11 (Soler 2012).

It has been hypothesized that this cemetery represented three distinct phases of use. Phase I included two disturbed later Kushite burials located in the southeastern region of the cemetery. One of these was represented only by grave goods while the other was a north-south oriented subterranean chamber with a large amount of grave inclusions (Ginns, 2010 b, p I). Phase II included narrow graves covered with flat stone slabs and featured interments positioned on either the back or side along with the frequent inclusion of ceramic vessels (Ginns, 2010 b, p II). None of the Phase II graves were marked by monuments and the majority had been disturbed by subsequent burials (Ginns, 2010 b, p II). Phase III was the last phase of use and contained three general grave types (Ginns, 2010 b, p II):

1. Graves with supine individuals with heads protected by rocks or mud-bricks.
2. Graves with supine or individuals placed on their side with no head protection.
3. Graves sealed or partially sealed with rocks over supine individuals.

The only surviving grave monuments in cemetery 3-J-11 were from Phase III burials, and included:

1. FF03a: as described above.
2. FF03c: as described above
3. FF02f (X11): stone slabs placed as a pavement over grave cut (Borcowski and Welsby, 2009, p 6).
4. X10: single row of mud-brick pavement (Ginns, 2010 b, pp III–IV).

Materials

The materials utilized in this study included the archaeological data of 405 excavated medieval graves (Figure 3.2 and 3.3) of individuals spanning the ages from fetal to over 50 years (see Table 3.1). Since the focus of this study was Christian burial practices, the graves pre-dating this period were not included in the analysis. The current author completed the assessment of age

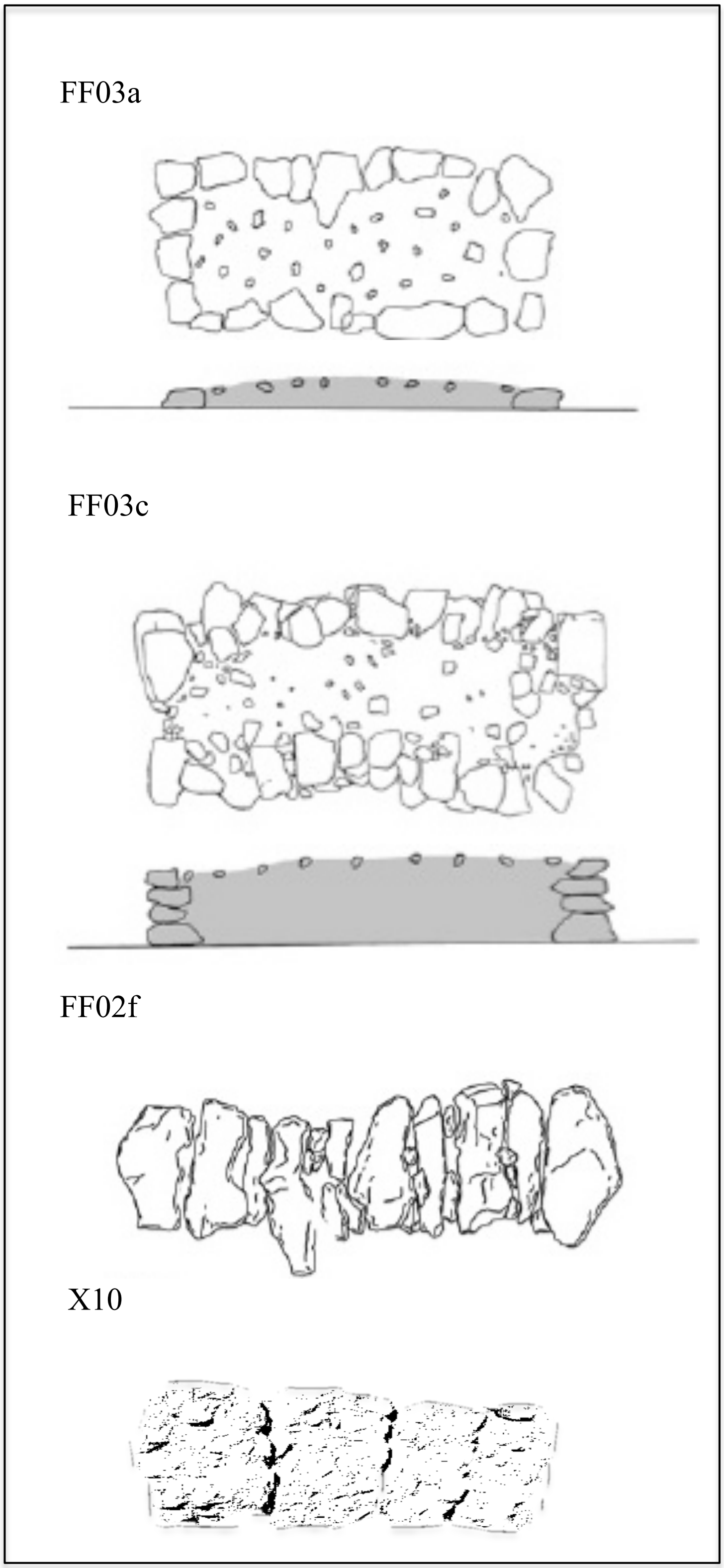

Figure 3.4: The grave monument types at Mis Island adapted from Borcowski and Welsby (2009, pp 8–9) and Ginns (2010 b, p IV).

for individuals less than 20 years, while Dr. Angela Soler assessed the ages for individuals 20 years of age and older (Soler, 2012). Individuals in the "Adult" category were found to be skeletally mature, but further refinement of age could not be accomplished. The single individual in the "Unknown" category had mortuary data available but was not present in the skeletal materials analyzed and no indication of age was present in the excavation documents. The mortuary data was compiled by Dr. Angela Soler from draft reports of cemetery 3-J-10 and 3-J-11 by the archaeological director, Andrew Ginns (2010 a; b). The current author contributed additional information and slightly modified the variables for the purposes of this examination.

Table 3.1. Ages of individuals utilized in mortuary analysis.

MATERIALS	**3-J-10**		**3-J-11**		**COMBINED**	
	n	%	*n*	%	*n*	%
Infant (<3 yrs)	24	19.0%	42	15.1%	66	16.3%
Child (3-12 yrs)	22	17.5%	73	26.2%	95	23.5%
Adolescent (12-20 yrs)	5	4.0%	22	7.9%	27	6.7%
Young Adult (20-35 yrs)	16	12.7%	37	13.3%	53	13.1%
Middle Adult (35-50 yrs)	39	31.0%	60	21.5%	99	24.4%
Older Adult (>50 yrs)	13	10.3%	33	11.8%	46	11.4%
Adult (>20 yrs)	7	5.6%	11	3.9%	18	4.4%
Unknown	0	0.0%	1	0.4%	1	0.2%
TOTAL	**126**	**100%**	**279**	**100%**	**405**	**100%**

Methods

Each excavated grave was assessed for a number of mortuary variables, including type of grave monument, body covering, body orientation, body position, head direction, leg position, grave inclusions, and personal adornment. These variables were mapped in ArcGIS to assess spatial relations within each cemetery. Variables from skeletal analyses, including age and pathology, were also mapped to assess spatial relations. This study did not include the analysis of sex because it was included in a previous analysis by Soler (2012). Variables included in this study are further discussed below.

Mortuary Variables

Grave Monument

The grave monument represents the superstructure, or the above ground demarcation of the burial. At Mis Island, monuments observed included mastaba types FF03a, FF03c, FF02f, and X10 (see Figure 3.3). If a superstructure did not classify into one of these categories it was demarcated “Other”. If excavation notes reported the monument had been denuded, these were considered missing data and were not included in the analysis. Alternatively, a grave with no sign of a monument was reported as absent.

Body Covering

Body covering was the positioning of stones, bricks, or a combination of the two over the deceased’s head or body during internment. At cemeteries 3-J-10 and 3-J-11, coverings were coded as body covering, head covering, absent, or disturbed. Adams (1998, p 36) found from his meta-analysis of medieval cemeteries a general change from stone to brick in both superstructures and body coverings at the end of the Early Christian period (*c*. AD 850). Thus, head coverings were further divided into three types based on materials used, including stone, mud-brick, and a combination of both stone and mud-brick.

<u>Body Orientation</u>

Body orientation concerns the cardinal directions of the long axis of the grave in which an individual was interred. Christian burial practices required burials to be aligned east-west with heads placed to the west. While this was generally followed at Mis Island, there were individuals with reversed body positions. Body orientation was assessed as west (normal) or east (reversed).

<u>Body Position</u>

Body position refers to how an individual was positioned within the grave. While interments on the back, or supine, are considered the pervasive Christian practice (Adams, 1998, p 28), it is not uncommon to find individuals positioned in a variety of ways including on the side or face down at Mis Island and in other medieval Nubian cemeteries. Body position for this analysis was coded as supine, right side, left side, prone, or disturbed.

<u>Head Direction</u>

Head direction describes the direction an individual is facing within the grave. Adams (1998, p 28) found that variability in head direction was common in medieval cemeteries south of the Second Cataract, with a large majority turned towards the north. The direction a head was facing was assessed for individuals buried in the supine position at Mis Island. Heads that remained straight (not turned to either side) were scored as “Up”, and heads turned to the side were assessed as turned to either the “North” or “South”.

Leg Position

Leg position refers to the degree of contraction displayed by the lower appendages. The position of legs in medieval Christian cemeteries is generally extended, a significant change from the flexed position common in pre-Christian practices. Leg position was assessed as one of four categories. “Extended,” described legs that were completely straight. “Slight flex,” indicated that the legs showed a slight bend, sometimes caused by a grave cut of inadequate length. “Flexed,” denoted legs that were bent significantly and intentionally. Lastly, “Both,” was used to distinguish individuals in which one leg was extended and the other was flexed.

Grave Inclusions

Grave inclusions describe items purposefully placed in a grave with the decedent. While grave goods were common features of pagan burial contexts, proper Christian burials were not to include such items. Grave inclusions were simply scored as present or absent for burials that did not show signs of disturbance.

Personal Adornment

Personal adornment refers to any artifacts that may have been worn by the deceased when they were interred. For the Mis Island sample, rings, necklaces, beads, or other jewelry items were considered personal adornment. This variable was scored as present or absent for undisturbed burials.

Skeletal Variables

Variables assessed from skeletal analysis included age and disease activity. Age estimates were divided by the age cohorts suggested by Buikstra and Ubelaker (1994). The activity of cribra orbitalia, porotic hyperostosis, and periostitis lesions were mapped by grave to assess whether spatial clustering occurred. Activity included active lesions, healed lesions, or mixed lesions where characteristics of both active and healed were present.

Statistical Analysis

Pearson chi-square tests were utilized to assess the significance of associations between two variables, with $p < .05$ indicating a statistically significant association. In cases where more than 20% of the cells had expected counts less than five, a Fisher's exact test or Monte Carlo method was used to assess significance. A symmetric measure, *phi* for 2x2 contingency tables and Cramer's V for larger tables, was used to assess the strength of association for significant results. A measure of ±0.1 indicates a small association, ±0.3 a medium, and ±0.5 a large strength of association (Field, 2009, p 698). Furthermore, if chi-square results were significant, contingency tables were evaluated for significant standardized residuals. These residuals represent a z score and measure the error between the model's prediction and the observed data, or where the significance detected in the chi-square occurred (Field, 2009, p 699). Standardized residuals are significant at the $p < .05$ level when they are ±1.96, the $p < .01$ level when they are ±2.58, and the highly significant $p < .001$ level when they reach ±3.29.

Results: Cemetery 3-J-10

Cemetery 3-J-10 included individuals of all ages from fetal to adults over 50 years of age. Notably, there was a discernible cluster of subadult burials on the eastern extremity of the cemetery (Fig. 3.5). This area of 29 graves contained mostly subadult infants and children, with an average age of approximately 3 years. While the majority (68.9%) fell into the infant category, only three individuals were above the age of five. Burial 75 was estimated to be between six and eight years old, Burial 66 between ten and thirteen, and Burial 61 between eleven and thirteen years of age. As Figure 3.5 shows, Burials 61 and 66 are on the periphery of this cluster and may not represent true members. If these two burials are eliminated, the average age decreases to approximately 2.5 years. Furthermore, of all of the infants excavated at cemetery 3-J-10 (n = 24), 83.3% were located in this burial cluster. The only excavated infant graves outside of the eastern cluster were Burial 24, 38, 110, and 121. Except for Burial 24, these graves were all located at the periphery of the cemetery.

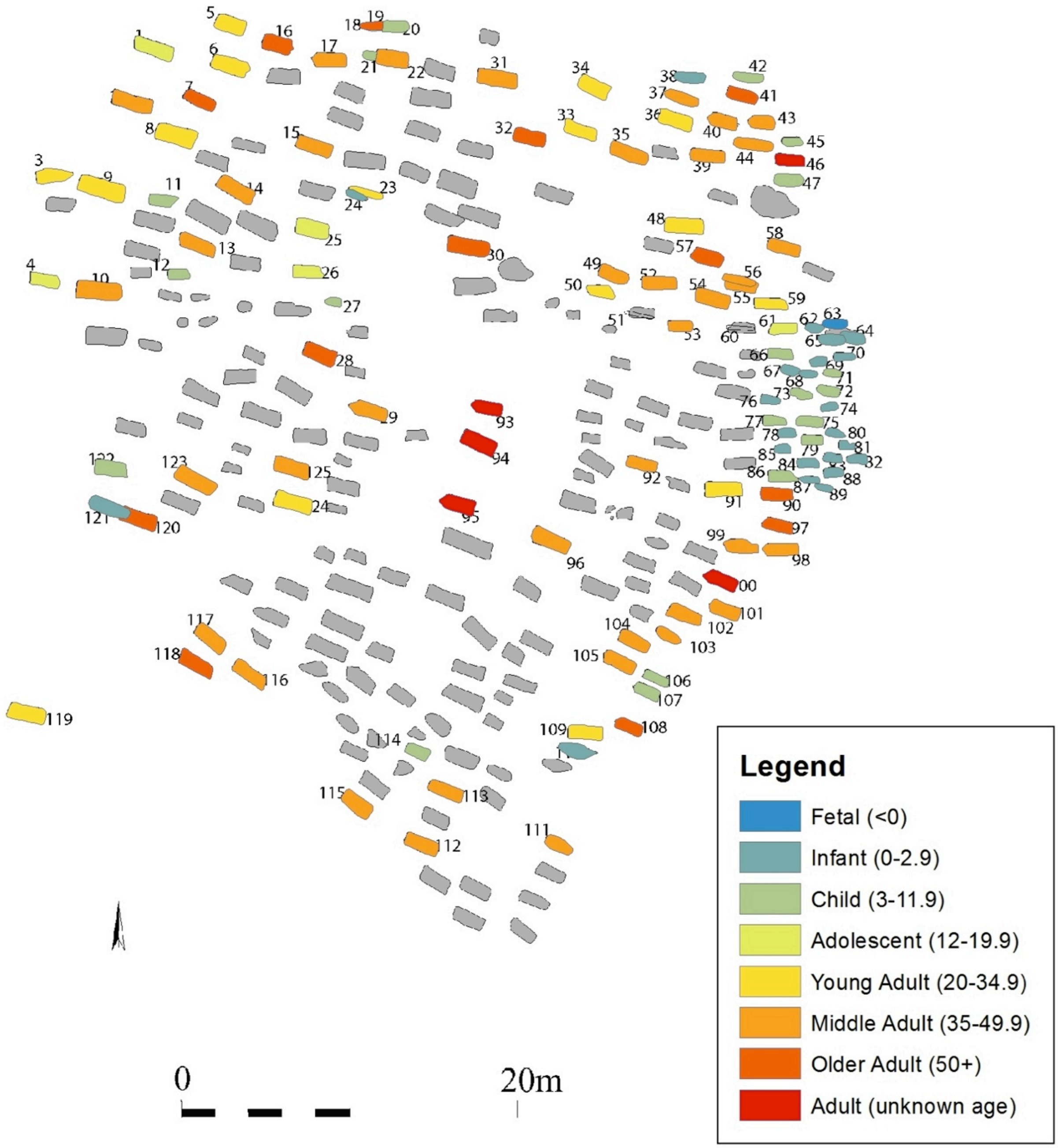

Figure 3.5: Spatial distribution of age cohorts at cemetery 3-J-10.

Grave Monument

Cemetery 3-J-10 had FF03a and FF03c mastabas. Figure 3.6 shows the distribution of monument types throughout cemetery 3-J-10. The cluster of subadults on the eastern edge of the cemetery had monuments of the FF03a type, while the FF03c type was distributed throughout. The FF03c superstructures were the most prevalent comprising 72.2% (n = 115) of the undisturbed burials (Table 3.2). When grave monuments are sorted by age (Table 3.2) it is clear that FF03a monuments were only found marking the graves of infants and children. Furthermore, these youngest age categories more commonly lacked a grave monument altogether. While lack of monument could be due to taphonomic factors, the relatively high prevalence in these particular age categories suggests an intentional mortuary practice. This was supported statistically as a Fisher's exact test indicated a highly significant association between age and monument type ($p < .001$). Significant standardized residuals occurred in the infant category for monument absence ($z = 3.2$), FF03a monument ($z = 4.4$) and a highly significant negative association with FF03c monuments ($z = –3.4$). The child cohort was also significantly associated with FF03a monuments ($z = 2.3$) and middle adults were negatively associated with FF03a monuments ($z = –2.5$).

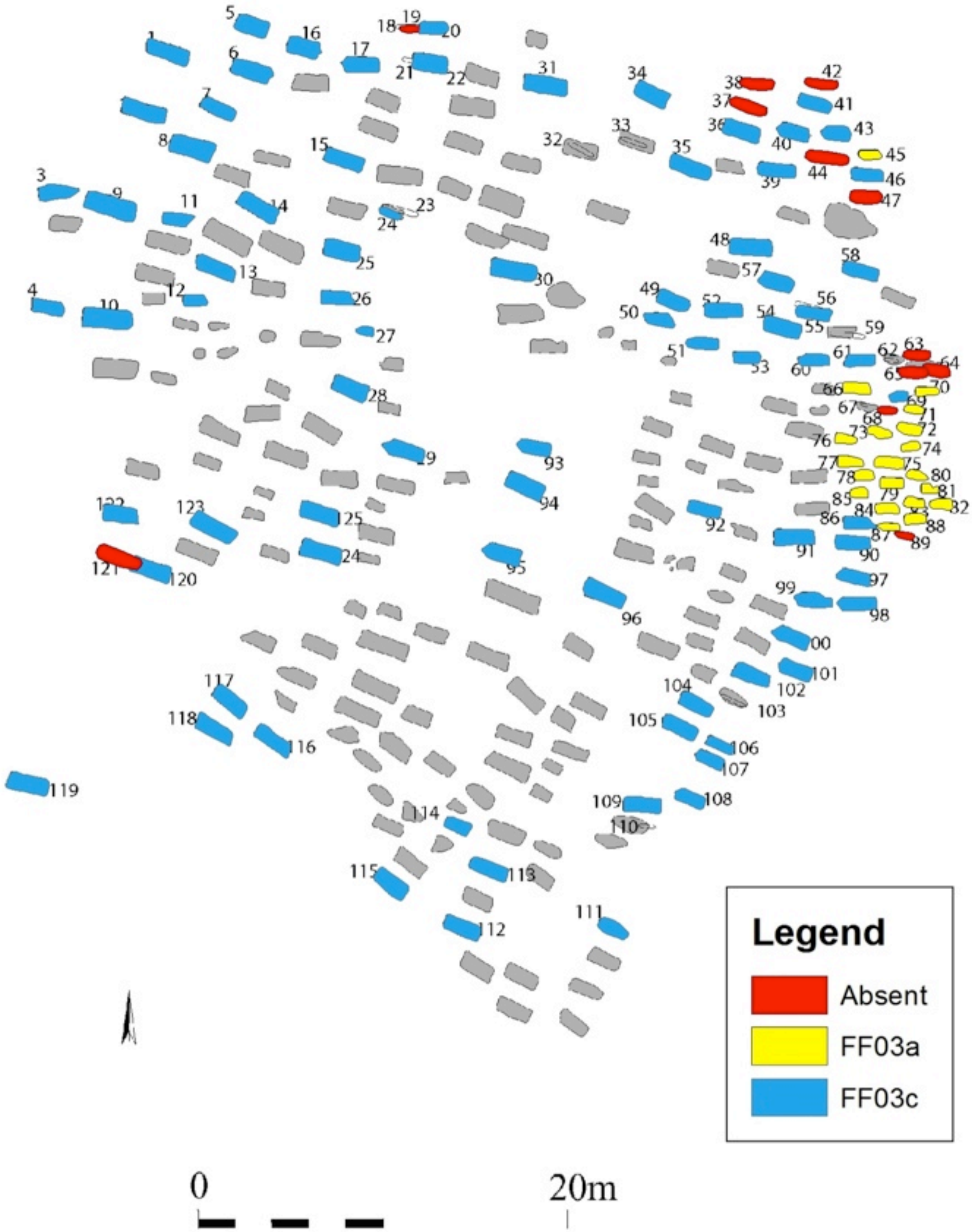

Figure 3.6: Spatial distribution of grave monument types at cemetery 3-J-10.

Table 3.2: Grave monuments by Standards age categories for 3-J-10.

3-J-10 Monument	Absent		FF03a		FF03c		TOTAL
	#	%	#	%	#	%	*n*
Infant (<3 yrs)	7	33.3%	12	57.1%	2	9.5%	21
Child (3-12 yrs)	3	14.3%	8	38.1%	10	47.6%	21
Adolescent (12-20 yrs)	0	0.0%	0	0.0%	5	100%	5
Young Adult (20-35 yrs)	0	0.0%	0	0.0%	13	100%	13
Middle Adult (35-50 yrs)	2	5.4%	0	0.0%	35	94.6%	37
Older Adult (>50 yrs)	0	0.0%	0	0.0%	11	100%	11
Adult (>20 yrs)	0	0.0%	0	0.0%	7	100%	7
TOTAL	**12**	**10.4%**	**20**	**17.4%**	**83**	**72.2%**	**115**

Body Covering

The practice of protecting the body of the deceased within the grave was found at cemetery 3-J-10, but only in the form of head coverings. Figure 3.7 illustrates the head covering types found throughout the cemetery. Again, a clear pattern was discernible in the child and infant burial group, with no head or body covering. This was also evident in adult and subadult graves along the cemetery's periphery. Throughout the cemetery, the graves with head coverings were mostly commonly comprised of stone. Table 3.3 shows the type of head covering by age. Overall, head protection by stones was the most prevalent (50.8%, n = 126), with the absence of head covering only slightly less common (46.8%). Only one grave (Burial 35, a middle adult) had a combination of stone and mud-bricks protecting the head and two others (Burials 8, a young adult, and 10, a middle adult) utilized only mud-brick. Assessment by age showed that

95.8% ($n = 24$) of infants did not have any type of head or body covering and 63.6% ($n = 22$) of children also lacked corporeal protection. For older age cohorts, the majority of individuals had head coverings comprised of stones. A Monte Carlo test showed a highly significant ($p < .001$) association between age and body covering variables. Standardized residuals were significant in the infant category with a positive association with absence of head or body covering ($z = 3.5$) and negative association with presence of covering ($z = -3.3$). In fact, the only infant with any type of head covering was Burial 110 in the southeastern perimeter of the cemetery. This was also one of the few infants excavated outside of the eastern cluster and the use of head covering could indicate chronological difference or personal preference. Further investigation into bodily covering showed no significant association between materials used in head protection and age ($p = .920$).

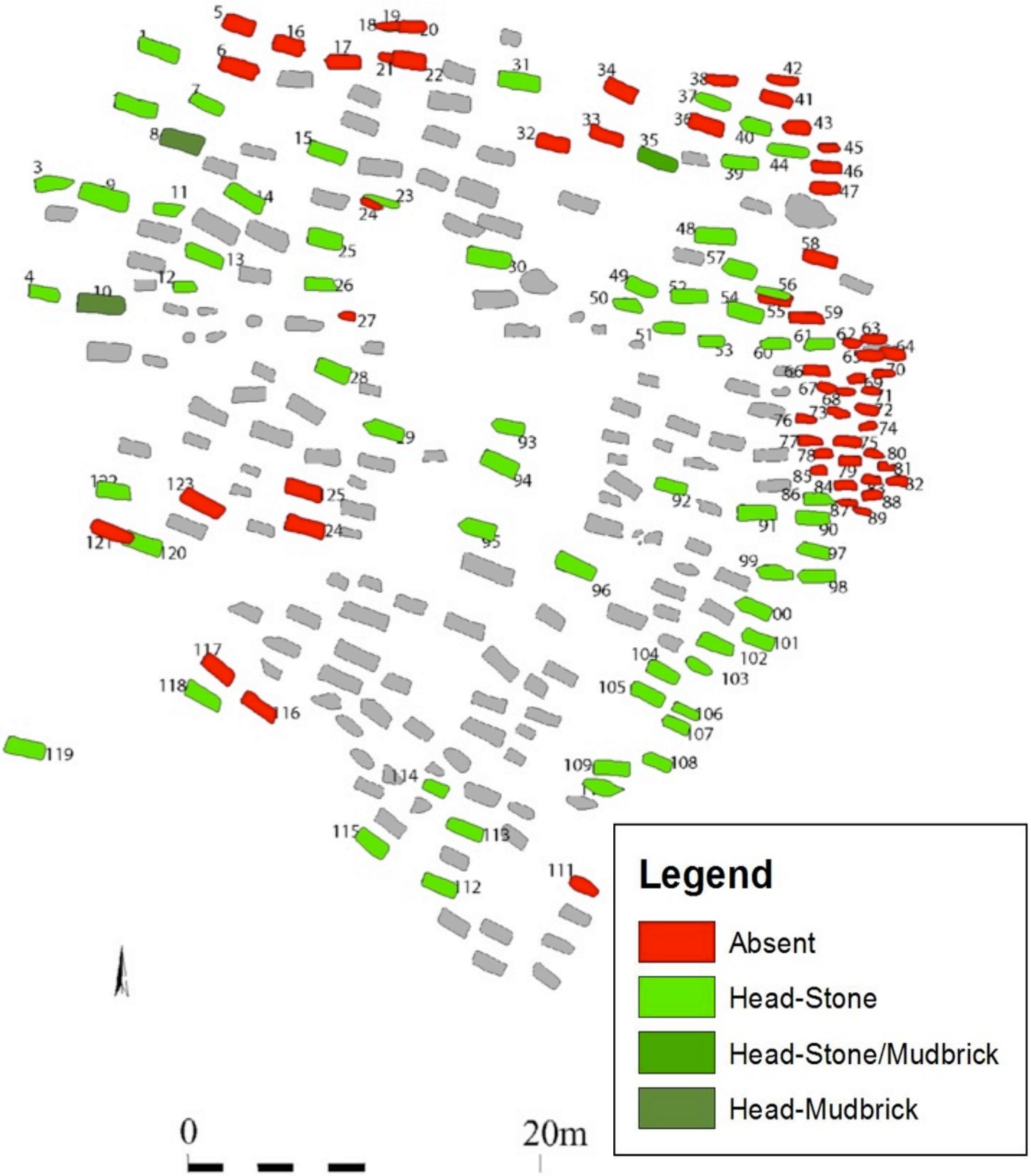

Figure 3.7: Spatial distribution of body covering type at cemetery 3-J-10.

Table 3.3: Body covering by Standards age category for 3-J-10.

3-J-10 Covering	Absent		Body		Head/Stone		Head/Both		Head/Brick		TOTAL
	#	%	#	%	#	%	#	%	#	%	*n*
Infant (<3 yrs)	23	95.8%	0	0.0%	1	4.2%	0	0.0%	0	0.0%	24
Child (3-12 yrs)	14	63.6%	0	0.0%	8	36.4%	0	0.0%	0	0.0%	22
Adolescent (12-20 yrs)	0	0.0%	0	0.0%	5	100%	0	0.0%	0	0.0%	5
Young Adult (20-35 yrs)	7	43.8%	0	0.0%	8	50%	0	0.0%	1	6.3%	16
Middle Adult (35-50 yrs)	10	25.6%	0	0.0%	27	69.2%	1	2.6%	1	2.6%	39
Older Adult (>50 yrs)	4	30.8%	0	0.0%	9	69%	0	0.0%	0	0.0%	13
Adult (>20 yrs)	1	14.3%	0	0.0%	6	86%	0	0.0%	0	0.0%	7
TOTAL	**59**	**46.8%**	**0**	**0.0%**	**64**	**50.8%**	**1**	**0.8%**	**2**	**1.6%**	**126**

Body Orientation

Only three individuals at cemetery 3-J-10 had reversed orientation with heads to the east. They were all infants buried at the eastern edge of the cemetery in the cluster of subadult burials. Despite the unusual orientation of these three, there are no other mortuary factors distinguishing these burials from those adjacent.

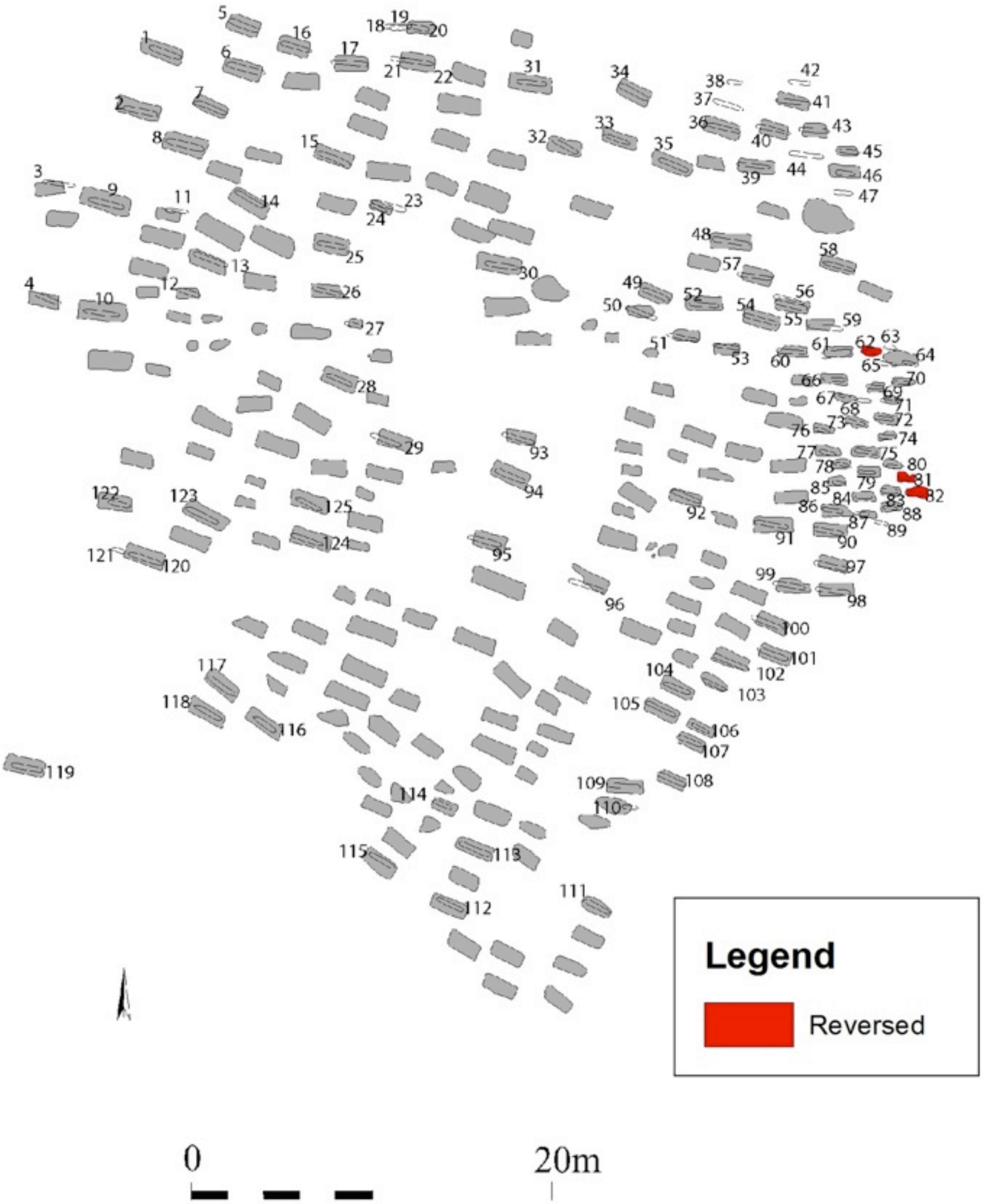

Figure 3.8: Spatial distribution of reversed body orientation at cemetery 3-J-10.

Body Position

At cemetery 3-J-10, individuals were buried in a supine position, on their left or right side, or in rare cases in a prone, or facedown, position (Fig. 3.9, Table 3.4). While supine burials were distributed throughout the cemetery, side burials were found near the cemetery's perimeter. The eastern subadult cluster contained examples of each of the body positions showing the greatest variety within the cemetery. Table 3.4 shows, the majority of individuals (65.8%, n = 120) were laid in a supine position, but 27.5% were interred on their side, with the majority on the right, facing south (78.8%, n = 33). Burials on the left side were only observed in infants and children, but of any burial position infants were most often (56.5%, n = 23) interred on their right side. Prone burials were also restricted to the infant and child age categories. A Monte Carlo test showed a highly significant association between age and body position ($p < .001$). Infants had a highly significant association with burial on the right side ($z = 3.6$) and a significant negative association with supine burial ($z = –2.9$). Children showed significant associations with both burial on the left side ($z = 2.5$) and prone burial ($z = 3.0$).

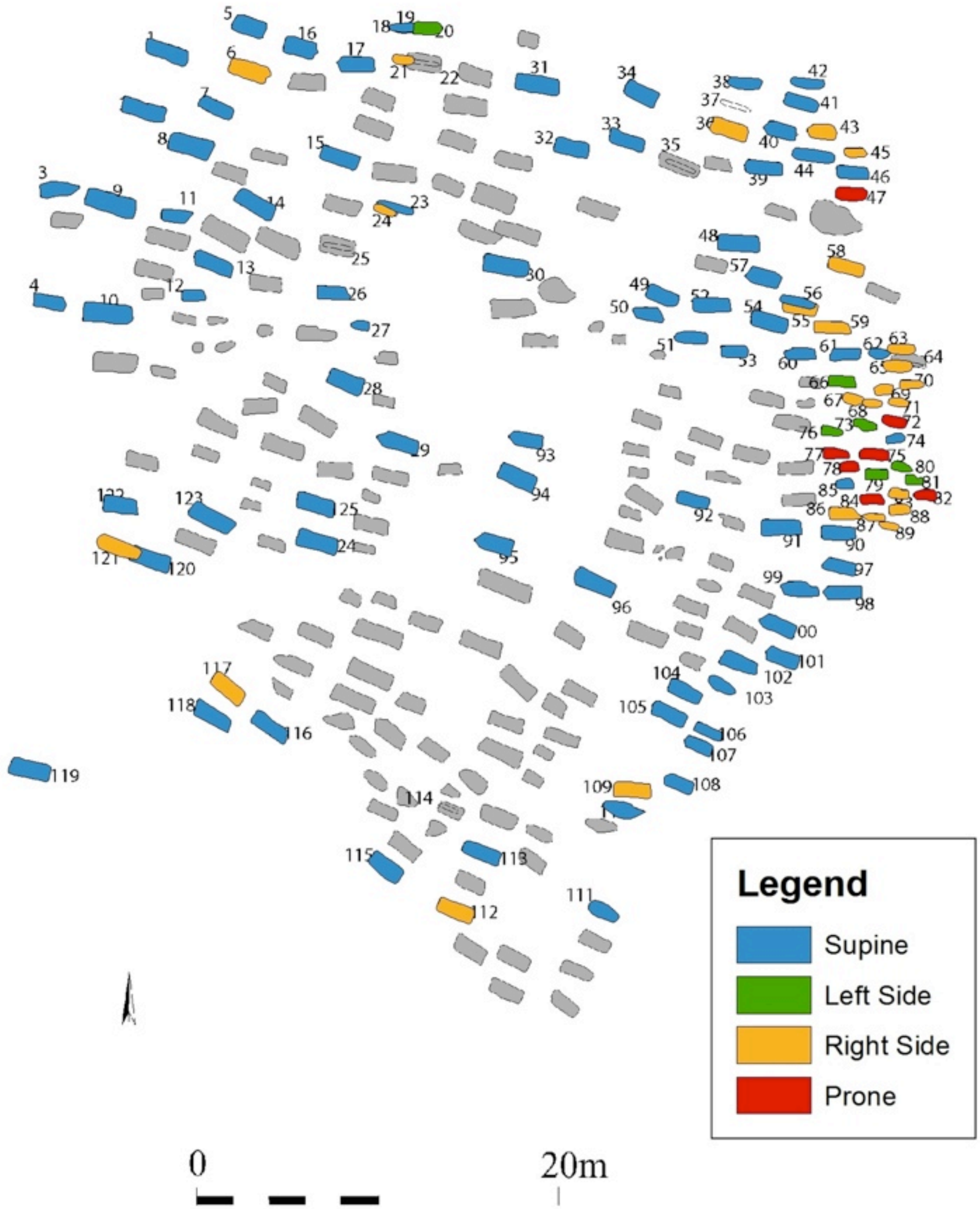

Figure 3.9: Spatial distribution of body position at cemetery 3-J-10.

Table 3.4: Body position by Standards age category for 3-J-10.

3-J-10 Body Position	Supine		Left Side		Right Side		Prone		TOTAL
	#	%	#	%	#	%	#	%	*n*
Infant (<3 yrs)	4	17.4%	3	13.0%	13	56.5%	3	13.0%	23
Child (3-12 yrs)	8	38.1%	4	19.0%	4	19.0%	5	23.8%	21
Adolescent (12-20 yrs)	4	100%	0	0.0%	0	0.0%	0	0.0%	4
Young Adult (20-35 yrs)	12	75%	0	0.0%	4	25.0%	0	0.0%	16
Middle Adult (35-50 yrs)	31	86.1%	0	0.0%	5	13.9%	0	0.0%	36
Older Adult (>50 yrs)	13	100%	0	0.0%	0	0.0%	0	0.0%	13
Adult (>20 yrs)	7	100%	0	0.0%	0	0.0%	0	0.0%	7
TOTAL	**79**	**65.8%**	**7**	**5.8%**	**26**	**21.7%**	**8**	**6.7%**	**120**

Head Direction

Head direction for supine burials at cemetery 3-J-10 is displayed in Figure 3.10 and Table 3.5 and included facing upwards (54.2%, n = 83), heads turned to the north (22.9%), and heads turned to the south (22.9%). Each head direction appeared to be spatially distributed throughout the cemetery with no areas favoring a particular manner of head placement (Figure 3.10). Head direction by age group was also investigated. The dominant practice for supine individuals was direction of head facing upwards (54.3%, n = 81). Beyond this, however, there did not appear to be any pattern to how an individual's head was placed during interment. A Fisher's exact test also indicated that there was no significant association between head direction and age (p = .534).

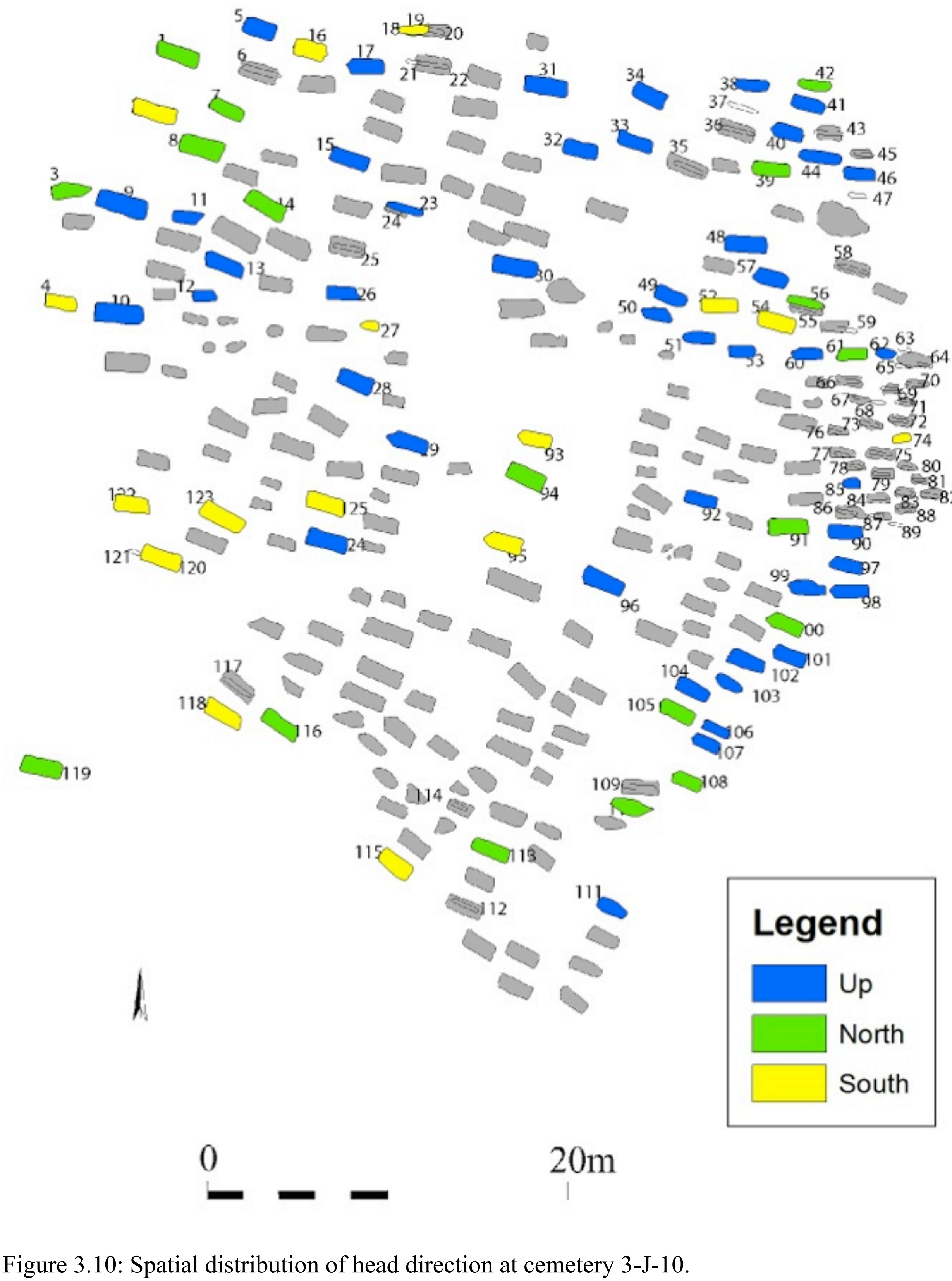

Figure 3.10: Spatial distribution of head direction at cemetery 3-J-10.

Table 3.5: Head direction by Standards age categories for 3-J-10.

3-J-10 Head Direction	Up		North		South		TOTAL
	#	%	#	%	#	%	*n*
Infant (<3 yrs)	2	40.0%	1	20.0%	2	40.0%	5
Child (3-12 yrs)	4	44.4%	2	22.2%	3	33.3%	9
Adolescent (12-20 yrs)	1	25.0%	2	50.0%	1	25.0%	4
Young Adult (20-35 yrs)	8	66.7%	4	33.3%	0	0.0%	12
Middle Adult (35-50 yrs)	19	61.3%	6	19.4%	6	19.4%	31
Older Adult (>50 yrs)	7	53.8%	2	15.4%	4	30.8%	13
Adult (>20 yrs)	3	42.9%	2	28.6%	2	28.6%	7
TOTAL	**44**	**54.3%**	**19**	**23.5%**	**18**	**22.2%**	**81**

Leg Position

Leg positions at 3-J-10 varied from the traditional Christian extended position to flexed, with some individuals displaying only a slight flex and others with both, one leg extended and the other flexed (Figure 3.11, Table 3.6). The most variety of leg positions was observed in the eastern cluster of subadults. Outside of this area, however, there were few individuals without extended legs. The vast majority of individuals were interred with extended legs (75.2%, n = 125), followed by slightly flexed legs (14.4%). A slightly flexed position may have resulted from a grave cut of inadequate length, but the majority of individuals with slightly flexed legs (77.8%, n = 18) were infants or children. Furthermore, most (72.2%) of the individuals with slightly flexed legs were buried on their sides, so this may have been a function of the body position rather than intentional placement. A Monte Carlo test showed that differences by age were significant ($p < .001$) and the infant group had significant associations with slight flex (z = 3.7), both (z = 2.9) and a negative relation to extended leg position (z = –2.7).

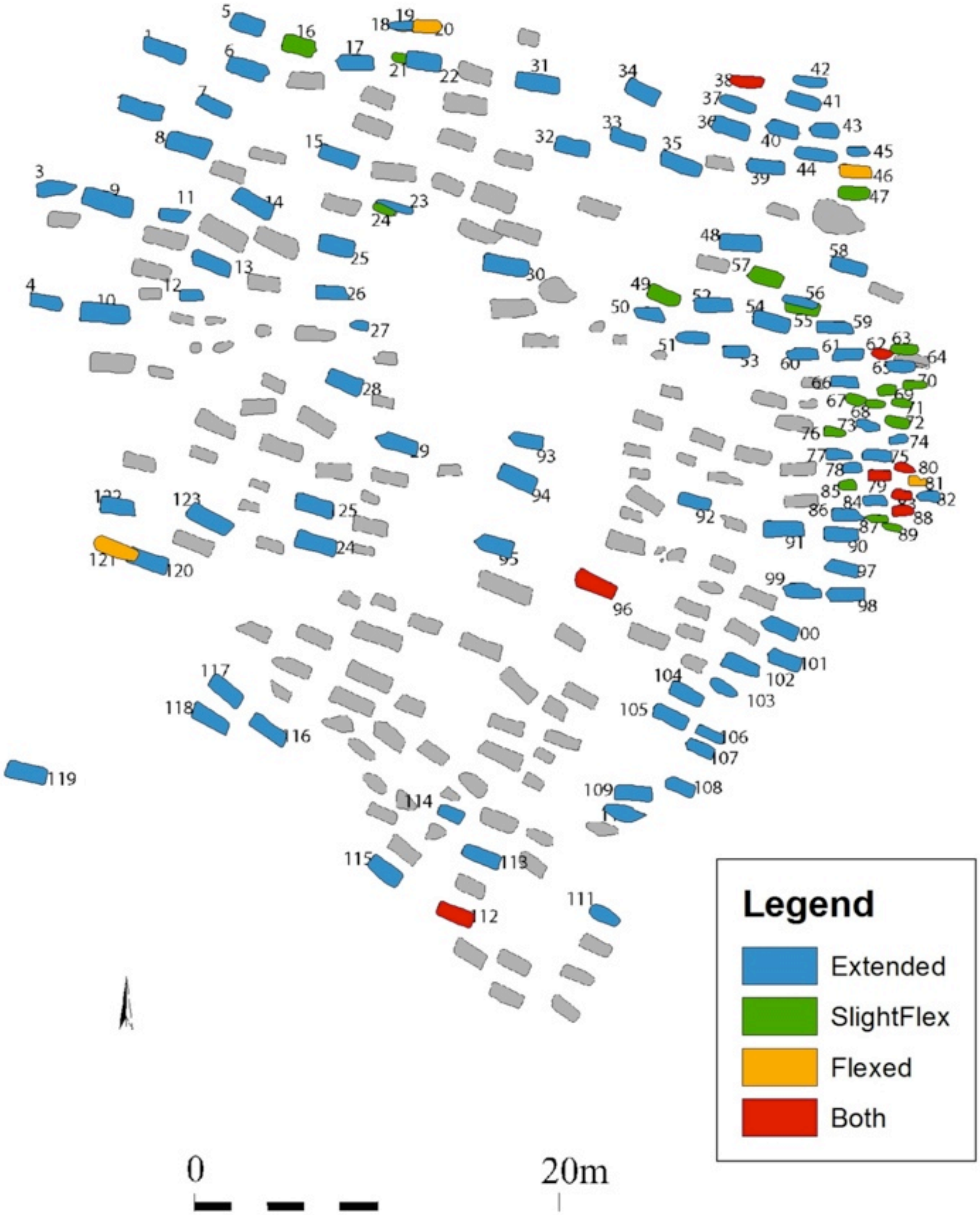

Figure 3.11: Spatial distribution of leg position at cemetery 3-J-10.

Table 3.6: Leg position by Standards age categories at 3-J-10.

3-J-10 Leg Position	Extended		Flexed		Slight Flex		Both		TOTAL
	#	%	#	%	#	%	#	%	*n*
Infant (<3 yrs)	6	26.1%	2	8.7%	10	43.5%	5	21.7%	23
Child (3-12 yrs)	15	68.2%	2	9.1%	4	18.2%	1	4.5%	22
Adolescent (12-20 yrs)	5	100%	0	0.0%	0	0.0%	0	0.0%	5
Young Adult (20-35 yrs)	16	100%	0	0.0%	0	0.0%	0	0.0%	16
Middle Adult (35-50 yrs)	35	89.7%	0	0.0%	2	5.1%	2	5.1%	39
Older Adult (>50 yrs)	11	84.6%	0	0.0%	2	15.4%	0	0.0%	13
Adult (>20 yrs)	6	85.7%	1	14.3%	0	0.0%	0	0.0%	7
TOTAL	**94**	**75.2%**	**5**	**4.0%**	**18**	**14.4%**	**8**	**6.4%**	**125**

Grave Inclusions

The vast majority of individuals (96.8%, $n = 124$) at cemetery 3-J-10 did not have any objects included in the burial. Those with grave inclusions ranged in age from infant to older adult, suggesting that this variable was not related to age. A Fisher's exact test confirmed this, showing no significant association between age and presence of grave goods ($p = .278$). The significance of grave inclusions is difficult to ascertain. Only Burial 38 had a ceramic pot within the grave placed over the pelvis of an infant, while the other graves had objects found in the backfill making it difficult to determine whether these were placed intentionally or were incorporated during the digging and/or filling of the grave.

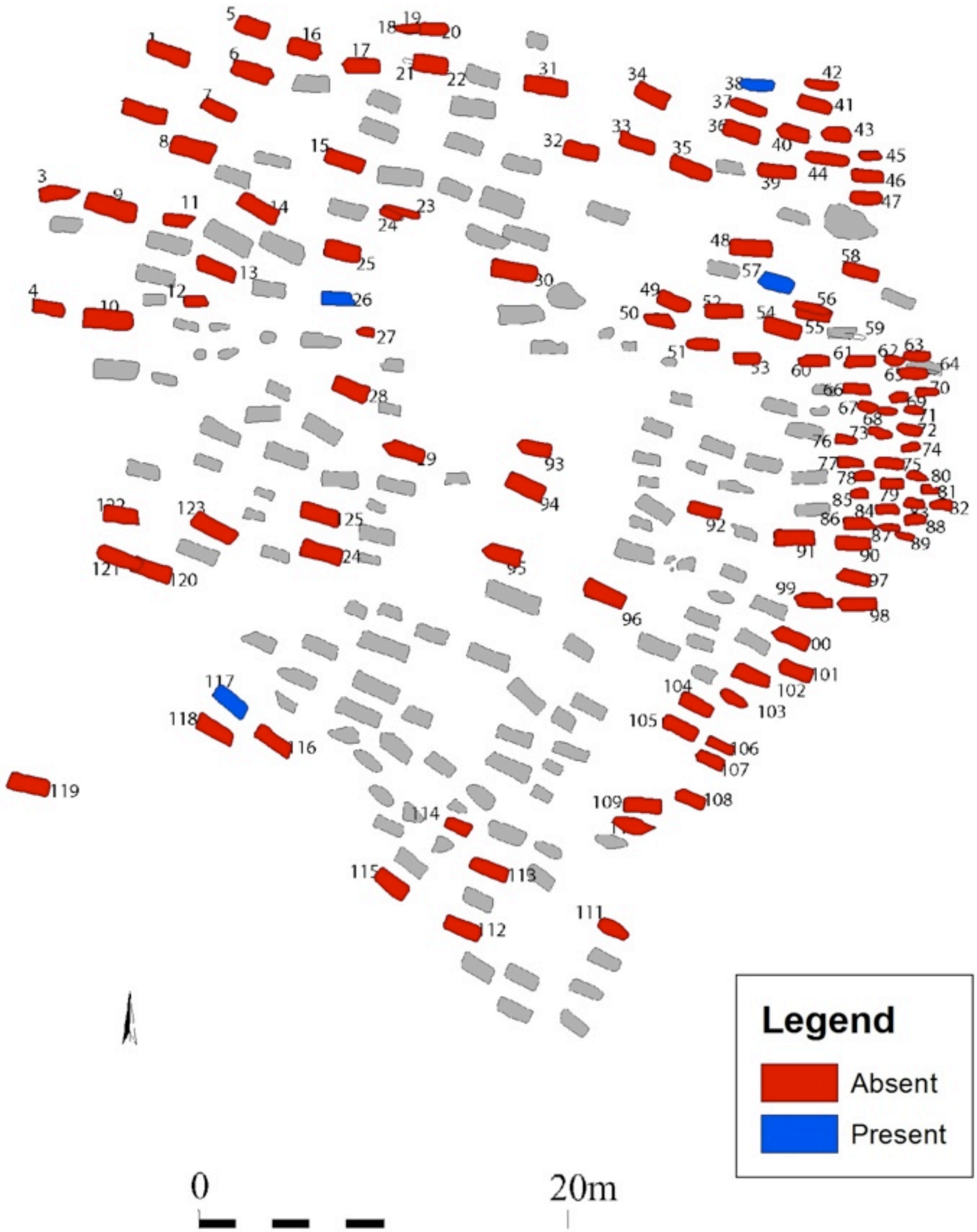

Figure 3.12: Spatial distribution of grave inclusions at cemetery 3-J-10.

Table 3.7: Grave inclusions by Standards age categories for 3-J-10.

3-J-10 Grave Inclusions	Absent		Present		TOTAL
	#	%	#	%	*n*
Infant (<3 yrs)	22	95.7%	1	4.3%	23
Child (3-12 yrs)	21	100%	0	0.0%	21
Adolescent (12-20 yrs)	4	80.0%	1	20.0%	5
Young Adult (20-35 yrs)	16	100%	0	0.0%	16
Middle Adult (35-50 yrs)	38	97.4%	1	2.6%	39
Older Adult (>50 yrs)	12	92.3%	1	7.7%	13
Adult (>20 yrs)	7	100%	0	0.0%	7
TOTAL	**120**	**96.8%**	**4**	**3.2%**	**124**

Personal Adornment

Items of adornment consisted of various types of beads and were found on 11.3% (n = 124) of individuals in undisturbed graves at 3-J-10 (Table 3.8). Although these were not restricted to a particular age category, adornment was more common in the infant, child, and adolescent age cohorts. Figure 3.13 shows the majority of adornment occurred in the eastern cluster of subadults. The two adults with personal adornment were a young adult in Burial 91 and a middle adult in Burial 115. A Fisher's exact test showed that the association with age was significant (p = .005). The infant category had a significant standardized residual with the presence of personal adornment (z = 3.4).

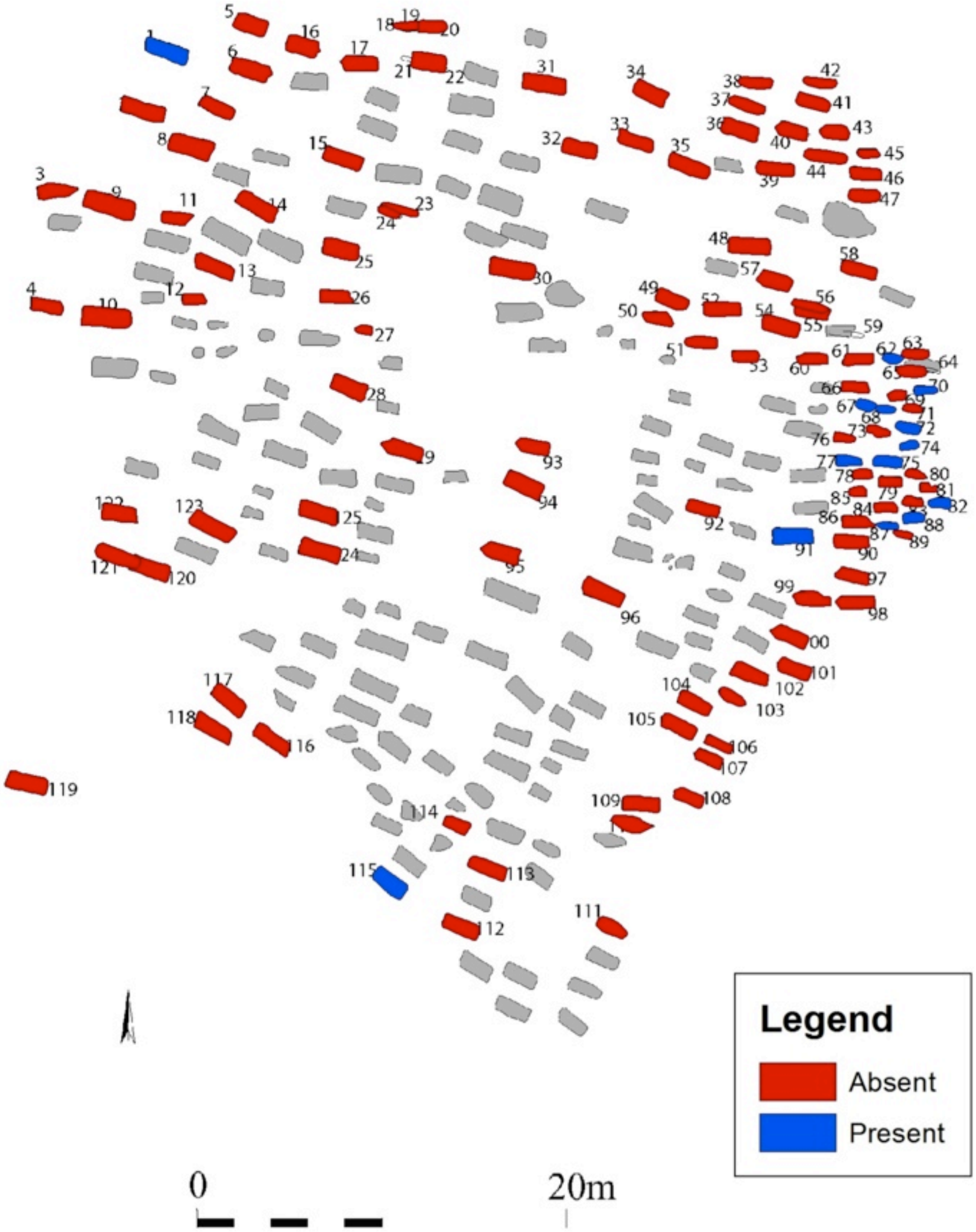

Figure 3.13: Spatial distribution of personal adornment at cemetery 3-J-10.

Table 3.8: Personal adornment by Standards age categories for 3-J-10.

3-J-10 Adornment	Absent		Present		TOTAL
	#	%	#	%	*n*
Infant (<3 yrs)	15	65.2%	8	34.8%	23
Child (3-12 yrs)	18	85.7%	3	14.3%	21
Adolescent (12-20 yrs)	4	80.0%	1	20.0%	5
Young Adult (20-35 yrs)	15	93.8%	1	6.3%	16
Middle Adult (35-50 yrs)	38	97.4%	1	2.6%	39
Older Adult (>50 yrs)	13	100%	0	0.0%	13
Adult (>20 yrs)	7	100%	0	0.0%	7
TOTAL	**110**	**88.7%**	**14**	**11.3%**	**124**

Spatial Analysis of Disease

The investigation of the spatial distribution of disease activity within cemetery 3-J-10 is displayed in Figures 3.14 to 3.16. In each map, graves that have been highlighted represent affected individuals and the color denotes the activity – active, healed, or mixed. Cribra orbitalia, a lesion of the orbital roof, has most recently been linked to vitamin C deficiency. Figure 3.14 shows a concentration of active lesions concentrated in the eastern cluster of subadults and in a few isolated individuals throughout the rest of the cemetery. As Table 3.9 demonstrates, only one adult had active cribra orbitalia (Burial 23). All infants (100%, n = 16), the majority of children (68.8%, n = 16), and one adolescent (50%, n = 2) with cribra orbitalia had active lesions (Table 3.9). For the young, middle, and older adult age categories, healed lesions were most prevalent. A Monte Carlo test showed a highly significant ($p < .001$) and large (V = .717) association between age and cribra orbitalia activity. Infants were positively associated with active lesions (z

= 3.0) and negatively associated (z = –2.5) with healed lesions. Children were also negatively associated with healed lesions (z = –2.1). Middle adults showed a positive relation with healed lesions (z = 3.4) and a negative association with active (z = –2.5). Lastly, older adults demonstrated a positive association with healed lesions (z = 2.1).

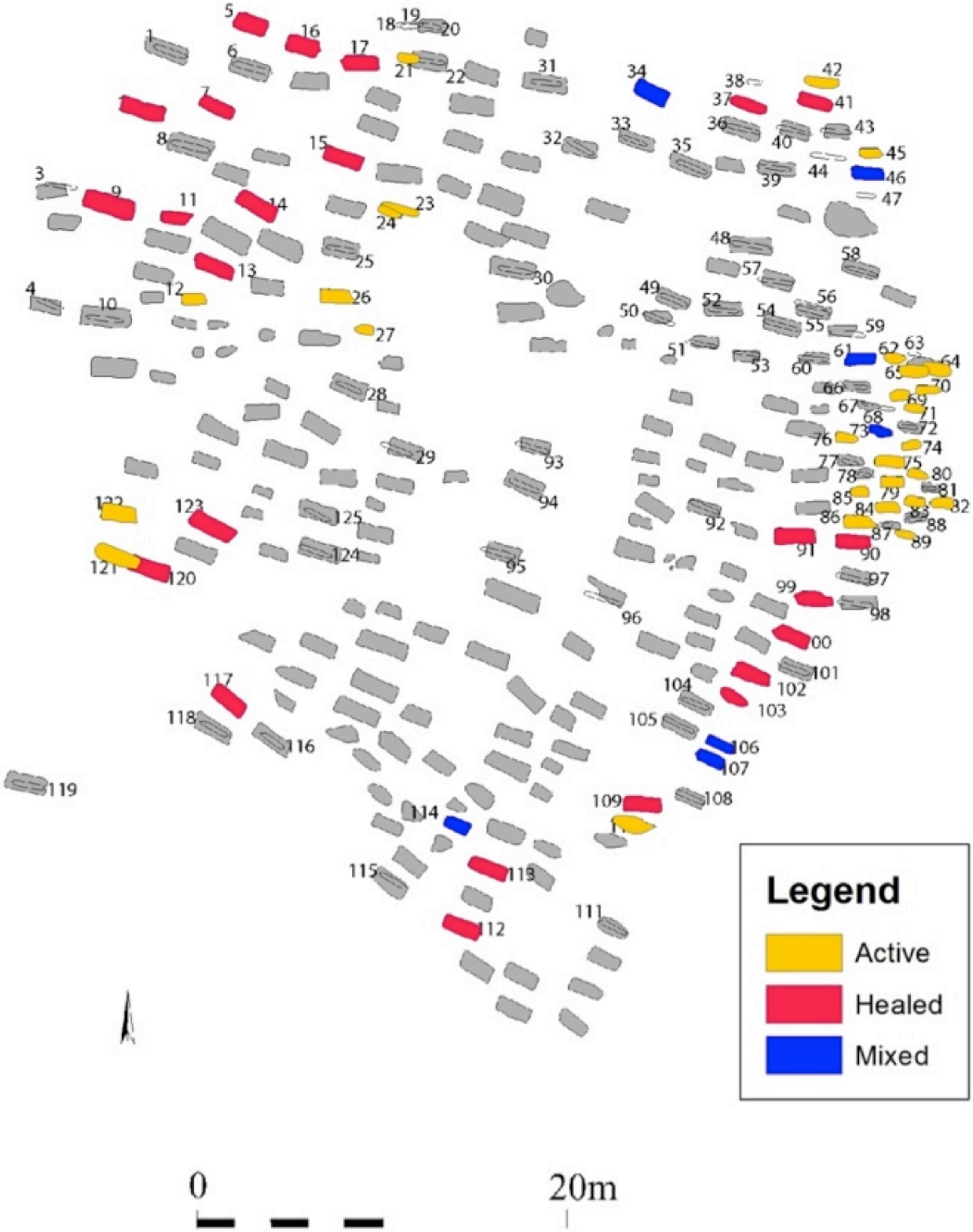

Figure 3.14: Spatial distribution of cribra orbitalia activity at cemetery 3-J-10.

Table 3.9: Cribra orbitalia activity by Standards age categories for 3-J-10.

3-J-10 CO Activity	Active		Healed		Mixed		TOTAL
	#	%	#	%	#	%	*n*
Infant (<3 yrs)	16	100.0%	0	0.0%	0	0.0%	16
Child (3-12 yrs)	11	68.8%	1	6.3%	4	25.0%	16
Adolescent (12-20 yrs)	1	50.0%	0	0.0%	1	50%	2
Young Adult (20-35 yrs)	1	16.7%	4	66.7%	1	17%	6
Middle Adult (35-50 yrs)	0	0.0%	13	100.0%	0	0.0%	13
Older Adult (>50 yrs)	0	0.0%	5	100.0%	0	0%	5
Adult (>20 yrs)	0	0.0%	1	50.0%	1	50%	2
TOTAL	**29**	**48.3%**	**24**	**40.0%**	**7**	**11.7%**	**60**

Porotic hyperostosis is a skeletal indicator of megaloblastic or another type of hemolytic anemia. As both Fig. 3.15 and Table 3.10 demonstrate, only three subadults in the eastern cluster had active porotic hyperostosis lesions. The majority of individuals (86.8%, n = 68) had healed evidence of porotic hyperostosis and they were distributed throughout the cemetery. The few individuals who had a mixed reaction, displaying characteristics of both active and healed lesions, were either children or adolescents. A Monte Carlo test showed a significant and large association between porotic hyperostosis activity and age (p < .001, V = .572) with significant standardized residuals in the infant/active (z = 3.8) and child/mixed cells (z = 4.1).

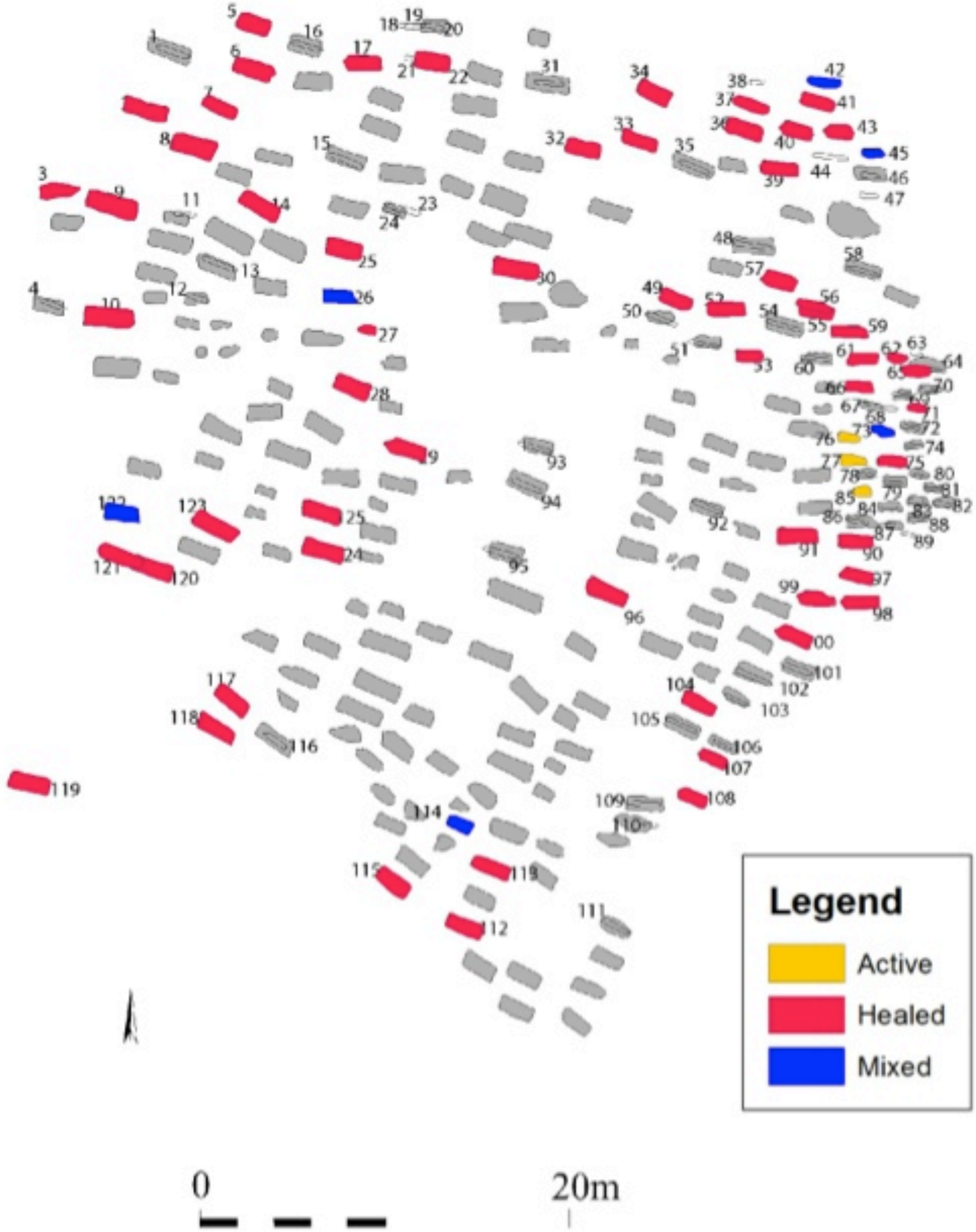

Figure 3.15: Spatial distribution of porotic hyperostosis activity at cemetery 3-J-10.

Table 3.10: Porotic hyperostosis activity by Standards age categories for 3-J-10.

3-J-10 PH Activity	**Active**		**Healed**		**Mixed**		**TOTAL**
	#	%	#	%	#	%	*n*
Infant (<3 yrs)	2	40.0%	3	60.0%	0	0.0%	5
Child (3-12 yrs)	1	9.1%	5	45.5%	5	45.5%	11
Adolescent (12-20 yrs)	0	0.0%	2	66.7%	1	33%	3
Young Adult (20-35 yrs)	0	0.0%	12	100.0%	0	0%	12
Middle Adult (35-50 yrs)	0	0.0%	25	100.0%	0	0.0%	25
Older Adult (>50 yrs)	0	0.0%	11	100.0%	0	0%	11
Adult (>20 yrs)	0	0.0%	1	100.0%	0	0%	1
TOTAL	**3**	**4.4%**	**59**	**86.8%**	**6**	**8.8%**	**68**

Periostitis is a non-specific skeletal lesion that can be indicative of a systemic infection or any disturbance of the periosteum, the membrane sheathing the bone, resulting in bony deposition. The types of periostitis correlate with the activity. Woven bone is new bone that has recently been laid down and lamellar bone is the healing form. Only 8 individuals (10%, n = 80) had active lesions. These were all infants or children and were located on the eastern border of the cemetery (Fig. 3.16). The healing lamellar form of periostitis was most prevalent (77.5%, n = 80) at 3-J-10 and for each age category (Table 3.11). The mixed reaction occurred in both subadults and adults (12.5%, n = 80) signifying that chronic periosteal inflammation was experienced at all ages. A Monte Carlo test showed a significant association (p = .021, V = .284) between age and periostitis activity. The only significant standardized residual was in the infant cohort with a positive relation to woven activity (z = 2.5).

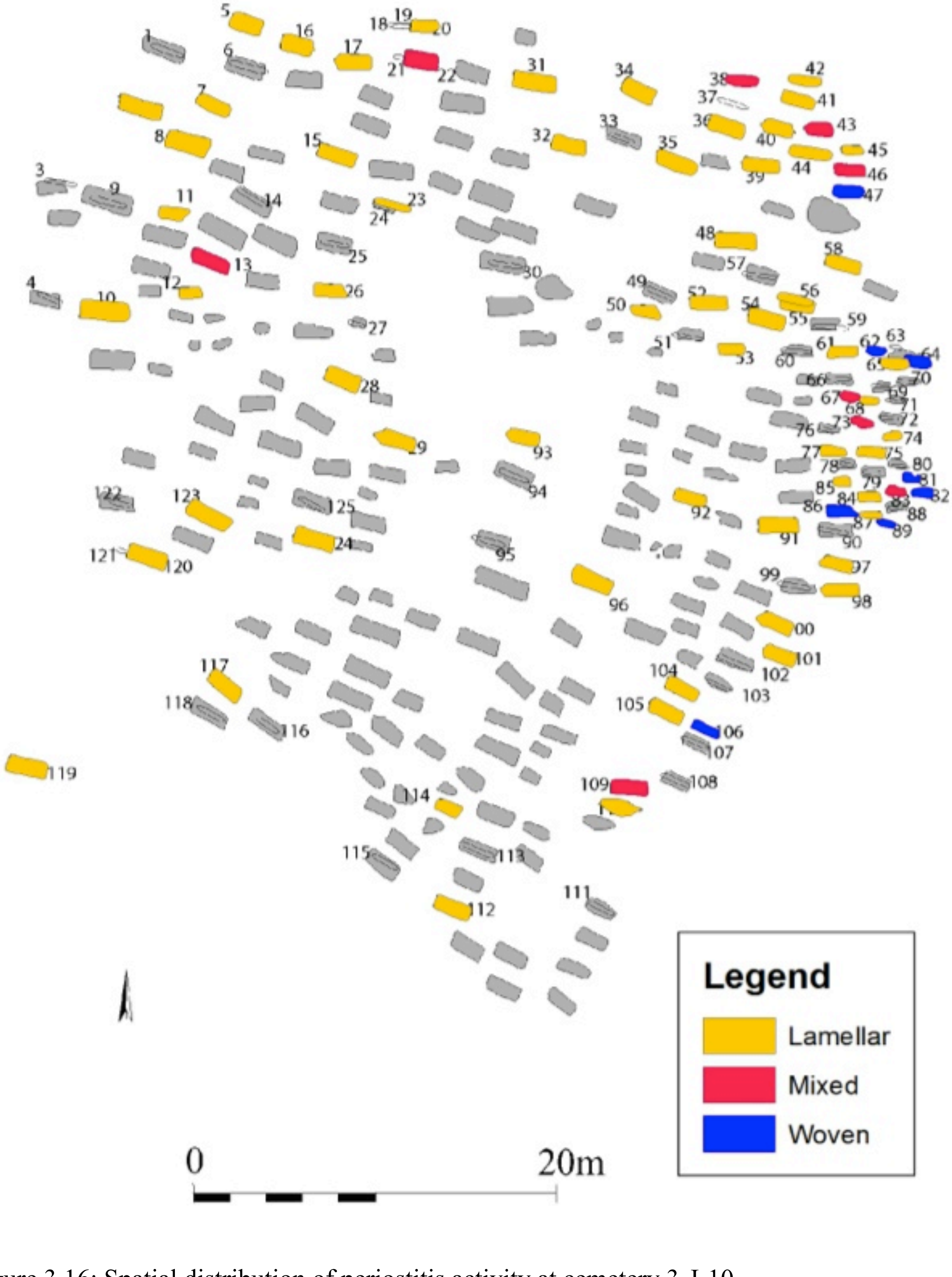

Figure 3.16: Spatial distribution of periostitis activity at cemetery 3-J-10.

Table 3.11: Periostitis activity by Standards age categories for 3-J-10.

3-J-10 Peri. Activity	Woven		Lamellar		Mixed		TOTAL
	#	%	#	%	#	%	*n*
Infant (<3 yrs)	5	29.4%	8	47.1%	4	23.5%	17
Child (3-12 yrs)	3	25.0%	8	66.7%	1	8.3%	12
Adolescent (12-20 yrs)	0	0.0%	2	100.0%	0	0%	2
Young Adult (20-35 yrs)	0	0.0%	10	90.9%	1	9%	11
Middle Adult (35-50 yrs)	0	0.0%	25	89.3%	3	10.7%	28
Older Adult (>50 yrs)	0	0.0%	7	100.0%	0	0%	7
Adult (>20 yrs)	0	0.0%	2	66.7%	1	33%	3
TOTAL	**8**	**10.0%**	**62**	**77.5%**	**10**	**12.5%**	**80**

Results: Cemetery 3-J-11

Cemetery 3-J-11 at Mis Island (Fig. 3.17) showed no clearly circumscribed area reserved for a certain age category like the infant and young child cluster at 3-J-10. Each age category was distributed throughout the cemetery. Upon closer inspection of the subadults, however, clusters become more apparent. Figure 3.18 highlights only the infants, and it is evident that the majority of these children were buried in proximity to other infants. When the child cohort is also added (Fig. 3.19), a number of areas of infant and child clustering emerge. While not as clearly defined as the eastern grouping at 3-J-10, there is evidence that the youngest cohorts were buried in particular areas in proximity to others of similar age. Unfortunately, extensive damage from agriculture and the nature of this salvage excavation left a number of areas damaged or unexcavated limiting the archaeological interpretations that can be made.

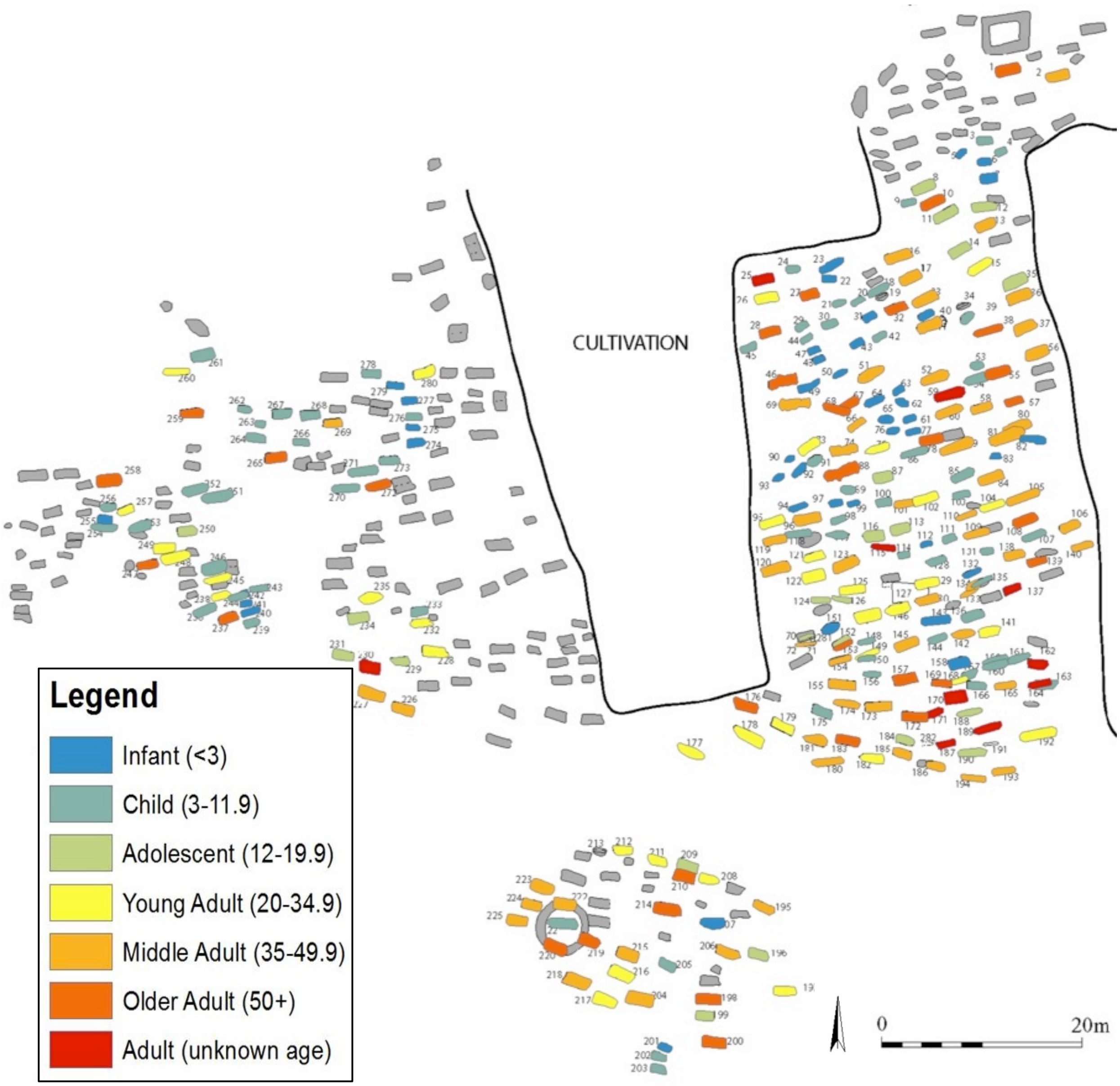

Figure 3.17: Spatial distribution of age cohorts at cemetery 3-J-11.

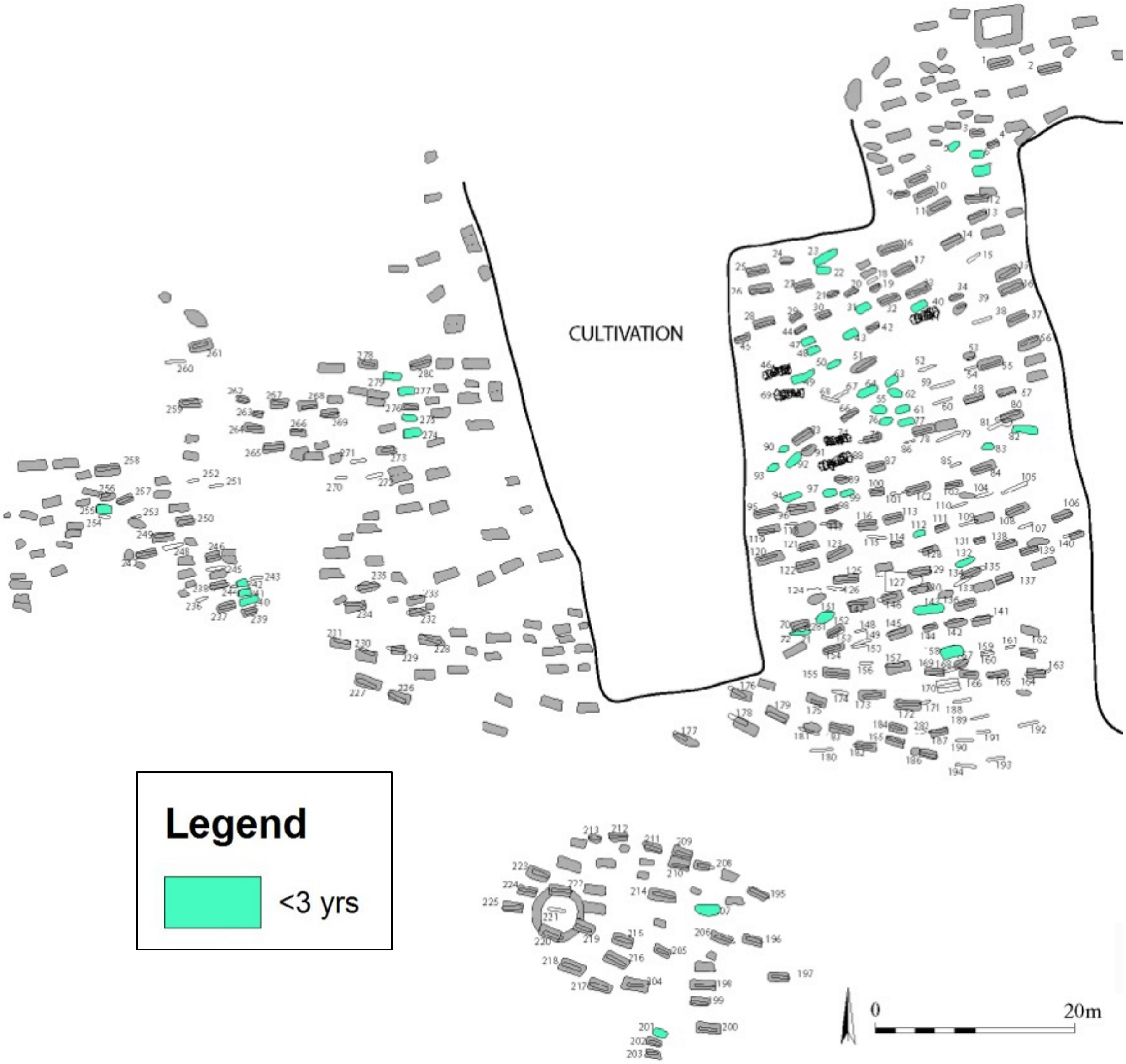

Figure 3.18: Spatial distribution of infants at cemetery 3-J-11.

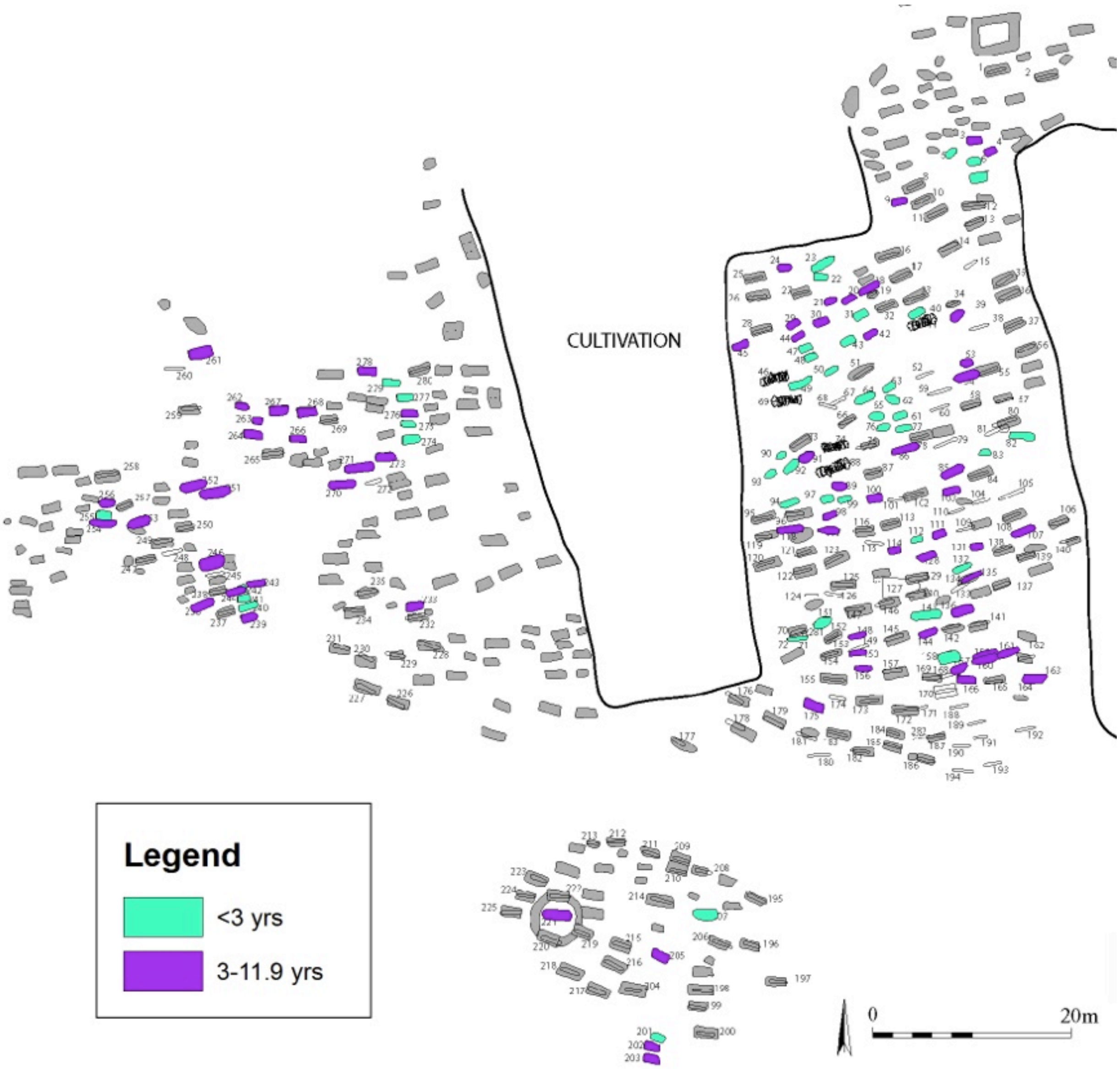

Figure 3.19: Spatial distribution of infants and children at cemetery 3-J-11.

Grave Monument

Cemetery 3-J-11 contained four recognizable grave monument types, FF03a, FF03c, FF02f, and X10. In addition, there was a single grave (Burial 221) in the southern cluster of burials that lacked a traditional monument but was surrounded by a ring of stones. Figure 3.20 shows the distribution of monument types throughout the cemetery. FF03c monuments were abundant throughout the cemetery and FF03a monuments had widespread distribution. The FF02f monuments, however, were restricted to the eastern area of the cemetery. It also seems that the absence of monuments occurred in the eastern area and the far western extent of the cemetery. As in cemetery 3-J-10, the most abundant monument type in 3-J-11 was FF03c comprising 74.0% (n = 242) of undisturbed graves (Table 3.12). The absence of a superstructure was the next highest prevalence (14.5%) followed by FF03a monuments (8.7%). FF03c monuments also had the highest frequency in each age cohort, indicating that this monument type was accessible for all age categories. The FF03a monument, however, seemed to be reserved for mostly subadults, although one young adult female in the western section (Burial 257) also had this monument type. The FF02f type was used exclusively for middle and older adults, but the sample size was small (n = 5) making any association tentative. Finally, a single infant burial had an X10 monument (Burial 62). A Monte Carlo test showed a highly significant association with age ($p < .001$; V = .219). There was a highly significant association ($p < .001$) between the infant cohort and FF03a monument ($z = 3.9$) and X10 monument ($z = 2.2$) and a negative association between middle adults and FF03a monuments ($z = –2.1$).

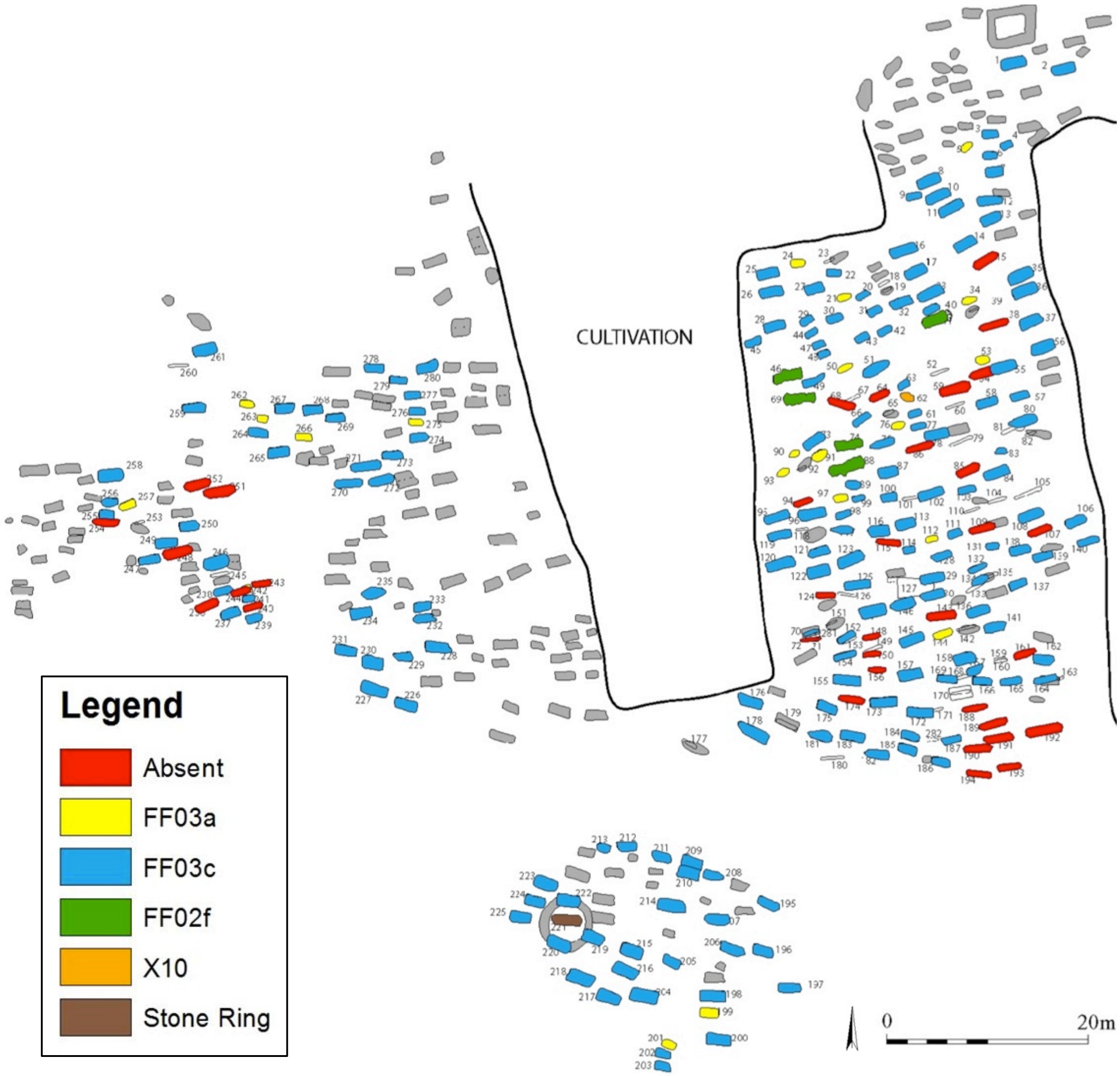

Figure 3.20: Spatial distribution of grave monument types at cemetery 3-J-11.

Table 3.12: Grave monuments by Standards age categories for 3-J-11.

3-J-11	Absent		FF03a		FF03c		FF02f		X10		Stone Ring		TOTAL
Monument	#	%	#	%	#	%	#	%	#	%	#	%	*n*
Infant (<3 yrs)	4	11.1%	10	27.8%	21	58.3%	0	0.0%	1	2.8%	0	0.0%	36
Child (3-12 yrs)	15	23.1%	9	13.8%	40	61.5%	0	0.0%	0	0.0%	1	1.5%	65
Adolescent (12-20 yrs)	3	14.3%	1	4.8%	17	81.0%	0	0.0%	0	0.0%	0	0.0%	21
Young Adult (20-35)	3	10.0%	1	3.3%	26	86.7%	0	0.0%	0	0.0%	0	0.0%	30
Middle Adult (35-50 yrs)	5	10.0%	0	0.0%	42	84.0%	3	6.0%	0	0.0%	0	0.0%	50
Older Adult (>50 yrs)	2	6.5%	0	0.0%	27	87.1%	2	6.5%	0	0.0%	0	0.0%	31
Adult (>20 yrs)	3	33.3%	0	0.0%	6	66.7%	0	0.0%	0	0.0%	0	0.0%	9
TOTAL	**35**	**14.5%**	**21**	**8.7%**	**179**	**74.0%**	**5**	**2.1%**	**1**	**0.4%**	**1**	**0.4%**	**242**

Body Covering

Cemetery 3-J-11 had a variety of body covering practices, including the use of stones to cover the entire body and head coverings of stone, stone and mud-brick, and mud-brick only. Figure 3.21 plots the body covering types used throughout cemetery 3-J-11. The western edge of the cemetery had a number of graves without any type of body protection. The small circular group (Figure 3.21, circled in black) contained ten excavated graves including two infants, five children, two young adult males, and one older adult female. The absence of body covering in this group does not appear related to age or sex characteristics. This practice also occurred in the northeastern section and intermittently in the remainder of the eastern portion in a variety of age groups. In the southern cluster of graves, only an infant (Burial 201) was devoid of body covering. Covering of the entire body was present in 9.8% (n = 265) of excavated graves and occurred for individuals of all ages along the northern perimeter and sporadically in the eastern section of 3-J-11. Head protection occurred throughout the cemetery with stone, stone and mud-brick, and mud-brick only materials. While head coverings with stone were well distributed throughout the cemetery, mud-brick coverings were mostly found in the eastern section. Only five individuals (Burials 16, 74, 86, 118, 217), two children, a young adult female, and two middle adult females had head protection of mixed stones and bricks. Table 3.13 shows the distribution of body covering type by age cohort. The majority (54.7%, $n = 265$) of individuals had head coverings of stone, followed far behind by the absence of covering (17.7%). Every age cohort showed highest prevalence in the head stone category. Monte Carlo tests showed no significant association by age for body covering type ($p = .336$) or body versus head stone covering ($p = .057$).

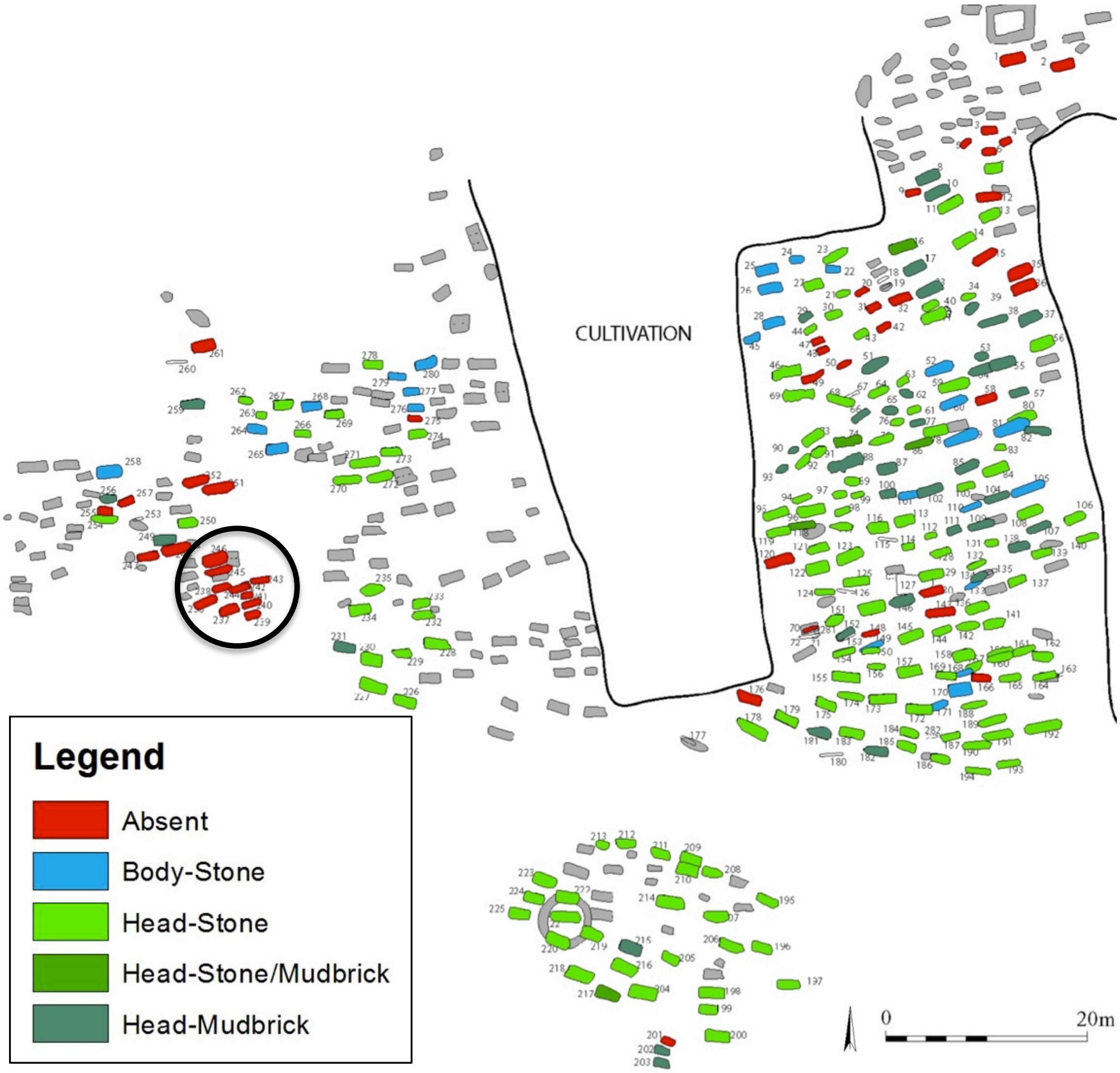

Figure 3.21: Spatial distribution of body covering type at cemetery 3-J-11.

Table 3.13: Body covering by Standards age categories for 3-J-11.

3-J-11 Covering	Absent		Body		Head/Stone		Head/Both		Head/Brick		TOTAL
	#	%	#	%	#	%	#	%	#	%	*n*
Infant (<3 yrs)	14	34.1%	3	7.3%	19	46.3%	0	0.0%	5	12.2%	41
Child (3-12 yrs)	15	21.7%	5	7.2%	35	50.7%	2	2.9%	12	17.4%	69
Adolescent (12-20 yrs)	3	14.3%	0	0.0%	14	66.7%	0	0.0%	4	19.0%	21
Young Adult (20-35)	5	14.3%	4	11.4%	20	57.1%	1	2.9%	5	14.3%	35
Middle Adult (35-50 yrs)	5	8.6%	8	13.8%	33	56.9%	2	3.4%	10	17.2%	58
Older Adult (>50 yrs)	5	16.1%	3	9.7%	17	54.8%	0	0.0%	6	19.4%	31
Adult (>20 yrs)	0	0.0%	3	30.0%	7	70.0%	0	0.0%	0	0.0%	10
TOTAL	**47**	**17.7%**	**26**	**9.8%**	**145**	**54.7%**	**5**	**1.9%**	**42**	**15.8%**	**265**

Body Orientation

All individuals excavated at cemetery 3-J-11 were buried with their heads to the west.

Body Position

Individuals at 3-J-11 were interred in a variety of body positions (Table 3.14), including supine (90.8%, n = 260), on either left or right side (8.8%), or a single individual in the prone position (0.4%). It is evident, however, that throughout the cemetery supine burial was preferred (Fig. 3.22) and was the standard for individuals of all ages (Table 3.14). Side burials were not restricted to a certain age group either and they occurred on the western edge, sporadically through the eastern portion of the cemetery, and for one infant (Burial 201) in the southern cluster. The single individual in the prone position (Burial 273) was a child around three years of age and occurred in the northwestern portion adjacent to a number of supine burials. Whether this was intentional is difficult to determine since other mortuary variables of this grave were similar to surrounding interments. A Fisher's exact test demonstrated no significant association between age and body position (p = .403) indicating variation from supine did not occur systematically.

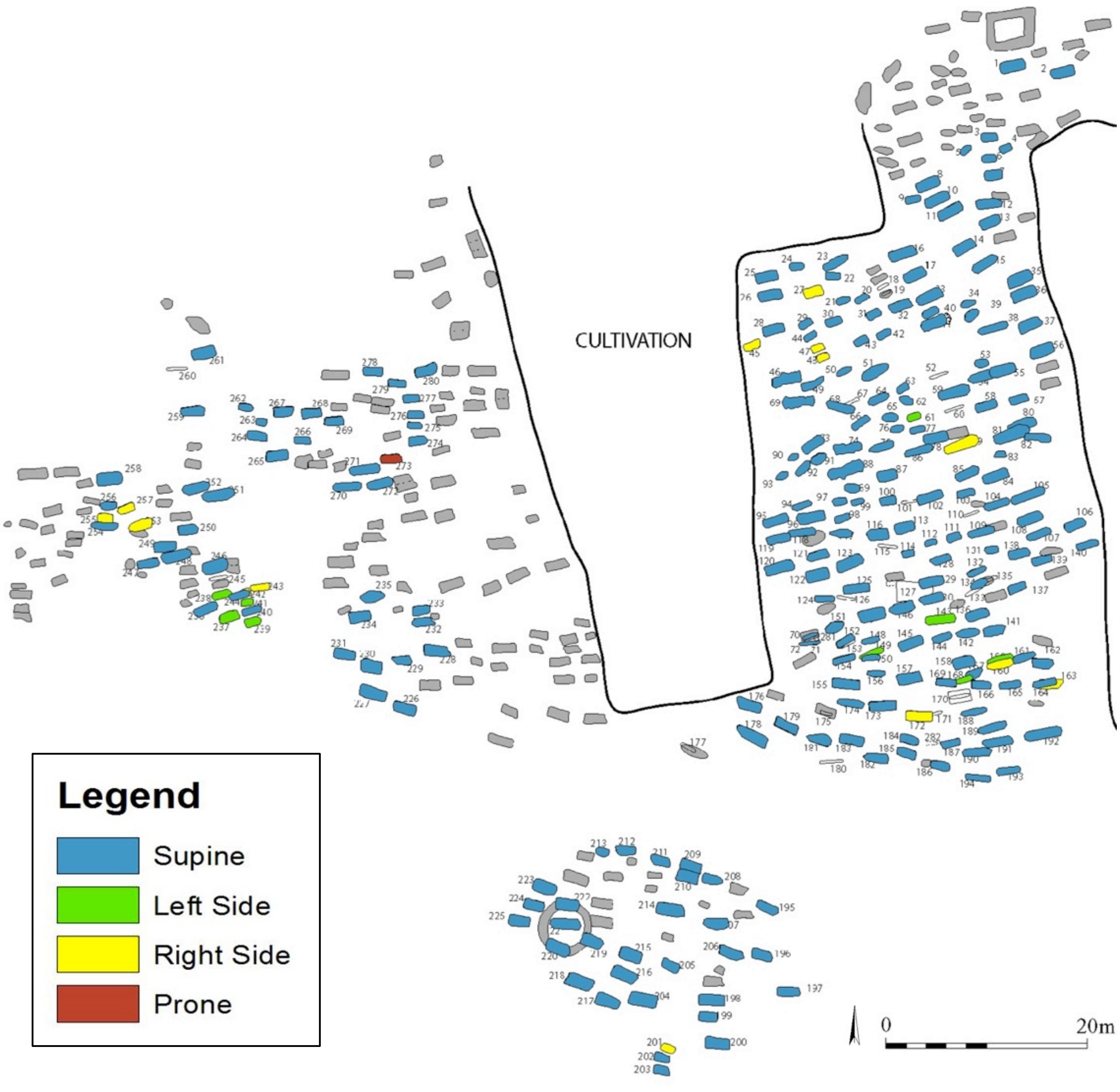

Figure 3.22: Spatial distribution of body positioning at cemetery 3-J-11.

Table 3.14. Body position by Standards age categories for 3-J-11.

3-J-11 Body Position	Supine		Left Side		Right Side		Prone		TOTAL
	#	%	#	%	#	%	#	%	*n*
Infant (<3 yrs)	33	80.5%	3	7.3%	5	12.2%	0	0.0%	41
Child (3-12 yrs)	63	90.0%	1	1.4%	5	7.1%	1	1.4%	70
Adolescent (12-20 yrs)	21	100%	0	0.0%	0	0.0%	0	0.0%	21
Young Adult (20-35)	30	88.2%	3	8.8%	1	2.9%	0	0.0%	34
Middle Adult (35-50 yrs)	53	96.4%	1	1.8%	1	1.8%	0	0.0%	55
Older Adult (>50 yrs)	28	90.3%	1	3.2%	2	6.5%	0	0.0%	31
Adult (>20 yrs)	8	100%	0	0.0%	0	0.0%	0	0.0%	8
TOTAL	**236**	**90.8%**	**9**	**3.5%**	**14**	**5.4%**	**1**	**0.4%**	**260**

Head Direction

Head direction for supine burials at cemetery 3-J-11 included those with their head straight or up and those with their head turned to the side, either north or south (Table 3.15). While facing upwards was the most prevalent head position (63.1%, $n = 236$), there were 36.9% of supine individuals with turned heads with a slight preference for heads facing north (19.1%). Spatial distribution of head direction (Fig. 3.23) showed no apparent patterns or clusters. Investigating differences by age revealed no apparent trends either, suggesting that head direction was not a spatially relevant or age-related variable. A Monte Carlo test confirmed that there was not a significant association between age and head direction ($p = .514$).

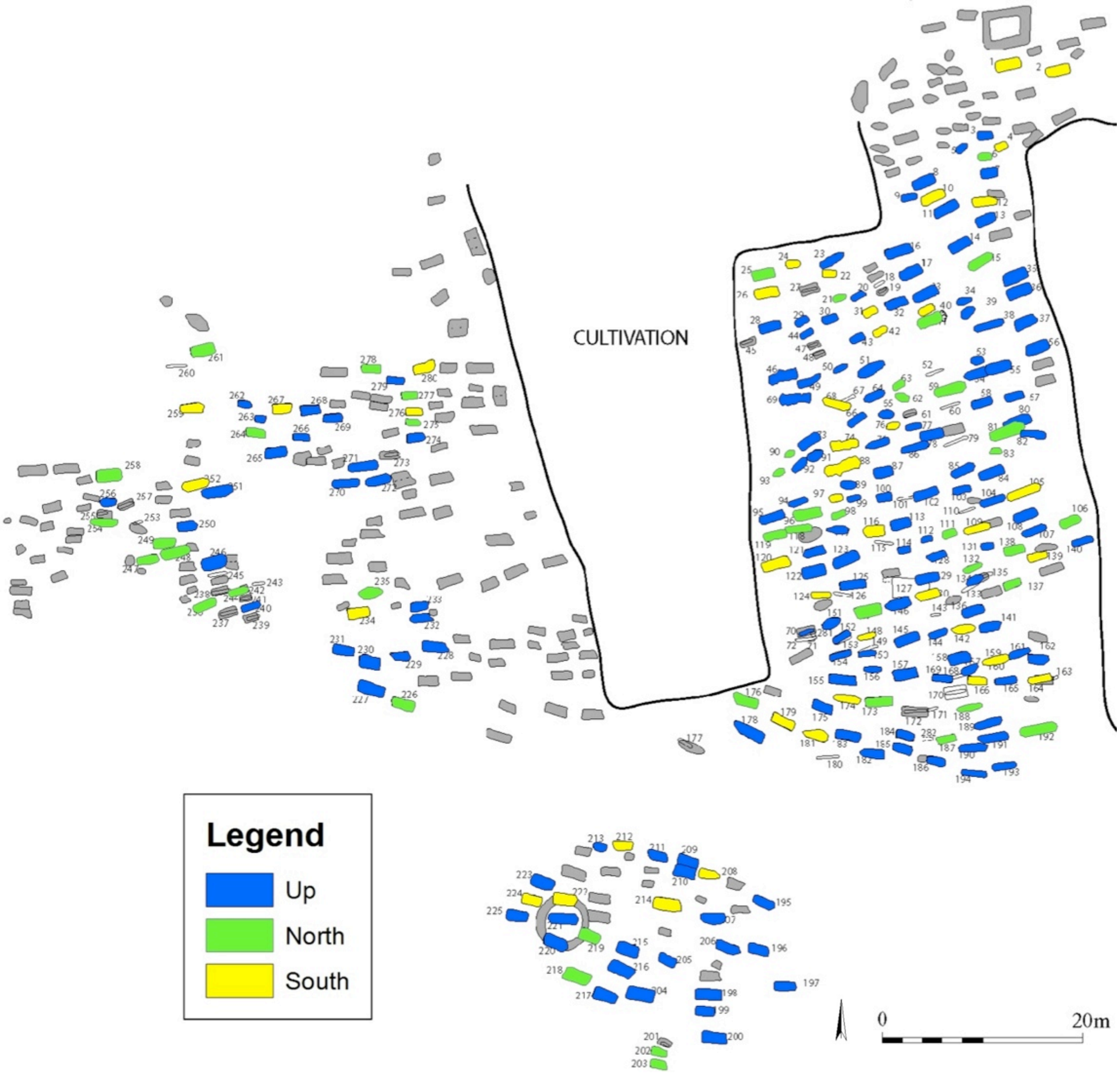

Figure 3.23: Spatial distribution of head direction at cemetery 3-J-11.

Table 3.15: Head direction by Standards age categories for 3-J-11.

3-J-11 Head Direction	Up		North		South		TOTAL
	#	%	#	%	#	%	*n*
Infant (<3 yrs)	19	57.6%	9	27.3%	5	15.2%	33
Child (3-12 yrs)	43	67.2%	12	18.8%	9	14.1%	64
Adolescent (12-20 yrs)	16	76.2%	1	4.8%	4	19.0%	21
Young Adult (20-35)	19	63.3%	6	20.0%	5	16.7%	30
Middle Adult (35-50 yrs)	32	61.5%	9	17.3%	11	21.2%	52
Older Adult (>50 yrs)	17	60.7%	4	14.3%	7	25.0%	28
Adult (>20 yrs)	3	37.5%	4	50.0%	1	12.5%	8
TOTAL	**149**	**63.1%**	**45**	**19.1%**	**42**	**17.8%**	**236**

Leg Position

Leg positions at 3-J-11 included fully extended, slightly flexed, completely flexed, and one leg extended and the other flexed. Extended legs occurred throughout the cemetery, with small pockets of burials with slightly flexed decedents (Fig. 3.24). These slightly flexed groupings coincided with areas of child and infant burials. The “flexed” and “both” categories were uncommon and occurred sporadically. Notably, the only individuals in the southern cluster with legs in a position other than extended were the two infants (Burials 201 and 207). As Table 3.16 shows, the vast majority (82.3%, n = 260) of undisturbed individuals at 3-J-11 had fully extended legs. The next most prevalent, slightly flexed, was much lower (10.4%). This category is comprised mostly of infants and children (77.8%, n = 27), but one adolescent (Burial 190), two middle adults (Burials 165 and 194) and three older adults (Burials 25, 68, and 258) also had slightly flexed legs. The majority (90%, $n = 10$) of individuals with flexed legs were subadults and only one young adult (Burial 15) had legs in this position. Infants and children comprised the vast majority (88.9%, $n = 9$) of the "both" category, with only a single adult burial (Burial 25). Overall, there was far more variety in the leg positions of subadults. A Monte Carlo test showed that these differences by age were significant ($p < .001$). Infants were significantly associated with the slightly flexed ($z = 4.7$) and both categories ($z = 3.0$) and negatively related to the extended category ($z = -2.5$). Adolescents had a significant standardized residual in the flexed category ($z = 2.4$).

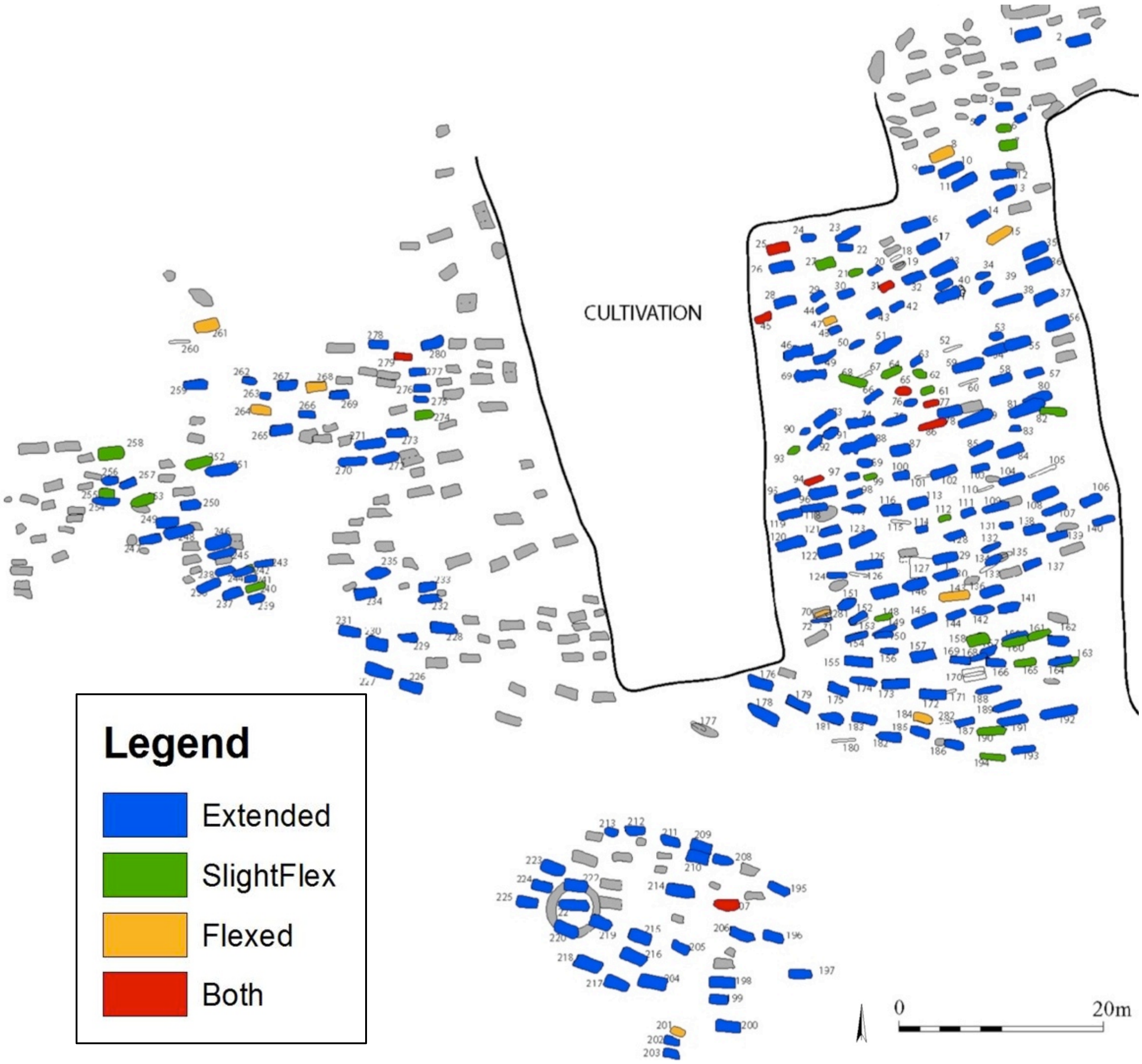

Figure 3.24: Spatial distribution of leg position at cemetery 3-J-11.

Table 3.16: Leg position by Standards age categories for 3-J-11.

3-J-11 Leg Position	Extended		Flexed		Slight Flex		Both		TOTAL
	#	%	#	%	#	%	#	%	*n*
Infant (<3 yrs)	19	46.3%	3	7.3%	14	34.1%	5	12.2%	41
Child (3-12 yrs)	57	81.4%	3	4.3%	7	10.0%	3	4.3%	70
Adolescent (12-20 yrs)	17	81.0%	3	14.3%	1	4.8%	0	0.0%	21
Young Adult (20-35)	34	97.1%	1	2.9%	0	0.0%	0	0.0%	35
Middle Adult (35-50 yrs)	52	96.3%	0	0.0%	2	3.7%	0	0.0%	54
Older Adult (>50 yrs)	28	90.3%	0	0.0%	3	9.7%	0	0.0%	31
Adult (>20 yrs)	7	87.5%	0	0.0%	0	0.0%	1	12.5%	8
TOTAL	**214**	**82.3%**	**10**	**3.8%**	**27**	**10.4%**	**9**	**3.5%**	**260**

Grave Inclusions

Throughout cemetery 3-J-11, there were 13 individuals (4.9%, n = 266) interred with grave goods (Table 3.17). These individuals were all located in the eastern portion of the cemetery (Figure 3.25). The practice of interment with grave inclusions was restricted to adults, as only individuals 20 years and older received such treatment (Table 3.14). A Fisher's exact test showed there was a significant association between age and presence of grave inclusions (p = .001, V = .293). Notably, 10 of those with grave goods also had complete body covering, while two had disturbed coverings and Burial 57, the most northeastern of the graves with inclusions, had head covering rather than body covering. In this final burial, however, the ceramic artifacts were discovered in the grave fill along with human and animal bones (Ginns, 2010 b, p LVIII) providing strong evidence that these materials had been disturbed from another grave upon the digging of Burial 57. The association of these two transitional or Early Christian practices suggests these graves represent some of the first Christian burials at 3-J-11. Thus, the eastern portion of the cemetery is likely the oldest, which is supported by its high density of graves and the frequency of disturbed burials.

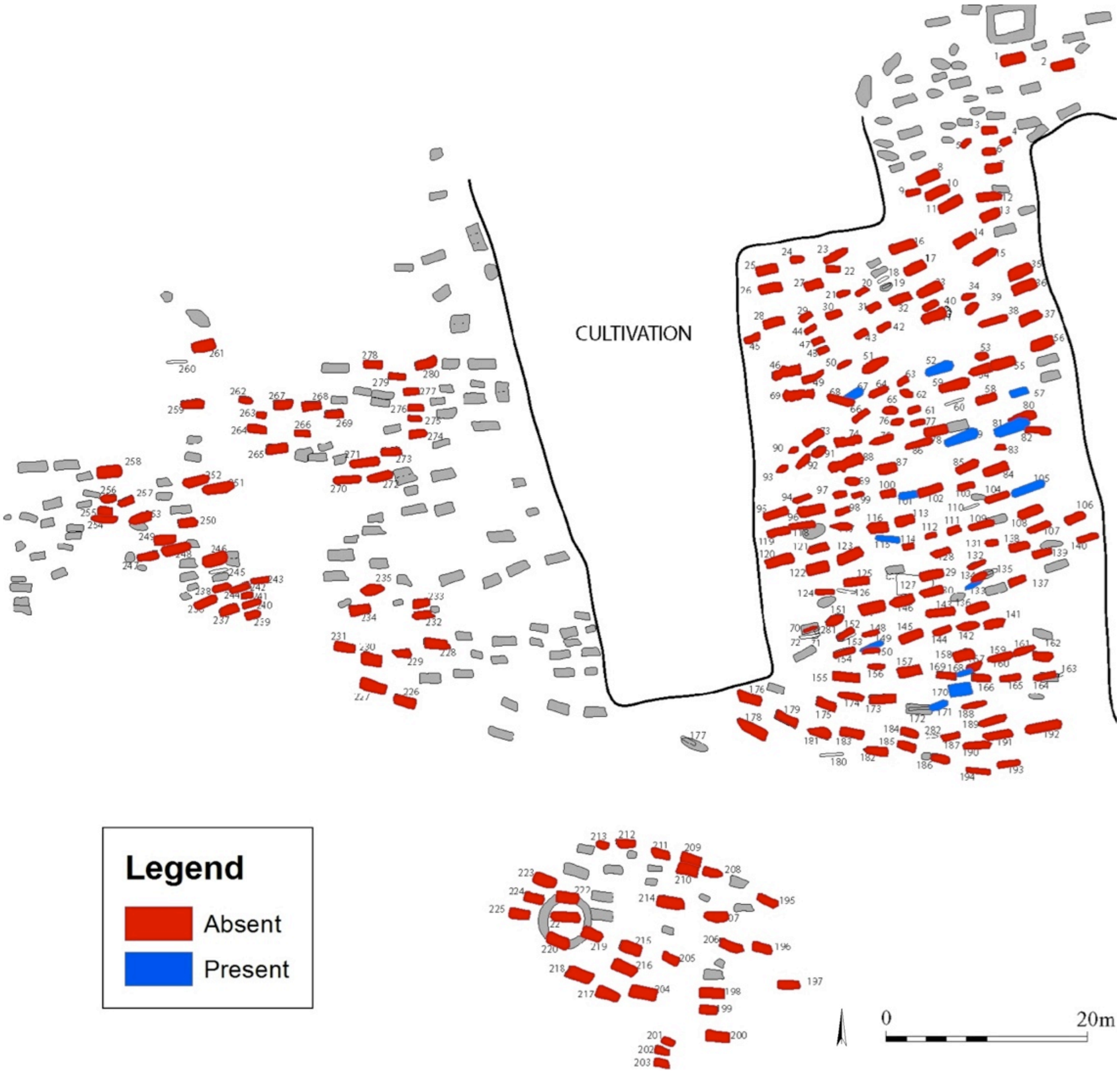

Figure 3.25: Spatial distribution of grave inclusions at cemetery 3-J-11.

Table 3.17: Grave inclusions by Standards age categories for 3-J-11.

3-J-11 Grave Inclusions	**Absent**		**Present**		**TOTAL**
	#	%	#	%	*n*
Infant (<3 yrs)	41	100%	0	0.0%	41
Child (3-12 yrs)	71	100%	0	0.0%	71
Adolescent (12-20 yrs)	21	100%	0	0.0%	21
Young Adult (20-35)	32	94.1%	2	5.9%	34
Middle Adult (35-50 yrs)	51	89.5%	6	10.5%	57
Older Adult (>50 yrs)	29	93.5%	2	6.5%	31
Adult (>20 yrs)	8	72.7%	3	27.3%	11
TOTAL	**253**	**95.1%**	**13**	**4.9%**	**266**

Personal Adornment

Most individuals (96.2%, n = 262) in cemetery 3-J-11 were not found with personal adornment, but 10 individuals did have items of personal adornment including various types of beads, an iron earring, iron rings, and an iron crucifix on a cord. Most of the beads seemed to be from necklaces as they were found in the neck area. Individuals with personal adornment were located in the western and eastern portions of the cemetery (Figure 3.26) and were from all age categories, except adolescence. Thus, personal adornment did not seem to coincide with age for the 3-J-11 cemetery population. A Fisher's exact test confirmed this, showing no significant association between these two variables (p = .711).

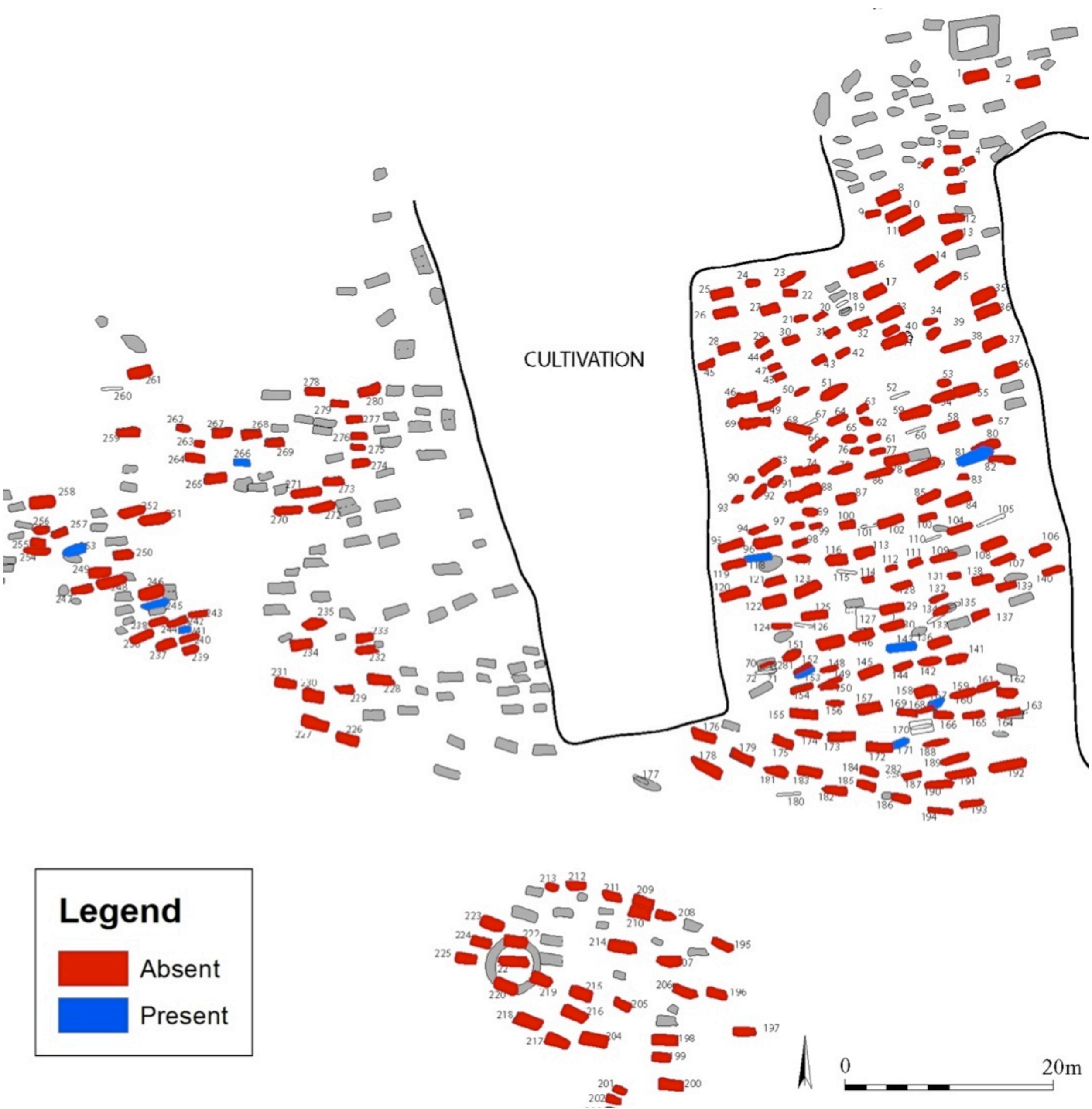

Figure 3.26: Spatial distribution of personal adornment at cemetery 3-J-11.

Table 3.15: Personal adornment by Standards age categories for 3-J-11.

3-J-11 Adornment	Absent		Present		TOTAL
	#	%	#	%	*n*
Infant (<3 yrs)	39	95.1%	2	4.9%	41
Child (3-12 yrs)	67	94.4%	4	5.6%	71
Adolescent (12-20 yrs)	21	100%	0	0.0%	21
Young Adult (20-35)	34	97.1%	1	2.9%	35
Middle Adult (35-50 yrs)	52	98.1%	1	1.9%	53
Older Adult (>50 yrs)	31	96.9%	1	3.1%	32
Adult (>20 yrs)	8	88.9%	1	11.1%	9
TOTAL	**252**	**96.2%**	**10**	**3.8%**	**262**

Spatial Analysis of Disease

Cribra orbitalia occurred throughout cemetery 3-J-11. Active lesions were most prevalent (52.5%, $n = 158$) but occurred almost exclusively in subadult age categories (Table 3.16). The three adults that had active lesions were Burial 58, 121, and 125. The latter two burials were adjacent to each other suggesting these two young adult individuals may have died during the same general time period. The other active lesions occurred in the clusters of subadults (Fig. 3.19). Healed lesions occurred in 36.1% ($n = 158$) of cases mostly concentrated in the adult age cohorts and distributed throughout the cemetery. A Monte Carlo test identified a highly significant ($p < .001$) and large (V = .592) association between cribra orbitalia activity and age. Significant standardized residuals occurred in the infant category for active ($z = 2.5$) and healed lesions ($z = -3.2$). The child cohort was also positively associated with active lesions ($z = 3.2$) and negatively associated with healed ($z = -3.8$). Adult cohorts showed the inverse relationships, with young adults, middle adults, and older adults negatively associated with active lesions ($z = -2.6$, $z = -3.0$, and $z = -2.9$, respectively) and positive associations with healed ($z = 2.9$, $z = 4.2$, and $z = 3.8$, respectively).

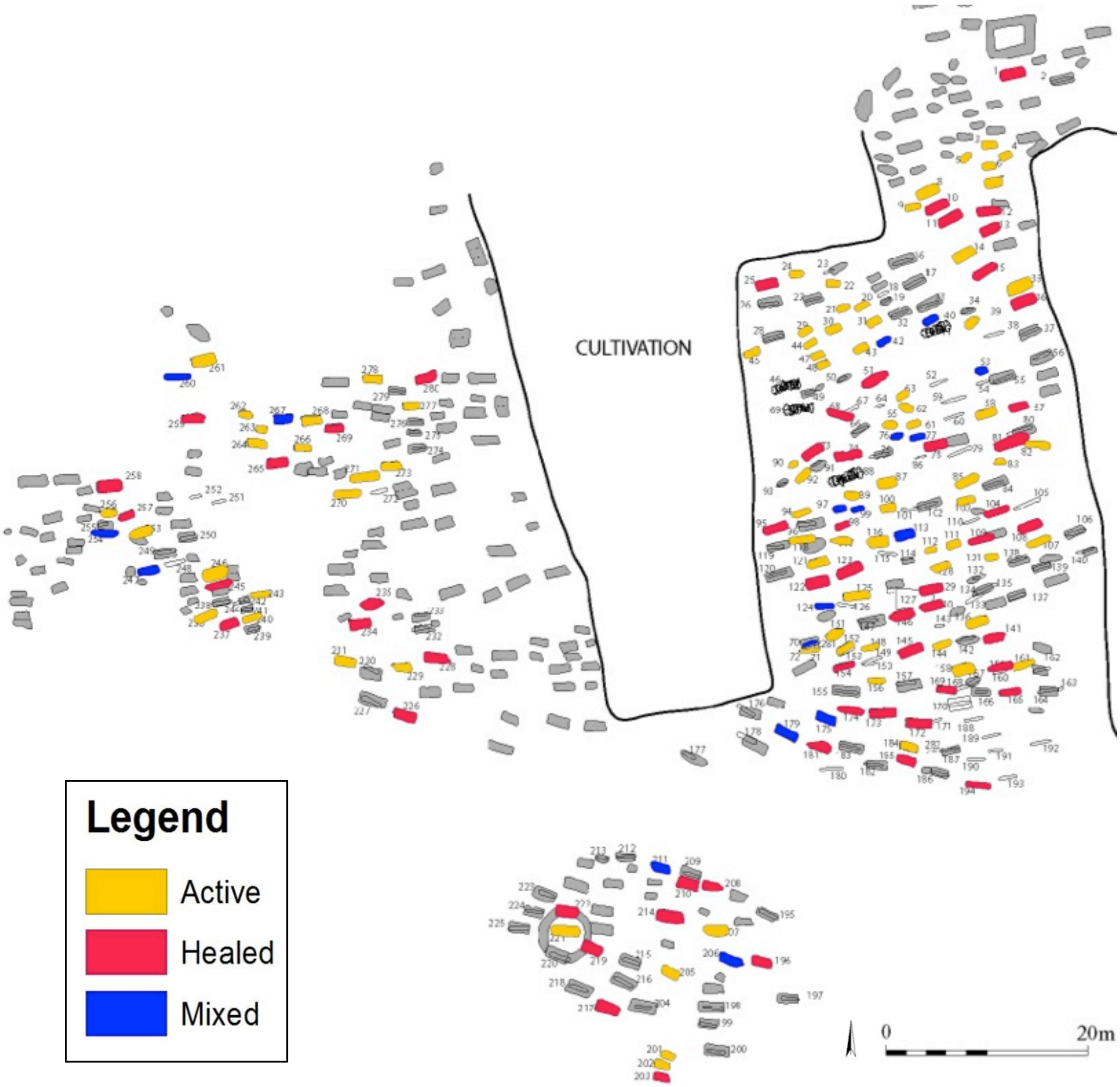

Figure 3.27: Spatial distribution of cribra orbitalia activity at cemetery 3-J-11.

Table 3.16: Cribra orbitalia activity by Standards age categories for 3-J-11.

3-J-11 CO Activity	Active		Healed		Mixed		TOTAL
	#	%	#	%	#	%	*n*
Infant (<3 yrs)	25	86.2%	0	0.0%	4	13.8%	29
Child (3-12 yrs)	46	83.6%	3	5.5%	6	10.9%	55
Adolescent (12-20 yrs)	9	56.3%	4	25.0%	3	18.8%	16
Young Adult (20-35 yrs)	2	10.0%	15	75.0%	3	15.0%	20
Middle Adult (35-50 yrs)	1	4.8%	19	90.5%	1	4.8%	21
Older Adult (>50 yrs)	0	0.0%	15	93.8%	1	6.3%	16
Adult (>20 yrs)	0	0.0%	1	100.0%	0	0.0%	1
TOTAL	**83**	**52.5%**	**57**	**36.1%**	**18**	**11.4%**	**158**

The majority (63.4%, $n = 131$) of porotic hyperostosis lesions at cemetery 3-J-11 were healed (Table 3.17). Active lesions occurred exclusively in subadult age cohorts, notably for infants (85.7%, $n = 14$), but were randomly distributed throughout the cemetery. A Monte Carlo test showed a highly significant ($p < .001$) and strong association (V = .609) between age and porotic hyperostosis activity. Infants were strongly associated with active lesions ($z = 5.1$) and negatively associated ($z = –3.0$) with healed lesions. Children were also negatively related to healed lesions ($z = –2.2$) but positively associated with mixed reactions ($z = 2.6$). Adolescents also showed a positive relation to mixed ($z = 2.4$). Young adults were negatively associated with active ($z = –2.2$) and positively related to healed ($z = 2.1$). Middle adults and older adults showed this same pattern of negative association with active lesions ($z = –2.4$ and $z = –2.2$, respectively) and positive association with healed ($z = 2.2$ for both).

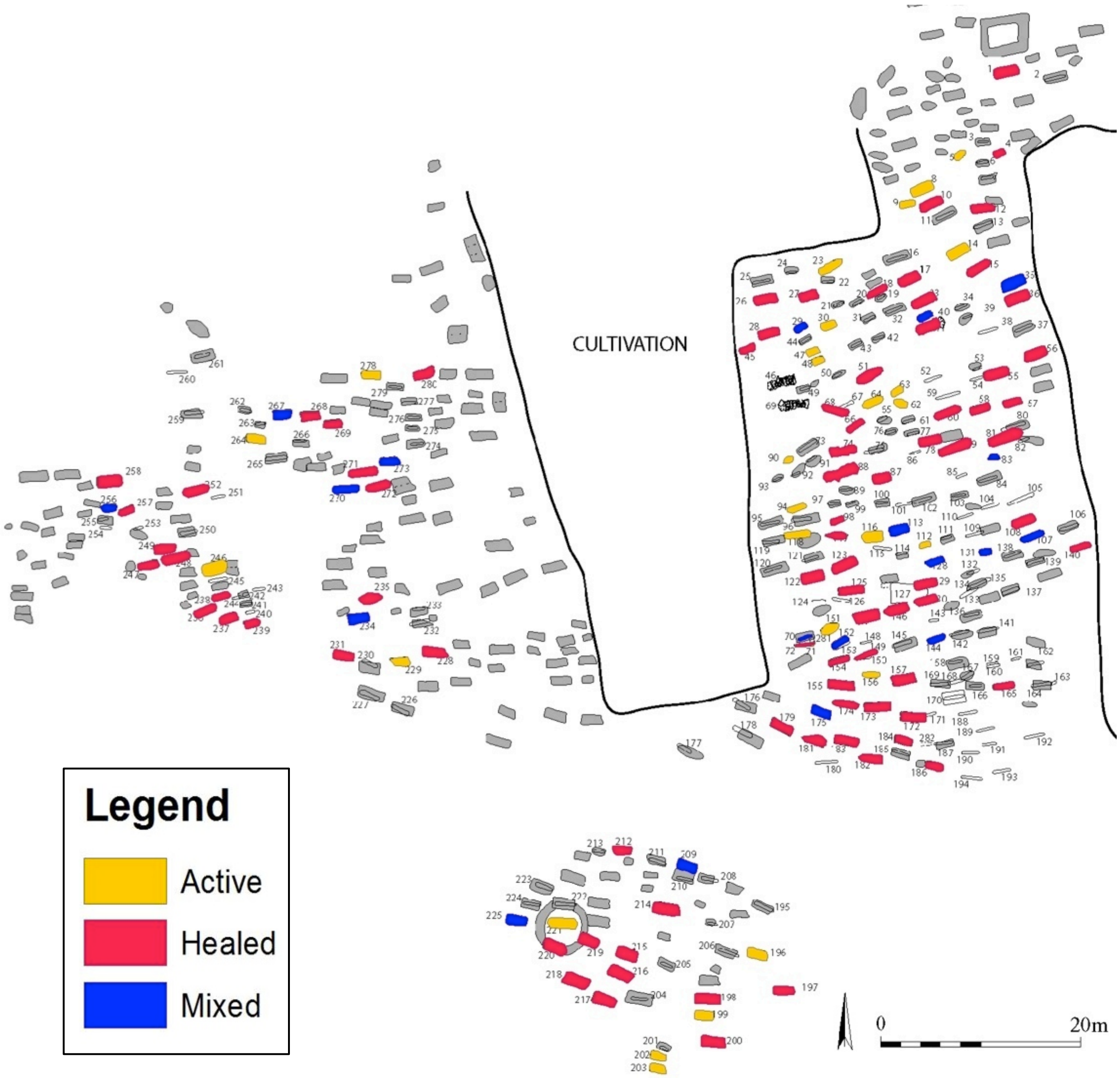

Figure 3.28: Spatial distribution of porotic hyperostosis activity at cemetery 3-J-11.

Table 3.17: Porotic hyperostosis activity by Standards age categories for 3-J-11.

3-J-11 PH Activity	Active		Healed		Mixed		TOTAL
	#	%	#	%	#	%	*n*
Infant (<3 yrs)	12	85.7%	0	0.0%	2	14.3%	14
Child (3-12 yrs)	11	35.5%	10	32.3%	10	32.3%	31
Adolescent (12-20 yrs)	6	37.5%	4	25.0%	6	37.5%	16
Young Adult (20-35 yrs)	0	0.0%	21	100.0%	0	0.0%	21
Middle Adult (35-50 yrs)	0	0.0%	26	96.3%	1	3.7%	27
Older Adult (>50 yrs)	0	0.0%	22	100.0%	0	0.0%	22
TOTAL	**29**	**22.1%**	**83**	**63.4%**	**19**	**14.5%**	**131**

Periostitis was a common lesion throughout cemetery 3-J-11. Figure 3.29 and Table 3.18 show the lamellar, or healed, type was most prevalent (67.4%, $n = 144$) suggesting that the proximate causes of periostitis were not often fatal. Mixed lesions occurred mostly in the eastern portion of the cemetery, afflicting all age groups. Woven lesions were only present in 9.7% ($n = 144$) of individuals with periostitis, but also occurred in most age cohorts. The mix of periostitis type throughout the cemetery and all age cohorts suggests everyone had an equivalent chance of being affected. A Monte Carlo test did find a small (V = .284) significant ($p = .021$) association between age and periostitis activity. Only the infant cohort had a significant standardized residual occurring in the mixed category ($z = 2.9$).

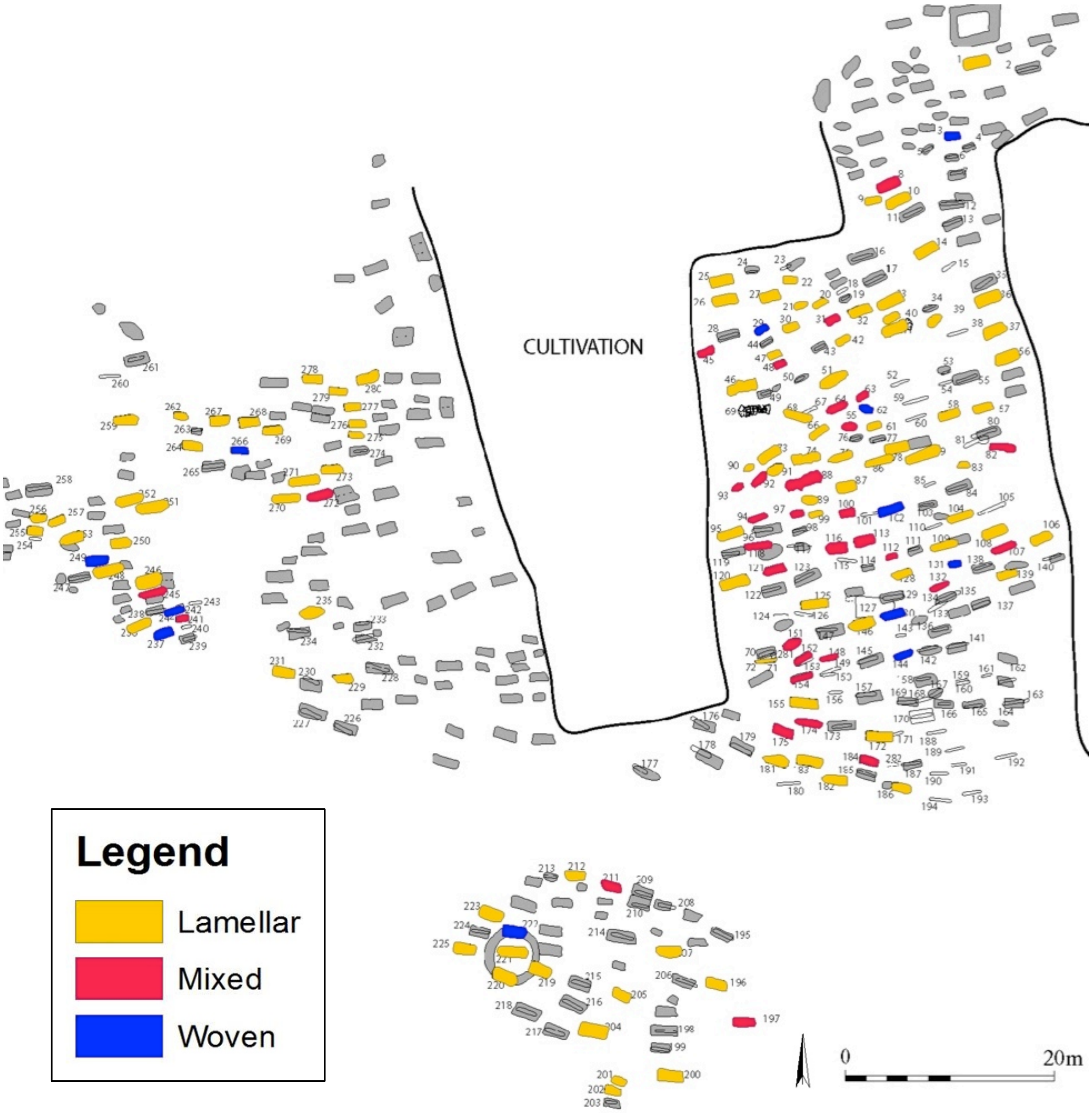

Figure 3.29: Spatial distribution of periostitis activity at cemetery 3-J-11.

Table 3.18: Periostitis activity by Standards age categories for 3-J-11.

3-J-11 Periostitis	Woven		Lamellar		Mixed		TOTAL
	#	%	#	%	#	%	*n*
Infant (<3 yrs)	2	6.9%	13	44.8%	14	48.3%	29
Child (3-12 yrs)	6	15.0%	28	70.0%	6	15.0%	40
Adolescent (12-20 yrs)	0	0.0%	6	54.5%	5	45.5%	11
Young Adult (20-35 yrs)	2	10.5%	13	68.4%	4	21.1%	19
Middle Adult (35-50 yrs)	2	8.0%	21	84.0%	2	8.0%	25
Older Adult (>50 yrs)	1	5.3%	16	84.2%	2	10.5%	19
Adult (>20 yrs)	1	100.0%	0	0.0%	0	0.0%	1
TOTAL	**14**	**9.7%**	**97**	**67.4%**	**33**	**22.9%**	**144**

Discussion

The results indicate that while the inhabitants at Mis Island followed basic tenants of Christian mortuary practice, like other Nubian populations, their burials displayed a considerable degree of variation. For both cemeteries, the standard practice included FF03c monuments with the individual interred with stones protecting the head in the western end of the grave. Bodies were typically placed in an extended supine position with heads facing upwards without any grave inclusions or personal adornment. Deviation from this suite of mortuary features was observable both between and within cemeteries.

Cemetery 3-J-10 showed a pattern of variation by age, including monument type, body covering, leg position, body position, and personal adornment. For monument type, infants and children were significantly associated with the FF03a monument rather than the standard FF03c. Furthermore, while FF03c monuments were found marking the graves of individuals of all ages, FF03a monuments were only present covering the burials of infants and children. This indicates that FF03a monuments were reserved for these youngest age cohorts. Infants were also significantly associated with an absence of body or head covering, while most individuals had a covering of the head with stones. Deviating from the supine body position that occurred most frequently at 3-J-10, infants had a significant relation to right side burial while children had significant associations with left side and prone burial. Leg position was also significantly different for infants who were associated with slight flex or each leg positioned differently rather than the typical extended positions. Personal adornment was not typically present in medieval graves at 3-J-10, but infants were significantly associated with this feature. Furthermore, although it was not statistically significant, it is noteworthy that the only individuals oriented with heads to the east were infants as well. Overall, the infant cohort varied most from standard practice at the cemetery. The youngest age cohorts were not only distinguished by mortuary variables, but were also afforded spatial distinction in a group on the eastern border of the cemetery.

The concentration of the infants and children in this eastern cluster could be indicative of a number of potential factors, including a single death event or lack of incorporation into the community. A disease epidemic that causes the death of the youngest individuals can occur since these are usually the most vulnerable group in a community. The fact that only a few infants and children were buried outside of this cluster undermines such a conclusion because it would be expected that subadult burials would be distributed throughout the cemetery in the 300 years of its use. Rather, the subadult burial pattern suggests a specialized area of internment for infants and children on the edge of the main cemetery. The mortuary and spatial distinction may indicate that infants and young children had not yet been afforded full membership into the community.

Cemetery 3-J-11 showed an even greater degree of variation than 3-J-10. This burial ground is thought to have been in use from AD 300 to AD 1400, thus a certain degree of this variation can be attributed to temporal changes. The body covering of stones and grave inclusions were two mortuary variables considered either transitional or Early Christian practices. The act of protecting the deceased with some type of stone or brick over the body or head is considered a relic of Pharaonic Egyptian eschatology in which the corporeal body required preservation for its journey to the afterworld (Adams, 1998, p 27). This custom continued in both Nubia and Egypt but the form of bodily protection simplified over time with rudimentary head coverings considered the final expression of this practice (Adams, 1998, p 28). The provisioning of grave goods for the deceased also declined as Christianity became established and medieval Nubians subscribed to the belief of the transmigration of the soul rather than the body (Adams, 1998, p 29). At cemetery 3-J-11, there were graves with complete body covering and grave goods. These burials were located in the eastern portion of the cemetery. Considering this is also the area with a large number of graves disturbed by later internments, these may represent some of the earliest Christian burials at 3-J-11.

The mortuary variables of monument type, leg position, and grave inclusion all showed a significant difference by age cohort at cemetery 3-J-11. Similar to 3-J-10, the FF03a monument type was significantly associated with infants and almost exclusively used to demarcate infant and child burials. The X10 monument was also significantly associated with the infant cohort, but there was only a single example of this monument type making any conclusion rather tenuous. Middle adults had a near significant association with the FF02f type, a monument only used to mark the graves of middle and older adults. Leg position was typically extended in this cemetery, but infants were associated with slightly flexed legs and each leg in a different position. While the intentional positioning of legs cannot be discounted, the legs of infants tend to rest in a slightly flexed position and thus these significant associations may be more related to biology than mortuary practices. Finally, while the majority of individuals had no grave inclusions, graves that contained artifacts were significantly associated with adults of unknown age. These graves likely represent the oldest Christian burials at 3-J-11, and thus for these early burials the inclusion of grave goods was reserved for adults. While this practice did not continue, it provides additional evidence about the distinction made between adults and subadults.

The spatial distinction of infants and children at 3-J-10 was distinct on the eastern edge of the cemetery. Interment of the youngest members of a community in specialized burial areas is not uncommon. On the Island of Sai in Upper Nubia, an infant cemetery was discovered dating to the Classic Kerma period (Murail et al., 2004). This cemetery was comprised of a single adult female and male and 64 subadults under the age of four, with over 80% of those representing stillborn infants or neonates (Murail et al., 2004, p 270). Infant burials in Nubia have also been found within or adjacent to houses. At Debeira West, several burials of young infants were found in large cooking pots under the floor or outside the door of houses (Shinnie and Shinnie, 1978, p 107). A similar practice occurred in Lower Nubia at the site of Arminna West where fetal remains were buried in a water jar used in waterwheels known as a *saqia* (Anderson, 2004, p 63). At the site of Soba, the capital of the southernmost medieval Nubian Kingdom Alwa, there is evidence that females and infants were buried in a specific area separate from the males (Filer, 1998, p 227). Thus it is not surprising that these age cohorts would be demarcated within a larger cemetery.

The location of infant burials in cemeteries 3-J-10 and 3-J-11 differed. In contrast to 3-J-10, the youngest burials at 3-J-11 were not restricted to the perimeter of the cemetery, but rather seemed to be incorporated into the larger group. This pattern suggests a principal of cemetery organization that differs between 3-J-10 and 3-J-11. At 3-J-10 there was one common area for these burials, while at 3-J-11 there were multiple areas in which these subadults were buried. Surrounding the infant and child clusters at 3-J-11 were the graves of individuals of various ages reminiscent of a family grouping. Large spatially clustered burials with relatively homogenous mortuary variables at the western and southern extremities of the cemetery were also comprised of individuals of various ages. This evidence supports a family-based organization to cemetery 3-J-11. It was difficult to discern such groups in the eastern portion of the cemetery, as the density of graves was high and burial disturbances common.

The overall widespread distribution of skeletal indicators of disease suggest everyone at 3-J-10 and 3-J-11 were susceptible to these pathologies. However, the activity state of the pathologies showed areas of clustering and statistical tests found significant associations between active lesions and age. The areas of active cribra orbitalia, porotic hyperostosis, and periostitis evident at both cemeteries coincide with infant graves who would have been most likely to have active lesions at time of death. Infants and young children are not only susceptible to malnutrition and disease from weaning practices, but passive immunity from the mother is also lost leaving an undeveloped immune system vulnerable to insults. Infants may also be more susceptible to cribra orbitalia and periostitis because in children the periosteum is more active and less affixed to the bone (Rana et al., 2009, p W259).

Conclusion

The mortuary and spatial analyses of the Mis Island cemeteries 3-J-10 and 3-J-11 have illustrated a general pattern of Christian burial practice with variation by age, through time, and between cemeteries. In both cemeteries, infants were demarcated spatially and/or through the type of mortuary treatment. This suggests that this age was significant at Mis Island, and may have marked a pivotal transition into full incorporation into a community. At 3-J-10, most of the deviation from traditional burial practice was evident in the eastern cluster of infant and child burials. This specific burial area seems to have been used by the entire community utilizing 3-J-10, as only a few infants and children were found outside of this area. Unfortunately, much of the cemetery was unexcavated making it difficult to fully understand the mortuary patterns observed.

Cemetery 3-J-11 showed a considerable degree of variation in mortuary variables. While many of the differences were attributable to differential treatment of infants and young children, body covering and grave inclusions were Early Christian practices that were discontinued. Furthermore, the spatial patterning of 3-J-11 was indicative of family burial clusters, with infants concentrated within a larger diverse group. Contrasting spatial patterns at 3-J-10 and 3-J-11 show two different organizing principles – 3-J-10 as a community burial ground and 3-J-11 as numerous family burial locations within a larger cemetery. The variation in this spatial organization of cemeteries and the concurrent use of the two cemeteries near the end of the Christian period may indicate different communities with different organizing principles were present at Mis Island.

LITERATURE CITED

LITERATURE CITED

Adams WY. 1998. Toward a Comparative Study of Christian Nubian Burial Practice. Archéologie du Nil Moyen 8:13–41.

Anderson JR. 2004. The Medieval Kingdoms of Nubia. In: Welsby DA, Anderson JR, editors. Sudan: Ancient Treasures. London: British Museum Press.

Borcowski Z, and Welsby DA. 2009. The Merowe Dam Archaeological Salvage Project: Provisional type series of monuments. Available from: http://www.nubiansociety.org/PDF/MDASP/MDASP-TypeSeries12-09.pdf

Buikstra JE, and Ubelaker DH. 1994. Standards for Data Collection from Human Skeletal Remains. Fayetteville: Arkansas Archeological Survey.

Field A. 2009. Discovering Statistics Using SPSS. 3rd ed. London: SAGE Publications Ltd.

Filer J. 1998. The Skeletal Remains. In: Soba II: Renewed Excavations within the metropolis of the Kingdom of Alwa in Central Sudan. British Institute in Eastern Africa Memoir 15. London: British Museum Press. p 213–232.

Ginns A. 2006. Preliminary Report on the Excavations Conducted on Mis Island (AKSC), 2005-2006. Sudan & Nubia 10:13–19.

Ginns A. 2007. Preliminary Report on the Second Season of Excavations Conducted on Mis Island (AKSC). Sudan & Nubia 11:20–25.

Ginns A. 2010a. Medieval Cemetery 3-J-10. Draft Site Report. Available from: http://www.sudarchrs.org.uk/AKS_draft_publications.htm

Ginns A. 2010b. Medieval Cemetery 3-J-11. Draft Site Report. Available from: http://www.sudarchrs.org.uk/AKS_draft_publications.htm

Murail P, Maureille B, Peresinotto D, and Geus F. 2004. An Infant Cemetery of the Classic Kerma Period (1750-1500 BC, Island of Sai, Sudan). Antiquity 78:267–277.

Rana RS, Wu JS, and Eisenberg RL. 2009. Periosteal Reaction. Am. J. Roentgenol. 193:W259–W272.

Shinnie PL, and Shinnie M. 1978. Debeira West, a Medieval Nubian Town: University of Ghana Expedition to Nubia. Warminster: Aris and Phillips.

Soler A. 2012. Life and Death in a Medieval Nubian Farming Community: The Experience at Mis Island [dissertation]. [East Lansing, (MI)]: Michigan State University.

Welsby DA. 1998. Soba II: Renewed Excavations within the Metropolis of the Kingdom of Alwa in Central Sudan. London: British Museum Press.

Welsby DA. 2002. The Medieval Kingdoms of Nubia. London: The British Museum Press.

Żurawski B. 2006. Nubian Mortuary Complex of the Christian Period. In: Caneva I, Roccati A, editors. Acta Nubica: proceedings of the X International Conference of Nubian studies, Rome, 9-14 September 2002. Rome: Istituto Poligrafico e Zecca dello Stato, Libreria dello Stato. p 171–187.

CHAPTER 4 – HEALTH AND NUTRITION

Introduction

The study of paleopathology can reveal a great deal about the ability of a society to adapt to its environment. Successful cultural adaptations allow a population to prosper, while extremely harsh environments or failed adaptation may result in the death or necessary migration of a group. Differences in health and disease within a population can also indicate aspects of social organization, including important sex, age, or status groups. The wealth of skeletal remains excavated from Egypt and Nubia provides an ideal opportunity for in depth investigations of communities to shed light on their life experiences and the stressors that were a natural part of daily living.

The study of populational stress has become a major focus of research in bioarchaeology. This began when Goodman and colleagues (1984) advocated for a shift in bioarchaeology away from case studies of specific pathologies to a biocultural approach. Such an approach had the advantage of contributing to anthropological questions through the study of health and disease at the population level. The stress model (Fig. 4.1) of Goodman and colleagues (1984) contextualizes disease as biological response to stressors that are induced by both environmental and societal factors that cannot be ameliorated through cultural or biological means. Goodman and colleagues (1988, p 177) define stress as a physiological response to a real or perceived threat to homeostasis. These stressors may result in biologic consequences if behavioral and cultural buffers cannot adequately neutralize the stress and return the body to homeostasis. These biological consequences, if prolonged, may impact the skeletal system and become recorded in bone.

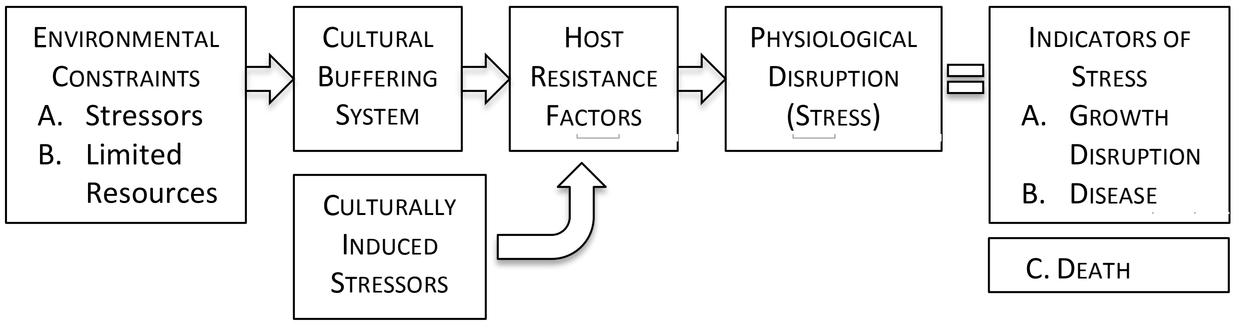

Figure 4.1: Skeletal stress model reproduced from Goodman et al. (1984).

There are various forms of skeletal indicators of stress and they are classified as general cumulative, general episodic, and specific (Goodman et al., 1984, p 15). General indicators are indiscriminate responses to threatening stimuli. These stress markers cannot be definitively associated with a particular stressor because numerous conditions may produce the same lesion. This reflects inherent properties of the skeletal system, where response to stressors is limited to bone resorption or deposition. General stress indicators can be further divided into cumulative and episodic categories. Cumulative markers represent the summation of an individual's stress experience over extended time periods, including a lifetime, while episodic manifestations signify a particular disease episode (Goodman et al., 1984, p 15).

In contrast to general stress indicators, specific stress indicators are symptomatic of a particular pathology. These are identified by their pattern and distribution throughout the skeleton. Examples of specific diseases that have recognizable skeletal signatures include tuberculosis, syphilis, leprosy, rickets, and scurvy. By investigating the type of skeletal lesions in a population and those afflicted, it is possible to extrapolate to the greater sociopolitical environment in an effort to identify potential causes of these stressors and their influence on the general health of a population (Goodman et al., 1988, p 197).

Paleopathology is an important tool in skeletal analyses, but the limitations and potential bias of the sample must be taken into consideration. As Wood and colleagues (1992) highlight, there are numerous problems inherent to drawing inferences regarding the health of entire populations from skeletal remains. The age-at-death distributions of skeletal samples may be affected by migration or changes in birth rates, confounding factors that can influence interpretations of the overall health of the population. In addition, selective mortality of particular age cohorts and hidden heterogeneity of individual frailty can also bias understandings of past health. In addition, a seemingly healthy sample with no indicators of pathology may actually represent the victims of a virulent pathogen that caused death before skeletal lesions could manifest. On the other hand, a mortality sample with a high prevalence of lesions may indicate a resilient population able to survive an environment with numerous biological and social stressors. Each of these possibilities needs to be taken into consideration when assessing the health of past populations through skeletal analyses. To address these potentially confounding factors, a biocultural approach is utilized to contextualize the skeletal population in both space and time and an effort is made to understand the stressors that may be impacting individuals within this community.

Skeletal Indicators of Stress

Localized Hypoplasia of the Primary Canine (LHPC)

Localized hypoplasia of the primary canine is a roughly circular enamel defect on the facial aspect of the deciduous canine crown. This unique type of hypoplastic expression was first described by Jørgensen (1956) in his study of the deciduous dentition of medieval and modern Danish children. The exploration of its etiology began in the 1980s and Skinner (1986, p 59) hypothesized the lesion was caused by stress near the time of birth involving the thin alveolar bone covering the crypt of the deciduous canine. Skinner and Hung (1989) revised the age of occurrence to approximately six months and attributed the defect to trauma inflicted to the forming canine during the normal developmental period when infants explore their environment by mouthing objects. In addition, results from a modern sample of children suggested that canine vulnerability was due to reduced cortical bone density caused by nutritional deficiencies of the mother or young infant. Further investigation has implicated maternal deficiencies in vitamin A for the occurrence of LHPC (Skinner et al., 1994; Skinner and Newell, 2000, 2003; Stojanowski and Carver, 2011) and dietary fats, which are necessary for the absorption of this nutrient (Skinner and Newell, 2000). Since LHPC occurs around six months of age, nutritional deficiencies leading to this lesion must have initiated earlier in the child's life. Thus LHPC is indicative of nutritional stress in prenatal or neonatal life presumably from poor fetal environment, maternal breast milk, or breastfeeding practices.

Tuberculosis

Tuberculosis (TB) is a chronic infectious disease caused by various species of the *Mycobacterium tuberculosis* (MTB) complex, including the human pathogens *Mycobacetrium tuberculosis, Mycobacterium bovis, Mycobacterium canetti,* and *Mycobacterium africanum* (Ortner, 2003, p 227; Donoghue, 2008, p 76). TB is contracted through the ingestion of tubercle bacilli. This primarily occurs from the inhalation of infected aerosols, but infection may also occur with the consumption of contaminated animal products (Kelley and El-Najjar, 1980, p 153; Donoghue, 2008, p 76). Upon infection, the host's immune system will detect the foreign bodies and form a granuloma around the tubercle bacilli, effectively inhibiting its spread. The bacillus is not eliminated, however, and can remain viable for years to be reactivated when the immune system is compromised (Roberts and Buikstra, 2003, p 17; Donoghue, 2008, p 76). When this occurs, TB bacteria spread from the initial foci of infection through the circulatory or lymphatic system to affect tissue and/or bone throughout the body (Roberts and Buikstra, 2003, p 19; Donoghue, 2008, p 76). The bacteria tends to migrate to areas of hemopoietic bone marrow, including the vertebrae, ribs, and sternum in adults (Ortner, 2003, p 228; Roberts and Buikstra, 2003, p 89). In young children, a greater degree of the skeleton is involved in red blood cell production, thus tuberculosis foci include the tubular bones of the hands and feet and ossification centers in the tarsals and carpals (Ortner, 2003, pp 228–229; Roberts and Buikstra, 2003, p 107).

Skeletal TB usually results in bone destruction via resorptive lesions, but ribs may display an osteoblastic reaction in response to TB infection in the lungs (Roberts and Buikstra, 2003, p 88). The spine is the most common and characteristic site of infection (Ortner, 2003, p 230). The number of vertebrae involved can vary, but the lower thoracic and lumbar portions of the spine are the most commonly affected (Roberts and Buikstra, 2003, p 92). Infection typically develops between the vertebral body and the anterior longitudinal ligament. Thus lesions are usually found on the body of the vertebra while the neural arch remains unaffected (Roberts and Buikstra, 2003, pp 91–92). Substantial architectural damage can compromise the structural integrity of the vertebra, which may result in the collapse of the anterior aspect of the body. This causes a characteristic spinal angulation known as Pott's Disease that may give an individual a stooped or hunched-back appearance (Roberts and Buikstra, 2003, p 89; Donoghue, 2008, p 78).

Other areas of skeletal involvement in tuberculosis include the joints and visceral surfaces of the ribs. Joints, especially the hip and the knee, may be affected by dissemination of tuberculosis either through the synovial membrane or by adjacent bone infection (Ortner, 2003, p

230; Roberts and Buikstra, 2003, p 96). Joint involvement may lead to the destruction of the articular surface and/or the epiphysis, but if the infection is limited to the joint capsule, these regions may be spared (Ortner, 2003, p 230; Roberts and Buikstra, 2003, p 96). Ribs are often utilized in the osteological diagnosis of TB, since primary lung infection can lead to proliferative bone formation on the visceral surface (Roberts et al., 1998). However, ribs should not be used in isolation for a TB diagnosis since there are multiple etiologies that produce similar lesions (Roberts and Buikstra, 2003, p 101; Steckel et al., 2011, p 34). Mays and colleagues (2002) tested visceral rib lesions for traces of ancient DNA of the *Mycobacterium tuberculosis* complex and found no consistent correlation between lesions and tuberculosis. This highlights the importance of using multiple skeletal indicators to arrive at a differential diagnosis of a specific disease.

An individual's nutritional status can also affect the disease progression of tuberculosis. Research by Wilbur and colleagues (Wilbur et al., 2008) investigated the interactions between nutritional status and the degree of skeletal involvement of an exposed individual. They argued that an individual who is protein deficient would have a compromised immune system that would be ineffective in neutralizing tuberculosis bacilli. Conversely, adequate amounts of iron will actually stimulate the growth of the mycobacteria and may even make reactivation of latent infection possible. Such considerations allow the bioarchaeologist with contextual paleodietary information to predict the skeletal response in populations exposed to tuberculosis.

Periostitis

Periostitis is a postcranial indicator of stress and is conventionally described as a new layer of bone deposited on the cortical surface beneath the periosteum resulting from trauma or infection. As Gladykowska-Rzeczycka (1998) reported, such periosteal change may be caused by a number of insults, including infectious diseases, trauma, tumors, and abscesses, making its exact etiology very difficult to ascertain. Weston (2008) attempted to distinguish different periosteal changes and correlate them with particular etiologies. Using macroscopic and radiographic analyses of long bones with periostitis from St. George's Hospital Pathology Museum and the Hunterian Museum in London, he found that disease progression was a greater determinant of lesion appearance than type of disease. Weston (2008) also expanded the list of potential contributors to periostitis by adding that compensation for underlying bone resorption, tumor containment, and altered circulation could all play a role. Thus, the presence of periostitis serves as an indicator of some type of physiological stress, but other evidence is required for a more precise diagnosis.

Cribra Orbitalia

Cribra orbitalia is a lesion of the orbital roof marked by abnormal porosity penetrating the cortex of the bone (Schultz, 2001, pp 132–134; Walker et al., 2009, p 109). As Schultz (2001, p 106) stated, cribra orbitalia is a descriptive term that describes, "a morphological symptom of various diseases." Etiologies attributed to cribra orbitalia have included iron deficiency anemia, megaloblastic anemia, vitamin C deficiency, subperiosteal hematoma, and trauma to the eye orbit. Thus, without additional skeletal indicators or analyses, cribra orbitalia can only be considered a non-specific indicator of physiological stress (Schultz, 2001, pp 132–134; Steckel et al., 2011, p 13).

Porotic Hyperostosis

Porotic hyperostosis is a lesion of the cranial vault that manifests as a circumscribed area of porotic cortical bone in the region of the parietals and occipital (Schultz, 2001, p 107; Walker et al., 2009, p 109; Steckel et al., 2011, p 13). It ranges in severity from small, scattered foramina to outgrowth from the cortex (Stuart-Macadam, 1985, p 392, 1989, pp 187–188). Since many underlying conditions may macroscopically present as porotic hyperostosis, it is conservative, without histological or radiographic analyses or other skeletal indicators of disease, to classify it as an indicator of non-specific stress (Schultz, 2001, pp 132–134; Steckel et al., 2011, p 13).

Cribra Orbitalia and Porotic Hyperostosis: Changing Interpretations

Cribra orbitalia and porotic hyperostosis are two of the mostly commonly seen pathological lesions in bioarchaeological investigations and have traditionally been interpreted as indicators of iron-deficiency anemia caused by iron-poor diets of agriculturalists reliant upon cereals for subsistence (Stuart-Macadam, 1992 a; Holland and O'Brien, 1997; Walker et al., 2009). This nutritional stress was believed to stimulate an increase in the production of red blood cells. To compensate for this, the erythropoietic, or red blood cell producing, diploë of the cranial vault would expand to provide a greater area for red blood cell production. If unmitigated, the expanding diploë impedes on the outer cortex causing it to thin resulting in the characteristic porosity of porotic hyperostosis and cribra orbitalia (Steinbock, 1976; Stuart-Macadam, 1992 b, p 39, c, p 151). Stuart-Macadam (1992) challenged this traditional nutrition-based interpretation of porotic hyperostosis and cribra orbitalia and asserted that iron-deficiency anemia had little to do with diet. Rather, she proposed that this type of anemia was a result of hypoferremia, or iron withholding, as an adaptive defense mechanism of the body to combat invasive pathogens. Hypoferremia is the sequestration of the body's iron supplies in the liver to inhibit the growth and development of invading organisms in the system. If prolonged, due to a high and constant pathogen load, hypoferremia can lead to symptoms of iron-deficiency anemia and its related skeletal lesions.

Holland and O'Brien (1997) challenged Stuart-Macadam's (1992) approach and argued that a parasite model was too simplistic and completely disregarded the many correlations found between cereal subsistence and porosity of the cranial vault and orbits. In addition, they contended that hypoferremia is not an adaptation, but rather a symptom signifying a harsh environment with a high pathogen load. Their argument was based on clinical evidence that found even mild iron deficiency could result in long-term detrimental effects, including decreased cell-mediated immunity and disorders of both physical and intellectual growth. Holland and O'Brien (1997) concluded that porotic hyperostosis and cribra orbitalia were most likely the result of the synergistic effects of poor nutritional quality of cereals, high pathogen loads due to sedentism and poor sanitation, and the concomitant detrimental effects of illness, such as the malabsorption of minerals, that results from malnutrition and infection.

Walker and colleagues (2009) contributed to the debate by stating that iron-deficiency was not the cause of porotic hyperostosis or cribra orbitalia. The authors cited clinical studies showing iron deficiency actually suppressed red blood cell production. The marrow hypertrophy that results in porotic hyperostosis and cribra orbitalia is caused by prolonged elevation of erythropoiesis. This increased red blood cell production will not occur if there are insufficient levels of iron to contribute. Rather than iron-deficiency anemia, Walker and colleagues (2009) pointed to either hemolytic or megaloblastic anemia as the causative mechanisms of cranial porosity. Hemolytic anemias are caused by premature red blood cell destruction. These can include the genetic anemias, like thalassemia and sickle cell anemia, where intrinsic factors of the red blood cell cause early destruction. Extrinsic factors, like toxins, drug use, or certain congenital heart defects, can also result in red blood cell death and hemolytic anemia. Alternatively, megaloblastic anemia is the result of B_{12} or folic acid deficiency. These deficiencies alter DNA synthesis causing the formation of enlarged macrocytes (marrow cells) with large nuclei that are unable to properly divide. These defective red blood cells are prone to early death. In both hemolytic and megaloblastic anemia, premature red blood cell death stimulates erythropoiesis, which has the potential to cause marrow hypertrophy and porotic hyperostosis.

Vitamin C Deficiency

Walker and colleagues (2009) also provided evidence to decouple porotic hyperostosis and cribra orbitalia. In many bioarchaeological investigations, porotic hyperostosis and cribra orbitalia do not occur together. Each can appear in isolation, suggesting separate etiologies may be responsible for these lesions. Moreover, the orbital roof has relatively small amounts of diploë making it an unlikely site of marrow hypertrophy. Walker and colleagues (2009) suggest cribra orbitalia may be the result of subperiosteal hematoma, a consequence of a number of diseases including scurvy. Scurvy is a pathological deficiency in vitamin C, caused by prolonged inadequate intake of dietary sources of this essential nutrient (Ortner, 2003, p 383). Vitamin C (ascorbic acid) is an essential component of collagen synthesis. Without adequate levels of vitamin C to produce collagen, osteoid formation is also impaired resulting in the manufacture of fragile blood vessels that are easily ruptured (Brickley and Ives, 2006, 2008, p

47). Sharpey's fibers, the collagenous connective tissue that secures the periosteum to the bone, can also be weakened with vitamin C deficiency. If the Sharpey's fibers break, the periosteum can be stripped from the bone resulting in a subperiosteal hematoma, which would manifest as cribra orbitalia in the eye orbits (Walker et al. 2009). Brickley and Ives (2006) added that in cases of scurvy, orbital lesions are unlikely to appear in isolation. Rather, a constellation of areas of abnormal porosity are identifiable, including around the infraorbital foramina of the maxilla, the posterior hard palate, the inner aspect of the mandibular ramus, the parietals, the occipital, the greater wing of the sphenoid, and the supraspinous and infraspinous fossae of the scapula.

Co-Morbidity in Cases of Cribra Orbitalia and Porotic Hyperostosis

The large amounts of both clinical and bioarchaeological research on anemia and scurvy indicate the likelihood of co-morbidity between these and other pathologies. For instance, many of the foods that contain vitamin C are also good sources of folic acid. Thus a diet that does not include the appropriate foods could result in both scurvy and megaloblastic anemia. One of the most intensely studied subjects in paleopathology research is the detrimental health outcome of agricultural subsistence. Although iron-deficiency is no longer considered the cause of porotic hyperostosis, the effects of agricultural subsistence may still have contributed to these skeletal lesions. Subsistence practices reliant on cereal staples, like maize, millet, or sorghum, lack many essential nutrients that are necessary for growth, development, and normal functioning. Furthermore, the concentration of populations in sedentary communities provides an ideal environment for infectious pathogens. Various infections induce symptoms, like diarrhea and vomiting, that can deplete B complex vitamins, vitamin C, vitamin E, selenium, and iron, further contributing to the development of scurvy and megaloblastic anemia (Long et al., 2007). Nutritional deficiencies also depress the immune system, leaving a person vulnerable to further infection and contributing to a dangerous synergistic relationship between malnutrition and disease (Walker et al., 2009). The intricate commingling of scurvy, megaloblastic anemia, and infection makes it nearly impossible to disentangle one from another, and highlights the importance of considering co-morbidity in skeletal analyses.

Materials and Methods

This paleopathological research investigated the skeletal remains of 188 subadults from cemeteries 3-J-10 (*n* = 52) and 3-J-11 (*n* = 136) from the site of Mis Island. This island site was located near the Fourth Cataract of the Nile and was excavated between 2005 and 2007 by the Sudan Archaeological Research Society as part of the Merowe Dam Archaeological Salvage Project (Ginns, 2006, 2007). Although the cemeteries represented typical mortuary contexts with adult males, females, and children, the focus of this study is on subadults from fetal to just under 20 years of age (see Table 4.1). This demarcation between adults and subadults was chosen to represent a developmental age at which skeletal growth has completed and all long bone epiphyses have fused.

Table 4.1: Mis Island subadult skeletal samples.

	3-J-10		**3-J-11**		**COMBINED**	
	n	%	*n*	%	*N*	%
Fetal (<0 yrs)	1	1.9%	0	0.0%	1	0.5%
Infant (0-3 yrs)	23	44.2%	42	30.9%	65	34.6%
Child (3-12 yrs)	23	44.2%	72	52.9%	95	50.5%
Adol. (12-20 yrs)	5	9.6%	22	16.2%	27	14.4%
TOTAL	**52**		**136**		**188**	

Each subadult skeleton was macroscopically analyzed for evidence of specific and non-specific indicators of stress and disease, dental health, and, when possible, differential diagnosis was used to indicate the presence of a particular disease. Although the entire skeleton was examined for abnormal bony reaction, certain bones or landmarks were evaluated for particular pathology. In these cases, the areas of interest were examined and scored as “present,” indicating the skeletal pathology was observable; “absent” indicating the areas of interest were not afflicted with the skeletal pathology; or “unscorable” to indicate that the area of interest was not present or was damaged to the extent that it was impossible to determine if the pathology had been present. The scoring of particular skeletal lesions is discussed below.

Localized Hypoplasia of the Primary Canine

All deciduous canines with the majority of the facial crown surface observable were examined for localized hypoplastic defects. These defects were identified based on the presence of a circumscribed region of deficient enamel, often oval or roughly circular in shape, that may or may not extend to the underlying dentine (Skinner, 1986, p 59; Stojanowski and Carver, 2011, p 91). These defects were scored as either present, absent, or unobservable and were evaluated by individual for statistical analyses.

Tuberculosis

The primary diagnostic criterion for tuberculosis is the presence of lytic lesions of vertebral centra, most often involving the lower thoracic and upper lumbar vertebrae, which may result in the collapse of the bodies and spinal angulation in advanced cases (Ortner, 2003, p 230; Roberts and Buikstra, 2003, pp 89–92; Donoghue, 2008, p 78; Steckel et al., 2011, pp 34–35).

Tuberculosis was considered present if erosive lesions were observable on at least one thoracic or vertebral body. Secondary indicators of tuberculosis were the presence of proliferative lesions on the pleural surface of the ribs or destructive lesions in the hip or knee joints, but in isolation these were not considered diagnostic of tuberculosis (Mays et al., 2002; Ortner, 2003, p 230; Roberts and Buikstra, 2003, pp 96–101; Steckel et al., 2011, pp 34–35). This pathology was considered present, absent, or unscorable if the necessary skeletal elements were not observable.

Periostitis

In this study, long bone shafts were macroscopically examined for the presence of periosteal reaction indicated by a plaque-like bony deposition on the cortical surface (Ortner, 2003, p 206; Steckel et al., 2011, p 30). Diaphyses were the focus of investigation because the developing metaphyseal area of a subadult may resemble periosteal reactions (Buikstra and Ubelaker, 1994, p 108). If periostitis was present, the bone or bones afflicted, the type of reaction, and the severity were also recorded.

Periosteal reactions were considered active, healed, or mixed. Active lesions demonstrated newly formed woven bone deposition on the cortex while healed or healing lesions had smoother surfaces of sclerotic bone becoming incorporated into the cortex, indicating the processes of remodeling (Buikstra and Ubelaker, 1994, p 118). The third category, mixed, was utilized when both woven and sclerotic bone were present. Severity was recorded as barely discernible, moderate, or extreme. Severity was considered barely discernible if the lesion consisted of only small patches of minor bone deposition. Moderate expression signified bone with marked periosteal reaction evident on the diaphysis. Finally, extreme severity included cases where a thick layer of deposition was evident on a large portion of the diaphysis resulting in deformation of the bone. While periostitis is common during the remodeling process following a fracture, such manifestations were not included in this study as they represent a traumatic event rather than a non-specific stress marker.

Osteomyelitis

Akin to periostitis, osteomyelitis is an infectious lesion marked by the involvement of the bone marrow and is diagnosed by the presence of one of the following: a cloaca, which is a penetrating canal that allows for drainage; a sequestrum, which is a portion of necrotic bone; and/or an involucrum, which is the sheath of new bone that forms around a sequestrum (Ortner, 2003, p 199). While the investigation of such pathological manifestations was originally part of this study, no lesions in this sample could be definitively associated with osteomyelitis.

Cribra Orbitalia

Cribra orbitalia was assessed on individuals with at least one observable eye orbit. Cribra orbitalia was considered present if the orbital roof displayed unusual porosity beyond what may be expected during normal growth and development. If the presence of cribra orbitalia was established, severity and activity were also scored. Severity could be scored at one of four levels, from scattered fine foramina, to large and small isolated foramina, to the more serious expressions of foramina linked in a trabecular structure, or the most severe expression of osseous outgrowth in a trabecular form (Stuart-Macadam, 1989, pp 187–188). Activity signified whether the lesion was active, with well-defined foramina borders, healed with more rounded edges and blunt foramina margins, or mixed where both active and healed portions of bone were present.

Porotic Hyperostosis

Due to the ongoing scholarly discussion regarding the possible etiologies of cribra orbitalia and porotic hyperostosis, these two lesions were scored similarly but separately. Porotic hyperostosis is any degree of unusual porosity on the non-orbital, external surface of the cranial vault (Steckel et al., 2011, p 13). The evaluation of lesions included location on the cranial vault, severity and activity, utilizing the same criteria as described for cribra orbitalia ((Stuart-Macadam, 1989, pp 187–188).

Scurvy

The diagnosis of scurvy was based on a constellation of osseous lesions and their distribution across the skeleton. Each individual was macroscopically examined for abnormal porosity signifying an increased vascular response and/or proliferative bone lesions resulting from subperiosteal hemorrhage of the cranial bones, long bones, or scapulae. Specifically, the presence of scurvy was indicated by pathological porosity and/or osseous apposition in the areas of the greater wings of the sphenoid, the infraorbital foramina of the maxilla, the internal aspects of the zygomatic bones, the posterior maxillae, the cranial vault, the orbital roofs, the posterior hard palate, the inner aspect of the mandibular rami, supraspinous and infraspinous fossae of the scapulae, and diaphyses of long bones (Ortner and Ericksen, 1997, pp 213–214; Ortner et al., 1999, p 324, 2001, pp 346–348; Brickley and Ives, 2006, pp 163–164, 2008, pp 56–61; Steckel et al., 2011, p 35). Since many pathologies can produce areas of porous, abnormal bone formation, the presence of lesions at multiple anatomical sites was considered necessary for the diagnosis of scurvy. In particular, lesions of the greater wing of the sphenoid were considered important as this area is considered pathognomic for this condition (Ortner and Ericksen, 1997, p 214).

Statistical Assessment

Frequency distributions were determined for age cohorts of both cemetery 3-J-10 and 3-J-11 for each type of pathology. Two different age classification systems were used to investigate the data for significant differences. The age categories from *Standards for Data Collection from Human Skeletal Remains* (Buikstra and Ubelaker, 1994) have become the accepted format in the United States and were used for the ease of comparison to other bioarchaeological studies (Table 4.2). In addition, the age categories utilized in the Human Bioarchaeological Database (Redfern, 2010) were also explored to discern any finer distinctions between age categories (Table 4.2). The demographics of cemeteries 3-J-10, 3-J-11, and the combined sample are shown both according to the Standards age categories (Table 4.3) as well as the Human Bioarchaeological Database (HBD) age cohorts (Table 4.4).

Table 4.2: Original age categories utilized in the comparison of pathology.

Buikstra & Ubelaker (1994)	Human Bioarchaeological Database
Fetal (<Birth)	Preterm (<37 weeks)
Infant (0-3 years)	Full-term (37-42 weeks)
Child (3-12 years)	Infancy (42 weeks to 3 years)
Adolescent (12-20 years)	Childhood (3-7 years)
	Juvenile (8-16 years)
	Adolescent (17-20 years)

Table 4.3: Samples divided by Standards age categories.

STANDARDS	3-J-10		3-J-11		COMBINED	
	n	%	*n*	%	*N*	%
Fetal (<0 yrs)	1	1.9%	0	0.0%	1	0.5%
Infant (0-3 yrs)	23	44.2%	42	30.9%	65	34.6%
Child (3-12 yrs)	23	44.2%	72	52.9%	95	50.5%
Adol. (12-20 yrs)	5	9.6%	22	16.2%	27	14.4%
TOTAL	**52**		**136**		**188**	

Table 4.4: Samples divided by Human Bioarchaeological Database age categories.

HBD	3-J-10		3-J-11		COMBINED	
	n	%	*n*	%	*N*	%
Preterm (<0 yrs)	1	1.9%	0	0.0%	1	0.5%
Fullterm (0 yrs)	2	3.8%	1	0.7%	3	1.6%
Infant (0-3 yrs)	21	40.4%	41	30.1%	62	33.0%
Child (3-7 yrs)	15	28.8%	59	43.4%	74	39.4%
Juvenile (8-16 yrs)	11	21.2%	26	19.1%	37	19.7%
Adol. (17-20 yrs)	2	3.8%	9	6.6%	11	5.9%
TOTAL	**52**		**136**		**188**	

Some of the age categories used in the frequency distributions of the 3-J-10 and 3-J-11 skeletal samples had age categories with small sample sizes of only one or two individuals. This made it necessary to collapse particular cohorts in order to increase the cell counts for each age category. Thus, the fetal and infant categories from *Standards* (Buikstra and Ubelaker, 1994) were collapsed into a single category representing all individuals less than 3 years (Table 4.5). For the Human Bioarchaeological Database cohorts, the preterm, full-term, and infancy groups were collapsed into a single category encapsulating all individuals under three years of age (Table 4.5).

Table 4.5: Revised age categories used in statistical analyses of pathology.

Revised Buikstra & Ubelaker	**Revised Human Bioarchaeological Database**
Infant (<3 years)	Infant (<3 years)
Child (3-12 years)	Childhood (3-7 years)
Adolescent (12-20 years)	Juvenile (8-16 years)
	Adolescent (17-20 years)

Chi-square tests were used to compare age cohorts within each cemetery and between the two cemeteries. If more than 20% of expected frequencies were less than five, however, a Fisher's exact test was employed. A $p < .05$ level was used to determine if significant associations were present. If a significant result was indicated, further investigation into the standardized residuals was undertaken. Standardized residuals can serve as an indication of where the significance within a sample lies. A standardized residual represents a *z*-score and is considered significant at the $p < .05$ level if the value lies outside of ±1.96. If the value is beyond ±2.58, it is significant at the $p < .01$ level, and if it is outside ±3.29 then its significance lies at the $p < .001$ level (Field, 2009, p 699). In addition, the strength of association between variables is measured by *phi* for 2x2 contingency tables and Cramer's V for larger tables. If the value of either of these measures is ±0.1 then the association is considered small. A result of ±0.3 indicates a medium association, and ±0.5 a large association (Field, 2009, p 698).

Results

Localized Hypoplasia of the Primary Canine

Localized hypoplasia of the primary canine (LHPC) was assessed for maxillary and mandibular deciduous canines from the left side of the mouth. Since deciduous teeth are normally lost by the age of 11 years, no individuals in the adolescent category retained any deciduous canines to evaluate. In the 3-J-10 sample, 36 individuals were assessed for LHPC. Nearly half of the subadults (47.2%) demonstrated LHPC, with 52.6% of the child category (*n* = 19) and 41.2% of the infant group (*n* = 17) with observable deciduous canines displaying a lesion. A chi-square revealed no association between LHPC presence and age, $\chi^2(1, n = 36) = .47, p = .492$. Sorting the data by the revised Human Bioarchaeological Database (HBD) categories (Table 4.7) showed a slightly higher prevalence in the child age category (53.3%, *n* = 15) and 50.0% in the juvenile cateogy (*n* = 4). A Fisher's exact test revealed no significant relationship between LHPC status and age (*p* = .891).

Table 4.6: Localized hypoplasia prevalence by cemetery and revised Standards ages.

LHPC	3-J-10			3-J-11			COMBINED		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	7	17	41.2%	18	32	56.3%	25	49	51.0%
Child (3-12 yrs)	10	19	52.6%	32	67	47.8%	42	86	48.8%
Adolescent (12-20 yrs)	0	0	0.0%	0	0	0.0%	0	0	0.0%
TOTAL	**17**	**36**	**47.2%**	**50**	**99**	**50.5%**	**67**	**135**	**49.6%**

Table 4.7: Localized hypoplasia prevalence by cemetery and revised HBD ages.

LHPC	3-J-10			3-J-11			COMBINED		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	7	17	41.2%	18	32	56.3%	25	49	51.0%
Child (3-7 yrs)	8	15	53.3%	28	58	48.3%	36	73	49.3%
Juvenile (8-16 yrs)	2	4	50.0%	4	9	44.4%	6	13	46.2%
Adolescent (17-20 yrs)	0	0	0.0%	0	0	0.0%	0	0	0.0%
TOTAL	**17**	**36**	**47.2%**	**50**	**99**	**50.5%**	**67**	**135**	**49.6%**

The cemetery 3-J-11 had a prevalence of 50.5% of observable subadults (n = 99) with LHPC. In this sample, 56.3% (n = 32) of the infants and 47.8% (n = 67) of the children were affected. A chi-square test showed no significant association between LHPC and age, $\chi^2(1, n = 99) = .62, p = .429$. Table 4.7 displays the 3-J-11 LHPC data by the revised HBD age cohorts. A Fisher's exact test showed there was a significant association between these age cohorts and LHPC prevalence (p = .048). The standardized residuals were not significant but juvenile cohort had a negative association with LHPC prevalence (z = –1.7) and a positive correlation with its absence (z = 1.7). In other words, juveniles in this sample did not typically have LHPC lesions.

A chi-square test to determine whether the cemeteries were significantly different showed no difference in LHPC prevalence, $\chi^2(1, n = 135) = .11, p = .736$. This allowed for the collapse of the two cemeteries into a single Mis Island sample. This sample, as seen in the combined column of Table 4.6, had 135 individuals that could be evaluated for LHPC and 49.6% displayed a lesion. Although there were slight differences in the prevalence of LHPC for the infant and child categories, these were not significant, $\chi^2(1, n = 135) = .06, p = .807$. The HBD combined sample (Table 4.7), showed similar prevalence rates for the infant and child cohorts (51.0%, *n* = 49 and 53.4%, *n* = 73, respectively), but the juvenile group only reached a 23.1% (*n* = 13) prevalence. A chi-square test, however, showed no significant association between age cohort and LHPC status, $\chi^2(2, n = 135) = 4.13, p = .127$.

Tuberculosis

Only two individuals in the entire Mis Island subadult sample (*n* = 180) demonstrated vertebral lesions consistent with tuberculosis. Both SK 1425 (12-15 years) and SK 1170 (16-19 years) from cemetery 3-J-11 had destructive lesions of the vertebrae as well as proliferative lesions on the ribs. Statistically, tuberculosis was significantly associated with adolescence for both the revised Standards and HBD age categories in cemetery 3-J-11 and in the combined cemetery sample (*p* = .029 and *p* = .026, respectively). These results suggest that either tuberculosis was a relatively rare infection for Mis Island, children died before characteristic skeletal lesions formed, or the ossification of vertebrae made it difficult to discern pathological lesions.

Periostitis

A total of 177 individuals in the Mis Island subadult skeletal sample were evaluated for periostitis. Of these individuals 63.8% displayed periosteal reactions. Table 4.8 displays the prevalence of periostitis by revised Standards age categories and Table 4.9 those by the revised Human Bioarchaeological Database (HBD) age categories. What is noticeable in these two tables is the low prevalence of periostitis in the HBD adolescent category, which was slightly masked in the Standards adolescent age category.

Table 4.8: Prevalence of periostitis by revised Standard age categories.

PERIOSTITIS	3-J-10			3-J-11			COMBINED		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	17	24	70.8%	29	40	72.5%	46	64	71.9%
Child (3-12 yrs)	13	22	59.1%	41	66	62.1%	54	88	61.4%
Adolescent (12-20 yrs)	2	5	40.0%	11	20	55.0%	13	25	52.0%
TOTAL	**32**	**51**	**62.7%**	**81**	**126**	**64.3%**	**113**	**177**	**63.8%**

Table 4.9: Prevalence of periostitis by revised HBD age categories.

PERIOSTITIS	3-J-10			3-J-11			COMBINED		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	17	24	70.8%	29	40	72.5%	46	64	71.9%
Child (3-7 yrs)	9	14	64.3%	35	56	62.5%	44	70	62.9%
Juvenile (8-16 yrs)	6	11	54.5%	15	22	68.2%	21	33	63.6%
Adolescent (17-20 yrs)	0	2	0%	2	8	25.0%	2	10	20.0%
TOTAL	**32**	**51**	**62.7%**	**81**	**126**	**64.3%**	**113**	**177**	**63.8%**

In cemetery 3-J-10, 51 individuals could be evaluated for periosteal reaction. It was found that 62.7% of the sample displayed periostitis. A Fisher's exact test indicated no significant differences between the presence of periostitis in this sample and the Standards (p = .365) or HBD age cohorts (p = .233). Investigation of the type of periosteal reaction by age category (Table 4.10) revealed that lamellar periostitis had the highest prevalence for all age groups. As expected, a Fisher's exact test demonstrated no relationship between age and type of periostitis (p = .673). Table 4.11 displays periostitis severity by age and it is apparent that most individuals with periostitis from 3-J-10 displayed only a minor expression. A Fisher's exact test, confirmed that there was no significant association between age and severity (p = .644).

Table 4.10: Prevalence of periostitis type by age for cemetery 3-J-10.

PERIOSTITIS TYPE	**3-J-10**						
	Lamellar		Woven		Mixed		
	Affected	%	Affected	%	Affected	%	*n*
Infant (<3 yrs)	8	47.1%	5	29.4%	4	23.5%	17
Child (3-12 yrs)	8	66.7%	3	25.0%	1	8.3%	12
Adolescent (12-20 yrs)	2	100.0%	0	0.0%	0	0.0%	2
TOTAL	**18**	**58.1%**	**8**	**25.8%**	**5**	**16.1%**	**31**

Table 4.11: Prevalence of periostitis severity by age for cemetery 3-J-10.

PERIOSTITIS SEVERITY	**3-J-10**						
	Minor		Moderate		Extreme		
	Affected	%	Affected	%	Affected	%	*n*
Infant (<3 yrs)	8	47.1%	7	41.2%	2	11.8%	17
Child (3-12 yrs)	9	69.2%	4	30.8%	0	0.0%	13
Adolescent (12-20 yrs)	1	50.0%	1	50.0%	0	0.0%	2
TOTAL	**18**	**56.3%**	**12**	**37.5%**	**2**	**6.3%**	**32**

The 3-J-11 sample contained 126 individuals that could be scored for the presence of periostitis. In this sample, 64.3% of subadults demonstrated some form of periostitis (Table 4.8 and Table 4.9). Table 4.8 shows the highest prevalence of periostitis occurred in the infant group (72.5%, n = 40) with decreasing prevalence with age. Table 4.9 displays the revised HBD categories and demonstrates a similar trend, but with a spike in prevalence occurring in the juvenile group (68.2%, n = 22) before a drop to 25.0% (n = 8) in the adolescent cohort. Chi-square tests showed no significant association between presence of periostitis and either Standards age groups, $\chi^2(2, n = 126) = 2.06$, $p = .357$ or HBD categories, $\chi^2(3, n = 126) = 6.78$, $p = .079$. Comparing the type of periostitis by age group (Table 4.12), a high percentage of lamellar reaction occurred in the child category (70.7%, n = 41) while the infant and adolescent categories were divided between the lamellar and mixed types. A Fisher's exact test revealed a significant association between age and periostitis type (p = .019). The child cohort had a nearly significant negative standardized residual (z = –1.9) for the mixed type indicating those with periostitis in this age category displayed few mixed periosteal reactions. Similar to 3-J-10, the majority of individuals in 3-J-11 had only a minor periosteal lesion (Table 4.13). Notably, however, those afflicted in the adolescent category were more likely to display a moderate expression (63.6%, n = 11). A Fisher's exact test, however, reported no significant result (p = .112).

Table 4.12: Prevalence of periostitis type by age for cemetery 3-J-11.

PERIOSTITIS TYPE	3-J-11						
	Lamellar		Woven		Mixed		
	Affected	%	Affected	%	Affected	%	*n*
Infant (<3 yrs)	13	44.8%	2	6.9%	14	48.3%	29
Child (3-12 yrs)	29	70.7%	6	14.6%	6	14.6%	41
Adolescent (12-20 yrs)	6	54.5%	0	0.0%	5	45.5%	11
TOTAL	**48**	**59.3%**	**8**	**9.9%**	**25**	**30.9%**	**81**

Table 4.13: Prevalence of periostitis severity for cemetery 3-J-11.

PERIOSTITIS SEVERITY	3-J-11						
	Minor		Moderate		Extreme		
	Affected	%	Affected	%	Affected	%	*n*
Infant (<3 yrs)	18	62.1%	11	37.9%	0	0.0%	29
Child (3-12 yrs)	26	63.4%	14	34.1%	1	2.4%	41
Adolescent (12-20 yrs)	3	27.3%	7	63.6%	1	9.1%	11
TOTAL	**47**	**58.0%**	**32**	**39.5%**	**2**	**2.5%**	**81**

A chi-square test of the prevalence of periostitis between cemeteries demonstrated no significant association between cemetery and periostitis prevalence, $\chi^2(1, n = 177) = .04$, $p = .847$. This allowed for the collapse of both cemeteries into a single Mis Island sample, represented by the combined columns in Table 4.8 and Table 4.9. A chi-square test of this combined sample revealed no significant association between the Standards age categories and the presence of periostitis, $\chi^2(2, n = 177) = 3.54$, $p = .170$. A chi-square test of the HBD groups, however, did show a significant association between age cohort and presence or absence of periostitis, $\chi^2(3, n = 177) = 10.15$, $p = .017$. Both Table 4.8 and Table 4.9 show the highest prevalence in the infant category and the lowest in the adolescent group. The standardized residuals for the HBD age cohorts revealed that adolescents had a significant ($p < .05$) absence of periostitis ($z = 2.3$). A Fisher's exact test for age and periostisis type on this combined sample (Table 4.14) revealed a significant ($p = .015$) association between these two variables. While none of the standardized residuals reached significance, the highest residuals were a negative correlation between the child cohort and a mixed reaction ($z = –1.9$) and a positive correlation between a mixed reaction and the infant group (*z* = 1.6). The relationship between periostitis severity and age (Table 4.15) was not statistically significant (*p* = .166).

Table 4.14: Prevalence of periostitis type by age for combined Mis Island sample.

PERIOSTITIS TYPE	COMBINED						
	Lamellar		Woven		Mixed		
	Affected	%	Affected	%	Affected	%	*n*
Infant (<3 yrs)	21	45.7%	7	15.2%	18	39.1%	46
Child (3-12 yrs)	37	69.8%	9	17.0%	7	13.2%	53
Adolescent (12-20 yrs)	8	61.5%	0	0.0%	5	38.5%	13
TOTAL	**66**	**58.9%**	**16**	**14.3%**	**30**	**26.8%**	**112**

Table 4.15: Prevalence of periostitis severity by age for combined Mis Island sample.

PERIOSTITIS SEVERITY	COMBINED						
	Minor		Moderate		Extreme		
	Affected	%	Affected	%	Affected	%	*n*
Infant (<3 yrs)	26	56.5%	18	39.1%	2	4.3%	46
Child (3-12 yrs)	35	64.8%	18	33.3%	1	1.9%	54
Adolescent (12-20 yrs)	4	30.8%	8	61.5%	1	7.7%	13
TOTAL	**65**	**57.5%**	**44**	**38.9%**	**4**	**3.5%**	**113**

Cribra Orbitalia

In the assessment of cribra orbitalia, 161 subadults had at least one orbit that could be assessed for this lesion, and of these individuals 83.2% were afflicted (Table 4.16, Table 4.17). In cemetery 3-J-10, a total of 70.8% (*n* = 48) of subadults with observable orbits had cribra orbitalia. For cemetery 3-J-10, both Table 4.16 and Table 4.17 demonstrate the highest prevalence of cribra orbitalia occurred in the child age category. A Fisher's exact test indicated, however, no significant association between age and cribra orbitalia affliction for the revised Standards (p = .102) or the revised HBD age categories (p = .140).

Table 4.16: Prevalence of cribra orbitalia by revised Standards age categories.

CRIBRA	**3-J-10**			**3-J-11**			**COMBINED**		
ORBITALIA	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	16	24	66.7%	29	34	85.3%	45	58	77.6%
Child (3-12 yrs)	16	19	84.2%	55	60	91.7%	71	79	89.9%
Adolescent (12-20 yrs)	2	5	40.0%	16	19	84.2%	18	24	75.0%
TOTAL	**34**	**48**	**70.8%**	**100**	**113**	**88.5%**	**134**	**161**	**83.2%**

Table 4.17: Prevalence of cribra orbitalia by revised HBD age categories.

CRIBRA	**3-J-10**			**3-J-11**			**COMBINED**		
ORBITALIA	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	16	24	66.7%	29	34	85.3%	45	58	77.6%
Child (3-7 yrs)	10	12	83.3%	47	51	92.2%	57	63	90.5%
Juvenile (8-16 yrs)	8	10	80.0%	19	20	95.0%	27	30	90.0%
Adolescent (17-20 yrs)	0	2	0%	5	8	62.5%	5	10	50.0%
TOTAL	**34**	**48**	**70.8%**	**100**	**113**	**88.5%**	**134**	**161**	**83.2%**

The severity and activity of the cribra orbitalia lesions were also investigated. Table 4.18 illustrates the prevalence of the different degrees of severity for the subadults of 3-J-10 afflicted with cribra orbitalia. The most minor expression was scattered and fine foramina with increasing severity to outgrowth in trabecular form. Table 4.18 clearly shows the majority of individuals (41.2%, n = 34) with cribra orbitalia had only minor severity with scattered and fine foramina. Severity by age group, however, showed some differences. While the infants displayed mostly minor expression (68.8%, n = 16), the child category is divided between large and small isolated foramina and foramina linked into a trabecular structure (31.3%, n = 16). The adolescents were also divided, with an even split between linked expression and outgrowth in trabecular form (50.0%, n =2). These results suggested that with advancing age severity increased. This could potentially be attributed to the fact that increased age provided a longer period of time for the skeletal lesion to progress to more advanced stages. A Fisher's exact test of severity by age indicated a significant (p = .007) association for these two variables. The largest standardized residuals were in the infant category where there was a positive association (z = 1.7) with scattered, fine foramina and a negative correlation (z = –1.7) with foramina linked into trabecular structure.

Table 4.18: Prevalence of cribra orbitalia severity for cemetery 3-J-10.

CRIBRA ORBITALIA SEVERITY	**3-J-10**								
	Scattered/Fine		Large + Small		Linked		Outgrowth		
	Affect.	%	Affect.	%	Affect.	%	Affect.	%	*n*
Infant (<3 yrs)	11	68.8%	2	12.5%	0	0.0%	3	18.8%	16
Child (3-12 yrs)	3	18.8%	5	31.3%	5	31.3%	3	18.8%	16
Adolescent (12-20 yrs)	0	0.0%	0	0.0%	1	50.0%	1	50.0%	2
TOTAL	**14**	**41.2%**	**7**	**20.6%**	**6**	**17.6%**	**7**	**20.6%**	**34**

The activity of the lesion was also assessed to determine if it was active, healed, or mixed. Table 4.19 shows the activity score prevalence for each age category. Of those with cribra orbitalia, 82.4% (*n* = 34) had active lesions, suggesting the underlying cause of the lesion had not been resolved by the time of death and may have been a contributing factor. In the infant category, 100.0% (*n* = 16) had active lesions, in the child category this drops to 68.8% (*n* = 16), and for the two adolescents with cribra orbitalia one had an active lesion and the other had a mixed lesion. A Fisher's exact test was significant ($p = .040$) between age category and lesion activity. No standardized residuals reached significance, but the largest were in the healed category where infants were negatively associated ($z = -1.5$) and adolescents were positively associated ($z = 1.3$).

Table 4.19: Prevalence of cribra orbitalia activity for cemetery 3-J-10.

CRIBRA ORBITALIA ACTIVITY	**3-J-10**						
	Active		Healed		Mixed		
	Affected	%	Affected	%	Affected	%	*n*
Infant (<3 yrs)	16	100.0%	0	0.0%	0	0.0%	16
Child (3-12 yrs)	11	68.8%	1	6.3%	4	25.0%	16
Adolescent (12-20 yrs)	1	50.0%	0	0.0%	1	50.0%	2
TOTAL	**28**	**82.4%**	**1**	**2.9%**	**5**	**14.7%**	**34**

Cemetery 3-J-11 had a higher overall prevalence of cribra orbitalia at 88.5% (*n* = 113) than 3-J-10. Of subadults in the revised Standards child category, 91.7% (*n* = 60) displayed a lesion (Table 4.16). While this value is high, a Fisher's exact test did not indicate there was a significant difference between age cohorts and cribra orbitalia prevalence ($p = .517$). Table 4.17

of the revised HBD categories also shows high frequencies of cribra orbitalia, with 94.0% (n = 50) for the child cohort. A Fisher's exact test was not significant (p = .087), however, demonstrating a weak association between age and cribra orbitalia prevalence for the 3-J-11 subadult sample.

The severity of cribra orbitalia lesions in cemetery 3-J-11 is displayed in Table 4.20. The majority of subadults with cribra orbitalia in this sample had a minor expression of scattered and fine foramina (45.0%, n = 100). Each of the age categories also showed scattered and fine foramina as the dominant expression of cribra orbitalia severity. Notably, the highest prevalence of outgrowth, the most severe expression of cribra orbitalia, was in the infant category (17.2%, n = 5) while the child and adolescent category both decreased in prevalence with greater severity. Although this was an interesting pattern, a Fisher's exact test of the association between severity and age was not significant (p = .079).

Table 4.20: Prevalence of cribra orbitalia severity for cemetery 3-J-11.

CRIBRA ORBITALIA SEVERITY	**3-J-11**								
	Scattered/Fine		Large + Small		Linked		Outgrowth		
	Affect.	%	Affect.	%	Affect.	%	Affect.	%	*n*
Infant (<3 yrs)	18	62.1%	5	17.2%	1	3.4%	5	17.2%	29
Child (3-12 yrs)	20	36.4%	18	32.7%	12	21.8%	5	9.1%	55
Adolescent (12-20 yrs)	7	43.8%	4	25.0%	4	25.0%	1	6.3%	16
TOTAL	**45**	**45.0%**	**27**	**27.0%**	**17**	**17.0%**	**11**	**11.0%**	**100**

The individuals with cribra orbitalia in cemetery 3-J-11 (Table 4.21) overwhelmingly displayed active lesions (80.0%, n = 100), with only 7.0% with a healed lesion. As the age cohort increased, the prevalence of healed lesions also increased, with 25% of affected adolescents (n = 16) with healed cribra orbitalia. A Fisher's exact test showed a significant association (p = .031) between age and cribra orbitalia activity. A highly significant standardized residual (z = 2.7) occurred in the healed category for adolescents indicating this age group is more likely to display healed lesions.

Table 4.21: Prevalence of cribra orbitalia activity for cemetery 3-J-11.

CRIBRA ORBITALIA ACTIVITY	3-J-11						
	Active		Healed		Mixed		
	Affected	%	Affected	%	Affected	%	*n*
Infant (<3 yrs)	25	86.2%	0	0.0%	4	13.8%	29
Child (3-12 yrs)	46	83.6%	3	5.5%	6	10.9%	55
Adolescent (12-20 yrs)	9	56.3%	4	25.0%	3	18.8%	16
TOTAL	**80**	**80.0%**	**7**	**7.0%**	**13**	**13.0%**	**100**

While both cemeteries demonstrated high prevalence of cribra orbitalia, cemetery 3-J-11 had an overall prevalence approximately 14% higher than 3-J-10. A chi-square test of the prevalence of cribra orbitalia between the two cemeteries revealed a significant difference, $\chi^2(1, n = 161) = 7.53$, p = .006, did exist between the two cemeteries. The standardized residuals indicated 3-J-10 individuals had a significant number of cases of absent cribra orbitalia (z = 2.1). The higher amounts of cribra orbitalia in all cohorts of 3-J-11, and its statistically significant difference to cemetery 3-J-10 in overall cribra orbitalia prevalence suggests there may have been differential experience of disease in these two cemeteries. In fact, an odds ratio showed that subadults in cemetery 3-J-11 were 3.17 times more likely to have cribra orbitalia than those of cemetery 3-J-10. Since these two cemeteries were found to be statistically different, they were not collapsed to test for further differences in age categories.

Porotic Hyperostosis

It was possible to assess porotic hyperostosis on a total of 176 subadults from Mis Island. For cemetery 3-J-10, 39.2% (n = 51) of individuals displayed lesions consistent with porotic hyperostosis. The highest prevalence (80.0%, n = 5) was in the adolescent category of the revised Standards age groups (Table 4.22), and in the juvenile cohort (81.8%, n = 11) of the revised HBD categories (Table 4.23). A Fisher's exact test revealed a significant association between age and prevalence of porotic hyperostosis for the revised Standards groupings (p = .019) and the revised HBD categories (p = .004). Only the revised HBD age cohorts had significant standardized residuals, with the juvenile group having a significant (z = 2.2) presence of porotic hyperostosis and a significantly negative association (z = –2.2) with its absence. Cramer's V, a measure of the strength of association, indicated that there was a medium degree of association for both the Standards cohorts (V = .395) and for the HBD groups (V = .484) between age and porotic hyperostosis lesions.

Table 4.22: Prevalence of porotic hyperostosis by revised Standards age categories.

POROTIC HYPEROSTOSIS	**3-J-10**			**3-J-11**			**COMBINED**		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	5	24	20.8%	14	40	35.0%	19	64	29.7%
Child (3-12 yrs)	11	22	50.0%	31	66	47.0%	42	88	47.7%
Adolescent (12-20 yrs)	4	5	80.0%	16	19	84.2%	20	24	83.3%
TOTAL	**20**	**51**	**39.2%**	**61**	**125**	**48.8%**	**81**	**176**	**46.0%**

Table 4.23: Prevalence of porotic hyperostosis by revised HBD age categories.

POROTIC HYPEROSTOSIS	3-J-10			3-J-11			COMBINED		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	5	24	20.8%	14	40	35.0%	19	64	29.7%
Child (3-7 yrs)	5	14	35.7%	23	55	41.8%	28	69	40.6%
Juvenile (8-16 yrs)	9	11	81.8%	18	22	81.8%	27	33	81.8%
Adolescent (17-20 yrs)	1	2	50%	6	8	75.0%	7	10	70.0%
TOTAL	**20**	**51**	**39.2%**	**61**	**125**	**48.8%**	**81**	**176**	**46.0%**

The severity and activity of porotic hyperostosis at cemetery 3-J-10 were also investigated. Table 4.24 shows the prevalence of different degrees of severity within the sample. The majority of the sample (75.0%, n = 20) had only minor lesions and none displayed foramina linked into a trabecular structure or an outgrowth in trabecular form from the cranial vault. Since no age cohorts displayed a vastly different pattern of severity, it was not surprising that a Fisher's exact test showed the association between age and severity was not significant (p = .645).

Table 4.24: Prevalence of porotic hyperostosis severity for cemetery 3-J-10.

POROTIC HYPEROSTOSIS SEVERITY	3-J-10								
	Scattered/Fine		Large + Small		Linked		Outgrowth		
	Affect.	%	Affect.	%	Affect.	%	Affect.	%	*n*
Infant (<3 yrs)	4	80.0%	1	20.0%	0	0.0%	0	0.0%	5
Child (3-12 yrs)	9	81.8%	2	18.2%	0	0.0%	0	0.0%	11
Adolescent (12-20 yrs)	2	50.0%	2	50.0%	0	0.0%	0	0.0%	4
TOTAL	**15**	**75.0%**	**5**	**25.0%**	**0**	**0.0%**	**0**	**0.0%**	**20**

The lesion activity was defined as either active, healed, or mixed. In 3-J-10, the majority of the lesions (55.0%, n = 20) were healed (Table 4.25), suggesting that the cause of the porotic hyperostosis had resolved and the individual was recovering. Infants had the highest prevalence in the active category (40.0%, n = 5) and children had the highest prevalence in the mixed category (45.5%, n = 11). A Fisher's exact test revealed no significant relationship between age and porotic hyperostosis activity (p = .247).

Table 4.25: Prevalence of porotic hyperostosis activity for cemetery 3-J-10.

POROTIC HYPEROSTOSIS ACTIVITY	**3-J-10**						
	Active		Healed		Mixed		
	Affected	%	Affected	%	Affected	%	*n*
Infant (<3 yrs)	2	40.0%	3	60.0%	0	0.0%	5
Child (3-12 yrs)	1	9.1%	5	45.5%	5	45.5%	11
Adolescent (12-20 yrs)	0	0.0%	3	75.0%	1	25.0%	4
TOTAL	**3**	**15.0%**	**11**	**55.0%**	**6**	**30.0%**	**20**

Cemetery 3-J-11 had a higher overall prevalence of porotic hyperostosis (48.8%, n = 125). Similar to 3-J-10, the highest frequencies were in the revised Standards adolescent cohort (Table 4.22) and the juvenile category in the revised HBD age groups (Table 4.23). A chi-square test showed the prevalence of porotic hyperostosis significantly differed by revised Standards age cohort, $\chi^2(2, n = 125) = 12.67, p = .002$. Cramer's V for this sample indicated a medium association (V = .318) between age and presence of porotic hyperostosis. The standardized residuals for this test showed the adolescent age group had a significant positive association with presence of porotic hyperostosis (z = 2.2) and conversely a significant negative correlation with the absence of porotic hyperostosis (z = –2.2). A Fisher's exact test on the revised HBD categories revealed a highly significant relationship between age cohort and porotic hyperostosis status (p = .001) with a medium strength of association (V = .357). In this case, the juvenile age category had standardized residuals that indicated a significantly positive correlation (z = 2.2) with porotic hyperostosis presence and a significantly negative correlation (z = –2.2) with its absence.

The severity and activity of the 3-J-11 sample are represented in Table 4.26 and Table 4.27. The severity was mostly (72.1%, n = 61) minor in expression with scattered and fine foramina and prevalence decreased with greater levels of severity. This general trend for 3-J-11 was not followed in the infant category, which had its highest percentage in the large, and small isolated foramina category (50.0%, n = 14). These differences proved to be highly significant (p < .001). The significant standardized residuals fell into the infant category, where there was a negative correlation (z = –2.2) with scattered and fine foramina, a positive correlation (z = 2.3) with large and small isolated foramina, and a larger positive correlation (z = 2.8) with foramina linked into a trabecular structure.

Table 4.26: Prevalence of porotic hyperostosis severity for cemetery 3-J-11.

POROTIC HYPEROSTOSIS SEVERITY	**3-J-11**								
	Scattered/Fine		Large + Small		Linked		Outgrowth		
	Affect.	%	Affect.	%	Affect.	%	Affect.	%	*n*
Infant (<3 yrs)	3	21.4%	7	50.0%	3	21.4%	1	7.1%	14
Child (3-12 yrs)	28	90.3%	3	9.7%	0	0.0%	0	0.0%	31
Adolescent (12-20 yrs)	13	81.3%	3	18.8%	0	0.0%	0	0.0%	16
TOTAL	**44**	**72.1%**	**13**	**21.3%**	**3**	**4.9%**	**1**	**1.6%**	**61**

The activity of the lesions in subadults affected by porotic hyperostosis in cemetery 3-J-11 is displayed in Table 4.27. Nearly half (47.5%, n = 61) of those with porotic hyperostosis had active lesions. This overall trend did not hold true for the individual age categories. Although the overwhelming majority in the infant cohort had active lesions (85.7%, n = 14), the child category had relatively even representation in each activity category, and the adolescents had 37.5% (n = 16) in both the active and mixed categories. A Fisher's exact test revealed a significant association (p = .019) between age and porotic hyperostosis activity with a medium (V = .307) strength of association. There was a single significant standardized residual in the infant/active lesion cell (z = 2.1) suggesting infants were likely to demonstrate active lesions.

Table 4.27: Prevalence of porotic hyperostosis activity for cemetery 3-J-11.

POROTIC HYPEROSTOSIS ACTIVITY	3-J-11						
	Active		Healed		Mixed		
	Affected	%	Affected	%	Affected	%	*n*
Infant (<3 yrs)	12	85.7%	0	0.0%	2	14.3%	14
Child (3-12 yrs)	11	35.5%	10	32.3%	10	32.3%	31
Adolescent (12-20 yrs)	6	37.5%	4	25.0%	6	37.5%	16
TOTAL	**29**	**47.5%**	**14**	**23.0%**	**18**	**29.5%**	**61**

A comparison between cemeteries showed a higher prevalence of porotic hyperostosis at 3-J-11 in every age category, except the revised Standards child group (Table 4.22). However, a chi-square test revealed no statistically significant difference between cemeteries, $\chi^2(1, n = 176) = 1.34, p = .247$. This allowed for the collapse of the two cemeteries and a test of the relation between age cohorts and porotic hyperostosis condition. A chi-square test revealed a highly significant association between revised Standards ages and porotic hyperostosis, $\chi^2(2, n = 176) = 20.43$, $p < .001$, with a medium strength of association (V = .341). The standardized residuals in the adolescent group demonstrated a significantly positive ($z = 2.7$) association with the presence of porotic hyperostosis and a signficantly negative association ($z = -2.5$) with its absence. Nearly reaching significance, the infant catogry had a negative correlation ($z = -1.9$) with the presence of porotic hyperostosis and a positive association ($z = 1.8$) with its absence. The revised HBD categories also demonstrated a statistically significantly association, $\chi^2(3, n = 176) = 27.03$, $p < .001$, with a medium association (V = .392). Interestingly, in this analysis, the standardized residuals for the adolescent category were no longer significant ($z = 1.1$ and $z = -1.0$) , indicating the age category was not associated with either the presence or absence of porotic hyperostosis. The juvenile group, however, had large standardized residuals, demonstrating statistically significant associations at the $p<.001$ level for a positive association ($z = 3.0$) with porotic hyperostosis presence and a negative association ($z = -2.8$) with its absence. This demonstrates that in the case of porotic hyperostosis, the revised Standards age categories slightly masked the the highest significant correlations.

Assessing the severity and activity of porotic hyperostosis by age in this combined sample revealed a significant relationship for both in relation to age cohort. Table 4.28 shows that the majority of Mis Island subadults had only minor expression of porotic hyperostosis (72.8%, $n = 81$). All the individuals afflicted with porotic hyperostosis in the child and adolescent categories had severity confined to the two most minor expressions. Infants, on the other hand, had individuals that displayed both linked foramina and outgrowth in a trabecular form. A Fisher's exact test for severity and age was highly significant ($p < .001$). The standardized residuals for this test showed a significant ($z = 2.7$) association between infants and linked foramina, as well as a nearly significant association (z = 1.8) with large and small isolated foramina and a negative association (z = –1.8) with the minor expression of scattered and fine foramina.

Table 4.28: Prevalence of porotic hyperostosis severity for Mis Island subadults.

POROTIC HYPEROSTOSIS SEVERITY	COMBINED								
	Scattered/Fine		Large + Small		Linked		Outgrowth		
	Affect.	%	Affect.	%	Affect.	%	Affect.	%	*n*
Infant (<3 yrs)	7	36.8%	8	42.1%	3	15.8%	1	5.3%	19
Child (3-12 yrs)	37	88.1%	5	11.9%	0	0.0%	0	0.0%	42
Adolescent (12-20 yrs)	15	75.0%	5	25.0%	0	0.0%	0	0.0%	20
TOTAL	**59**	**72.8%**	**18**	**22.2%**	**3**	**3.7%**	**1**	**1.2%**	**81**

The evaluation of lesion activity, as presented in Table 4.29, demonstrates that active lesions comprised the majority (39.5%, n = 81) of the Mis Island sample. The number of infants with active lesions (73.7%, n = 19) inflated this overall percentage, however, as active lesions had the lowest prevalence in the child and adolescent cohorts. A chi-square test showed these difference were statistically significant, $\chi^2(4, n = 81) = 12.24$, p = .016, with a small association (V = .275). The significant standardized residual occurred in the infant column for active lesion expression (z = 2.4) indicating individuals in this cohort were significantly more likely to have active lesions.

Table 4.29: Prevalence of porotic hyperostosis activity for Mis Island subadults.

POROTIC HYPEROSTOSIS ACTIVITY	COMBINED						
	Active		Healed		Mixed		
	Affect.	%	Affect.	%	Affect.	%	*n*
Infant (<3 yrs)	14	73.7%	3	15.8%	2	10.5%	19
Child (3-12 yrs)	12	28.6%	15	35.7%	15	35.7%	42
Adolescent (12-20 yrs)	6	30.0%	7	35.0%	7	35.0%	20
TOTAL	**32**	**39.5%**	**25**	**30.9%**	**24**	**29.6%**	**81**

Scurvy

The overall prevalence of scurvy in the Mis Island subadult sample was 65.9% (n = 179). Cemetery 3-J-10 had an overall prevalence of 55.8% (n = 52) with its peak occurring in the child category (65.2%, n = 23) for the revised Standards age categories (Table 4.30). The lowest percentage occurred in the adolescent category with 40.0% of individuals afflicted (n = 5). A Fisher's exact test revealed no significant associations between age categories and scurvy status (p = .468). The revised HBD categories also had the highest prevalence in the child cohort (66.7%, n = 15) and notably 0.0% affliction in the adolescent category (n = 2). This latter result, however may be a reflection of the small sample size of this age group rather than reality. A Fisher's exact test showed that there was no significant difference between age groups and scorbutic lesion status (p = .307).

Table 4.30: Prevalence of porotic hyperostosis by revised Standards age categories.

SCURVY	3-J-10			3-J-11			COMBINED		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	12	24	50.0%	29	40	72.5%	41	64	64.1%
Child (3-12 yrs)	15	23	65.2%	48	68	70.6%	63	91	69.2%
Adolescent (12-20 yrs)	2	5	40.0%	12	19	63.2%	14	24	58.3%
TOTAL	**29**	**52**	**55.8%**	**89**	**127**	**70.1%**	**118**	**179**	**65.9%**

Table 4.31: Prevalence of porotic hyperostosis by revised HBD age categories.

SCURVY	3-J-10			3-J-11			COMBINED		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	12	24	50.0%	29	40	72.5%	41	64	64.1%
Child (3-7 yrs)	10	15	66.7%	39	57	68.4%	49	72	68.1%
Juvenile (8-16 yrs)	7	11	63.6%	18	22	81.8%	25	33	75.8%
Adolescent (17-20 yrs)	0	2	0.0%	3	8	37.5%	3	10	30.0%
TOTAL	**29**	**52**	**55.8%**	**89**	**127**	**70.1%**	**118**	**179**	**65.9%**

Cemetery 3-J-11 had a sample of 127 individuals that could be assessed for scorbutic lesions with 70.1% of subadults exhibiting signs of scurvy. The infant category of the revised Standards age groups (Table 4.30) had the highest prevalence of scorbutic lesions (72.5%, n = 40), followed closely by the child cohort (70.6%, n = 68). A chi-square test showed that differences between age categories were not statistically significant, $\chi^2(2, n = 127) = .55, p = .758$. In the revised HBD categories (Table 4.31), juveniles had the highest frequency of lesions at 81.8% (n = 22) while only 37.5% (n = 8) of adolescents were affected. A chi-square test revealed no significant differences between revised HBD age categories, $\chi^2(3, n = 127) = 5.68$, $p < .128$.

Comparisons of the two cemeteries revealed higher prevalences of scurvy for all age groups of cemetery 3-J-11 (Table 4.30 and Table 4.31). Despite these differences, however, a Pearson's chi-square test revealed no statistically significant difference between cemetery 3-J-10 and 3-J-11 for frequency of scorbutic lesions, $\chi^2(1, n = 179) = 3.36$, $p = .067$. The combined column in Table 4.30 and 4.31 show the collapsed 3-J-10 and 3-J-11 samples. For both the revised Standards and revised HBD age groups, the combination of the two cemeteries equalized the percentage of those afflicted across the age categories. A chi-square test confirmed that there were no significant differences between the revised Standards cohorts, $\chi^2(2, n = 179) = 1.16$, $p = .561$, or the revised HBD age categories, $\chi^2(3, n = 179) = 7.41$, $p = .060$ and scorbutic lesions for the combined Mis Island sample.

Correlations Between Pathological Variables

Scurvy is a disease with multiple skeletal indicators, including forms of cribra orbitalia, porotic hyperostosis, and periostitis. Chi-square tests were utilized to investigate any statistical relations between prevalence of scurvy, cribra orbitalia, and porotic hyperostosis. Table 4.32 displays the total number of individuals who could be evaluated for both scurvy and cribra orbitalia ($N = 158$) as well as the number and prevalence of individuals with both scurvy and cribra orbitalia (65.8%), without pathognomic skeletal lesions of either disease (12.7%), and those with indicators of only cribra orbitalia (17.7%) or only scurvy (3.8%). A chi-square test showed a highly significant statistical association between scurvy and cribra orbitalia, $\chi^2(1, n =$

158) = 31.88, $p < .001$, with a medium strength of association (*phi* = .449). Standardized residuals showed a highly significantly positive association ($z = 4.3$) between the absence of both pathologies. There was also a highly significant negative association ($z = –2.8$) between the presence of scurvy and the absence of cribra orbitalia. Both of these standardized residuals indicated that an individual who did not have cribra orbitalia was highly unlikely to have other scorbutic lesions.

Table 4.32: Correlation between scurvy and cribra orbitalia.

		Scurvy		
		Present	Absent	**TOTAL**
Cribra Orbitalia	Present	104	28	**132**
	% Total *N*	65.8%	17.7%	**83.5%**
	Absent	6	20	**26**
	% Total *N*	3.8%	12.7%	**16.5%**
	TOTAL	**110**	**48**	**158**
	% Total N	**70%**	**30%**	**100%**

The association between scurvy and porotic hyperostosis was also tested. Table 4.33 shows the number of individuals afflicted with both scurvy and porotic hyperostosis (33.9%), those with neither pathology (20.1%), and those that demonstrate skeletal lesions of either scurvy (33.3%) or porotic hyperostosis (12.6%) only. A chi-square test revealed no significant association between these two lesions, $\chi^2(1, n = 174) = 2.16$, $p = .142$. This suggests that each of these pathologies occurred in isolation and thus may have separate etiologies.

Table 4.33: Correlation between scurvy and porotic hyperostosis.

		Scurvy		
		Present	Absent	**TOTAL**
Porotic Hyperostosis	Present	59	22	**81**
	% Total *N*	33.9%	12.6%	**46.6%**
	Absent	58	35	**93**
	% Total *N*	33.3%	20.1%	**53.4%**
	TOTAL	**117**	**57**	**174**
	% Total N	**67.2%**	**32.8%**	**100.0%**

A chi-square test, $\chi^2(1, n = 175) = 1.09, p = .297$ shows that the relationship between scurvy and periostitis was also not significant. Table 4.34 demonstrates the count and prevalence of individuals in each category of affliction. Of the 175 subadults evaluated for both scurvy and periostitis, 44.6% had lesions of both pathologies, 22.3% had only scurvy, 19.4% only periostitis, and 13.7% with neither. While these lesions may occur together, the non-significant association suggests that for the Mis Island subadults, not all periostitis is associated with scurvy and not all scurvy produces periosteal lesions.

Table 4.34: Correlation between scurvy and periostitis.

		Scurvy		
		Present	Absent	**TOTAL**
Periostitis	Present	78	34	**112**
	% Total *N*	44.6%	19.4%	**64.0%**
	Absent	39	24	**63**
	% Total *N*	22.3%	13.7%	**36.0%**
	TOTAL	**117**	**58**	**175**
	% Total *N*	**66.9%**	**33.1%**	**100.0%**

Cribra orbitalia and porotic hyperostosis have long been associated and researchers tend to group them together as different manifestations of the same disease, namely iron deficiency anemia. Recently, however, the etiologies of these two skeletal lesions have been critically re-evaluated. Table 4.35 shows the correlation of the two skeletal lesions in this study. Of the 158 subadults evaluated, 44.3% had both cribra orbitalia and porotic hyperostosis, 12.0% had neither skeletal lesion, 39.2% had only cribra orbitalia, and 4.4% had only porotic hyperostosis. A chi-square test investigating the relationship between cribra orbitalia and porotic hyperostosis revealed a statistically significant result, $\chi^2(1, n = 158) = 5.93$, $p = .015$, with a small strength of association (*phi* = .194). Although the standarized residuals did not reach significance, there was a trend towards a positive association between the absence of both lesions ($z = 1.6$), and a negative association between the presence of porotic hyperostosis and the absence of cribra orbitalia ($z = -1.6$). In other words, if an individual did not have cribra orbitalia they were unlikely to have porotic hyperostosis.

Table 4.35: Correlation between cribra orbitalia and porotic hyperostosis.

		Cribra Orbitalia		
		Present	Absent	**TOTAL**
Porotic Hyperostosis	Present	70	7	**77**
	% Total *N*	44.3%	4.4%	**48.7%**
	Absent	62	19	**81**
	% Total *N*	39.2%	12.0%	**51.3%**
	TOTAL	**132**	**26**	**158**
	% Total *N*	**83.5%**	**16.5%**	**100.0%**

Current evidence suggests localized hypoplasia of the primary canine (LHPC) is caused by malnutrition in the fetal environment. Thus, the presence of LHPC may indicate a child did not have the appropriate nutrients *in utero* or during the neonatal period which may make them susceptible to other pathological conditions. The association between LHPC and periostitis was examined (Table 4.36). In this sample (n = 131), 38.2% of individuals had both LHPC and periostitis. While this did not constitute the majority of individuals, it was the highest prevalence of the four potential disease states. A chi-square test revealed a significant association between these two conditions, $\chi^2(1, n = 131) = 8.21, p = .004$, with a small level of association (*phi* = .250). No standardized residuals reached significance, but the highest occurred in the cell representing the absence of both pathologies (z = 1.6) and a negative association between the presence of LHPC and the absence of periostitis (z = –1.6). This indicated a trend toward LHPC and periostitis occurring together.

Table 4.36: Correlation between periostitis and LHPC.

		Periostitis		
		Present	Absent	**TOTAL**
LHPC	Present	50	15	**65**
	% Total *N*	38.2%	11.5%	**49.6%**
	Absent	35	31	**66**
	% Total *N*	26.7%	23.7%	**53.3%**
	TOTAL	**85**	**46**	**131**
	% Total *N*	**64.9%**	**35.1%**	**100.0%**

Table 4.37 shows the prevalence of the co-occurrence of LHPC and porotic hyperostosis. The table demonstrates that the highest prevalence occurred with the presence of LHPC and the absence of porotic hyperostosis (30.0%, n = 130), but all cells have prevalence values between 20% and 30%. This suggests there was little correlation between these two lesions. A chi-square test confirmed that there was no significant association between these two variables, $\chi^2(1, n = 130) = .02, p = .882$. Thus the presence of LHPC was not a significant predictor of porotic hyperostosis. This may mean that these two skeletal lesions have unrelated etiologies.

Table 4.37: Correlation between porotic hyperostosis and LHPC.

		Porotic Hyperostosis		
		Present	Absent	**TOTAL**
LHPC	Present	27	39	**66**
	% Total *N*	20.8%	30.0%	**50.8%**
	Absent	27	37	**64**
	% Total *N*	20.8%	28.5%	**93.1%**
	TOTAL	**54**	**76**	**130**
	% Total *N*	**41.5%**	**58.5%**	**100.0%**

Cribra orbitalia and LHPC were evaluated together in Table 4.38. While there was clearly a high prevalence of cribra orbitalia presence (89.7%, n = 116), it does not seem to be associated with LHPC presence as there are nearly equal values in the cribra orbitalia present/LHPC present cell (46.6%) and the cribra orbitalia present/LHPC absent cell (43.1%). A chi-square test confirmed the lack of significance between cribra orbitalia and LHPC, $\chi^2(1, n = 116) = 1.487, p = .223$.

Table 4.38: Correlation between cribra orbitalia and LHPC.

		Cribra Orbitalia		
		Present	Absent	**TOTAL**
LHPC	Present	54	4	**58**
	% Total *N*	46.6%	3.4%	**50.0%**
	Absent	50	8	**58**
	% Total *N*	43.1%	6.9%	**54.5%**
	TOTAL	**104**	**12**	**116**
	% Total *N*	**89.7%**	**10.3%**	**100.0%**

A chi-square test also revealed there was no significant association between scurvy and LHPC, $\chi^2(1, n = 133) = 2.30, p = .129$. Table 4.39 demonstrates the prevalence of individuals in each disease combination category. Although the highest prevalence was in the category representing the presence of both lesions (36.8%, n = 133), this was closely followed by the cell representing scurvy presence with LHPC absence (32.3%), an indicator that these conditions were not predictive of each other.

Table 4.39: Correlation between scurvy and LHPC.

		Scurvy		
		Present	Absent	**TOTAL**
LHPC	Present	49	16	**65**
	% Total *N*	36.8%	12.0%	**48.9%**
	Absent	43	25	**68**
	% Total *N*	32.3%	18.8%	**91.7%**
	TOTAL	**92**	**41**	**133**
	% Total *N*	**69.2%**	**30.8%**	**100.0%**

Discussion

The presence and degree of various pathological conditions at cemeteries 3-J-10 and 3-J-11 were evaluated and tested for significant associations between variables of interest. For the majority of skeletal lesions, cemetery 3-J-11 had an overall higher prevalence than cemetery 3-J-10, but these differences only proved to be significant in the case of cribra orbitalia. However, it is still noteworthy that 3-J-11 had prevalences 9.6% higher for porotic hyperostosis and 14.3% higher for scorbutic lesions in addition to the 17.7% higher prevalence for cribra orbitalia. These data indicate greater amounts of biological stressors impacting individuals represented in cemetery 3-J-11.

While it is not possible to discount the difference in sample size between the two cemeteries as a potential source of error, environmental factors may have played a contributing role in the discrepancy of skeletal indicators of stress. Cemetery 3-J-10 was utilized from approximately AD 1100 to 1400, while 3-J-11 spanned the period from AD 300 to 1400. High Nile levels have been predicted for the later medieval period, which would have provided moisture and nutrients to *seluka*, or flood plain, land and would have made irrigation easier by decreasing the height water would need to be lifted to fill irrigation channels (Welsby, 2002, pp 183–184; Edwards, 2004, pp 213–214). It has been postulated that prior to this period, however, exceptionally low river levels occurred between AD 828 and 837 and again from AD 939 to 948 (Edwards, 2004, pp 213–214). In an environment that was heavily dependent on seasonal floods for agriculture and survival, a succession of drought-induced low Niles would have been devastating. Thus, portions of cemetery 3-J-11 may reflect higher levels of morbidity and mortality that occurred during these periods of impoverishment.

Localized hypoplasias of the primary canine afflicted 49.6% (n = 135) of the observable Mis Island subadult sample. There was no significant difference between 3-J-10 and 3-J-11 as prevalence of LHPC was similar in both cemeteries (47.2%, n = 36; 50.5%, n = 99, respectively). A significant result was obtained in comparing the HBD age categories with lesion presence for cemetery 3-J-11. In this case, the largest, but non-significant, standardized residuals were in the juvenile cohort with a positive association (z = 1.7) with LHPC absence and a negative correlation (z = –1.7) with its presence. LHPC is a lesion that occurs at approximately the same age in all individuals, during the period of crown development in the deciduous canines. While it is generally accepted that LHPC form after birth, the conditions required to predispose an infant to LHPC are probably related to the prenatal environment (Halcrow and Tayles, 2008, p 2217).

The etiology of LHPC is believed to be trauma to the developing canine as the alveolus is impacted during a child's normal developmental stage of mouthing objects. An LHPC will occur if the alveolar bone overlying the crypt of the canine is unusually thin or fenestrated as a result of nutritional deficiencies. The association between LHPC and trauma has been documented in modern human cases involving the piercing of bone over the unerupted canine as a traditional treatment for teething and other illnesses in parts of the Sudan (Rasmussen et al., 1992). Work by Skinner and colleagues found significant associations between LHPC and nutritional factors in a modern sample of Canadian children (Skinner and Hung, 1989; Skinner et al., 1994). Specifically, nutritional deficiencies of calcium, vitamin D, and vitamin A have been implicated (McDonell and Oxenham, 2012, pp 4–5). Skinner and Hung (1989) found a higher frequency of LHPC in children whose mothers practiced some degree of cultural milk avoidance, suggesting maternal calcium levels may not have been adequate during gestation. Calcium deficiency is a well-documented cause of osteopenia and thus it was hypothesized that this could lead to a pathologically thin alveolus leaving the canine susceptible to traumatic impacts (Skinner and Hung, 1989, pp 170–171; McDonell and Oxenham, 2012, pp 4–5). Clinical studies have also implicated vitamin D deficiency for LHPC prevalence, as children born during months of decreased sunlight had higher rates of this lesion (Skinner et al., 1994; Lukacs and Walimbe, 1998, p 577). Vitamin D is imperative for proper mineralization of bones, and its deficiency is well known to contribute to the softening of bones that characterizes rickets. Few foods naturally contain vitamin D, thus adequate levels of sun exposure are critical for its production.

In the case of Mis Island subadults, it is unlikely that vitamin D deficiency played a role in the prevalence of LHPC. Inadequate levels of vitamin D would eventually lead to the characteristic skeletal manifestations of rickets, a pathology that is conspicuously absent in the Mis Island sample. If the environment is taken into consideration, it also seems unlikely that a population living on an island in the Nile would fail to receive adequate levels of sun exposure.

Further research on LHPC by Skinner and colleagues (1994, p 111) found only the consumption of vitamin A, in the form of fortified milk and fresh produce, was conspicuously low in mothers of children with LHPC (p 111). Vitamin A is necessary for equilibrium between bone deposition and bone resorption. Deficiency of this nutrient causes osteoclastic activity to increase and, if unmitigated, can result in osteopenia (Lukacs and Walimbe, 1998, p 577; Stojanowski and Carver, 2011, p 90; McDonell and Oxenham, 2012, p 5). Addressing the previous vitamin D hypothesis, Skinner and associates (1994, pp 112–113) attributed the lack of fresh produce in the winter to the increased rate of LHPC in infants born in these months, rather than lower amounts of sunlight.

Vitamin A is an essential micronutrient that is not synthesized in the human body so must be consumed as part of the diet. There are both animal and plant sources of vitamin A. Animal sources occur in the form of retinol and include liver, eggs, milk products, fish, meat, and breast milk. Darkly colored fruits and vegetables contain beta-carotene, a vitamin A precursor, which is less bioavailable than animal sources, meaning less of the vitamin A from produce will be absorbed by the body. Vitamin A plays a crucial role in a number of physiological functions besides bone metabolism, most notably eye health and immune function. Newborns are especially vulnerable to vitamin A deficiency. They are completely dependent on breast milk for vitamin A to fulfill both physiological needs and to build liver stores that will be necessary after weaning (Stoltzfus and Underwood, 1995). Inadequate vitamin A levels also increase rates of death from diarrhea, measles, and malaria (Black, 2003). Even subclinical levels of this deficiency can compromise immune function resulting in a 25% to 30% increase in death for afflicted children (Micronutrient Initiative and UNICEF, 2004, p 3) Thus, if the instances of LHPC in young children at Mis Island are indicative of vitamin A deficiency, due to inadequate maternal resources or early weaning, this presents serious implications for childhood morbidity and mortality.

Periostitis prevalence in the Mis Island sample was 63.8% with no significant difference between cemeteries 3-J-10 and 3-J-11. The combined sample did show a significant difference in periostitis prevalence and HBD age cohort. Adolescents presented with a significant positive association with the absence of periostitis. This result reflects the decrease in periostitis prevalence with age in both the 3-J-10 and 3-J-11 samples, suggesting that periostitis was a skeletal lesion common in young children but gradually resolved with age. An investigation of periostitis type, which corresponds to a state of active, healing, or mixed reaction, showed adolescents did not have any lesions that were classified as woven (active), so all lesions in this age group were at least partially healing. This evidence suggests that by adolescence the underlying cause of periostitis had been resolved.

The skeletal lesion with the highest prevalence in the Mis Island collection was cribra orbitalia. A remarkable 83.2% of the 161 individuals displayed lesions of the orbital roof. This was also the only pathology evaluated where significant differences existed between the two cemeteries, with 88.5% presence in 3-J-11 compared to the 70.8% in 3-J-10. Although there was no significant relationship between age cohort and cribra orbitalia presence in either of the cemeteries, the pattern of prevalence from infant to adolescent was interesting. For both cemeteries, affliction rate peaked in the child category for both the revised Standards and HBD age categories. The severity in cemetery 3-J-10 showed a significant relationship with age. Specifically, infants trended toward a positive association with the least severe expression, scattered and fine foramina, and a negative association with linked foramina. As infants would have the shortest amount of time to develop lesions, it is expected they would show the earliest stages of severity. Both of the cemeteries demonstrated a significant association between age and the activity of cribra orbitalia lesions. In 3-J-10, no standardized residuals reached significance but infants had a negative association with healed lesions and adolescents had a positive association. In 3-J-11, a similar pattern emerged with infants being negatively associated with healed lesions and adolescents had a significant positive relationship with healed cribra orbitalia. Despite this significance, the majority of adolescents had active lesions (56.3%, n = 16). Thus the underlying cause of cribra orbitalia continued to afflict individuals into adolescence. In fact, in both cemeteries, active lesions accounted for 80% or more of the cribra orbitalia cases, suggesting the etiology of this disease may have directly contributed to their deaths. The overall pattern of cribra orbitalia shows initial disease occurred in infancy. The number affected or dying increased in childhood, and during adolescence, some individuals showed signs of healing, but the majority maintained active lesions.

At 46.0%, the incidence of porotic hyperostosis in the Mis Island sample was much lower than the rate of cribra orbitalia. This fact adds further support to the idea that these two skeletal lesions were not caused by the same pathology. Both cemeteries showed significant associations between age and the presence or absence of porotic hyperostosis. For cemetery 3-J-10 and 3-J-11, the standardized residuals for the revised HBD age groups showed a significant association between juveniles and the presence of porotic hyperostosis and a negative association between this age group and the absence of porotic hyperostosis. These results coincided with the age cohort with the highest prevalence of porotic hyperostosis. The cemetery samples showed an increase from the infant to the child age groups and then a noticeable jump in prevalence in the juvenile group. After this spike in the juvenile cohort, the adolescent group showed a decrease in the percentage of individuals afflicted. In the combined sample, the juvenile cohort displayed highly significant standardized residuals, with a positive association with porotic hyperostosis presence and a negative association with its absence.

The severity of expression showed the highest prevalence in the scattered and fine foramina category for both cemeteries. In 3-J-11, there was significant relationship between severity and age, with the infant group showing a significantly positive association with the expression of large and small isolated foramina and a greater correlation with the linked expression. These results are reflective of the fact that only infants displayed either of these expressions of porotic hyperostosis. This was a surprising result since this age group has the shortest period of time to develop such serious manifestations. Infants also had a significant negative association with the presence of scattered and fine foramina. In the combined sample, these associations remained, but were less significant. Activity for cemetery 3-J-10 was concentrated in the healed category, while the highest prevalence for 3-J-11 was in the active category. 3-J-11 also demonstrated a significant relationship between the activity and age and infants had a positive correlation with active lesions. This same result occurred in the combined sample.

Finally, scurvy was present in 65.9% of the Mis Island subadults. Although 3-J-10 had a prevalence of 55.8% and 3-J-11 was much higher at 70.1% the two cemeteries were not statistically different. The patterns of prevalence, however, were different in the cemeteries. For 3-J-10, the highest percentage of scorbutic lesions occurred in the child age category followed by juveniles in the revised HBD groups. For 3-J-11, the juveniles had the highest frequency of scorbutic lesions followed by the infants. Despite the discrepancies between the two cemeteries, it is clear that skeletal manifestations of scurvy began to take place in infancy and continued through adolescence. Since severity and activity were not collected on scorbutic lesions, it is not possible to determine if or when vitamin C deficiency started to resolve in the subadults of Mis Island.

When the relationship between skeletal pathologies was investigated, results showed significant relationships between scorbutic lesions and cribra orbitalia, cribra orbitalia and porotic hyperostosis, and LHPC and periostitis. The most significant association was between scurvy and cribra orbitalia ($p < .001$), with highly significant residuals for the absence of both lesions and a negative association with the presence of scurvy and the absence of cribra orbitalia. None of the other significant relationships between skeletal lesions had significant standardized residuals. Although a number of skeletal lesions showed significant associations, this does not mean they arise from the same etiology. Unfortunately, the synergistic relationships between many disease states can make it nearly impossible to disentangle the specific diseases responsible for particular skeletal lesions.

Potential Pathological Stressors at Mis Island

It is impossible to definitively associate the skeletal lesions at Mis Island with specific infections, nutritional deficiencies, or parasites. Skeletal lesions and their etiologies are still poorly understood and can be difficult to differentially diagnose without destructive tests, such as histological, isotopic, or genetic analyses. Furthermore, diseases rarely occur in isolation and there are large amounts of research on the interactions and co-morbidities of malnutrition, vitamin deficiencies, and infectious disease. By contextualizing the Mis Island population as agents within a larger ecosystem, we can begin to understand potential causes of biological stress.

Unfortunately, there are no archaeological indicators of subsistence practices from Mis Island so information from other medieval Nubian sites and historical texts must be utilized. Paleobotanical analyses from the medieval site of Nauri, located just upstream of the Third Cataract, was dominated by cereals (Fuller and Edwards, 2001). As is common in most agriculturally dependent communities in northern Sudan today, cereals constitute the staple of the diet and are utilized in making gruel, bread, and beer (Fuller and Edwards, 2001, p 98). In the samples analyzed, sorghum and barley were the most abundant grains but free-threshing bread wheat, pearl millet, and foxtail millet were also present. Secondary staple foods were peas, cowpeas, and lentils and identifiable fruits included dates, figs, and seeds from watermelons and grapes (Fuller and Edwards, 2001, pp 100–101).

Work at the site of Debeira West in Lower Nubia discovered archaeological material indicative of irrigation cereal subsistence, in the form of iron sickle blades, large amounts of *saqia* pot knobs, and fragments of *doka*, the large flat dishes used to make *kisra*, the local, unleavened sorghum bread. An abundance of date stones suggested this fruit played a significant role in the diet of Debeira West inhabitants. In addition, seeds of the cucumber, ground nut, dom palm nut, and castor oil were also found (Shinnie and Shinnie, 1978, p 107). Also, the bones of sheep/goat, cattle, pig, and fish were also recovered, but in relatively small numbers suggesting meat may not have been a regular part of the diet. The significant amounts of goat coprolites, however, indicated that herds were kept, and these may have been used for milk or meat (Shinnie and Shinnie, 1978, p 107).

Research on the human remains from the site of Kulubnarti has also examined dietary components of its medieval inhabitants. Trace element analysis of hair (Sandford, 1983; Sandford and Kissling, 1994) provided evidence that inhabitants of Kulubnarti relied more on vegetarian sources in their diet than animal protein. This supported the research on coprolites by Cummings (1989), who found that cereal grains and dates were present in 100% of the samples analyzed. Other abundant food items present in more than 25% of coprolite samples included: legumes, black-eyed peas, and various leafy greens, while meat occurred in less than 25% of samples analyzed. Overall, research has shown that foods consumed at Kulubnarti consisted predominantly of cereals, dates, and legumes in a primarily vegetarian diet.

The availability of such nutrient sources also varied seasonally. The summer months in the Nile Valley are extremely hot and dry with appreciably lower Nile levels limiting the amount of irrigable land and the types of crops that can be grown. Plants that are able to sustain such environmental stresses are known as C_4 plants and they constitute grasses that are able to withstand high temperatures and intense sunlight. Examples of C_4 plants include maize, sugar cane, millet, sorghum, and crabgrass. In the rainy winter season, however, it is possible for the Nile Valley to support C_3 plants with the aid of irrigation. C_3 plants are the most abundant worldwide, constituting approximately 85% of all plant species including wheat, barley, rice, vegetables, fruits and most trees.

Isotopic studies utilizing mummified hair from Wadi Halfa and Kulubnarti have confirmed that seasonal cropping, made possible in many areas by the *saqia*, was practiced during the medieval period in Nubia (White and Schwarcz, 1994; Schwarcz and White, 2004; Turner et al., 2007). White (1993) found evidence of seasonal shifts from C_3 resources to C_4 plants in the summer months. This was consistent with contemporary practices in the Wadi Halfa region where sorghum/millet were planted in March as summer crops (White, 1993, p 664). Schwarcz and White (2004) expanded this research and determined that the medieval diet was comprised of 75% C_3 foods in the winter and 75% C_4 foods in the summer, with small amounts of winter foods, or animal products, presumably stored and used in the summer (p 753). In addition, hair samples suggested that nearly twice as many individuals perished in the mid to late summer months (White, 1993, p 664). These deaths were attributed to a combination of climatic and nutritional factors, including extreme heat, and scarcity of diverse foods to fulfill nutritional requirements in the dry summer season. It has been reported that modern populations experienced similar spikes in morbidity and mortality during the late summer months. Both scurvy, an endemic condition in Sudan, and pellagra, a deficiency of niacin, were reported to peak during this time when nutrient rich fruit and vegetable sources were diminished (Corkill, 1949, pp 301–302; White, 1993, p 665).

In addition to seasonal changes, diets also vary over the lifetime according to both biological and cultural influences. Most notably, infants are reliant on breast milk before they are gradually transitioned to other foods. Turner and colleagues (2007) investigated the isotopic signatures of bones from the Kulubnarti cemetery samples. Their work revealed significant associations between age and isotopic carbon and nitrogen levels. Specifically, this research demonstrated dietary differences between infants, post-weaning children, and adults in protein intake, with children having the lowest levels compared to the other two cohorts. While the presence of a weaning diet is common among cultures utilizing soft foods, like gruel, during and immediately after weaning, a discrete diet for children after this age is less known. The authors suggested that the diets of children, defined as individuals between four and seventeen years, contained foods that were isotopically depleted. This suggests they no longer received the nutritional benefits of breast milk but had not yet assumed an adult pattern of diet (Turner et al., 2007, p 21).

The paleopathological data from Mis Island showed the majority of skeletal lesions were most prevalent in the youngest age groups. Although this may represent the individuals who did not survive early insults to their developing immune system, it does demonstrate that the underlying causes of these lesions were occurring very early in life. Perhaps the earliest stress indicators were the localized hypoplasias of the primary canine (LHPC). These lesions have been associated with maternal vitamin A deficiency that impacts the infant. The most bioavailable source of vitamin A are animal products, including liver, eggs, fish, and dairy. Although archaeological evidence supports the presence of herd animals in Nubia, the amount of bone was quite small supporting the trace element and isotopic evidence that meat consumption was not a normal part of the diet (Shinnie and Shinnie, 1978, p 107; Turner, 1990, p 20; Sandford and Kissling, 1994, pp 49–50; Welsby, 2002, p 187). In addition, there is relatively little evidence of fishing, in the form of fish bones or artifacts related to fishing, from medieval archaeological contexts (Shinnie and Shinnie, 1978, p 107; Welsby, 2002, p 188).

Plant resources can also be sources of vitamin A, but these occur in the form of beta-carotene that must be synthesized in the body to produce this essential nutrient. Green and leafy vegetables, orange and yellow vegetables, tomato products[2], and fruits are all potential sources of beta-carotene. Unfortunately, these also represent C_3 plants that can only be grown seasonally in the Nile Valley. A primarily cereal diet with inadequate amounts of animal products or plant resources rich in beta-carotene could cause deficiencies in vitamin A, leading to LHPC. Vitamin A deficiencies are far more serious than a small defect on a primary canine. Vitamin A deficiencies are still a global health concern as they can lead to blindness and seriously

[2] Although a source of beta-carotene, tomatoes did not grow in medieval Nubia as they are a New World plant.

compromise immune function. In 2004, inadequate amounts of vitamin A led to the deaths of 670,000 children under five years of age in developing countries worldwide, despite widespread supplementation programs (Black et al., 2008, p 253). Thus, a deficiency in vitamin A leaves a child extremely vulnerable to infectious disease and at an increased risk of death from measles, malaria, and diarrhea (Black, 2003, p 79). The incidence of LHPC at Mis Island is significant, at 49.6% it is higher than the 19 living and skeletal research samples reported by (Lukacs and Walimbe, 1998, p 580) and reproduced in Table 4.40. Thus vitamin A deficits at Mis Island were widespread and may have been a significant contributor to subadult morbidity and mortality.

Scurvy was another prominent nutritional deficiency that first appeared in infancy at Mis Island. Although cribra orbitalia could potentially result form other physiological stressors, its highly significant association with scurvy indicates that the majority of cribra orbitalia lesions in the Mis Island sample were related to other scorbutic lesions. Vitamin C is not synthesized in the body so it must be consumed from dietary sources of fruits and vegetables. Whether the prevalence of scurvy reflected a paucity of vitamin C rich foods, a vitamin C deficient age-related diet, or cooking and storage methods that caused the leaching of vitamin C is difficult to ascertain.

Table 4.40: LHPC prevalence of research samples from Lukacs and Walimbe (1998).

Study Group	Type	Affect.	*N*	%	Source
Burnaby, BC	living	13	2380	0.5	Skinner & Hung, 1986
Vancouver, BC	living	32	1350	2.4	Skinner & Hung, 1989
White, Mississippi*	living	80	1231	6.5	Duncan et al., 1994
Sudan, non-haifat	living	25	309	8.4	Rasmussen et al., 1992
Black, Mississippi*	living	141	1332	10.6	Duncan et al., 1994
Sudan, total	living	50	398	12.6	Rasmussen et al., 1992
White, Mississippi†	living	205	1192	17.2	Silberman et al., 1991
Danish, modern	living	144	688	21.0	Jørgensen, 1956
Danish, medieval	skeletal	51	182	28.0	Jørgensen, 1956
Sudan, haifat	living	25	89	28.4	Rasmussen et al., 1992
Vancouver, BC	living	30	96	31.2	Skinner et al., 1994
Black, Mississippi†	living	429	1291	33.2	Silberman et al., 1991
Harappa, Pakistan	living	39	113	34.5	Lukacs, 1991
Late Jorwe (INM)	prehistoric	15	47	35.7	Lukacs & Walimbe, 1998
Bloomington, IN	living	40	112	35.7	Brown & Smith, 1986
Inamgaon	prehistoric	26	66	39.4	Lukacs & Walimbe, 1998
Calcutta, India	skeletal	20	45	44.4	Skinner, 1986
Kentucky	living	25	55	45.5	Badger, 1985
Early Jorwe (INM)	prehistoric	9	19	47.4	Lukacs & Walimbe, 1998

*Maxillary teeth only.
†Mandibular teeth only.

It is well established that sorghum was the staple grain of medieval Nubia. This cereal was used in a variety of ways, including in the production of beer known as *mizr* or *marisa* and for the traditional fermented bread, *kisra* (Welsby, 2002, pp 185–186). While sorghum is a good source of B-complex vitamins, it is generally not considered a good source of vitamin C (Food and Agriculture Organization of the United Nations, 1995, p 81). Interestingly, fermentation of sorghum has been found to increase levels of vitamin C, and research showed that sorghum beers were nutritionally superior to sorghum flour, with iron absorption more than 12 times higher from the beverage form (Food and Agriculture Organization of the United Nations, 1995, p 108). Vitamin C is not naturally present in grains, eliminating other cereals as potential sources for the

Mis Island inhabitants. Dates are another widespread crop valued in the Sudan today and found in large numbers in archaeological contexts. The fruit of the date palm is a high energy fruit that provides a variety of nutrients including B-complex vitamins, vitamin A, and folic acid, but does not provide significant amounts of essential vitamin C (El-Sohaimy and Hafez, 2010, p 1063).

Fruits and vegetables provide the best sources of this essential nutrient, including citrus, peppers, broccoli, and spinach. Potential sources for medieval Nubians included lentils, cowpeas, watermelon, grapes, and greens. Unfortunately, prolonged storage or cooking of these foods cause the depletion of vitamin C. A modern study of individuals in the *Batn el Hajar* region found vitamin C sources were limited to bean leaves (Corkill, 1949). Moreover, it was common practices to utilize these in relishes and sauces that required boiling of the greens for over an hour, greatly depleting most, if not all, of the vitamin C present (Corkill, 1949). Thus, potential sources of vitamin C for the Mis Island population would have been limited to seasonal fruits or vegetables. In addition, these foods would have had a short storage life and would need to be eaten raw to provide substantial amounts of this nutrient.

Beyond clinical manifestations of scurvy, deficient levels of vitamin C are known to impair folate metabolism, which may contribute to the development of megaloblastic anemia (Brickley and Ives, 2008, p 47). Megaloblastic anemia is caused by pathological deficiencies in vitamin B_{12} and/or folic acid and has been recently implicated for the marrow hypertrophy characteristic of porotic hyperostosis (Walker et al., 2009). Sources of vitamin B_{12} are restricted to animal products, including fish, meat, poultry, eggs, milk, and milk products (Office of Dietary Supplements, National Institutes of Health, 2011). Folate, however, is present in a variety of foods, including dark green leafy vegetables, fruits, nuts, beans, peas, dairy products, poultry, meat, eggs, and seafood (Office of Dietary Supplements, National Institutes of Health, 2012). Nubian individuals may have had seasonal access to greens, beans, peas, and dates as well as milk to fulfill folic acid needs. Folic acid levels in the body, however, are sensitive to ultraviolet radiation and may become depleted due to chronic sun exposure (Borradale and Kimlin, 2012, p 414). In addition, pregnancy increases folate requirements and is vital for the prevention of neural tube defects in the developing infant (Borradale and Kimlin, 2012, p 414; Office of Dietary Supplements, National Institutes of Health, 2012). Thus, diets with limited animal protein sources and seasonally available produce are at risk for deficiencies of both vitamin B_{12} and folic acid, which may be further exasperated by scurvy and high levels of ultraviolet radiation.

Dietary concerns represent a substantial source of environmental stress for the Mis Island inhabitants. Food resources, however, are only one aspect of the environment that cultures must face. Infections, viruses, and parasites have been impacting and co-evolving with human populations throughout human's evolutionary history. Malaria is a parasitic infection that remains a serious concern for populations in Africa. Malaria is transmitted by infected *Anopheles* mosquitoes and can be life-threatening if untreated. Individuals who live in moderate to high transmission areas can develop immunity that decreases the risk of serious infection, but this requires years of exposure. Young children without this immunity, however, are considered at high risk for malarial infection (World Health Organization, 2013). The World Health Organization reports that a child dies every minute from malarial complications (World Health Organization, 2013). Infants, who are initially protected by maternal antibodies acquired *in utero* and through breast milk, become vulnerable to malarial attack at approximately three months of age when this passive immunity begins to decline (World Health Organization, 2013). Acute or repeated infections, common in endemic areas, can lead to malarial anemia. Anemia results when the accelerated removal of red blood cells characteristic of malaria is not compensated for by hematopoiesis in the bone marrow, which is often suppressed in severe cases (Helleberg et al., 2005, p 56; Haldar et al., 2007, p 219). Vitamin A has been shown to be protective against severe malarial morbidity and mortality thus deficiencies in this nutrient could contribute to disease and death at Mis Island.

Schistosomiasis is a disease caused by parasitic worms that contaminate water sources through snail vectors. It is considered the second most devastating parasitic disease in the world, behind malaria (Center for Disease Control and Prevention, 2012). Parasites are able to penetrate skin and invade hosts when contact is made with infected water. These worms then travel through the host's tissues until they mature, mate, and the female produces eggs. These eggs pass through the host's body and some will be expelled in stool or urine, potentially deposited in a water source where snails become infected and the cycle begins again. Without treatment, schistosomiasis may become chronic causing anemia from blood lost through urine or stool, sequestration of red blood cells in the spleen, immune-mediated premature red blood cell destruction, or anemia of chronic disease (Friedman et al., 2005, pp 388–389). The Nile Valley in Sudan and Egypt is a region known for human schistosomiasis infection (Center for Disease Control and Prevention, 2012). It has been found that both slow moving Nile waters and irrigation canals, like those that would have accompanied *saqia* agriculture, provide ideal habitats for the snails that harbor schistosomiasis (Fenwick et al., 1981). Evidence of schistosomiasis infection in medieval Nubia has been documented in both Wadi Halfa and Kulubnarti (Hibbs et al., 2011). The sample from the Lower Nubian site of Wadi Halfa, which had archaeological evidence of irrigation agriculture, showed significantly higher prevalence of schistosomiasis infection than the Kulubnarti sample, thought to have utilized flood plain agriculture (Hibbs et al., 2011, p 290). While inhabitant at Wadi Halfa had a significantly higher prevalence of schistosomasis infection, evidence from Kulubnarti showed individuals from this site were also susceptible, potentially exposed to infected snails during flood plain agriculture or during the summer when the Nile flowed more slowly. It is difficult to estimate the potential degree of schistosomiasis exposure at Mis Island since farming practices are unknown. However, even if they did not utilize irrigation techniques, the risk of infection remained as shown by the work of Hibbs and colleagues (2011).

Tuberculosis (TB) is an infectious disease that is widespread, with an estimated one-third of the world's population infected (World Health Organization, 2012). It is also the second deadliest infectious disease behind human immune-deficiency virus (World Health Organization, 2012). Fortunately, tuberculosis is relatively well controlled by the immune system and only about 10% of infected individuals will become ill with active disease (Donoghue, 2008, p 75; World Health Organization, 2012). However, those with weakened immune systems or malnourishment are at higher risk of developing the disease (Donoghue, 2008, p 75). Tuberculosis has a long history in the Nile Valley, with some of the earliest skeletal evidence coming from Predynastic (ca. 3,500 – 2,650 B.C.) Egypt (Zink et al., 2001). A large study was undertaken to test for ancient DNA of *Mycobacterium tuberculosis* on the partially mummified remains from Kulubnarti. In this population, TB was widespread with higher prevalence in young adults and children under five years of age (Donoghue, 2009, p 1160). Although the incidence of tuberculosis in the subadults at Mis Island was limited to only two individuals, this is evidence that the disease was present in the population. In fact, infection may have been considerably higher as ancient tuberculosis DNA has been recovered from skeletal remains with no paleopathological signs of infection (Donoghue, 2009, p 1160). With the nutritional deficiencies and other environmental stressors discussed above, it is likely that individuals who contracted tuberculosis would be at risk for developing active infections which may have contributed to mortality in the sample.

Conclusion

The skeletal evidence from the subadult samples from Mis Island show that skeletal lesions have a high prevalence in the youngest age groups, suggesting that biological stressors occurred early in life, but may remain unresolved into adolescence. The appearance of scorbutic lesions, including cribra orbitalia, in children clearly demonstrates insufficiency of vitamin C, which could be attributable to a seasonal deficiency, an age-based diet, or a combination. Anecdotal reports from Nubian excavations identified millet gruel as a commonly used supplemental food for weaning (Turner et al., 2007), which would provide few of the essential vitamins necessary to support normal growth and development. Porotic hyperostosis does not peak until the juvenile years and may represent an exasperation of folate or B_{12} stores in the body, especially if this marks an age where milk is no longer provided as a weaning supplement. Alternatively, it may reflect a cultural transition with responsibilities that exposed these individuals to greater amounts of ultraviolet radiation, depleting the meager folic acid stores and resulting in megaloblastic anemia.

The degree of environmental stressors that were likely present in the medieval period on Mis Island more than adequately account for the paleopathological lesions observed. While it is difficult to determine the specific etiology of skeletal lesions, it is likely that they resulted from a combination of various nutritional and infectious disease related factors. With a mostly vegetarian diet reliant on cereal grains, Mis Islanders would have suffered deficiencies in essential nutrients, including vitamin A, vitamin C, vitamin B_{12}, and folic acid. While sources of vitamin C and folate may have been available from fruits and vegetables, these foods would likely only be available seasonally and are prone to nutrient loss during storage or cooking. Thus, for at least a portion of the year, the Mis Island communities would be subsisting on nutrient-poor foods, compromising immunity and increasing risks of scurvy and megaloblastic anemia. In addition, a wide variety of infectious pathogens have been known to afflict African populations in the past and present, including malaria, schistosomiasis, and tuberculosis. Overall, it is clear that inhabitants of Mis Island were faced with numerous chronic biological stressors that synergistically interacted to produce skeletal lesions. These stressors began in infancy and contributed to the morbidity and mortality observed throughout the subadult age cohorts.

LITERATURE CITED

LITERATURE CITED

Black R. 2003. Micronutrient Deficiency : An Underlying Cause of Morbidity and Mortality. B. World Health Organ. 81:79.

Black RE, Allen LH, Bhutta ZA, Caulfield LE, De Onis M, Ezzati M, Mathers C, and Rivera J. 2008. Maternal and Child Undernutrition: Global and Regional Exposures and Health Consequences. The Lancet 371:243–260.

Borradale DC, and Kimlin MG. 2012. Folate Degradation due to Ultraviolet Radiation: Possible Implications for Human Health and Nutrition. Nutr. Rev. 70:414–422.

Brickley M, and Ives R. 2006. Skeletal Manifestations of Infantile Scurvy. Am. J. Phys. Anthropol. 129:163–172.

Brickley M, and Ives R. 2008. The Bioarchaeology of Metabolic Bone Disease. Oxford: Academic Press.

Buikstra JE, and Ubelaker DH. 1994. Standards for Data Collection from Human Skeletal Remains. Fayetteville: Arkansas Archeological Survey.

Center for Disease Control and Prevention. 2012. Schistosomiasis. Centers for Disease Control and Prevention [Internet]. Available from: http://www.cdc.gov/parasites/schistosomiasis/

Corkill NL. 1949. A Scorbutic Diet in a Nile Cataract Community. T. Roy. S. Trop. Med H. 43:293–302.

Cummings LS. 1989. Coprolites from Medieval Christian Nubia: An Interpretation of Diet and Nutritional Stress [dissertation]. [Boulder, (CO)]: University of Colorado.

Donoghue HD. 2008. Palaemicrobiology of Tuberculosis. In: Raoult D, Drancourt M, editors. Paleomicrobiology: Past Human Infections. Berlin: Springer-Verlag. p 75–97.

Donoghue HD. 2009. Human Tuberculosis: An Ancient Disease, as Elucidated by Ancient Microbial Biomolecules. Microbes Infect. 11:1156–1162.

Edwards DN. 2004. The Nubian Past: An Archaeology of the Sudan. London: Routledge.

El-Sohaimy SA, and Hafez EE. 2010. Biochemical and Nutritional Characterizations of Date Palm Fruits (Phoenix dactylifera L.). Journal of Applied Sciences Research 6:1060–1067.

Fenwick A, Cheesmond AK, and Amin MA. 1981. The Role of Field Irrigation Canals in the Transmission of Schistosoma mansoni in the Gezira Scheme, Sudan. B. World Health Organ. 59:777–786.

Field A. 2009. Discovering Statistics Using SPSS. 3rd ed. London: SAGE Publications Ltd.

Food and Agriculture Organization of the United Nations. 1995. Sorghum and Millets in Human Nutrition. Rome: FAO.

Friedman JF, Kanzaria HK, and McGarvey ST. 2005. Human Schistosomiasis and Anemia: The Relationship and Potential Mechanisms. Trends. Parasitol. 21:386–392.

Fuller DQ, and Edwards DN. 2001. Medieval Plant Economy in Middle Nubia: Preliminary Archaeobotanical Evidence from Nauri. Sudan & Nubia 5:97–103.

Ginns A. 2006. Preliminary Report on the Excavations Conducted on Mis Island (AKSC), 2005-2006. Sudan & Nubia 10:13–19.

Ginns A. 2007. Preliminary Report on the Second Season of Excavations Conducted on Mis Island (AKSC). Sudan & Nubia 11:20–25.

Goodman AH, Martin DL, Armelagos GJ, and Clark G. 1984. Indications of Stress from Bone and Teeth. In: Cohen M, Armelagos G, editors. Paleopathology at the Origins of Agriculture. New York: Academic Press. p 13–49.

Goodman AH, Thomas RB, Swedlund AC, and Armelagos GJ. 1988. Biocultural Perspectives on Stress in Prehistoric, Historical, and Contemporary Population Research. Yearb. Phys. Anthropol. 31:169–202.

Halcrow SE, and Tayles N. 2008. Stress Near the Start of Life? Localised Enamel Hypoplasia of the Primary Canine in Late Prehistoric Mainland Southeast Asia. J. Archaeol. Sci. 35:2215–2222.

Haldar K, Murphy SC, Milner DA, and Taylor TE. 2007. Malaria: Mechanisms of Erythrocytic Infection and Pathological Correlates of Severe Disease. Annu. Rev. Pathol. 2:217–249.

Helleberg M, Goka BQ, Akanmori BD, Obeng-Adjei G, Rodriques O, and Kurtzhals JAL. 2005. Bone Marrow Suppression and Severe Anaemia Associated with Persistent Plasmodium falciparum Infection in African Children with Microscopically Undetectable Parasitaemia. Malar. J. 4:56.

Hibbs AC, Secor WE, Van Gerven D, and Armelagos G. 2011. Irrigation and Infection: The Immunoepidemiology of Schistosomiasis in Ancient Nubia. Am. J. Phys. Anthropol. 145:290–298.

Holland TD, and O'Brien MJ. 1997. Parasites, Porotic Hyperostosis, and the Implications of Changing Perspectives. Am. Antiquity 62:183.

Jørgensen KD. 1956. The Deciduous Dentition: A Descriptive and Comparative Anatomical Study. København: Bianco Lunos Bogtrykkeri A-S.

Kelley MA, and El-Najjar MY. 1980. Natural Variation and Differential Diagnosis of Skeletal Changes in Tuberculosis. Am. J. Phys. Anthropol. 52:153–167.

Long KZ, Rosado JL, and Fawzi W. 2007. The Comparative Impact of Iron, the B-complex Vitamins, Vitamins C and E, and Selenium on Diarrheal Pathogen Outcomes Relative to the Impact Produced by Vitamin A and Zinc. Nutr. Rev. 65:218–232.

Lukacs JR, and Walimbe SR. 1998. Physiological Stress in Prehistoric India: New Data on Localized Hypoplasia of Primary Canines Linked to Climate and Subsistence Change. J. Archaeol. Sci. 25:571–585.

Mays S, Fysh E, and Taylor GM. 2002. Investigation of the Link Between Visceral Surface Rib Lesions and Tuberculosis in a Medieval Skeletal Series from England Using Ancient DNA. Am. J. Phys. Anthropol. 119:27–36.

McDonell A, and Oxenham MF. 2012. Localised Primary Canine Hypoplasia: Implications for Maternal and Infant Health at Man Bac, Vietnam, 4000–3500 years BP. Int. J. Osteoarchaeol.:[Early View].

Micronutrient Initiative and UNICEF. 2004. Vitamin and Mineral Deficiency Reports - A Global Progress Report. Oxforshire, UK. Available from: http://www.micronutrient.org/english/View.asp?x=614

Office of Dietary Supplements, National Institutes of Health. 2011. Dietary Supplement Fact Sheet: Vitamin B12. Office of Dietary Supplements [Internet]. Available from: http://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/

Office of Dietary Supplements, National Institutes of Health. 2012. Dietary Supplement Fact Sheet: Folate. Office of Dietary Supplements [Internet]. Available from: http://ods.od.nih.gov/factsheets/Folate-HealthProfessional/

Ortner DJ, Butler W, Cafarella J, and Milligan L. 2001. Evidence of Probable Scurvy in Subadults from Archeological Sites in North America. Am. J. Phys. Anthropol. 114:343–351.

Ortner DJ, and Ericksen MF. 1997. Bone Changes in the Human Skull Probably Resulting from Scurvy in Infancy and Childhood. Int. J. Osteoarchaeol. 7:212–220.

Ortner DJ, Kimmerle EH, and Diez M. 1999. Probable Evidence of Scurvy in Subadults from Archeological Sites in Peru. Am. J. Phys. Anthropol. 108:321–331.

Ortner DJ. 2003. Identification of Pathological Conditions in Human Skeletal Remains. 2nd ed. San Diego, CA: Academic Press.

Rasmussen P, Elhassan FE, and Raadal M. 1992. Enamel Defects in Primary Canines Related to Traditional Treatment of Teething Problems in Sudan. Int. J. Paediatr. Dent. 2:151–155.

Redfern R. 2010. Human Bioarchaeological Database. London: The British Museum.

Roberts CA, Boylston A, Buckley L, Chamberlain AC, and Murphy EM. 1998. Rib Lesions and Tuberculosis: The Palaeopathological Evidence. Tubercle Lung Dis. 79:55–60.

Roberts CA, and Buikstra JE. 2003. The Bioarchaeology of Tuberculosis: A Global View on a Reemerging Disease. Gainesville: University Press of Florida.

Sandford MK, and Kissling GE. 1994. Multivariate Analyses of Elemental Hair Concentrations from a Medieval Nubian Population. Am. J. Phys. Anthropol. 95:41–52.

Sandford MK. 1983. Elemental Hair Analysis: New Evidence on the Etiology of Cribra Orbitalia in Sudanese Nubia. Hum. Biol. 55:831–844.

Schultz M. 2001. Paleohistopathology of Bone: A New Approach to the Study of Ancient Diseases. Am. J. Phys. Anthropol. Suppl 33:106–147.

Schwarcz HP, and White CD. 2004. The Grasshopper or the Ant?: Cultigen-use Strategies in Ancient Nubia from C-13 Analyses of Human Hair. J. Archaeol. Sci. 31:753–762.

Shinnie PL, and Shinnie M. 1978. Debeira West, a Medieval Nubian Town: University of Ghana Expedition to Nubia. Warminster: Aris and Phillips.

Skinner M, and Newell E. 2000. A Re-evaluation of Localized Hypoplasia of the Primary Canine as a Marker of Craniofacial Osteopenia in European Upper Paleolithic Infants. Acta Univ. Carol. Med. (Praha) 41:41–58.

Skinner MF, Hadaway W, and Dickie J. 1994. Effects of Ethnicity and Birth Month on Localized Enamel Hypoplasia of the Primary Canine. ASDC J. Dent. Child. 61:109–113.

Skinner MF, and Hung JT. 1989. Social and Biological Correlates of Localized Enamel Hypoplasia of the Human Deciduous Canine Tooth. Am. J. Phys. Anthropol. 79:159–175.

Skinner MF, and Newell EA. 2003. Localized Hypoplasia of the Primary Canine in Bonobos, Orangutans, and Gibbons. Am. J. Phys. Anthropol. 120:61–72.

Skinner MF. 1986. An Enigmatic Hypoplastic Defect of the Deciduous Canine. Am. J. Phys. Anthropol. 69:59–69.

Steckel RH, Spencer Larsen C, Sciulli PW, and Walker PL. 2011. The Global History of Health Project Data Collection Codebook.

Steinbock R. 1976. Hematological Disorders: The Anemias. In: Steinbock R, editor. Paleopathological Diagnosis and Interpretation. Springfield: Charles C. Thomas.

Stojanowski CM, and Carver CL. 2011. Inference of Emergent Cattle Pastoralism in the Southern Sahara Desert Based on Localized Hypoplasia of the Primary Canine. Int. J. Paleopathol. 1:89–97.

Stoltzfus RJ, and Underwood BA. 1995. Breast-milk Vitamin A as an Indicator of the Vitamin A Status of Women and Infants. Bull. World Health Organ. 73:703–711.

Stuart-Macadam P. 1985. Porotic Hyperostosis: Representative of a Childhood Condition. Am. J. Phys. Anthropol. 66:391–398.

Stuart-Macadam P. 1989. Porotic Hyperostosis: Relationship Between Orbital and Vault Lesions. Am. J. Phys. Anthropol. 80:187–193.

Stuart-Macadam P. 1992a. Anemia Reevaluated: A Look to the Future. In: Stuart-Macadam P, Kent S, editors. Diet, Demography and Disease, Changing Perspectives on Anemia. New York: Aldine.

Stuart-Macadam P. 1992b. Porotic Hyperostosis: A New Perspective. Am. J. Phys. Anthropol. 87:39–47.

Stuart-Macadam P. 1992c. Anemia in Past Human Populations. In: Stuart-Macadam P, Kent S, editors. Diet, Demography and Disease, Changing Perspectives on Anemia. New York: Aldine. p 151–170.

Turner BL, Edwards JL, Quinn EA, Kingston JD, and Van Gerven DP. 2007. Age-related Variation in Isotopic Indicators of Diet at Medieval Kulubnarti, Sudanese Nubia. Int. J. Osteoarchaeol. 17:1–25.

Turner CG. 1990. Major Features of Sundadonty and Sinodonty, Including Suggestions About East Asian Microevolution, Population History, and Late Pleistocene Relationships with Australian Aboriginals. Am. J. Phys. Anthropol. 82:295–317.

Walker PL, Bathurst RR, Richman R, Gjerdrum T, and Andrushko VA. 2009. The Causes of Porotic Hyperostosis and Cribra Orbitalia: A Reappraisal of the Iron-Deficiency-Anemia Hypothesis. Am. J. Phys. Anthropol. 139:109–125.

Welsby DA. 2002. The Medieval Kingdoms of Nubia. London: The British Museum Press.

White CD, and Schwarcz HP. 1994. Temporal Trends in Stable Isotopes for Nubian Mummy Tissues. Am. J. Phys. Anthropol. 93:165–187.

White CD. 1993. Isotopic Determination of Seasonality in Diet and Death from Nubian Mummy Hair. J. Archaeol. Sci. 20:657–666.

Wilbur AK, Farnbach AW, Knudson KJ, and Buikstra JE. 2008. Diet, Tuberculosis, and the Paleopathological Record. Curr. Anthropol. 49:963–991.

Wood JW, Milner GR, Harpending HC, Weiss KM, Cohen MN, Eisenberg LE, Hutchinson DL, Jankauskas R, Česnys G, et al. 1992. The Osteological Paradox: Problems of Inferring Prehistoric Health from Skeletal Samples. Curr. Anthropol. 33:343–370.

World Health Organization. 2012. WHO | Tuberculosis. WHO [Internet]. Available from: http://www.who.int/mediacentre/factsheets/fs104/en/index.html

World Health Organization. 2013. Malaria. World Health Organization [Internet]. Available from: http://www.who.int/mediacentre/factsheets/fs094/en/index.html

Zink AR, Haas CJ, Reischl UDO, Szeimies U, and Nerlich AG. 2001. Molecular Analysis of Skeletal Tuberculosis in an Ancient Egyptian Population. J Med Microbiol 50:355–366.

Chapter 5 – Subadult and Adult Comparison

Introduction

The Classic Christian period (AD 850 to 1100) of medieval Nubia has been known as a time of prosperity with peace and flourishing trade relations with the Muslim rulers in Egypt. This golden era began with the signing of the *Baqt*, a bilateral peace agreement between the Egyptian rulers and the medieval Nubian kingdoms that guaranteed peace and required an annual exchange of goods. This period of stability in Nubia was marked by drastic religious changes—a conversion to Christianity at its beginning and a change to the Muslim faith at its end. While these political events have been chronicled by Arabic and Christian historians, our understanding of medieval Nubia is inadequate due to the lack of secular texts about the culture and practices of its inhabitants. Thus, Nubian researchers must rely on archaeological information in order to gain a better understanding of the medieval period. Fortunately, the dry climate of the region has preserved many clues from the past under the accumulating sands of the Nile Valley, however, these data are not without their own set of challenges.

Early archaeological endeavors were primarily focused on the racial affinity of Nubian cultures and the discovery of exciting sites and artifacts (Adams, 1998, p 13). Such limited goals precluded the intensive investigation of Christian cemeteries, the occupants which were held to be closely related to modern populations as well as devoid of any grave goods (Adams, 1998, p 13). The interest in Christian cemeteries was revived, however, in the 1960s with the United Nations Educational, Scientific, and Cultural Organization (UNESCO) Campaign to Save the Monuments of Nubia. This project brought a new generation of researchers to Nubia to excavate archaeological sites before flooding from the construction of the Aswan High Dam caused their destruction. Unlike their forbearers, these scholars were not interested in determining racial affinity but in answering anthropological questions about Nubian populations and their cultural and biological adaptations to environmental stresses (Adams, 1998, p 16).

The excavations at Mis Island have followed in the tradition of rescue archaeology with the goal of answering anthropological questions about Nubia's past. The Island of Mis was excavated as part of the Sudan Archaeological Research Society's concession during the Merowe Dam Archaeological Salvage Project (1999-2010) prior to the flooding of the Fourth Cataract. The island was surveyed in 1999 and excavations occurred in two field seasons from 2005 to 2007 (Ginns, 2006, p 13, 2007, p 20). The salvage archaeological nature of the project precluded a complete excavation of identified sites, but efforts were made to collect representative samples from each area of interest (Ginns, 2010 a, p I, b, p I). The focus of this study was the skeletal remains excavated from the Christian cemeteries 3-J-10 and 3-J-11 on Mis Island. The goal of analyses was to assess age, sex, and pathology of each skeleton to reconstruct the demographic patterns, understand the biological stressors facing these populations, and assess whether the life experiences of these two groups was homogenous.

Materials

This research involved the analysis of a sample of 401 individuals from cemetery 3-J-10 (n = 126) and 3-J-11 (n = 275) from Mis Island (Table 5.1). Both males and females were represented and ages ranged from fetal to more than 50 years of age. Overall, the sample was fairly balanced with a relatively even split between adults (53.1%, N = 401) and subadults (46.9%) as well as females (49.3%, n = 213) and males (46.5%) (Table 5.1 and 5.2). The assessment of sex, age, and paleopathology for the adults (>20 years) in the Mis Island Collection was completed by Dr. Angela Soler (Soler, 2012), while subadult data was collected by the current author. This boundary between adults and subadults was chosen to represent a developmental age at which skeletal growth has completed and all long bone epiphyses have fused.

Table 5.1: Adults and subadults by cemetery at Mis Island.

MATERIALS	3-J-10		3-J-11		COMBINED	
	n	%	*n*	%	*n*	%
Subadults	52	41.3%	136	49.5%	188	46.9%
Adults	74	58.7%	139	50.5%	213	53.1%
TOTAL	**126**	**100.0%**	**275**	**100.0%**	**401**	**100.0%**

Table 5.2: Adult males and females by cemetery at Mis Island.

SEX	3-J-10		3-J-11		COMBINED	
	n	%	*n*	%	*n*	%
Female	35	47.3%	70	50.4%	105	49.3%
Male	38	51.4%	61	43.9%	99	46.5%
Ambiguous	1	1.4%	8	5.8%	9	4.2%
TOTAL	**74**	**100.0%**	**139**	**100.0%**	**213**	**100.0%**

Methods

Each skeleton was macroscopically assessed for skeletal lesions indicative of biological stress and disease. Although the entire skeleton was analyzed, certain pathognomic areas were focused on for particular pathologies. In these cases, the areas of interest were examined and scored as “present,” indicating the skeletal pathology was observable; “absent” indicating the areas of interest were not afflicted with the skeletal pathology; or “unscorable” to indicate that the area of interest was not present or was damaged to the extent that it was impossible to determine if the pathology had been present. If the area was unscorable, it was not included in the calculation of prevalence rates or statistical tests. This research focused on the following skeletal indicators of stress: linear enamel hypoplasia, cribra orbitalia, porotic hyperostosis, periostitis, scurvy, and tuberculosis.

Enamel Hypoplasias

Stressors occurring at the time of dental development in fetal or postnatal life may leave a visual record on an individual's teeth. Since enamel does not remodel once it has formed, any defects etched in a permanent tooth can provide an enduring chronological record of stress in the first seven years of life. Dental enamel hypoplasias are local deficiencies in enamel thickness that result from a physiological disruption during amelogenesis, the process of forming enamel on teeth (Goodman and Rose, 1990; Hillson, 1996, pp 165–167, 2006, pp 168–171). The most common type of enamel defect, and those examined in this research, manifest as linear circumferential depressions in a tooth's outer surface and are known as linear enamel hypoplasias. While enamel hypoplasias can be caused by hereditary anomalies or localized trauma, the vast majority of enamel hypoplasias in archaeological populations are caused by systemic metabolic stress, and therefore serve as sensitive, yet non-specific, indicators of biological stress (Goodman and Rose, 1990, pp 64–65). Systemic metabolic disruptions may be caused by high fevers, illness, or malnutrition and may be observable in a number of teeth developing at the time of the stress event. Only enamel hypoplasias related to such disruptions were recorded since dental trauma and inherited defects are infrequent and reveal little about a population's health (Buikstra and Ubelaker, 1994, p 56).

The method for scoring enamel hypoplasias followed the recommendations of Buikstra and Ubelaker (1994, pp 56–57). All observable teeth were examined for the presence and number of enamel hypoplasias on the crown surface. The criteria for a tooth to be considered observable required the presence of a representative portion of the crown's buccal surface without significant segments of missing enamel or obstruction by dental calculus. Teeth that met these qualifications were macroscopically examined under diffuse lighting without aid of microscopy or magnification to identify the presence of linear enamel hypoplasias (LEH). An LEH was defined as a linear, trough-like deficiency in the enamel thickness that extended across the facial crown surface (Goodman and Rose, 1990, pp 70–71).

While all teeth were assessed for linear enamel hypoplasias, only the incisors and canines from the left side were tabulated and utilized in calculating prevalence rates and statistical analyses. Research has shown that incisor and canines, for both the permanent and deciduous dentitions, have the highest prevalence of linear enamel hypoplasias and are the most frequently cited in research (Goodman and Armelagos, 1985 a, p 503, b, p 490; Goodman and Rose, 1990, p 91; Steckel et al., 2011, p 16). Since the progression of tooth development is equivalent on the left and right sides of the mouth, antimeric teeth are influenced by the same physiological stressors and resulting hypoplasia. Thus, to avoid duplicate data, only the left incisors and canines were scored, with the right being substituted if the left was missing or damaged.

Cribra Orbitalia

Cribra orbitalia is a abnormal porosity of the roof of the eye orbit that penetrates the cortex of the bone (Schultz, 2001, pp 132–134; Walker et al., 2009, p 109). Cribra orbitalia is believed to result from subperiosteal hematoma to the orbital roof, a consequence of a number of diseases including scurvy. In the case of scurvy, the pathological deficiency of vitamin C causes the manufacture of weak Sharpey's fibers, which secure the periosteal tissue to the bone. If these

Sharpey's fibers break the periosteum can be stripped from the orbital roof inducing an osteoblastic, or bone depositing, response (Walker et al., 2009).

Cribra orbitalia was assessed on individuals with at least one observable eye orbit. Cribra orbitalia was considered present if the orbital roof displayed unusual porosity. Activity signified whether the lesion was active, with well defined foramina borders, healed with more rounded edges and blunt foramina margins, or mixed where both active and healed portions of bone were present.

Porotic Hyperostosis

Porotic hyperostosis is a lesion of the cranial vault that manifests as a circumscribed area of porotic cortical bone in the region of the parietals and occipital (Schultz, 2001, p 107; Walker et al., 2009, p 109; Steckel et al., 2011, p 13). It has long been linked to an increased demand for red blood cell production where the erythropoietic, or red blood cell producing, diploë of the cranial vault expands to provide a greater area for this purpose. If unmitigated, the expanding diploë impedes on the outer cortex causing it to thin and manifest as porotic hyperostosis (Steinbock, 1976; Stuart-Macadam, 1992 a, p 39, b, p 151). Historically, iron-deficiency anemia was considered the proximate cause of porotic hyperostosis, but it is now known that this type of anemia suppresses red blood cell production and thus cannot cause porotic hyperostosis (Walker et al., 2009). Porotic hyperostosis is now attributed to hemolytic anemias, those that cause premature destruction of red blood cells. These include sickle cell anemia, thalassemia, and megaloblastic anemia. Thalassemia and sickle cell are genetic anemias with characteristic craniofacial and postcranial lesions beyond porotic hyperostosis (Hershkovitz et al., 1997; Lagia et al., 2007). Megaloblastic anemia is nutritionally induced from folic acid or vitamin B_{12}

deficiency, which alters DNA synthesis, resulting in enlarged red blood cells that cannot properly divide and are prone to early death.

Presence of porotic hyperostosis was evaluated as unusual porosity penetrating the cortex on the non-orbital, external surface of the cranial vault (Steckel et al., 2011, p 13). It ranged in severity from to outgrowth from the cortex (Stuart-Macadam, 1985, p 392, 1989, pp 187–188). Lesions were evaluated for the activity of the bony response and were scored as active, healed, or mixed in the same way as lesions of cribra orbitalia were evaluated.

Periostitis

Periostitis is a postcranial indicator of stress and is conventionally described as a new layer of bone deposited on the cortical surface beneath the periosteum. This osteoblastic, or bone-building, response can result from trauma, infection, or disturbance of the periosteum. In this study, long bone shafts were macroscopically examined for the presence of periosteal reaction indicated by a plaque-like bony deposition on the cortical surface (Ortner, 2003, p 206; Steckel et al., 2011, p 30). Diaphyses were the focus of investigation because the developing metaphyseal area of a subadult may resemble periosteal reactions (Buikstra and Ubelaker, 1994, p 108).

The activity of periosteal reactions was evaluated as active, healed, or mixed. Active lesions demonstrated newly formed woven bone deposition on the cortex while healed or healing lesions had smoother surfaces of sclerotic bone becoming incorporated into the cortex, indicating the processes of remodeling (Buikstra and Ubelaker, 1994, p 118). The third category, mixed, was utilized when both woven and sclerotic bone were present. While periostitis is common during the remodeling process following a fracture, such manifestations were not included in this study as they represent a traumatic event rather than a non-specific stress marker.

Scurvy

Unlike the previously listed non-specific skeletal stress indicators, certain diseases and nutritional deficiencies can be identified by the type and pattern of skeletal lesions. One of these specific skeletal indicators of stress is scurvy, a pathological deficiency in vitamin C caused by prolonged inadequate intake of dietary sources of this essential nutrient (Ortner, 2003, p 383). Inadequate levels of vitamin C impair osteoid formation and result in the manufacture of fragile blood vessels (Brickley and Ives, 2006, 2008, p 47). Minor trauma to these blood vessels can cause their rupture and the recruitment of additional blood vessels for repair. These new vessels are also weak and prone to damage exacerbating the process. Furthermore, the collagenous connective tissue that secures the periosteum to the bone known as Sharpey's fibers are also weakened with vitamin C deficiency. If the Sharpey's fibers break, the periosteum can be stripped from the bone resulting in a subperiosteal hematoma. Both of these processes result in abnormal porosity on the cortical surface of bones.

The diagnosis of scurvy was based on a constellation of osseous lesions and their distribution across the skeleton. Each individual was macroscopically examined for abnormal porosity signifying an increased vascular response and/or proliferative bone lesions resulting from subperiosteal hemorrhage of the cranial bones, long bones, or scapulae (Ortner and Ericksen, 1997, pp 213–214; Ortner et al., 1999, p 324, 2001, pp 346–348; Brickley and Ives, 2006, pp 163–164, 2008, pp 56–61; Steckel et al., 2011, p 35). Since many pathologies can produce areas of porous, abnormal bone formation, the presence of lesions at multiple anatomical sites was considered necessary for the diagnosis of scurvy, especially lesions of the greater wing of the sphenoid since this area is considered pathognomic for this condition (Ortner and Ericksen, 1997, p 214).

Tuberculosis

Tuberculosis is a chronic infectious disease contracted through the inhalation of infected aerosols or consumption of contaminated animal products (Kelley and El-Najjar, 1980, p 153; Donoghue, 2008, p 76). While tuberculosis infection usually involves the lungs, skeletal lesions may occur in response to soft tissue infection or directly when skeletal tuberculosis results from the progression of infection. Skeletal manifestations generally occur as resorptive lesions of vertebral bodies, but osteoblastic deposition on the ribs can develop from proximity to infected lung tissue (Roberts and Buikstra, 2003, p 88).

Tuberculosis was considered present if erosive lesions were observable on at least one thoracic or vertebral body. In advanced cases the structural integrity of the vertebral bodies may be compromised to the extent that they collapse. This can cause the characteristic spinal angulation known as Pott's Disease (Ortner, 2003, p 230; Roberts and Buikstra, 2003, pp 89–92; Donoghue, 2008, p 78; Steckel et al., 2011, pp 34–35). Secondary indicators of tuberculosis including proliferative lesions on the pleural surface of the ribs or destructive lesions in the hip or knee joints were used to strengthen the differential diagnosis, but were not considered diagnostic of tuberculosis in isolation (Mays et al., 2002; Ortner, 2003, p 230; Roberts and Buikstra, 2003, pp 96–101; Steckel et al., 2011, pp 34–35).

Statistical Methods

To interpret the data collected from this sample, numerous statistical tests were employed. Chi-square tests were used to compare age cohorts within each cemetery and between the two cemeteries. If more than 20% of expected frequencies were less than five, however, a Fisher's exact test was employed. The Monte Carlo method was utilized when contingency tables were too large for the calculation of a Fisher's exact test. A $p < .05$ level was used as a threshold for determining whether significant associations were present. When significance occurred, standardized residuals, which can serve as an indication of the source of significance within a contingency table, were investigated. A standardized residual represents a z-score and is considered significant at the $p < .05$ level if the value lies outside of ±1.96. If the value is beyond ±2.58, it is significant at the $p < .01$ level, and if it is outside ±3.29 then its significance lies at the $p < .001$ level (Field, 2009, p 699). In addition, the strength of association between variables was measured by *phi* for 2x2 contingency tables and Cramer's V for larger tables. If the value of either of these measures is ±0.1 then the association is considered small. A result of ±0.3 indicates a medium association, and ±0.5 a large association (Field, 2009, p 698).

Results

Mortality Profiles

The classification of the Mis Island sample by age cohort is represented in Table 5.3. The overall pattern at Mis Island showed the age group with the highest representation was middle adults (24.9%, $N = 401$) followed by children (23.7%). The lowest frequencies occurred in fetal (0.2%) and adolescent (6.7%) categories for individuals with age estimates. At Mis Island, subadult mortality was high, 16.5% of the sample died before reaching age 3, 40.2% died before age 12, and 46.9% of the sample died before the completion of skeletal development at age 20. Both male and female frequencies peaked in the middle adult cohort (Table 5.4), but there was a higher percentage of females in the older adult category (30.5%, n = 105) than males (14.1%, n = 99), suggesting that females lived longer than their male counterparts.

Table 5.3: Mis Island skeletal samples by Standards age cohort.

MATERIALS	3-J-10		3-J-11		COMBINED	
	n	%	*n*	%	*n*	%
Fetal (<birth)	1	0.8%	0	0.0%	1	0.2%
Infant (0-3 yrs)	23	18.3%	42	15.3%	65	16.2%
Child (3-12 yrs)	23	18.3%	72	26.2%	95	23.7%
Adol. (12-20 yrs)	5	4.0%	22	8.0%	27	6.7%
Young (20-35 yrs)	16	12.7%	37	13.5%	53	13.2%
Middle (35-50 yrs)	39	31.0%	61	22.2%	100	24.9%
Older (50+ yrs)	13	10.3%	33	12.0%	46	11.5%
Adult (>20 yrs)	6	4.8%	8	2.9%	14	3.5%
TOTAL	**126**	**100.0%**	**275**	**100.0%**	**401**	**100.0%**

The mortality profile for cemetery 3-J-10 (Table 5.3) also showed a mortality peak in the middle adult cohort (31.0%, n = 126), followed by equal proportions in the infant and child groups (18.3% for both). Assessing the survivorship in this cemetery, 19.0% of the sample died in infancy, 37.3% before age 12, and 41.3% before age 20. Males and females both had the highest representation in the middle adult age group (42.9%, n = 35 and 60.5% n = 38 respectively), but more males died during young (31.6%, n = 38) and middle adulthood while a greater percentage of females were in the older adult group (31.4%, n = 35). A chi-square test showed a significant association between age and sex, $\chi^2(2, n = 67) = 11.31, p = .004$, V = .411. Females had a significant standardized residual (z = 2.1) in the older adult category.

Table 5.4: Adult sex by Standards age categories.

ADULT AGE & SEX		Female		Male		Ambiguous		TOTAL	
		n	%	*n*	%	*n*	%	*n*	%
3-J-10	Young (20-35)	4	25.0%	12	75.0%	0	0.0%	16	100.0%
	Middle (35-50)	15	38.5%	23	59.0%	1	2.6%	39	100.0%
	Older (50+)	11	84.6%	2	15.4%	0	0.0%	13	100.0%
	Adult (>20)	5	83.3%	1	16.7%	0	0.0%	6	100.0%
	TOTAL	**35**	**47.3%**	**38**	**51.4%**	**1**	**1.4%**	**74**	100.0%
3-J-11	Young (20-35)	20	54.1%	15	40.5%	2	5.4%	37	100.0%
	Middle (35-50)	27	44.3%	33	54.1%	1	1.6%	61	100.0%
	Older (50+)	21	63.6%	12	36.4%	0	0.0%	33	100.0%
	Adult (>20)	2	25.0%	1	12.5%	5	62.5%	8	100.0%
	TOTAL	**70**	**50.4%**	**61**	**43.9%**	**8**	**5.8%**	**139**	100.0%
COMBINED	Young (20-35)	24	45.3%	27	50.9%	2	3.8%	53	100.0%
	Middle (35-50)	42	42.0%	56	56.0%	2	2.0%	100	100.0%
	Older (50+)	32	69.6%	14	30.4%	0	0.0%	46	100.0%
	Adult (>20)	7	50.0%	2	14.3%	5	35.7%	14	100.0%
	TOTAL	**105**	**49.3%**	**99**	**46.5%**	**9**	**4.2%**	**213**	100.0%

The cemetery sample from 3-J-11 showed a different mortality profile than that of 3-J-10 (Table 5.3). Unlike 3-J-10, children had the highest representation (26.2%, *n* = 275) followed by middle adults (22.2%). Also, there were no fetal remains recovered at 3-J-11, suggesting that premature infants were buried elsewhere. Even without this youngest age cohort, the subadult mortality at 3-J-11 was very high. Of the excavated sample, 15.3% died before the age of 3, 41.5% perished before the age of 12, and a staggering 49.5% died before the age of 20. This means that nearly half of the cemetery population died before they had completed skeletal development. The representation of males and females in the adult age cohorts is presented in Table 5.4. In a similar pattern to 3-J-10, the majority of females (38.6%, n = 70) and males (54.1%, n = 61) in the 3-J-11 cemetery sample were middle adults. Females also had a higher proportion in the young (28.6%, n = 70) and older (30.0%) adult categories than males (24.6% and 19.7%, n = 61, respectively). This likely reflects the increased risk of death from childbearing for young adult females and the greater longevity of females who survive childbearing to outlive their male counterparts into older adulthood. A chi-square test, however, showed no significant association between adult age cohort and sex for cemetery 3-J-11, $\chi^2(2, n = 128) = 3.28, p = .194$.

Cemetery mortality profiles were compared for statistical differences in the representation of each age group in the sample. As Table 5.3 shows, a higher portion of the 3-J-10 sample was comprised of infants and middle adults, while cemetery 3-J-11 had a larger prevalence of children. A Pearson chi-square test, however, showed no significant difference between the mortality profiles at each cemetery, $\chi^2(6, n = 387) = 9.99, p = .125$. Comparisons of sex representations at each cemetery were also undertaken. A chi-square test showed that overall, there was not a significant difference between cemeteries for prevalence of males and females, $\chi^2(1, n = 204) = .57, p = .452$. Comparisons of each age cohort independently for male and female prevalence were also not signfiicant, except for young adults. For this cohort, the chi-square test showed a significant difference between the cemeteries, $\chi^2(1, n = 51) = 4.55, p = .033$, $phi = –.299$. Although no standardized residuals were significant, the percentage of young adult females at 3-J-10 is markedly lower than the males at this cemetery, or the males and females at 3-J-11.

Linear Enamel Hypoplasias

Linear enamel hypoplasias were scored on both deciduous and permanent anterior teeth of the maxilla and mandible with complete and observable crowns. Table 5.5 shows the prevalence of linear enamel hypoplasias by deciduous tooth type. Clearly, linear enamel hypoplasias did not often occur on deciduous teeth. In fact, all the affected deciduous teeth from cemetery 3-J-10 belonged to a single individual, SK 5028. In the entire Mis Island sample, only two individuals had deciduous teeth that displayed linear enamel hypoplasias. This limited sample size rendered statistical tests untenable.

Table 5.5: Prevalence of linear enamel hypoplasia by deciduous tooth type.

LEH	**3-J-10**			**3-J-11**			**COMBINED**		
DECID.	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
#56 i1	1	28	3.6%	0	70	0.0%	1	98	1.0%
#57 i2	1	31	3.2%	0	81	0.0%	1	112	0.9%
#58 c	1	35	2.9%	0	88	0.0%	1	123	0.8%
#63 c	1	35	2.9%	1	90	1.1%	2	125	1.6%
#64 i2	1	34	2.9%	0	83	0.0%	1	117	0.9%
#65 i1	1	29	3.4%	0	73	0.0%	1	102	1.0%

Table 5.6 shows the prevalence of hypoplasias by permanent tooth type. The number of scorable teeth varied by tooth type and cemetery. The tooth type with the highest prevalence (69.5%, n = 190) of linear enamel hypoplasias in the combined sample was the mandibular canine (#22) and the tooth with the lowest percentage (36.7%, n = 150) was the central

mandibular incisor (#24) followed closely (37.9%, n = 161) by the maxillary lateral incisor (#10).

Table 5.6: Prevalence of linear enamel hypoplasia by permanent tooth type.

LEH PERM.	3-J-10			3-J-11			COMBINED		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
#9 I1	23	63	37.9%	43	95	45.3%	66	153	42.5%
#10 I2	19	62	32.7%	42	99	42.4%	61	151	39.1%
#11 C	31	57	52.9%	58	99	58.6%	89	150	56.7%
#22 C	47	67	70.0%	85	123	69.1%	132	183	69.4%
#23 I2	31	67	45.0%	43	102	42.2%	74	162	43.2%
#24 I1	15	51	30.4%	40	99	40.4%	55	145	37.2%

The data from cemetery 3-J-10 showed a range of prevalence from 29.4% (n = 51) for the mandibular central incisor to 70.1% (n = 67) for the mandibular canine (Table 5.6). Taking a closer look at 3-J-10 (Table 5.7), it is apparent that the highest prevalence of linear enamel hypoplasia in most tooth types occurred in the infant cohort, with this group showing 100% prevalence for the central and lateral maxillary incisors (n = 2 and n = 1, respectively) and the mandibular canine (n = 1). This is difficult to interpret, however, because these also represent the smallest sample sizes. Furthermore, the teeth of two individuals, SK 5028 (2-3 years) and SK 5160 (2-3 years) represent the hypoplasias in this category, thus it is not a robust sample of subadults under three years of age, but more likely two children who experienced acute illnesses. The next highest prevalence was in the mandibular lateral incisor category (#23), where the adolescent sample had a prevalence of 80.0% (n = 5) followed by the mandibular canine class (#22) in which middle adults had a prevalence of 76.9% (n = 26). Fisher's exact tests showed no significant association between age categories and hypoplasia on the maxillary central incisor (p

= .120), lateral incisor (*p* = .094), canine (*p* = .710), mandibular canine (*p* = .746), lateral incisor (*p* = .073), or central incisor (*p* = .317).

Table 5.7: Prevalence of LEH at 3-J-10 by permanent tooth type and age.

3-J-10 PERM.		#9 I1	#10 I2	#11 C	#22 C	#23 I2	#24 I1
Infant (<3 yrs)	Affect.	2	1	1	1	1	2
	n	2	1	5	1	2	3
	%	100.0%	100.0%	20.0%	100.0%	50.0%	66.7%
Child (3-12 yrs)	Affect.	6	5	1	9	11	5
	n	12	8	5	14	16	11
	%	50.0%	62.5%	20.0%	64.3%	68.8%	45.5%
Adolescent (12-20 yrs)	Affect.	1	2	3	3	4	2
	n	4	4	5	5	5	5
	%	25.0%	50.0%	60.0%	60.0%	80.0%	40.0%
Young Adult (20-35 yrs)	Affect.	3	2	7	10	5	1
	n	10	13	12	14	11	8
	%	30.0%	15.4%	58.3%	71.4%	45.5%	12.5%
Middle Adult (35-50 yrs)	Affect.	7	7	14	20	8	4
	n	28	29	26	26	26	20
	%	25.0%	24.1%	53.8%	76.9%	30.8%	20.0%
Older Adult (50+ yrs)	Affect.	4	2	4	3	1	1
	n	6	6	7	7	5	4
	%	57.1%	28.6%	62.5%	57.1%	28.6%	25.0%

An evaluation of cemetery 3-J-11 by tooth type and age (Table 5.8) showed a diverse range of linear enamel hypoplasia prevalence from 23.8% (*n* = 21) in the young adult central mandibular incisor group (#24) to 80.0% (*n* = 10) in the older adult maxillary canines (#11), excluding the infant tooth types that had *n* = 0. The child age category had the highest prevalence of linear enamel hypoplasias in the maxillary central (#9) and lateral (#10) incisor classes (66.7%, *n* = 21 and 68.4%, *n* = 19, respectively), as well as the mandibular lateral incisor category (#23; 56.7%, *n* = 30). Older adults had the highest prevalence for maxillary canines

(#11; 80.0%, $n = 10$) and mandibular central incisors (#24; 66.7%, $n = 3$) and adolescents had the highest percentage for mandibular canines (#22; 77.8%, $n = 18$). Fisher's exact tests of hypoplasia prevalence by age for each tooth type demonstrated no significant association for the maxillary canine ($p = .468$), mandibular canine ($p = .577$), lateral incisor ($p = .342$), or central incisor ($p = .112$). A significant result was obtained for the maxillary central incisor ($p = .039$). While no standardized residuals reached significance, children had an increased likelihood of displaying a linear enamel hypoplasia ($z = 1.6$), while middle adults were more likely to have an absence of linear enamel hypoplasia on tooth #9 ($z = 1.4$). The maxillary lateral incisor also showed a significant association ($p = .025$). No residuals were significant, but the child category had a strong positive correlation with linear enamel hypoplasia presence ($z = 1.8$) while middle adults had a negative correlation with hypoplasia presence ($z = -1.5$).

A comparison of linear enamel hypoplasias by tooth and cemetery showed no significant difference in hypoplasia prevalence for the maxillary central incisor ($\chi^2(1, n = 158) = 1.19, p = .275$), maxillary lateral incisor ($\chi^2(1, n = 161) = 2.25, p = .134$), maxillary canine ($\chi^2(1, n = 156) = .26, p = .610$), mandibular canine ($\chi^2(1, n = 190) = .02, p = .881$), mandibular lateral incisor ($\chi^2(1, n = 169) = .28, p = .598$), or the mandibular central incisor ($\chi^2(1, n = 150) = 1.75, p = .186$). With no significant differences between the cemeteries, it is reasonable to collapse the sample to create more robust counts in each category to test for age differences.

Table 5.8: Prevalence of LEH at 3-J-11 by permanent tooth type and age.

3-J-11 PERM.		#9 I1	#10 I2	#11 C	#22 C	#23 I2	#24 I1
Infant (<3 yrs)	Affect.	0	0	0	0	2	2
	n	0	1	0	1	4	5
	%	0.0%	0.0%	0.0%	0.0%	50.0%	40.0%
Child (3-12 yrs)	Affect.	14	13	6	19	17	17
	n	21	19	11	27	30	32
	%	66.7%	68.4%	54.5%	70.4%	56.7%	53.1%
Adolescent (12-20 yrs)	Affect.	3	8	11	14	6	8
	n	10	17	16	18	14	15
	%	30.0%	47.1%	68.8%	77.8%	42.9%	53.3%
Young Adult (20-35 yrs)	Affect.	14	9	16	24	9	5
	n	27	25	27	32	24	21
	%	51.9%	36.0%	59.3%	75.0%	37.5%	23.8%
Middle Adult (35-50 yrs)	Affect.	7	7	17	20	6	6
	n	28	29	34	31	23	23
	%	25.0%	24.1%	50.0%	64.5%	26.1%	26.1%
Older Adult (50+ yrs)	Affect.	3	4	8	8	3	2
	n	7	6	10	13	6	3
	%	42.9%	66.7%	80.0%	61.5%	50.0%	66.7%

The combined sample of 3-J-10 and 3-J-11 by tooth is demonstrated in Table 5.6. This table shows that the mandibular canine (#22) had the highest prevalence in the sample (69.5%, *n* = 190), followed by the maxillary canine (57.1%, *n* = 156). The classification of the combined sample by the age cohorts is presented in Table 5.9. Similar to the 3-J-11 sample, the child category in the combined sample demonstrated the highest prevalence across the majority of tooth types, including the maxillary lateral incisor (66.7%, *n* = 27), the mandibular lateral incisor (60.9%, *n* = 46) and the mandibular central incisor (51.2%, *n* = 43). The child category also had the second highest prevalence (60.6%, *n* = 33) after infants (100%, *n* = 2) for the maxillary central incisor. Older adults had the highest prevalence for maxillary canines (70.6%, *n* = 17) while the mandibular canines showed the highest prevalence in both the adolescent (73.9%, n = 23) and young adult (73.9%, n = 46) age categories.

Table 5.9: Prevalence of LEH in combined sample by permanent tooth type and age.

COMBINED PERM.		#9 I1	#10 I2	#11 C	#22 C	#23 I2	#24 I1
Infant (<3 yrs)	Affect.	2	1	1	1	3	4
	n	2	2	5	2	6	8
	%	100.0%	50.0%	20.0%	50.0%	50.0%	50.0%
Child (3-12 yrs)	Affect.	20	18	7	28	28	22
	n	33	27	16	41	46	43
	%	60.6%	66.7%	43.8%	68.3%	60.9%	51.2%
Adolescent (12-20 yrs)	Affect.	4	10	14	17	10	10
	n	14	21	21	23	19	20
	%	28.6%	47.6%	66.7%	73.9%	52.6%	50.0%
Young Adult (20-35 yrs)	Affect.	17	11	23	34	14	6
	n	37	38	39	46	35	29
	%	45.9%	28.9%	59.0%	73.9%	40.0%	20.7%
Middle Adult (35-50 yrs)	Affect.	14	14	31	40	14	10
	n	56	58	60	57	49	43
	%	25.0%	24.1%	51.7%	70.2%	28.6%	23.3%
Older Adult (50+ yrs)	Affect.	7	6	12	11	4	3
	n	13	12	17	19	11	7
	%	53.8%	50.0%	70.6%	57.9%	36.4%	42.9%

Chi-square tests, or Fisher's exact tests if more than 20% of cells had expected counts less than five, were performed for each tooth to determine whether there was a significant association between linear enamel hypoplasia status and age category. There was a significant association ($\chi^2(5, n = 155) = 16.16, p = .006$) for the maxillary central incisor (#9), with the greatest standardized residuals showing a positive correlation between the child category and presence of an LEH ($z = 1.7$) and a negative correlation between middle adult and LEH presence ($z = -1.9$). A significant Fisher's exact test results ($p = .002$) was obtained for the maxillary lateral incisor (#10). A significant standardized residual was found in the child category showing a positive correlation with LEH presence (z = 2.4). Other relatively high standardized residuals showed a negative correlation with LEH absence (z = –1.9) in the child category and a negative correlation with the presence of an LEH (z = –1.7) in the middle adult category. A chi-square test of the maxillary canine (#11) showed no significant association between LEH prevalence and age, $\chi^2(5, n = 154) = 4.74, p = .448$.

For the mandibular teeth, a chi-square test of the canine (#22) showed no significant association between LEH and age, $\chi^2(5, n = 188) = 2.25, p = .814$. A Fisher's exact test, however, did show a significant result (p = .042) between the lateral incisor (#23) and age. While no standardized residuals were significant, the child category was more likely to have a present LEH (z = 1.7) while the middle adult category was unlikely to have a LEH present (z = –1.6). Finally, the Fisher's exact test for the mandibular central incisor (#24) also demonstrated a significant association between LEH and age (p = .021). The highest standardized residuals in this case included a positive correlation between the child cohort and LEH presence (z = 1.6) and a negative correlation between middle adults and LEH presence (z = –1.5).

Teeth with linear enamel hypoplasia presence were evaluated to determine if the tooth was affected only once or if multiple LEHs were observable. Table 5.10 displays the results of the prevalence of multiple hypoplasias (2+) for the affected teeth (n). What is evident from this table is that the infant and child categories had the highest prevalence of the multiple linear enamel hypoplasias. If we focus on cells where $n \geq 5$, the child category had the highest prevalence for all tooth categories except for the mandibular canine (#22) where adolescents had the highest prevalence (47.1%, n = 17). A Fisher's exact test found no significant association between age and multiple hypoplasias for either the central or lateral maxillary incisors (p = .330

and p = .094, respectively). There was, however, a significant association between age and multiple hypoplasias for the maxillary canine (p = .017). Standardized residuals revealed that children were significantly more likely to display multiple linear hypoplasias (z = 2.1) on the maxillary canine. For the mandibular teeth, there was no significant result for the canine (p = .060) or lateral incisor (p = .205) but the central incisor did demonstrate a significant association between age and multiple hypoplasias (p = .019). Although none reached significance, the highest standardized residual showed a positive association between the child category and multiple hypoplasias (z = 1.6).

Table 5.10: Prevalence of multiple LEHs in affected teeth by tooth and age.

MULTIPLE LEH		#9 I1	#10 I2	#11 C	#22 C	#23 I2	#24 I1
Infant (<3 yrs)	2+	0	1	1	1	1	3
	n	2	1	1	1	3	4
	%	0.0%	100.0%	100.0%	100.0%	33.3%	75.0%
Child (3-12 yrs)	2+	12	8	4	12	11	13
	n	20	18	7	28	28	22
	%	60.0%	44.4%	57.1%	42.9%	39.3%	59.1%
Adolescent (12-20 yrs)	2+	2	0	3	8	2	1
	n	4	10	14	17	10	10
	%	50.0%	0.0%	21.4%	47.1%	20.0%	10.0%
Young Adult (20-35 yrs)	2+	6	4	3	7	3	2
	n	17	11	23	34	14	6
	%	35.3%	36.4%	13.0%	20.6%	21.4%	33.3%
Middle Adult (35-50 yrs)	2+	4	5	3	8	1	2
	n	14	14	31	40	14	10
	%	28.6%	35.7%	9.7%	20.0%	7.1%	20.0%
Older Adult (50+ yrs)	2+	2	2	4	3	2	0
	n	7	6	12	11	4	3
	%	28.6%	33.3%	33.3%	27.3%	50.0%	0.0%

Cribra Orbitalia

Cribra orbitalia was present in over half (64.2%, $N = 335$) of the individuals with observable eye orbits at Mis Island (Table 5.11). The highest prevalence occurred in the child category where nearly 90% ($n = 79$) displayed lesions, followed by infants (77.6%, $n = 58$) and adolescents (75.0%, $n = 24$). The adult cohorts showed lower prevalence between 40% and 55%, with a combined prevalence of 46.6% ($n = 174$). The difference in cribra orbitalia prevalence between adults (46.6%, $n = 174$) and subadults (83.2%, $n = 161$) was substantial, suggesting that cribra orbitalia was a lesion of childhood.

Table 5.11: Prevalence of cribra orbitalia at 3-J-10 and 3-J-11 at Mis Island.

CRIBRA ORBITALIA	3-J-10			3-J-11			COMBINED		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	16	24	66.7%	29	34	85.3%	45	58	77.6%
Child (3-12 yrs)	16	19	84.2%	55	60	91.7%	71	79	89.9%
Adolescent (12-20 yrs)	2	5	40.0%	16	19	84.2%	18	24	75.0%
SUBADULT SUBTOTAL	**34**	**48**	**70.8%**	**100**	**113**	**88.5%**	**134**	**161**	**83.2%**
Young Adult (20-35 yrs)	6	14	42.9%	20	34	58.8%	26	48	54.2%
Middle Adult (35-50 yrs)	13	30	43.3%	21	54	38.9%	34	84	40.5%
Older Adult (>50 yrs)	5	11	45.5%	16	31	51.6%	21	42	50.0%
ADULT SUBTOTAL	**24**	**55**	**43.6%**	**57**	**119**	**47.9%**	**81**	**174**	**46.6%**
TOTAL	**58**	**103**	**56.3%**	**157**	**232**	**67.7%**	**215**	**335**	**64.2%**

Table 5.11 shows that over half (56.3%, $n = 103$) of the 3-J-10 sample had cribra orbitalia lesions, with the highest prevalence in the child (84.2%, $n = 19$) and infant (66.7%, $n = 24$) cohorts. Adolescents had the lowest prevalence (40%, $n = 5$) of cribra orbitalia, but this sample was small and may not truly reflect the incidence of cribra orbitalia. The adult cohorts were all near 40%, with only a slight increase with age. A Fisher's exact test showed that there was a significant medium association ($p = .037$, V = .330) between age and cribra orbitalia, but no significant standardized residuals to report. Table 5.12 shows cribra orbitalia lesion activity by age at 3-J-10. Overall, the highest prevalence occurred in the active category (50.0%, $n = 58$), followed by healed (39.7%), and the lowest prevalence in the mixed category (10.3%). In the subadult cohorts, 82.4% ($n = 34$) had active lesions, including 100% ($n = 16$) of the infants. On the other hand, only one young adult (4.17%, $n = 24$) had an active lesion. The vast majority of adults (91.7%) showed healed cribra orbitalia, including 100% of the middle ($n = 13$) and older ($n = 5$) adults. A Fisher's exact test showed a highly significant ($p < .001$) and large (V = .712) association between age and cribra orbitalia activity. The standardized residuals showed a significant relation between infants and active lesions ($z = 2.8$) and a negative association with healed lesions ($z = -2.5$). The child cohort was also negatively related to the healed category ($z = -2.1$). Both middle and older adults had large significant associations to healed activity ($z = 3.5$ and $z = 2.1$, respectively).

Table 5.12: Cribra orbitalia activity by age at 3-J-10.

3-J-10	Active		Healed		Mixed		TOTAL
CO Activity	#	%	#	%	#	%	*n*
Infant (<3 yrs)	16	100.0%	0	0.0%	0	0.0%	16
Child (3-12 yrs)	11	68.8%	1	6.3%	4	25.0%	16
Adolescent (12-20 yrs)	1	50.0%	0	0.0%	1	50.0%	2
SUBADULT SUBTOTAL	**28**	**82.4%**	**1**	**2.9%**	**5**	**14.7%**	**34**
Young Adult (20-35 yrs)	1	16.7%	4	66.7%	1	16.7%	6
Middle Adult (35-50 yrs)	0	0.0%	13	100.0%	0	0.0%	13
Older Adult (>50 yrs)	0	0.0%	5	100.0%	0	0.0%	5
ADULT SUBTOTAL	**1**	**4.2%**	**22**	**91.7%**	**1**	**4.2%**	**24**
TOTAL	**29**	**50.0%**	**23**	**39.7%**	**6**	**10.3%**	**58**

Cemetery 3-J-11 had an overall prevalence of 67.7% (n =232) of cribra orbitalia, with the highest percentages in the subadult categories with a total of 88.5% exhibiting lesions (Table 5.11). Adults had lower percentages of cribra orbitalia presence as only 47.9% (n = 119) had lesions. The lowest occurrence of cribra orbitalia occurred in the middle adult category where only 38.9% (n = 54) of individuals were afflicted. A chi-square test showed a highly significant association between age and cribra orbitalia presence, $\chi^2(5, n = 232) = 48.31$, $p < .001$, with a medium strength of association (V = .456). The activity of the lesions was similar to 3-J-10, with the majority (52.9%, n = 157) of examples still in an active state, while few displayed a mixed reaction (11.5%, n = 157) (Table 5.13). Most subadults with cribra orbitalia had active lesions (80.0%, n = 100) while most afflicted adults had healed lesions(86.0%, n = 57). There were 7 subadults (7.0%, $n = 100$) with healed lesions showing that the underlying cause of cribra orbitalia had resolved in these individuals. The Monte Carlo method showed a highly significant result ($p < .001$) with a large strength of association (V = .590) between age and cribra orbitalia activity. Infants were significantly associated ($z = 2.5$) with active lesions and negatively associated ($z = –3.2$) with healed lesions. The child cohort demonstrated even stronger associations, with a positive association to active lesions ($z = 3.1$) and a negative association with healed lesions ($z = –3.8$). Young adults had a positive relation to healed lesions ($z = 2.9$) and a negative association ($z = –2.6$) to active. Middle and older adults showed the same pattern of association, with positive correlation to healed lesions ($z = 4.2$ and $z = 3.9$, respectively) and negative associations with active lesions ($z = –3.0$ and $z = –2.9$, respectively).

Table 5.13: Cribra orbitalia activity by age for 3-J-11.

3-J-11 CO Activity	**Active**		**Healed**		**Mixed**		**TOTAL**
	#	%	#	%	#	%	*n*
Infant (<3 yrs)	25	86.2%	0	0.0%	4	13.8%	29
Child (3-12 yrs)	46	83.6%	3	5.5%	6	10.9%	55
Adolescent (12-20 yrs)	9	56.3%	4	25.0%	3	18.8%	16
SUBADULT SUBTOTAL	**80**	**80.0%**	**7**	**7.0%**	**13**	**13.0%**	**100**
Young Adult (20-35 yrs)	2	10.0%	15	75.0%	3	15.0%	20
Middle Adult (35-50 yrs)	1	4.8%	19	90.5%	1	4.8%	21
Older Adult (>50 yrs)	0	0.0%	15	93.8%	1	6.3%	16
ADULT SUBTOTAL	**3**	**5.3%**	**49**	**86.0%**	**5**	**8.8%**	**57**
TOTAL	**83**	**52.9%**	**56**	**35.7%**	**18**	**11.5%**	**157**

Comparing the overall prevalence of cribra orbitalia at both cemeteries, a chi-square test revealed there was a significant difference, $\chi^2(1, n = 335) = 4.01$, $p = .045$, with a small strength of association (V = .109). There were no significant results, however, when each age cohort was compared between cemeteries. Comparison of activity overall and by age between the two cemeteries did not show any significant differences either. Overall, 3-J-11 had significantly higher amounts of cribra orbitalia but followed similar patterns to 3-J-10 in both prevalence and activity.

Porotic Hyperostosis

Unusual porosity of the cranial vault was observed in 54.0% (*n* = 367) of individuals from Mis Island (Table 5.14). The lowest percentage (29.7%, *n* = 64) occurred in the infant category, which helped contribute to the overall lower prevalence in the subadults (45.5%, *n* = 176) than the adults (61.8%, *n* = 191). The adolescents had the highest overall prevalence of porotic hyperostosis with 79.2% (*n* = 24) of individuals exhibiting this lesion. Interestingly, porotic hyperostosis increased in prevalence until it peaked in adolescence, then gradually declined in the young and middle adult categories, but peaked again in the older adult category.

In the sample from 3-J-10, 57.3% (*n* = 117) of individuals were afflicted with porotic hyperostosis. Masked within this number, however, was an interesting dichotomy between the appearance of lesions in adults and subadults. The subadults at 3-J-10 had a relatively low incidence of porotic hyperostosis (37.3%, *n* = 51), while the adults were relatively high (72.7%, *n* = 66). Infants had the lowest prevalence of cranial lesions (20.8%, *n* = 24), which increased with age to young adults (75.0%, *n* = 16), dipped slightly for middle adults (67.6%, *n* = 37), and peaked in older adults (84.6%, *n* = 66). The Pearson chi-square test showed a significant association between porotic hyperostosis and age, $\chi^2(5, n = 117) = 21.14$, $p = .001$, with a medium strength of association (V = .425). Infants had a significant positive standardized residual ($z = 2.7$) with porotic hyperostosis absence and a negative residual ($z = –2.4$) with its presence.

Table 5.14: Prevalence of porotic hyperostosis in 3-J-10 and 3-J-11 at Mis Island.

POROTIC HYPEROSTO	**3-J-10**			**3-J-11**			**COMBINED**		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	5	24	20.8%	14	40	35.0%	19	64	29.7%
Child (3-12 yrs)	11	22	50.0%	31	66	47.0%	42	88	47.7%
Adolescent (12-20 yrs)	3	5	60.0%	16	19	84.2%	19	24	79.2%
SUBADULT SUBTOTAL	**19**	**51**	**37.3%**	**61**	**125**	**48.8%**	**80**	**176**	**45.5%**
Young Adult (20-35 yrs)	12	16	75.0%	21	36	58.3%	33	52	63.5%
Middle Adult (35-50 yrs)	25	37	67.6%	27	57	47.4%	52	94	55.3%
Older Adult (>50 yrs)	11	13	84.6%	22	32	68.8%	33	45	73.3%
ADULT SUBTOTAL	**48**	**66**	**72.7%**	**70**	**125**	**56.0%**	**118**	**191**	**61.8%**
TOTAL	**67**	**117**	**57.3%**	**131**	**250**	**52.4%**	**198**	**367**	**54.0%**

It is apparent from Table 5.15, that the vast majority (86.6%, $n = 67$) of porotic hyperostosis lesions at cemetery 3-J-10 were healed. All of the adults ($n = 48$) had healed lesions, but only about half (52.6%, $n = 19$) of the subadults showed completely healed porotic hyperostosis. Infants ($n = 5$) were split between active (40.0%) and healed (60.0%), children ($n = 11$) were represented in each category but with the majority in healed and mixed (45.5% for both), and adolescents (n = 3) in healed (66.7%) and mixed (33.3%). A Fisher's exact test indicated that these differences in porotic hyperostosis activity by age were highly significant (p < .001) with a large strength of association (V = .571). Infants had a highly significant association with active (z = 3.8) and children had a highly significant association with mixed (z = 4.0).

Table 5.15: Porotic hyperostosis activity by age for 3-J-10.

3-J-10 PH Activity	**Active**		**Healed**		**Mixed**		**TOTAL**
	#	%	#	%	#	%	*n*
Infant (<3 yrs)	2	40.0%	3	60.0%	0	0.0%	5
Child (3-12 yrs)	1	9.1%	5	45.5%	5	45.5%	11
Adolescent (12-20 yrs)	0	0.0%	2	66.7%	1	33.3%	3
SUBADULT SUBTOTAL	**3**	**15.8%**	**10**	**52.6%**	**6**	**31.6%**	**19**
Young Adult (20-35 yrs)	0	0.0%	12	100.0%	0	0.0%	12
Middle Adult (35-50 yrs)	0	0.0%	25	100.0%	0	0.0%	25
Older Adult (>50 yrs)	0	0.0%	11	100.0%	0	0.0%	11
ADULT SUBTOTAL	**0**	**0.0%**	**48**	**100.0%**	**0**	**0.0%**	**48**
TOTAL	**3**	**4.5%**	**58**	**86.6%**	**6**	**9.0%**	**67**

Cemetery 3-J-11 had a lower overall prevalence (52.4%, n = 250) and a much lower adult prevalence (56.0%, n = 125) than 3-J-10, but a subadult prevalence (48.8%, n = 125) was more than 10% higher than observed at 3-J-10 (Table 5.14). The adolescents had the highest prevalence (84.2%, n = 19), followed by older adults (68.8%, n = 32) and young adults (58.3%, n

= 36). A similar pattern of lowest prevalence in infants (35.0%, $n = 40$) with a second peak in older adults was also observed at 3-J-11. A significant association between age and porotic hyperostosis was revealed by a chi-square test, $\chi^2(5, n = 250) = 17.86$, $p = .003$ with a small level of association (V = .267). The only significant standardized residual showed a negative association between the adolescent cohort and porotic hyperostosis absence ($z = -2.0$). Lesion activity at 3-J-11 was primarily healed (50.5%, $n = 192$), but there was also a fair representation in the active (30.2%) and healed (19.3%) categories (Table 5.16). Nearly all of the adults (98.6%, $n = 70$) had healed lesions, but one middle adult showed a mixed reaction. The subadults, on the other hand, had the highest prevalence in the active category (47.5%, $n = 61$), followed by mixed (29.5%), and lastly, healed lesions (23.0%). Infants ($n = 14$) had lesions that were fully active (85.7%) or mixed (14.3%), while children ($n = 31$) were fairly evenly split between active (35.5%), healed (32.3%), and mixed (32.3%). The adolescents ($n = 16$) had 25.0% with healed lesions and the rest were split between active and mixed (37.5% each). The Monte Carlo method showed a highly significant association between age and porotic hyperostosis activity ($p < .001$) with a large strength of association (V = .609). Infants had a highly significant association with active lesions ($z = 5.1$) and a significant negative relation to healed lesions ($z = -3.0$). The child cohort had a significant positive relationship to mixed lesions ($z = 2.6$) and a negative relationship to healed lesions ($z = -2.2$). Adolescents also had significant standardized residuals in the mixed category ($z = 2.4$). The young, middle, and older adult cohorts had positive associations with healed ($z = 2.1$, $z = 2.2$, and $z = 2.2$, respectively) and a negative association to active lesions ($z = -2.2$, $z = -2.4$, and $z = -2.2$, respectively).

Table 5.16: Porotic hyperostosis activity by age at 3-J-11.

3-J-11 PH Activity	Active		Healed		Mixed		TOTAL
	#	%	#	%	#	%	*n*
Infant (<3 yrs)	12	85.7%	0	0.0%	2	14.3%	14
Child (3-12 yrs)	11	35.5%	10	32.3%	10	32.3%	31
Adolescent (12-20 yrs)	6	37.5%	4	25.0%	6	37.5%	16
SUBADULT SUBTOTAL	**29**	**47.5%**	**14**	**23.0%**	**18**	**29.5%**	**61**
Young Adult (20-35 yrs)	0	0.0%	21	100.0%	0	0.0%	21
Middle Adult (35-50 yrs)	0	0.0%	26	96.3%	1	3.7%	27
Older Adult (>50 yrs)	0	0.0%	22	100.0%	0	0.0%	22
ADULT SUBTOTAL	**0**	**0.0%**	**69**	**98.6%**	**1**	**1.4%**	**70**
TOTAL	**58**	**30.2%**	**97**	**50.5%**	**37**	**19.3%**	**192**

Statistical comparisons of 3-J-10 and 3-J-11 showed that differences between the two cemeteries for porotic hyperostosis overall prevalence were not significant, $\chi^2(2, n = 367) = .759$, $p = .384$. Furthermore, there were no significant differences in prevalence by age group. A chi-square test did reveal a significant association between cemetery and activity, $\chi^2(2, n = 198) = 12.99$, $p = .002$, V = .256. The significant standardized residual showed that cemetery 3-J-10 was negatively associated ($z = –2.4$) with active lesions. A significant result was also obtained in a Fisher's exact test of age cohort activity between the two cemeteries. The infant group had statistically significant differences in activity between 3-J-10 and 3-J-11 ($p = .014$) with a very strong association (V = .731). The standardized residuals showed that 3-J-10 infants were significantly associated with healed lesions ($z = 2.5$). Comparing Table 5.15 and Table 5.16, infants at 3-J-10 (*n* = 5) had active (40.0%) and healed lesions (60.0%), while those at 3-J-11 (*n* = 14) had mostly active lesions (85.7%) and no healed lesions.

Periostitis

Periostitis was a common affliction on Mis Island with a total of 61.8% (*n* = 359) of the overall sample exhibiting such lesions (Table 5.17). Subadults had a slightly higher prevalence (63.8%, *n* = 177) than adults (59.9%, *n* = 182). The highest prevalence was in the infant category (71.9%, *n* = 64) and then decreased with age to the lowest overall prevalence in adolescence (52.0%, *n* = 25). The young adult age group (63.8%, *n* = 47) was approximately 10% higher than the adolescent age group, but a decrease with age was observed in the middle (59.6%, *n* = 46) and older adults (56.5%, *n* = 46).

Cemetery 3-J-10 (Table 5.17) had an overall prevalence of 67.8% (*n* = 115), with adults at 71.9% (*n* = 64) prevalence and subadults at 62.7% (*n* = 51). The range of periostitis prevalence at 3-J-10 was large; adolescents had the smallest affliction rate of periostitis at 40.0% (*n* = 5) while middle adults were the highest with 77.8% (*n* = 36) of individuals exhibiting periosteal lesions. Of the subadult groups, infants exhibited the most lesions (70.8%, *n* = 24), but prevalence decreased in the children and adolescents. For the adult cohorts, both the young and middle adults had periostitis prevalence over 70%, but the older adults showed a much lower incidence at 53.8% (*n* = 13). Despite these interesting patterns, a Fisher's exact test showed no significant association between age and presence of periostitis (*p* = .331).

Table 5.17: Prevalence of periostitis in 3-J-10 and 3-J-11 at Mis Island.

PERIOSTITIS	3-J-10			3-J-11			COMBINED		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	17	24	70.8%	29	40	72.5%	46	64	71.9%
Child (3-12 yrs)	13	22	59.1%	41	66	62.1%	54	88	61.4%
Adolescent (12-20 yrs)	2	5	40.0%	11	20	55.0%	13	25	52.0%
SUBADULT SUBTOTAL	**32**	**51**	**62.7%**	**81**	**126**	**64.3%**	**113**	**177**	**63.8%**
Young Adult (20-35 yrs)	11	15	73.3%	19	32	59.4%	30	47	63.8%
Middle Adult (35-50 yrs)	28	36	77.8%	25	53	47.2%	53	89	59.6%
Older Adult (>50 yrs)	7	13	53.8%	19	33	57.6%	26	46	56.5%
ADULT SUBTOTAL	**46**	**64**	**71.9%**	**63**	**118**	**53.4%**	**109**	**182**	**59.9%**
TOTAL	**78**	**115**	**67.8%**	**144**	**244**	**59.0%**	**222**	**359**	**61.8%**

Table 5.18 shows the lesion activity by age cohort at cemetery 3-J-10. Overall, the majority of individuals with periostitis exhibited healed lesions (63.6%, *n* = 77), followed by mixed lesions (23.4%, *n* = 77), with the fewest individuals (13.0%, *n* = 10) displaying periostitis lesions in an active state. The majority of subadults (58.1%, *n* = 31) and adults (67.4%, *n* = 46) with signs of periostitis demonstrated healed lesions. For subadults (*n* = 31), active lesions had the second highest prevalence (22.6%), followed closely by mixed lesions (19.4%). This was reversed in the adult group, however, with mixed lesions as the second highest prevalence (26.1%, *n* = 46), and only 6.5% displaying active lesions. Within the infant and child cohorts, the majority of individuals with lesions showed a healed expression (47.1%, *n* = 17 and 75.0%, *n* = 12, respectively), but there were also individuals from these age groups demonstrating both

active and mixed lesions (Table 5.18). The two individuals in the adolescent category with lesions were split, one with an active lesion and the other with a healed lesion. For the adult age cohorts, both young and middle adults were distributed across the three states of activity, but older adults only exhibited healed or mixed lesions. A Fisher's exact test did not show any significant associations between age and periostitis activity ($p = .099$).

Table 5.18: Periostitis activity by age at 3-J-10.

3-J-10	**Active**		**Healed**		**Mixed**		**TOTAL**
Peri. Activity	#	%	#	%	#	%	*n*
Infant (<3 yrs)	5	29.4%	8	47.1%	4	23.5%	17
Child (3-12 yrs)	1	8.3%	9	75.0%	2	16.7%	12
Adolescent (12-20 yrs)	1	50.0%	1	50.0%	0	0.0%	2
SUBADULT SUBTOTAL	**7**	**22.6%**	**18**	**58.1%**	**6**	**19.4%**	**31**
Young Adult (20-35 yrs)	2	18.2%	6	54.5%	3	27.3%	11
Middle Adult (35-50 yrs)	1	3.6%	22	78.6%	5	17.9%	28
Older Adult (>50 yrs)	0	0.0%	3	42.9%	4	57.1%	7
ADULT SUBTOTAL	**3**	**6.5%**	**31**	**67.4%**	**12**	**26.1%**	**46**
TOTAL	**10**	**13.0%**	**49**	**63.6%**	**18**	**23.4%**	**77**

Cemetery 3-J-11 had a lower overall affliction rate (59.0%, $n = 244$) of periostitis than 3-J-10 (Table 5.17). The prevalence in the subadults was comparable, but the adult prevalence was nearly 20% less (53.4%, $n = 118$) than exhibited at 3-J-10. The middle adult cohort had the lowest prevalence at 3-J-11 (47.2%, $n = 53$) and infants had the highest degree of affliction (72.5%, $n = 40$). Periostitis decreased with age in the subadult cohorts, but in the adult groups the young and older adults had similar rates near 60% and the middle adults were below 50%. A chi-square test showed no significant differences between age cohorts for periostitis affliction, $\chi^2(5, n = 244) = 6.51, p = .260$. This suggests that periostitis was not an age-related skeletal pathology. The periostitis lesions at 3-J-11 were mostly healed (65.3%, n = 144), but 41 individuals (28.5%) had mixed lesions and 9 (6.3%) had active lesions (Table 5.19). For those with active lesions, 66.7% (n = 9) were infants and children, but the remaining were middle adults. Every age cohort had the highest percentage in the healed category, except for infants, which had slightly more in the mixed category. Although nearly significant, a Fisher's exact test did not find a statistically relevant association between periostitis activity and age group (p = .052).

Table 5.19: Periostitis activity by age at 3-J-11.

3-J-11	**Active**		**Healed**		**Mixed**		**TOTAL**
Peri. Activity	#	%	#	%	#	%	*n*
Infant (<3 yrs)	2	6.9%	13	44.8%	14	48.3%	29
Child (3-12 yrs)	4	9.8%	30	73.2%	7	17.1%	41
Adolescent (12-20 yrs)	0	0.0%	6	54.5%	5	45.5%	11
SUBADULT SUBTOTAL	**6**	**7.4%**	**49**	**60.5%**	**26**	**32.1%**	**81**
Young Adult (20-35 yrs)	0	0.0%	16	84.2%	3	15.8%	19
Middle Adult (35-50 yrs)	3	12.0%	14	56.0%	8	32.0%	25
Older Adult (>50 yrs)	0	0.0%	15	78.9%	4	21.1%	19
ADULT SUBTOTAL	**3**	**4.8%**	**45**	**71.4%**	**15**	**23.8%**	**63**
TOTAL	**9**	**6.3%**	**94**	**65.3%**	**41**	**28.5%**	**144**

A chi-square test comparing the overall prevalence of periostitis between 3-J-10 and 3-J-11 was not significant, $\chi^2(1, n = 359) = 2.57, p = .109$. A comparison of each age cohort did reveal a significant chi-square result for middle adults, $\chi^2(1, n = 89) = 8.34, p = .004$, with a medium strength of association. This was not surprising as middle adults at 3-J-10 had the highest prevalence for periostitis within the cemetery, while those at 3-J-11 had the lowest prevalence. A test of the association between the cemeteries for activity did not yield a significant result, $\chi^2(2, n = 221) = 3.16, p = .206$. There was no difference between cemeteries at the age cohort level for periostitis activity either.

Scurvy

Scorbutic lesions were less prevalent at Mis Island than the skeletal lesions thus far investigated. Only 33.9% (*n* = 372) of individuals showing signs of this vitamin deficiency (Table 5.20), but this percentage masks the marked difference between prevalence in subadults (65.9%, *n* = 179) and adults (4.1%, *n* = 193). The highest affliction rate occurred in children (69.2%, *n* = 91) and the lowest rate was in middle adult category where only one individual showed signs of scurvy (1.0%, *n* = 96). Within the adult groups, the young adults had the highest incidence with 9.6% (*n* = 52) displaying lesions. The overall pattern at Mis Island then shows that scorbutic lesions were a relatively common occurrence for subadults and relatively rare for adults.

Cemetery 3-J-10 had 29 individuals (24.4%, *n* = 119) who had lesions consistent with scurvy (Table 5.20). Notably, these were all subadults; none of the 67 adults that were analyzed showed signs of scurvy. Half of the infants (50.0%, *n* = 24) displayed lesions, which increased to 65.2% (*n* = 23) in the child cohort, but decreased considerably in the adolescent group (40.0%,

$n = 5$). A Fisher's exact test shows a highly significant association between age and scurvy status ($p < .001$) with a large strength of association (V = .659). The standardized residuals show that the infants ($z = 2.5$) and children ($z = 4.0$) were significantly associated with scurvy presence. Children were negatively associated ($z = -2.3$) with its absence. Young adults ($z = -2.0$) and middle adults ($z = -3.0$) were negatively associated with its presence. Scorbutic lesions were not assessed for activity thus further investigation of the patterns of affliction could not be undertaken.

Table 5.20: Prevalence of scorbutic lesions in 3-J-10 and 3-J-11 at Mis Island.

SCURVY	3-J-10			3-J-11			COMBINED		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	12	24	50.0%	29	40	72.5%	41	64	64.1%
Child (3-12 yrs)	15	23	65.2%	48	68	70.6%	63	91	69.2%
Adolescent (12-20 yrs)	2	5	40.0%	12	19	63.2%	14	24	58.3%
SUBADULT SUBTOTAL	**29**	**52**	**55.8%**	**89**	**127**	**70.1%**	**118**	**179**	**65.9%**
Young Adult (20-35 yrs)	0	16	0.0%	5	36	13.9%	5	52	9.6%
Middle Adult (35-50 yrs)	0	38	0.0%	1	58	1.7%	1	96	1.0%
Older Adult (>50 yrs)	0	13	0.0%	2	32	6.3%	2	45	4.4%
ADULT SUBTOTAL	**0**	**67**	**0.0%**	**8**	**126**	**6.3%**	**8**	**193**	**4.1%**
TOTAL	**29**	**119**	**24.4%**	**97**	**253**	**38.3%**	**126**	**372**	**33.9%**

The sample from cemetery 3-J-11 had a higher prevalence of scorbutic lesions (38.3%, $n = 253$) than 3-J-10 and a higher percentage of adults who demonstrated lesions (6.3%, $n = 126$)

(Table 5.20). Among the adults, the young adult cohort had the highest prevalence of scurvy (13.9%, n = 36), with a lower prevalence among older adults (6.3%, n = 32), and only 1.7% (n = 58) of the middle adult cohort demonstrating scorbutic lesions. Overall the subadult cohorts had an appreciably higher prevalence (70.1%, n = 127) of lesions than their 3-J-10 counterparts. The infants in 3-J-11 showed the highest incidence (72.5%, n = 29), just slightly higher than the child cohort (70.6%, n = 68), and a much larger percentage of adolescents (63.2%, n = 19) at 3-J-11 displayed scorbutic lesions than the adolescents at 3-J-10. Not surprisingly, a chi-square test showed a highly significant association between age and scorbutic lesions, $\chi^2(5, n = 253) = 110.55$, $p < .001$, with a high level of association (V = .661). Investigation of the standardized residuals showed a similar pattern to cemetery 3-J-10. The infant (z = 3.5) and child (z = 4.3) cohorts were positively associated with scurvy presence and negatively associated with its absence (z = –2.8 and z = –3.4, respectively). For the adults, the young (z = –2.4), middle (z = –4.5), and older (z = –2.9) adults were negatively associated with scurvy presence. The middle (z = 3.6) and older (z = 2.3) adults also showed a significant positive correlation with its absence. A Pearson chi-square test investigating the differences between cemetery 3-J-10 and 3-J-11 found a significant result, $\chi^2(1, n = 372) = 7.05$, $p = .008$, with a small measure of association (*phi* = –.138). No standardized residuals reached significance in this case, but from Table 5.20 it is clear that 3-J-11 had a higher incidence of scorbutic lesions. A test of the association between cemetery and scurvy for each age cohort showed no significant results for any of the age groups.

Tuberculosis

Tuberculosis was present at Mis Island but only 2.4% (n = 377) showed lesions consistent with tuberculosis infection (Table 5.21). Overall there were two adolescents (7.7%, n

= 26), five middle adults (5.1%, *n* = 5.1%), a single young adult (1.9%, *n* = 53), and a single older adult (2.2%, *n* = 46) who had lesions consistent with skeletal tuberculosis. Only one individual from cemetery 3-J-10 (0.8%, *n* = 120), a middle adult, had characteristic lesions. A Fisher's exact test showed no significant association between age and tuberculosis ($p = 1.000$) at cemetery 3-J-10. The remainder of those afflicted were from cemetery 3-J-11 (3.1%, *n* = 257), with the highest prevalence in the adolescent cohort (9.5%, *n* = 21) despite only two individuals with evident lesions. The middle adults had a slightly lower percentage (6.8%, *n* = 59) and the young adults and older adults each had a single person with signs of tuberculosis (2.7%, *n* = 37 and 3.0%, *n* = 33, respectively). A Fisher's exact test for cemetery 3-J-11 showed no significant association between age cohort and tuberculosis affliction ($p = .053$). This result may be a reflection of the small sample of affected individuals, rather than a true non-significant result.

A comparison of the two cemeteries revealed no significant difference in tuberculosis presence ($p = .282$). This allowed for a combined 3-J-10 and 3-J-11 sample for further investigation of age differences. Interestingly, collapsing the two cemeteries into a single sample elucidated a significant Fisher's exact result ($p = .037$), but the strength of association between age and tuberculosis presence was low (V = .163) and none of the standardized residuals were significant.

Table 5.21: Prevalence of tuberculosis in 3-J-10 and 3-J-11 at Mis Island.

TB	3-J-10			3-J-11			COMBINED		
	Affect.	*n*	%	Affect.	*n*	%	Affect.	*n*	%
Infant (<3 yrs)	0	24	0.0%	0	42	0.0%	0	66	0.0%
Child (3-12 yrs)	0	23	0.0%	0	65	0.0%	0	88	0.0%
Adolescent (12-20 yrs)	0	5	0.0%	2	21	9.5%	2	26	7.7%
SUBADULT SUBTOTAL	**0**	**52**	**0.0%**	**2**	**128**	**1.6%**	**2**	**180**	**1.1%**
Young Adult (20-35 yrs)	0	16	0.0%	1	37	2.7%	1	53	1.9%
Middle Adult (35-50 yrs)	1	39	2.6%	4	59	6.8%	5	98	5.1%
Older Adult (>50 yrs)	0	13	0.0%	1	33	3.0%	1	46	2.2%
ADULT SUBTOTAL	**1**	**68**	**1.5%**	**6**	**129**	**4.7%**	**7**	**197**	**3.6%**
TOTAL	**1**	**120**	**0.8%**	**8**	**257**	**3.1%**	**9**	**377**	**2.4%**

Discussion

The presence and activity of various skeletal pathologies in samples from cemetery 3-J-10 and 3-J-11 at Mis Island were compared for significant differences between age cohorts and cemeteries. The mortality profiles of Mis Island demonstrated that at each cemetery and in the combined cemetery sample, middle adults and children accounted for the highest proportions of individuals represented. This suggests that during these two age periods, the risk of death was increased. For the middle adults, this was likely close to the average life expectancy for the Mis Island population. Although, this may seem young by modern standards, between the years of 1950 and 1955 the life expectancy in Egypt was 42.89 years and in Sudan 40.04 years (United Nations, Department of Economic and Social Affairs, Population Division, 2011a). The finding that more females reach older adulthood than males is not surprising since females generally have longer life expectancies than males. Furthermore, infant and young child mortality has been a common concern for human populations throughout history. It has been estimated that of the total deaths in Egypt and Sudan between 1995 and 2000, 23.4% and 42.3%, respectively, were children under the age of five (United Nations, Department of Economic and Social Affairs, Population Division, 2011b). In addition, the mortality rates for children under five were approximately 29% for Egypt and 27% for Sudan in 1950 (United Nations, Department of Economic and Social Affairs, Population Division, 2011 c; d). Thus the peaks in the mortality profiles at Mis Island in infancy and middle adulthood make sense in the context of mortality data from modern Egypt and Sudan.

While the overall pattern of mortality at Mis Island reflects a natural mortality profile, there are a few discrepancies in the results that must be addressed. From the entirety of the samples of 3-J-10 and 3-J-11, only one set of fetal remains was recovered. This suggests that premature infants were likely buried elsewhere, as was commonly seen throughout Nubia's history. For example at Debeira West, a Christian site in Lower Nubia, Shinnie and Shinnie (1978, p 107) found the remains of several young infants in large pots both under the floor of houses or just outside the door. A similar practice was documented at Arminna West, also a Lower Nubian Christian site, where fetal remains were found buried in the water jar of a *saqia* (Anderson, 2004, p 63).

The number of adolescent remains recovered was also low. This was especially apparent at cemetery 3-J-10 where only five individuals (4.0%, n = 126) of this age were recovered. While it is possible that more adolescent individuals may have been present in the unexcavated graves of the cemetery, the small representation of adolescents in comparison to the other age cohorts is surprising. Another potential hypothesis is that adolescents may have died and were buried away from the community. There has been no historical documentation of such a practice, however, making it difficult to accept this as the reason for so few adolescents. Alternatively, it may be that once subadults survived the vulnerable ages of infancy and childhood, adolescence was not a period of high mortality risk. Modern parallels support such a conclusion as data from Egypt and Sudan show that between 1995 and 2000, 5.99% and 2.87% of deaths in Sudan and Egypt, respectively, were of individuals between the ages of 10 and 19 years (United Nations, Department of Economic and Social Affairs, Population Division, 2011 b). Although this data does not have the same age divisions as were used in this research, it nevertheless shows that for an even larger age range the number of deaths was still relatively low. Demographic profiles from the two cemeteries at Kulubnarti, a contemporary Christian site upstream of the Second Cataract, show adolescents comprised a total of 9.0% (n = 399) of the sample, and at site 21-S-46 only 6.1% of the sample (n = 214) (Adams et al., 1999). Thus, while the numbers at Mis Island were still slightly lower, they may not be out of the range of normal mortality for adolescents during this time period.

The incidence of linear enamel hypoplasias was comparable in 3-J-10 and 3-J-11 and there was no significant difference between the cemeteries for each anterior tooth evaluated. For both 3-J-11 and the combined cemetery sample, the maxillary central incisor (#9) and the maxillary lateral incisor (#10) were the only teeth that were significantly associated with age. In both of these categories, the child cohort demonstrated the highest prevalence, and in the combined sample had a significant standardized residual illustrating the positive correlation between childhood and linear enamel hypoplasias of this tooth.

Linear enamel hypoplasias (LEH) are a difficult pathology to interpret because they do not represent health disparities in different age groups. Since an LEH occurs during tooth crown formation, it essentially represents the same period of time in every person's life. Beginning with the deciduous incisors, this encompasses a time period from approximately 14 weeks prenatal to 16 years when the third molar has completed crown formation. For the permanent anterior teeth evaluated in this study, the age range was 3 months postnatal to 7 years from crown initiation to crown completion (Hillson, 1996, pp 121–125). Rather than serving as an indicator of morbidity for different age classes, LEH's may be more appropriately interpreted as a measure of survivorship. An LEH represents the interruption of enamel deposition due to an acute stressor. The only way an LEH becomes visible, however, is if that individual recovers and re-initiates amelogenesis. Therefore, from this perspective, every person with an LEH survived an acute stress event. However, the presence of an LEH does represent a time when an individual's health was seriously compromised. This period of disease may be a reflection of inherent factors that predispose a person to disease, including genetic differences or human variation. Alternatively, the LEH event may be caused by environmental factors, such as parasites, infectious disease, or nutritional inadequacies that potentially impact the majority of the population. A third interpretation is that the physiological stressor that caused the LEH may have had prolonged effects that weakened an individual's immune system, leaving them vulnerable to other nutritional or infectious maladies. A final hypothesis is that the acute disease that caused the LEH was an isolated occurrence from which the person made a full recovery with no long-term detrimental effects. In attempting to understand which of these scenarios characterized individuals in the Mis Island sample, it is necessary to investigate how long people survived after an LEH incident. In other words, one needs to estimate the person's age at time of death.

Focusing on the teeth that had the largest representation in the combined sample, the maxillary and mandibular canines, it was apparent that the majority of teeth evaluated had at least one LEH. In each age group, there was at least one tooth type that reached a prevalence of 68% or higher. In addition, for the majority of tooth types there was no significant difference by age. This suggests that all individuals at Mis Island experienced similar physiological stressors during childhood, eliminating the scenario that LEH's in this population only occurred in frail individuals prone to disease. Without histological analyses it is difficult to estimate a specific age of LEH development. The high prevalence of these lesions, however, suggests a stressor that is consistent across the Mis Island populations and through time. Every child endures two major life events, birth and weaning. Since the affected teeth do not begin formation until three months after birth, this traumatic event cannot be the cause of the observed LEH's. Thus, the transitional time of weaning, which is often marked by nutritional inadequacies, infection, and diarrhea seems the mostly likely cause. Furthermore, these stressors associated with weaning may work synergistically to create a detrimental feedback loop of illness that could result in an LEH.

Although LEH's were common throughout the Mis Island sample, statistically significant associations by age were present. As noted above, for teeth with significant associations with age, the highest levels of LEH were in the child cohort. This indicates that individuals who experienced an LEH event impacting the maxillary incisors were at higher risk of mortality. Even more revealing was the presence of multiple LEH's in certain age groups. Again, children and infants had the highest prevalence in nearly every tooth type, including the maxillary canine (#11) and the mandibular central incisor (#24) that demonstrated a significant difference by age. A significant standardized residual also demonstrated a positive association between the child cohort and presence of multiple hypoplasias. Thus, the presence of multiple hypoplasias was positively associated with early mortality. It is impossible in the current study to disentangle whether these deaths resulted from intrinsic, environmental, or a combination of factors. What is evident, is that children with multiple LEH's were susceptible to bouts of acute illness that likely contributed to their untimely death.

Cribra orbitalia appeared to be relatively common at Mis Island with more than half of the individuals with lesions. The data showed that children had the highest prevalence of cribra orbitalia lesions, followed by infants, and most of these lesions were active at the time of death. This suggests that the underlying cause of cribra orbitalia began to impact individuals as early as infancy and may have directly contributed to their death. Although early manifestations were apparent, cribra orbitalia lesions persisted throughout the life course with adult cohorts demonstrating prevalence between approximately 40% and 50%. The difference for adults, however, was that the vast majority of these lesions were healed. This indicates that the underlying cause of this skeletal lesion had been resolved in the adult cohorts, allowing healing to occur.

Cribra orbitalia is considered a non-specific indicator of stress, meaning lesions are not indicative of a single specific disease. Research by Walker and colleagues (Walker et al., 2009), however, has suggested that cribra orbitalia lesions are formed from an osteoblastic response to subperiosteal hematoma in the eye orbit. Hematoma in the eye orbit can be induced from trauma; however, it can also result from a separation of the periosteum, the membrane that covers bones. This periosteal separation is more likely in young children because the membrane is not affixed as tightly as it is in adults (Rana et al., 2009, p W259). The likelihood of such periosteal disturbance may be further increased in cases of vitamin C deficiency. Vitamin C plays a vital role in the formation of collagen, which provides the structural integrity for blood vessels and Sharpey's fibers, the tissues responsible for connecting the periosteum to the bone. When adequate levels of vitamin C are not present in the diet, these Sharpey's fibers are prone to breakage causing the periosteum to be stripped from the bone and potentially causing cribra orbitalia lesions. Children at Mis Island may have had inadequate intake of this essential vitamin because of nutrient poor weanling and childhood diets. Seasonal deficiencies in vitamin C resources may have contributed to the exasperation of vitamin C stores and the development of cribra orbitalia.

Porotic hyperostosis was not as prevalent overall as cribra orbitalia but still afflicted more than half of the Mis Island cemetery population. A different pattern of morbidity occurred with porotic hyperostosis, with more adults affected than subadults. Although lesions were present in the infant cohort, this group showed the lowest prevalence overall and in both cemeteries independently. This was significant at 3-J-10, where infants were negatively associated with porotic hyperostosis presence and positively associated with its absence. At 3-J-10 the peak of prevalence occurred in the older adult category, followed by the young adults, but at 3-J-11 the peak was in the adolescents followed by the older adults. Older adults were commonly afflicted with porotic hyperostosis, but these lesions were almost entirely healed. These individuals may represent the resilient survivors of the population, those that were able to survive the underlying causes of porotic hyperostosis but retained the skeletal indicators of the stress event. The young adults at 3-J-10, where the other peaked occurred in this cemetery, also had healed lesions. At 3-J-11, the adolescent cohort had a much higher prevalence than the other age groups with mostly active or mixed lesions. While the mixed lesions indicate that some healing had occurred before death, active lesions suggest that the biological stressor causing porotic hyperostosis was still present when these individuals died. As the number of children with porotic hyperostosis was not markedly high, the increase in adolescent individuals may indicate an intensified stressor during this age period. Since lesions in young adults were all healed, this seems to represent a stressor that resolved during late adolescence or shortly thereafter.

Porotic hyperostosis has been linked to megaloblastic anemia since it stimulates red blood cell production, causing marrow hypertrophy and potentially the cortical thinning characteristic of porotic hyperostosis. Megaloblastic anemia is caused by pathologic deficiencies of vitamin B_{12} or folate, both nutrients that are often consumed as part of a balanced diet. Sources of vitamin B_{12} are limited to animal products, including fish, meat, eggs, milk, and milk products (Office of Dietary Supplements, National Institutes of Health, 2011). Folate is found in a greater diversity of foods, including dark green leafy vegetables, fruits, nuts, beans, meats, eggs, seafood, and dairy products (Office of Dietary Supplements, National Institutes of Health, 2012). Additional considerations for individual folate needs include increased requirements in pregnant women and depletion of levels in the body from exposure to the ultraviolet radiation from the sun (Borradale and Kimlin, 2012, p 414; Office of Dietary Supplements, National Institutes of Health, 2012).

The high prevalence of porotic hyperostosis in adolescents at 3-J-11 could be a reflection of a number of scenarios. The most obvious factor influencing porotic hyperostosis status would be dietary intake of folate and vitamin B_{12}. Fruit and vegetable folate sources would only have been available seasonally at Mis Island, since these crops would be unable to endure the hot and arid summer months. Meat products, a source of both folate and B_{12} may not have been available for consumption for this age group either. A study by Turner and colleagues (Turner et al., 2007) found isotopic differences in dietary consumption for infants, post-weaning subadults, and adults at Kulubnarti. Specifically, isotopic signatures suggested differential intake of animal protein in these age groups, with the most depleted levels occurring in the post-weaning subadults (4 to 17 years of age) (Turner et al., 2007, p 19). Such dietary signatures could be a reflection of food allocation practices. In modern Sudan villages, it is common for men to have the first meal, followed by women, and children eat last and dine on whatever remains (J. Anderson, personal communication). Pregnancy is another potential contributor to porotic hyperostosis, as first pregnancies were probably experienced during this time period. The combination of low intake of animal protein, seasonal deficiencies in produce, and increased folate needs during pregnancy would make young adolescent women vulnerable to megaloblastic anemia.

Periostitis was a common skeletal lesion at Mis Island, but with variable patterns of prevalence. Overall, infants were the group with the highest prevalence, followed by young adults. Adolescents had the lowest occurrence of periostitis with older adults just slightly higher. This was not the pattern at 3-J-10, however, where middle adults had the highest rates, followed by young adults and then infants. Cemetery 3-J-11 demonstrated yet another pattern, with infants and then children with the highest prevalence and middle adults with the lowest prevalence. Lesion activity was also variable both within and between cemeteries. Thus, it was not surprising that there were no significant differences by age for either prevalence of activity in either 3-J-10 or 3-J-11. Overall, the cemeteries were not significantly different either, but the middle adult cohorts from each cemetery were significantly different from each other in periostitis prevalence. While it is difficult to ascertain the sources of such differences, it is clear that periostitis was not biologically associated with developmental age. Its incidence may have more to do with individual exposure or risk than to a systematic difference in population subgroups. Furthermore, periostitis can be cause by trauma, local or systemic infection, or any disturbance of the periosteum. As outlined in the cribra orbitalia discussion, subadults have a periosteal covering that is more loosely attached than adults, which could be easily disrupted by activities such as crawling. For the adult groups, the sources of the periosteal disturbance are more difficult to pinpoint and may be related to low-level infections, subperiosteal hematoma, or trauma.

The incidence of scurvy was relatively low at Mis Island with only about one-third of individuals showing characteristic signs of this nutritional deficiency. The largest difference was seen between the adults and the subadults, with only about 4% of adults afflicted and nearly 70% of the subadults. While such a large discrepancy suggests drastic differences between adult and subadult diets, it can be explained by both cultural and biological factors. It is not surprising that individuals were experiencing vitamin C deficiency at Mis Island. The Nile River Valley was an oasis within a vast desert and populations relied on the life-giving waters of the Nile to provide the necessary moisture and soil to grow crops. The plants that could endure the high temperature and intense sunlight of Nubian summers were tropical grasses, including millet and sorghum, cereal crops that do not contain vitamin C. Although it may have been possible to grow fruits and vegetables in the winter months, there would have certainly been a seasonal deficiency in vitamin C resources. Furthermore, storage and cooking deplete levels of vitamin C in plant resources, making it difficult to maintain adequate levels of this nutrient.

Age differences in scurvy prevalence may results from the transition in children from breast milk to a nutrient poor weanling diet often comprised of cereal gruels. Diarrheal diseases and other infections that are common at this age can also cause the depletion of vitamin C levels in the body. The low level of scorbutic lesions in adults may indicate that sources of vitamin C were available year-round to these cohorts, but it is more likely that the lack of lesions can be attributed to the skeletal manifestation of scurvy in adults. Scurvy can easily be identified in young individuals because rapid growth and production of fragile blood vessels causes lesions in characteristic locations. Skeletal changes in adults are not nearly as obvious and none of the indicators are considered pathognomic for scurvy alone (Brickley and Ives, 2008, pp 61–62). Thus, recognizing and differentially diagnosing scurvy in adults is especially difficult. Scorbutic lesions in adults include new bone formation in the eye orbits, antemortem tooth loss, inflammation of the alveolus, osteopenia, transverse fractures of the anterior extremity of the ribs, and bone deposition on long bones (Brickley and Ives, 2008, p 61). Unfortunately, even if these lesions were detected in an adult they could easily be mistaken for another pathological condition.

Tuberculosis was the final disease that was investigated in this research. Although the number of individuals showing skeletal manifestations was small, they provide evidence that tuberculosis was present at Mis Island. Tuberculosis is a disease that can be controlled by the immune system in healthy individuals, but those with weakened immune systems are at a higher risk of developing disease (Donoghue, 2009, p 75). It is difficult to know the true prevalence rate of tuberculosis at Mis Island because it is possible that tuberculosis infections did not progress to skeletal infection or that affected vertebrae did not preserve due to their compromised structural integrity. Furthermore, ancient DNA (aDNA) research has found that individuals with no signs of skeletal infection tested positive for tuberculosis aDNA (Donoghue, 2009, p 1160). Thus, vertebral lesions may not be a particularly sensitive indicator of tuberculosis infection. With this evidence and the relative ease of spreading infected tuberculosis droplets it is likely that the prevalence was considerably higher at Mis Island than the skeletal remains may suggest.

The comparisons of the cemeteries 3-J-10 and 3-J-11 at Mis Island have shown variability in frequency and patterns of skeletal pathologies. Cemetery 3-J-10 had higher prevalence overall for porotic hyperostosis and periostitis, while 3-J-11 had a higher incidence of linear enamel hypoplasia, cribra orbitalia, scurvy, and tuberculosis. Despite these differences, for overall prevalence, only cribra orbitalia and scurvy were significantly different between the two cemeteries. Occupying the same island with access to the same natural resources, it is somewhat surprising that any differences would exist. Cemetery 3-J-11, however, was utilized for a much longer period and may have been impacted by low Niles thought to have occurred between AD 828 and 837 and from AD 939 to 948 (Edwards, 2004, pp 213–214). With no archaeological evidence recovered for irrigation agriculture, it is likely that the inhabitants of Mis relied on the cultivation of lands that were inundated during Nile floods, leaving behind rich and moist soil. Without regular Nile levels, it would be virtually impossible to cultivate crops even at subsistence levels. Archaeological data indicates that cemetery 3-J-10 was utilized between AD 1100 and 1400, thus its cemetery population would not reflect the mortality and morbidity of these harsh years.

Conclusion

The analyses of skeletal remains from cemetery 3-J-10 and 3-J-11 at Mis Island have provided a glimpse into the biological stressors facing these populations centuries ago. It is clear that chronic levels of disease were normal in the population as most individuals of all ages showed skeletal manifestations of disease. Due to the limited types of disease expression possible in bone, it is difficult to ascertain the underlying etiologies of skeletal lesions. The integration of the skeletal data with archaeological, environmental and health and disease information help to understand the potential causes of these paleopathologies. At Mis Island, the overall patterns of disease suggest nutritional deficiencies were typical, especially in vitamin C, vitamin B_{12}, and folic acid. The activity of skeletal lesions demonstrated that healing was able to occur and the underlying cause of the stressor may not have contributed directly to the individual's death. Thus biological stressors were endemic but not necessarily constant and were influenced by environmental conditions, seasonality, and age-related factors.

At the site of Mis Island, infants and children were particularly vulnerable age groups with high levels of morbidity and mortality. The high energy demands of growth and development during these stages coupled with a developing immune system, inadequate vitamin stores, and a poor weanling diet made these youngsters especially vulnerable to nutritional deficiencies, infection, and death. Adolescent individuals had an overall low mortality rate, but showed elevated levels of active porotic hyperostosis. As individuals at this age were becoming sexually mature, nutritional requirements may have changed before they transitioned to the adult diet with higher levels of animal protein consumption. Adults generally had lower prevalence of skeletal lesions and a higher prevalence of healed activity. Thus once adulthood was reached, these biological stressors remained but may not have posed as significant of a risk. The age of middle adulthood (30 to 44.9 years) likely represented the standard life expectancy of the Mis Island populations. While it was not unusual for individuals to reach older adulthood, the majority of the adult sample was comprised of middle adults.

This research provides a rare glimpse into peasant life in the Fourth Cataract during the medieval Christian period. Such analyses make important contributions to our understanding of medieval Nubian history and the people that lived during this period. The Island of Mis is now under the Merowe Dam's reservoir lake, making the investigation of the 3-J-10 and 3-J-11 populations of utmost importance. These populations represent the legacy of Mis Island and the last connection to these populations that lived hundreds of years ago.

LITERATURE CITED

LITERATURE CITED

Adams WY, Adams NK, VanGerven DP, and Greene DL. 1999. Kulubnarti III: The Cemeteries. London: SARS.

Adams WY. 1998. Toward a Comparative Study of Christian Nubian Burial Practice. Archéologie du Nil Moyen 8:13–41.

Anderson JR. 2004. The Medieval Kingdoms of Nubia. In: Welsby DA, Anderson JR, editors. Sudan: Ancient Treasures. London: British Museum Press.

Borradale DC, and Kimlin MG. 2012. Folate Degradation Due to Ultraviolet Radiation: Possible Implications for Human Health and Nutrition. Nutr. Rev. 70:414–422.

Brickley M, and Ives R. 2006. Skeletal Manifestations of Infantile Scurvy. Am. J. Phys. Anthropol. 129:163–172.

Brickley M, and Ives R. 2008. The Bioarchaeology of Metabolic Bone Disease. Oxford: Academic Press.

Buikstra JE, and Ubelaker DH. 1994. Standards for Data Collection from Human Skeletal Remains. Fayetteville: Arkansas Archeological Survey.

Donoghue HD. 2008. Palaeomicrobiology of Tuberculosis. In: Raoult D, Drancourt M, editors. Paleomicrobiology: Past Human Infections. Berlin: Springer-Verlag. p 75–97.

Donoghue HD. 2009. Human Tuberculosis: An Ancient Disease, As Elucidated by Ancient Microbial Biomolecules. Microbes Infect. 11:1156–1162.

Edwards DN. 2004. The Nubian Past: An Archaeology of the Sudan. London: Routledge.

Field A. 2009. Discovering Statistics Using SPSS. 3rd ed. London: SAGE Publications Ltd.

Ginns A. 2006. Preliminary Report on the Excavations Conducted on Mis Island (AKSC), 2005-2006. Sudan & Nubia 10:13–19.

Ginns A. 2007. Preliminary Report on the Second Season of Excavations Conducted on Mis Island (AKSC). Sudan & Nubia 11:20–25.

Ginns A. 2010a. Medieval Cemetery 3-J-10. Draft Site Report. Available from: http://www.sudarchrs.org.uk/AKS_draft_publications.htm

Ginns A. 2010b. Medieval Cemetery 3-J-11. Draft Site Report. Available from: http://www.sudarchrs.org.uk/AKS_draft_publications.htm

Goodman AH, and Armelagos GJ. 1985a. The Chronological Distribution of Enamel Hypoplasia in Human Permanent Incisor and Canine Teeth. Arch. Oral Biol. 30:503–507.

Goodman AH, and Armelagos GJ. 1985b. Factors Affecting the Distribution of Enamel Hypoplasias within the Human Permanent Dentition. Am. J. Phys. Anthropol. 68:479–493.

Goodman AH, and Rose JC. 1990. Assessment of Systemic Physiological Perturbations from Dental Enamel Hypoplasias and Associated Histological Structures. Am. J. Phys. Anthropol. 33:59–110.

Hershkovitz I, Rothschild BM, Latimer B, Dutour O, Léonetti G, Greenwald CM, Rothschild C, and Jellema LM. 1997. Recognition of Sickle Cell Anemia in Skeletal Remains of Children. Am. J. Phys. Anthropol. 104:213–226.

Hillson S. 1996. Dental Anthropology. Cambridge: Cambridge University Press.

Hillson S. 2006. Teeth. Cambridge: Cambridge University Press.

Kelley MA, and El-Najjar MY. 1980. Natural Variation and Differential Diagnosis of Skeletal Changes in Tuberculosis. Am. J. Phys. Anthropol. 52:153–167.

Lagia A, Eliopoulos C, and Manolis S. 2007. Thalassemia: Macroscopic and Radiological Study of a Case. Int. J. Osteoarchaeol. 17:269–285.

Mays S, Fysh E, and Taylor GM. 2002. Investigation of the Link Between Visceral Surface Rib Lesions and Tuberculosis in a Medieval Skeletal Series from England Using Ancient DNA. Am. J. Phys. Anthropol. 119:27–36.

Office of Dietary Supplements, National Institutes of Health. 2011. Dietary Supplement Fact Sheet: Vitamin B12. Office of Dietary Supplements [Internet]. Available from: http://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/

Office of Dietary Supplements, National Institutes of Health. 2012. Dietary Supplement Fact Sheet: Folate. Office of Dietary Supplements [Internet]. Available from: http://ods.od.nih.gov/factsheets/Folate-HealthProfessional/

Ortner DJ, Butler W, Cafarella J, and Milligan L. 2001. Evidence of Probable Scurvy in Subadults from Archeological Sites in North America. Am. J. Phys. Anthropol. 114:343–351.

Ortner DJ, and Ericksen MF. 1997. Bone Changes in the Human Skull Probably Resulting from Scurvy in Infancy and Childhood. Int. J. Osteoarchaeol. 7:212–220.

Ortner DJ, Kimmerle EH, and Diez M. 1999. Probable Evidence of Scurvy in Subadults from Archeological Sites in Peru. Am. J. Phys. Anthropol. 108:321–331.

Ortner DJ. 2003. Identification of Pathological Conditions in Human Skeletal Remains. 2nd ed. San Diego, CA: Academic Press.

Rana RS, Wu JS, and Eisenberg RL. 2009. Periosteal Reaction. Am. J. Roentgenol. 193:W259–W272.

Roberts CA, and Buikstra JE. 2003. The Bioarchaeology of Tuberculosis: A Global View on a Reemerging Disease. Gainesville: University Press of Florida.

Schultz M. 2001. Paleohistopathology of Bone: A New Approach to the Study of Ancient Diseases. Am. J. Phys. Anthropol. Suppl 33:106–147.

Shinnie PL, and Shinnie M. 1978. Debeira West, a Medieval Nubian Town: University of Ghana Expedition to Nubia. Warminster: Aris and Phillips.

Soler A. 2012. Life and Death in a Medieval Nubian Farming Community: The Experience at Mis Island [dissertation]. [East Lansing, (MI)]: Michigan State University.

Steckel RH, Spencer Larsen C, Sciulli PW, and Walker PL. 2011. The Global History of Health Project Data Collection Codebook. Columbus: Ohio State University.

Steinbock R. 1976. Hematological Disorders -- the Anemias. In: Steinbock R, editor. Paleopathological Diagnosis and Interpretation. Springfield: Charles C. Thomas.

Stuart-Macadam P. 1985. Porotic Hyperostosis: Representative of a Childhood Condition. Am. J. Phys. Anthropol. 66:391–398.

Stuart-Macadam P. 1989. Porotic Hyperostosis: Relationship Between Orbital and Vault Lesions. Am. J. Phys. Anthropol. 80:187–193.

Stuart-Macadam P. 1992a. Porotic Hyperostosis: A New Perspective. Am. J. Phys. Anthropol. 87:39–47.

Stuart-Macadam P. 1992b. Anemia in Past Human Populations. In: Stuart-Macadam P, Kent S, editors. Diet, Demography and Disease, Changing Perspectives on Anemia. New York: Aldine. p 151–170.

Turner BL, Edwards JL, Quinn EA, Kingston JD, and Van Gerven DP. 2007. Age-Related Variation in Isotopic Indicators of Diet at Medieval Kulubnarti, Sudanese Nubia. Int. J. Osteoarchaeol. 17:1–25.

United Nations, Department of Economic and Social Affairs, Population Division. 2011a. File 5-1: Life Expectancy at Birth (both sexes combined) by Major Area, Region and Country, 1950-2100 (years). In: World Population Prospects: The 2010 Revision, CD-ROM Edition. New York: United Nations. Available from: http://esa.un.org/unpd/wpp/Excel-Data/mortality.htm

United Nations, Department of Economic and Social Affairs, Population Division. 2011b. File 1: Deaths (both sexes combined) by Five-Year Age Group, Major Area, Region and Country, 1995-2100 (thousands). In: World Population Prospects: The 2010 Revision, CD-ROM Edition. New York: United Nations. Available from: http://esa.un.org/unpd/wpp/Excel-Data/mortality.htm

United Nations, Department of Economic and Social Affairs, Population Division. 2011c. Country Profile: Former Sudan. In: World Population Prospects: The 2010 Revision, CD-ROM Edition. New York: United Nations. Available from: http://esa.un.org/unpd/wpp/country-profiles/country-profiles_1.htm

United Nations, Department of Economic and Social Affairs, Population Division. 2011d. Country Profile: Egypt. In: World Population Prospects: The 2010 Revision, CD-ROM Edition. New York: United Nations. Available from: http://esa.un.org/unpd/wpp/country-profiles/country-profiles_1.htm

Walker PL, Bathurst RR, Richman R, Gjerdrum T, and Andrushko VA. 2009. The Causes of Porotic Hyperostosis and Cribra Orbitalia: A Reappraisal of the Iron-Deficiency-Anemia Hypothesis. Am. J. Phys. Anthropol. 139:109–125.

CHAPTER 6 – REGIONAL COMPARISON

Introduction

The morbidity and mortality of a past population sheds valuable light onto the daily stresses individuals had to overcome to maintain their health, which may have included harsh environmental conditions, nutritional deficiencies, infections, and parasites. The skeletal remains, which are able to chronicle an individual's health over a lifetime, offer an exceptionally rich source of evidence to this end. Understanding the results from such analyses can be difficult when viewed in isolation, thus it is beneficial to compare populations to other samples in similar contexts to appreciate how successful a population was in a particular environment. Such regional comparisons can reveal the diversity of life experiences across a region, or the relative homogeneity of morbidity and mortality.

The Nile Valley has seen a diversity of cultures throughout its history and has served as an oasis and thoroughfare through the harsh and arid Saharan desert. South of Egypt, the Nile River was controlled by the medieval kingdoms of Nubia, with Nobadia in the north from the First to the Third Cataracts, Makuria stretching from the Third to the Fifth Cataracts, and Alwa in the south upriver from Makuria. Each of these kingdoms was comprised of villages and cities located along the narrow stretches of the Nile Valley, reliant on its life-giving waters. While Egypt is well known for exploiting the seasonal floods of the Nile to create large tracts of fertile land for farming, the Nile in Nubia was not as prolific. South of the First Cataract, the Nile flows through high banks, greatly restricting the amount of land annually flooded (Welsby, 2002, p 183). An especially harsh region of the Nile is the *Batn el-Hajar*, or the "Belly of Rocks", an area wrought with rapids and land comprised of granite outcrops and barren alluvial plains (Van Gerven et al., 1981, p 397; Adams et al., 1999, p 1). Kulubnarti was one the of the sites of this region, located upstream of the Second Cataract and approximately 130 kilometers south of Wadi Halfa which is near the border of present day Egypt and Sudan (Van Gerven et al., 1995, p 470). Although Kulubnarti was not actually inundated, it was one of the many sites excavated through the UNESCO Campaign to Save the Monuments of Nubia (1960-1980) in advance of the flooding of the area from the construction of the Aswan High Dam. During the excavation of the settlement led by William Y. Adams in 1969, two cemeteries were discovered and partially excavated, but it was not until 1979 that the team of Dennis P. Van Gerven completed a more extensive excavation of these cemeteries. The extremely dry nature of the *Batn el-Hajar* provided ideal conditions for excellent preservation and in many cases naturally mummified remains from these cemeteries. Cemetery 21-S-46 was located on the west side of the island of Kulubnarti within a dry *wadi*, while 21-R-2 was discovered along the west bank of the Nile opposite the south end of the island (Adams, 1999a, p 1). Archaeological evidence indicated 21-S-46 was first used just prior to the conversion to Christianity and continued to be a burial site into the early Classic Christian period. Cemetery 21-R-2 had evidence supporting its history from the Early Christian period to modern times. However, the excavated graves of both are considered Early Christian (AD 550-800) based on burial patterns, associated textiles, and artifacts, in particular ceramics found within the graves (Adams, 1999 b, p 24,43).

The island of Mis was located in the Fourth Cataract of the Nile and was one of the many sites excavated by the Sudan Archaeological Research Society prior to the area's flooding by the construction of the Merowe Dam. This island was occupied from the Meroitic period to modern times when imminent flooding forced its inhabitants to relocate. The region of the Fourth Cataract received little attention prior to the Merowe Dam Archaeological Salvage Project because it was considered an inhospitable area that was unlikely to contain any substantial settlements (Welsby, 2008, p 33). The region had no floodplain on the banks of the Nile to provide the same seasonal agricultural opportunities that populations outside of this region relied upon. Any transportation by land would be encumbered by the rocky terrain, and river travel was difficult due to innumerable cataracts and a prevailing wind that followed the current, eliminating the possibility of sailing upstream (Welsby, 2008, p 33). Challenging this preconceived notion that the Fourth Cataract could not sustain major settlements, archaeological investigations revealed substantial architecture, including a pyramid and large medieval fortresses, prestige artifacts, and significant amounts of imported goods from as far as Egypt (Welsby, 2008, p 44). Changing perspectives now suggest that a significant amount of agricultural land was available when channels separating the numerous islands dried after seasonal flooding (Welsby, 2008, p 44). In addition to agricultural opportunity, the difficult access to the Fourth Cataract region may have also provided refuge during times of political insecurity (Welsby, 2008, p 44).

Skeletal analyses employing a biocultural approach allow investigators to understand how interactions between environmental and cultural factors can be a source of human variation. In the case of Nubia, with its limited written history and significant loss of archaeological material due to the construction of dams, these investigations are priceless since they can reveal details about the daily lives of the non-elites who are typically absent from historical sources. This study investigated the prevalence of cribra orbitalia in the cemetery samples 3-J-10 and 3-J-11 from Mis Island in comparison to cemeteries 21-S-46 and 21-R-2 from Kulubnarti to gain a regional perspective on cribra orbitalia as an indicator of health disparity in medieval Nubia.

Materials and Methods

This study examined the prevalence and severity of cribra orbitalia from a sample of 809 medieval Nubians from two sites, Mis Island and Kulubnarti. The Mis Island sample consisted of 402 individuals, with 126 individuals from Cemetery 3-J-10 and 276 from 3-J-11. The Kulubnarti cemeteries had a total of 407 individuals, with Cemetery 21-S-46 comprising 216 individuals and 21-R-2 with 191 individuals total (see Table 6.1). Both males and females are represented and ages range from fetal to more than 50 years of age.

Table 6.1: Mis Island and Kulubnarti skeletal samples by age.

SKELETAL SAMPLE AGE	Mis Island		Kulubnarti		TOTAL
	3-J-10	3-J-11	21-R-2	21-S-46	
Feta (<0 yrs)	1	0	0	0	**1**
Infant (0-3 yrs)	23	42	28	60	**153**
Child (3-12 yrs)	23	72	41	82	**218**
Adolescent (12-20 yrs	5	22	25	18	**70**
Young Adult (20-35 yrs	16	37	30	15	**98**
Middle Adult (35-50 yr	39	61	53	31	**184**
Older Adult (50+ yrs)	13	33	9	9	**64**
Adult (>20 yrs)	6	8	0	0	**14**
Unknown	0	0	5	1	**6**
TOTAL	**126**	**275**	**191**	**216**	**808**

Table 6.2: Mis Island and Kulubnarti skeletal samples by sex.

SKELETAL SAMPLE SEX	Mis Island		Kulubnarti		
	3-J-10	3-J-11	21-R-2	21-S-46	TOTAL
Female	35	73	67	34	209
Male	38	65	55	33	191
Ambiguous	1	10	5	2	18
Subadult	52	127	64	147	390
TOTAL	**126**	**275**	**191**	**216**	**808**

The assessment of sex, age estimation, and cribra orbitalia analysis for the adults (>20 years) in the Mis Island Collection was completed by Dr. Angela Soler (2012), while subadult data was collected by the current author. Cribra orbitalia was scored for presence and severity on all individuals with at least one intact orbit. Severity was scored according to the criteria of Stuart-Macadam (1989, p 187-188), with four levels of expression:

1. Scattered fine foramina
2. Large and small isolated foramina
3. Foramina that have linked into a trabecular structure
4. Outgrowth in trabecular form from the outer table surface

The Kulubnarti collection was previously analyzed for age and sex (see Van Gerven and Greene, 1999). The cribra orbitalia data was collected by Dr. Britney McIlvaine (personal communication) using the scoring criteria of Stuart-Macadam (1985, p 392):

1. Light: scattered fine foramina
2. Medium: small and large isolated foramina and foramina have linked to form a trabecular structure
3. Severe: outgrowth in trabecular structure from the normal contour of the outer bone table.

The slight discrepancy in the scales of severity necessitated the collapse of the Mis Island cribra orbitalia expressions 2 and 3 to coincide with the Kulubnarti stage of "Medium".

Chi-square tests were utilized to assess significance, except when more than 20% of cells had expected counts less than five necessitating the use of a Fisher's exact test. A $p < .05$ was the level used to demarcate significance. In cases of significance, the effect size and standardized residuals were investigated. Effect size measures the strength of association between variables.

An effect size of ±0.1 represents a small association, ±0.3 a medium association, and ±0.5 is considered a large association (Field, 2009, p 698). Standardized residuals are z-scores that represent the error between the statistical model's prediction and the data observed and thus demonstrate where the significance within a contingency table lies. A standardized residual is considered significant at the $p < .05$ level if the value lies beyond ±1.96. If the value is greater than ±2.58, it is significant at the $p < .01$ level, and if it is outside ±3.29 then its significance lies at the $p < .001$ level (Field, 2009, p 699).

Results

Prevalence of Cribra Orbitalia

Table 6.3 shows the prevalence of cribra orbitalia in each of the cemeteries of Mis Island and Kulubnarti. At Mis Island a total of 63.9% (n = 341) had signs of cribra orbitalia, while Kulubnarti had a significantly higher prevalence (78.1%, n = 319), $\chi^2(1, n = 660) = 15.90$, $p < .001$. The strength of association was small (*phi* = –0.155) and Mis Island had a significant association with cribra orbitalia absence (z = 2.3) while Kulubnarti had a significant negative association with absence (z = –2.4). This indicates that Mis Island had a significant absence of cribra orbitalia compared to the Kulubnarti sample.

Evaluation of the prevalence of cribra orbitalia by cemetery showed the lowest prevalence (56.6%, n = 106) in cemetery 3-J-10 and the highest (80.1%, N = 146) in cemetery 21-S-46. A chi-square test showed a highly significant association between cemetery and cribra orbitalia prevalence, $\chi^2(3, n = 660) = 20.45$, $p < .001$, with a small strength of association (V = .176). The standardized residuals for this test were significant for cemetery 21-S-46 with a negative correlation (z = –2.1) with cribra orbitalia absence and cemetery 3-J-10 had a positive association (z = 2.7) with its absence.

Table 6.3: Prevalence of cribra orbitalia at each cemetery.

	Affected	*n*	%
Mis Island	**218**	**341**	**63.9%**
3-J-10	60	106	56.6%
3-J-11	158	235	67.2%
Kulubnarti	**249**	**319**	**78.1%**
21-R-2	132	173	76.3%
21-S-46	117	146	80.1%
TOTAL	**467**	**660**	**70.8%**

Table 6.4 divides the sample into subadults (< 20 years) and adults (20+ years) to assess differences in prevalence between skeletally mature and immature individuals. While there was a highly significant difference in prevalence for the Mis Island adults and subadults, $\chi^2(1, n = 341) = 49.27$, $p < .001$, and the combined Mis Island and Kulubnarti sample, $\chi^2(1, n = 654) = 30.34$, $p < .001$, there was no significant difference in prevalence of cribra orbitalia and age for the Kulubnarti sample, $\chi^2(1, n = 313) = .14$, $p = .713$. As is evident in Table 6.4, the Kulubnarti adults had a slightly higher prevalence of cribra orbitalia than the subdaults. At the cemetery level, both Mis Island cemeteries had significant associations with age, with Cemetery 3-J-10, $\chi^2(1, n = 106) = 7.23$, $p =.007$ with a small association (*phi* = .261) and Cemetery 3-J-11 with a highly significant result, $\chi^2(1, n = 235) = 44.67$, $p < .001$ and a medium association (*phi* = .436). Neither 21-S-46 ($\chi^2(1, n = 168) = 2.04$, $p = .154$) or 21-R-2 ($\chi^2(1, n = 145) = .81$, $p = .369$) demonstrated a signficant association between cribra orbitalia lesion and age. These results

suggest at Mis Island the experience of cribra orbitalia was influenced by age, while at Kulubnarti all age groups showed high levels of cribra orbitalia prevalence.

Table 6.4: Prevalence of cribra orbitalia in subadults and adults at Mis Island and Kulubnarti.

	Subadult		Adult	
	Affected	%	Affected	%
Mis Island	**134**	**83.2%**	**84**	**46.7%**
3-J-10	34	70.8%	26	44.8%
3-J-11	100	88.5%	58	47.5%
Kulubnarti	**138**	**77.5%**	**107**	**79.3%**
21-R-2	56	71.8%	73	81.8%
21-S-46	82	82.0%	34	75.6%
TOTAL	**272**	**80.2%**	**191**	**60.6%**

Investigating further into these age discrepancies, Table 6.5 displays the Mis Island and Kulubnarti samples divided by age cohort. In the subadult years, both samples showed a peak in childhood (89.9%, n = 79 and 85.1%, n = 101, respectively). In the Mis Island sample, prevalence in adulthood decreased in the young adult and middle adult categories, with a slight rise in the older adult group. This pattern does not hold true for the Kulubnarti site as prevalence rates increased with age. Statistically, Mis Island had a highly significant association by age, $\chi^2(6, n = 341) = 55.09, p < .001$, with a medium level of association (V = .402). The standardized residuals in the child category showed significance at the $p < .01$ level for association with the presence of cribra orbitlia ($z = 2.9$) and a highly significant ($p < .001$) negative association with cribra orbitalia absence ($z = –3.8$). Significant residuals were also seen in the middle adult category with a significant negative association with cribra orbita presence ($z = –2.7$) and a highly significant association with its absence ($z = 3.6$). In other words, children on Mis Island were associated with cribra orbitalia while middle adults had relatively low prevalence of the lesion. A chi-square test of the Kulubnarti sample showed no significant association between age and cribra orbitalia prevalence, $\chi^2(5, n = 313) = 10.93, p = .053$, reflecting what is seen in Table 6.5 that all age groups in Kulubnarti had similar high percentages of affliction. Comparing each age category between sites confirmed that significant differences between sites occurred in the adult age categories. A chi-square test revealed significant differences between Mis Island and Kulubnarti for the young adults ($\chi^2(1, n = 65) = 4,74, p = .029$), middle adults ($\chi^2(1, n = 161) = 23.19, p < .001$), and older adults ($\chi^2(1, n = 58) = 9.42, p = .002$). The strength of these associations were V = .230, V = .379, and V = .403, respecitvely. The Kulubnarti adults have prevalence of cribra orbitalia between 22% and 43% higher than comparable cohorts at Mis Island.

Prevalence differences within age cohorts at the cemetery level showed significance only for middle adults ($\chi^2(3, n = 161) = 25.16, p < .001$) with a small level of association (V = .272) and older adults ($p = .013$) with a medium association (V = .413). Standardized residuals for the middle adult age category were significant for cemetery 21-R-2 with a positive association ($z = 2.3$) with cribra orbitalia presence and a negative association ($z = –2.8$) with its absence. Cemetery 3-J-11 had a significant assocation ($z = 2.2$) with cribra orbitalia absence. There were no significant standardized residuals for older adults, but cemetery 21-R-2 trended toward significance with a negative association with cribra orbitalia absence ($z = –1.8$). Overall, the results by age indicate that the largest differences occur in the adult age categories between Mis Island and Kulubnarti, especially cemeteries 21-R-2 and 3-J-11 in the middle adult category.

Table 6.5: Prevalence of cribra orbitalia by age at Mis Island and Kulubnarti cemeteries.

	Infant		Child		Adolescent	
	Affected	%	Affected	%	Affected	%
Mis Island	**45**	**77.6%**	**71**	**89.9%**	**18**	**75.0%**
3-J-10	16	66.7%	16	84.2%	2	40.0%
3-J-11	29	85.3%	55	91.7%	16	84.2%
Kulubnarti	**23**	**63.9%**	**86**	**85.1%**	**29**	**70.7%**
21-R-2	9	52.9%	31	86.1%	16	64.0%
21-S-46	14	73.7%	55	84.6%	13	81.2%
TOTAL	**68**	**72.3%**	**157**	**87.2%**	**47**	**72.3%**

	Young Adult		Middle Adult		Older Adult	
	Affected	%	Affected	%	Affected	%
Mis Island	**26**	**54.2%**	**34**	**40.5%**	**21**	**50.0%**
3-J-10	6	42.9%	13	43.3%	5	45.5%
3-J-11	20	58.8%	21	38.9%	16	51.6%
Kulubnarti	**32**	**76.2%**	**60**	**77.9%**	**15**	**93.8%**
21-R-2	20	71.4%	44	83.0%	9	100.0%
21-S-46	12	85.7%	16	66.7%	6	85.7%
TOTAL	**58**	**64.4%**	**94**	**58.4%**	**36**	**62.1%**

Severity of Cribra Orbitalia

Assessing the degree of severity by site (Table 6.6), Mis Island showed the highest prevalence in the medium severity category, while Kulubnarti had the highest prevalence in the light category. A chi-square test showed that these differences were highly significant, $\chi^2(2, n = 467) = 41.98$, $p < .001$, with a medium association (V = .300). Significant standardized residuals in the Mis Island sample included a negative association ($z = -2.5$) with light severity and a highly significant association ($z = 3.7$) with medium severity. Kulubnarti had inverse associations, with a positive correlation with light ($z = 2.3$) and a negative correlation with medium ($z = -3.5$).

Evaluating the severity by cemetery, the lowest frequency for each cemetery occurred in the severe category, but the highest occurred in the light category for both Kulubnarti cemeteries and the medium category for both Mis Island cemeteries. These differences were highly significant according to a chi-square test, $\chi^2(6, n = 467) = 44.67, p < .001$, with a small association (V = .219). Mis Island cemeteries 3-J-10 and 3-J-11 had significant standardized residuals ($z = 2.4$ and $z = 2.9$, respectively) in the medium category. Cemetery 21-R-2 had a significant standardized residual for light severity ($z = 2.2$) and a negative standardized residual for medium severity ($z = -2.6$) while 21-S-46 also had a negative correlation with medium ($z = -2.3$). These results indicate that Mis Islanders tended to have more serious cribra orbitalia manifestation than their Kulubnarti counterparts.

Table 6.6: Severity of cribra orbitalia at Mis Island and Kulubnarti cemeteries.

	Light		Medium		Severe	
	Affected	%	Affected	%	Affected	%
Mis Island	**77**	**35.3%**	**119**	**54.6%**	**22**	**10.1%**
3-J-10	18	30.0%	35	58.3%	7	11.7%
3-J-11	59	37.3%	84	53.2%	15	9.5%
Kulubnarti	**142**	**57.0%**	**63**	**25.3%**	**44**	**17.7%**
21-R-2	79	59.8%	33	25.0%	20	15.2%
21-S-46	63	53.8%	30	25.6%	24	20.5%
TOTAL	**219**	**46.9%**	**182**	**39.0%**	**66**	**14.1%**

Investigating the effects of age, a chi-square test indicated significance at both sites when the sample was divided into adults and subadults (Table 6.7). Mis Island showed a highly significant association between age and cribra orbitalia severity, $\chi^2(2, n = 218) = 20.56, p < .001$, with a medium strength of association ($z = .307$). The significant standardized residuals occurred in the adult age group in the light (z = –2.1) and medium (z = 2.4) cells. This indicates that adults were more likely to have medium severity of lesions than subadults. Kulubnarti also had a significant, , $\chi^2(2, n = 245) = 22.0, p < .001$, medium association (V = .300). Significant standardized reisduals occurred in both age groups, with subadults associated with severe lesions (z = 2.3) and adults positively associated with light (z = 2.2) and negatively associated with severe (z = –2.6).

Analyzing differences at the cemetery level, chi-square or Fisher's exact tests revealed significant associations between each cemetery and age. Cemetery 3-J-10 had a significant Fisher's exact test result (p = .001), but no significant standardized residuals. Table 6.7 illustrates the highest frequency in this sample occurred in medium severity for the adults, while the subadult sample was split between the light and medium categories. Cemetery 3-J-11 also had a significant ($\chi^2(2, n = 158) = 9.23, p = .010$) but small association (V = .242) with a similar pattern to 3-J-10, but to a lesser degree. A chi-square test showed Kulubnarti cemetery 21-R-2 had a significant ($\chi^2(2, n = 129) = 11.20, p = .004$) and small association (V = .295) between age and severity with subadults significantly associated with severe expression (z = 2.1). The significance for 21-S-46 ($\chi^2(2, n = 116) = 12.22, p = .002$) was medium (V = .325) with the adult category significantly associated with light severity (z = 2.0). The subadults had a similar pattern in all four cemeteries with highest frequencies in the light category and decreasing prevalence with severity. The adults of both Kulubnarti cemeteries followed this same pattern, but cemeteries 3-J-10 and 3-J-11 had highest percentages in the medium category. While there were no significant differences between the subadults by cemetery, the adults differed significantly by cemetery (p < .001). Cemetery 3-J-10 had a significant positive asociation with medium severity (z = 3.2) and negative association with light severity (z = –2.5). Cemetery 3-J-11 also had a positive association with medium severity (z = 2.9) and a negative correlation with light (z = –2.8). The Kulubnarti cemeteries had the opposite pattern. 21-R-2 had a significant positive association with light severity (z = 2.4) and a negative relation with medium (z = –2.6). Cemetery 21-R-46 also had positive correlation with light (z = 2.4) and negative with medium (z = –2.8). Thus, adults at the Mis Island cemeteries had significantly higher amount of medium severity compared to the adults of Kulubnarti, and Kulubnarti adults had significantly higher prevalence in the light category.

Table 6.7: Severity of cribra orbitalia for subadults and adults at Mis Island and Kulubnarti.

	Light				Medium				Severe			
	Subadult		Adult		Subadult		Adult		Subadult		Adult	
	Affect.	%	Affect.	%	Affect.	%	Affect.	%	Affect.	%	Affect.	%
Mis Isl.	**59**	**44.0%**	**18**	**21.4%**	**57**	**42.5%**	**62**	**73.8%**	**18**	**13.4%**	**4**	**4.8%**
3-J-10	14	41.2%	4	15.4%	13	38.2%	22	84.6%	7	20.6%	0	0.0%
3-J-11	45	45.0%	14	24.1%	44	44.0%	40	69.0%	11	11.0%	4	6.9%
Kulub.	**62**	**44.9%**	**78**	**72.9%**	**40**	**29.0%**	**21**	**19.6%**	**36**	**26.1%**	**8**	**7.5%**
21-R-2	26	46.4%	51	69.9%	15	26.8%	17	23.3%	15	26.8%	5	6.8%
21-S-46	36	43.9%	27	79.4%	25	30.5%	4	11.8%	21	25.6%	3	8.8%
TOTAL	**121**	**44.5%**	**96**	**44.2%**	**97**	**53.9%**	**83**	**43.5%**	**54**	**19.9%**	**12**	**6.3%**

Analysis of cribra orbitalia severity by age cohort for each cemetery is presented in Tables 6.8 to 6.11. For all cemeteries, the highest prevalence for the infant cohort was in the light category and the highest prevalence for the child group was medium severity. For adolescents, 3-J-10 had a split with one individual in both the medium and severe category. 3-J-11 had the largest percentage in medium, and 21-R-2 and 21-S-46 both had highest frequencies in the light category. Cemeteries 3-J-11, 21-R-2, and 21-S-46 all had their highest prevalence in the light category for young adults, while 3-J-10 had its highest frequency in medium severity. Both the middle adult and older adult groups showed the highest prevalence in medium severity for Mis Island and light severity for the Kulubnarti cemeteries. Within each cemetery there was a significant association with age and severity. A Fisher's exact test showed cemetery 3-J-10 had a highly significant ($p < .001$), medium association (V = .494) between age and severity, with significant residuals in the infant category demonstrating a positive relationship ($z = 2.9$) with light and a negative correlation ($z = –2.4$) with medium severity. Cemetery 3-J-11 had a significant ($p = .001$), medium result (V = .306) with a positive relationship between infants and light severity ($z = 2.2$) and negative association between this age group and medium severity ($z = –2.4$). There was also a negative association between older adults and light severity ($z = –2.0$) and a positive relation with medium severity ($z = 2.2$). Kulubnarti cemetery 21-R-2 had significant association between age and severity ($p = .011$), with a small strength of association (V = .295) and significant negative relationship between the child cohort and light severity ($z = –2.2$) and a positive association with severe ($z = 2.4$). A highly significant association occurred for cemetery 21-S-46 ($p < .001$), with a medium strength (V = .354) and a significant negative association between the child cohort and light severity ($z = –2.2$).

A comparison between cemeteries of prevalence within each age category was also completed. It was found that none of the subadult age categories showed significant differences between cemeteries. A Fisher's exact test for the young adult group showed significant association between severity and cemetery ($p = .004$), with medium strength of association (V = .398). In this cohort, there was a significant standardized residual for cemetery 3-J-10 in the medium severity category ($z = 2.6$). The middle adult cohort also showed a significant relationship between severity and cemetery, ($p < .001$), with medium strength (V = .409). The significant relationships for middle adults occurred in the medium category for 3-J-10 ($z = 2.2$), in the light ($z = -2.1$) and medium ($z = 2.3$) categories for 3-J-11, and in the light category for 21-S-46 ($z = 2.0$). A Fisher's exact test of the older adult cohort revealed a highly significant ($p < .001$), large association (V = .722) between severity and cemetery, with significant standardized residuals between 3-J-10 and light ($z = -2.0$) and medium severity ($z = 2.4$), cemetery 3-J-11 and medium severity ($z = 2.9$), 21-R-2 and light ($z = 2.1$) and medium ($z = -2.5$) severity, and 21-S-46 and medium severity ($z = -2.4$). These results confirm that adult cohorts from Mis Island, especially cemetery 3-J-10, displayed medium severity of cribra orbitalia while Kulubnarti cemeteries were positively correlated with light severity.

Table 6.8: Severity of cribra orbitalia by age for cemetery 3-J-10.

3-J-10 SEVERITY	3-J-10					
	Light		Medium		Severe	
	Affect.	%	Affect.	%	Affect.	%
Infant (<3 yrs)	11	68.8%	2	12.5%	3	18.8%
Child (3-12 yrs)	3	18.8%	10	62.5%	3	18.8%
Adolescent (12-20 yrs)	0	0.0%	1	50.0%	1	50.0%
Young Adult (20-35 yrs)	1	16.7%	5	83.3%	0	0.0%
Middle Adult (35-50 yrs)	2	15.4%	11	84.6%	0	0.0%
Older Adult (50+ yrs)	0	0.0%	5	100.0%	0	0.0%
TOTAL	**17**	**29.3%**	**34**	**58.6%**	**7**	**12.1%**

Table 6.9: Severity of cribra orbitalia by age for cemetery 3-J-11.

3-J-11 SEVERITY	3-J-11					
	Light		Medium		Severe	
	Affect.	%	Affect.	%	Affect.	%
Infant (<3 yrs)	18	62.1%	6	20.7%	5	17.2%
Child (3-12 yrs)	20	36.4%	30	54.5%	5	9.1%
Adolescent (12-20 yrs)	7	43.8%	8	50.0%	1	6.2%
Young Adult (20-35 yrs)	9	45.0%	8	40.0%	3	15.0%
Middle Adult (35-50 yrs)	4	19.0%	16	76.2%	1	4.8%
Older Adult (50+ yrs)	1	6.2%	15	93.8%	0	0.0%
TOTAL	**59**	**37.6%**	**83**	**52.9%**	**15**	**9.6%**

Table 6.10: Severity of cribra orbitalia by age for cemetery 21-R-2.

21-R-2 SEVERITY	21-R-2					
	Light		Medium		Severe	
	Affect.	%	Affect.	%	Affect.	%
Infant (<3 yrs)	7	77.8%	1	11.1%	1	11.1%
Child (3-12 yrs)	9	29.0%	12	38.7%	10	32.3%
Adolescent (12-20 yrs)	10	62.5%	2	12.5%	4	25.0%
Young Adult (20-35 yrs)	15	75.0%	3	15.0%	2	10.0%
Middle Adult (35-50 yrs)	29	65.9%	12	27.3%	3	6.8%
Older Adult (50+ yrs)	7	77.8%	2	22.2%	0	0.0%
TOTAL	**77**	**59.7%**	**32**	**24.8%**	**20**	**15.5%**

Table 6.11: Severity of cribra orbitalia by age for cemetery 21-S-46.

21-S-46 SEVERITY	**21-S-46**					
	Light		Medium		Severe	
	Affect.	%	Affect.	%	Affect.	%
Infant (<3 yrs)	11	78.6%	3	21.4%	0	0.0%
Child (3-12 yrs)	18	32.7%	20	36.4%	17	30.9%
Adolescent (12-20 yrs)	7	53.8%	2	15.4%	4	30.8%
Young Adult (20-35 yrs)	9	75.0%	0	0.0%	3	25.0%
Middle Adult (35-50 yrs)	14	87.5%	2	12.5%	0	0.0%
Older Adult (50+ yrs)	4	66.7%	2	33.3%	0	0.0%
TOTAL	**63**	**54.3%**	**29**	**25.0%**	**24**	**20.7%**

Sex Differences in Prevalence and Severity of Cribra Orbitalia

The distribution of cribra orbitalia was also analyzed by sex, as illustrated in Table 6.12. In the overall sample, 64.9% of females were afflicted and 55.9% of males, with no statistically significant difference between sexes ($\chi^2(1, n = 355) = 2.99, p = .084$). Investigation by site also revealed no significant difference between male and female prevalence in either the Mis Island ($\chi^2(1, n = 183) = .94, p = .333$) or the Kulubnarti cemetery ($\chi^2(1, n = 172) = 1.75, p = .186$). Analyses comparing sites, however, revealed that Kulubnarti and Mis Island had significant differences in female ($\chi^2(1, n = 185) = 17.74, p < .001$) and male prevalence ($\chi^2(1, n = 170) = 13.48, p < .001$). Fisher's exact tests also indicated there were no significant associations between sex and cribra orbitalia presence in cemeteries 3-J-10, 3-J-11, 21-R-2, or 21-S-46 ($p =$

1.000, p = .900, p = .593, and p = .882, respectively). Thus, within sites and within cemeteries, there was no significant difference in prevalence of cribra orbitalia between males and females.

Comparisons between cemeteries, however, did reveal significant differences. For females, a chi-square test showed a highly significant association between cribra orbitalia presence and cemetery, $\chi^2(3, n = 185) = 18.69, p < .001$, with a medium strength of association (V = .318). A significant standardized residual revealed a negative association between 21-R-2 and cribra orbitalia absence ($z = -2.0$). A chi-square test of males also showed a significant ($\chi^2(3, n = 170) = 13.84, p = .003$), small association (V = .285) with no significant residuals but Table 6.12 shows the Kulubnarti males had a much higher prevalence.

Table 6.12: Prevalence of cribra orbitalia by sex for Mis Island and Kulubnarti cemeteries.

	Female		Male	
	Affected	%	Affected	%
Mis Island	**46**	**50.0%**	**39**	**42.9%**
3-J-10	11	42.3%	15	46.9%
3-J-11	35	53.0%	24	40.7%
Kulubnarti	**74**	**79.6%**	**56**	**70.9%**
21-R-2	51	79.7%	38	71.7%
21-S-46	23	79.3%	18	69.2%
TOTAL	**120**	**64.9%**	**95**	**55.9%**

Degree of severity for males and females is shown in Table 6.13. There were no statistically significant differences between severity and sex for either Mis Island (p = .770) or Kulubnarti ($\chi^2(2, n = 130) = .16, p = .921$). Comparison between sites, showed a highly significant association between severity and cemetery for females ($\chi^2(2, n = 120) = 30.78, p < .001$), with a large strength of association (V = .506). Standardized residuals revealed a significant relationship between Mis Island and light severity ($z = -2.5$) and medium severity ($z = 3.4$) and a negative correlation between Kulubnarti and medium severity ($z = -2.7$). A highly significant result also occurred in the male group for severity by cemetery ($\chi^2(2, n = 95) = 28.73$, $p < .001$) with a large strength of association (V = .550). Mis Island males had a significant correlation with medium severity ($z = 3.1$) and a negative association with light ($z = -2.5$). Kulubnarti males were significantly associated with light expression ($z = 2.1$) and negatively associated with medium expression ($z = -2.6$).

Severity by cemetery for males and females was also explored. It was found that within cemeteries there was no significant difference between male and female severity of cribra orbitalia. Differences between cemeteries were detected. A Fisher's exact test revealed a significant association between cemetery and severity for females ($p < .001$), with a medium association (V = .367). Cemetery 3-J-10 was positively associated with medium severity ($z = 2.3$); cemetery 3-J-11 was negatively associated with light severity ($z = -2.0$) and positively associated with medium severity ($z = 2.6$); and cemetery 21-S-46 was negatively associated with medium severity ($z = -2.0$). Males also had a highly significant ($p < .001$), medium (V = .430) result. Significant standardized residuals for cemetery 3-J-10 were negative ($z = -2.0$) with light severity and positive ($z = 2.5$) with medium. Cemetery 3-J-11 also had a positive relationship with medium severity ($z = 2.0$). Cemetery 21-S-46 had a negative correlation with medium severity ($z = -2.1$) and a positive association with the severe expression ($z = 2.3$).

Table 6.13: Severity of cribra orbitalia by sex for Mis Island and Kulubnarti cemeteries.

	Light				Medium				Severe			
	Female		Male		Female		Male		Female		Male	
	Affect.	%	Affect.	%	Affect.	%	Affect.	%	Affect.	%	Affect.	%
Mis Isl.	**12**	**26.1%**	**8**	**20.5%**	**32**	**69.6%**	**30**	**76.9%**	**2**	**4.3%**	**1**	**2.6%**
3-J-10	2	18.2%	2	13.3%	9	81.8%	13	86.7%	0	0.0%	0	0.0%
3-J-11	10	28.6%	6	25.0%	23	65.7%	17	70.8%	2	5.7%	1	4.2%
Kulub.	**51**	**68.9%**	**38**	**67.9%**	**14**	**18.9%**	**12**	**21.4%**	**9**	**12.2%**	**6**	**10.7%**
21-R-2	34	66.7%	26	68.4%	11	21.6%	10	26.3%	6	11.8%	2	5.3%
21-S-46	17	73.9%	12	66.7%	3	13.0%	2	11.1%	3	13.0%	4	22.2%
TOTAL	**63**	**52.5%**	**46**	**48.4%**	**46**	**38.3%**	**42**	**44.2%**	**11**	**9.2%**	**7**	**7.4%**

Discussion

The comparison between the Mis Island and Kulubnarti cemetery samples revealed a number of significant differences between the two sites. The Kulubnarti sample had a significantly higher prevalence of cribra orbitalia than Mis Island. Although the subadults of Mis Island demonstrated a higher prevalence of cribra orbitalia than the Kulubnarti subadults, these differences were not significant. The main distinction between the two sites occurred in the adult category, with significantly higher prevalence in all adult age categories at Kulubnarti. This was also the reason that Kulubnarti adults did not significantly differ from the Kulubnarti subadults. At Mis Island there was a significant difference between adults and subadults for cribra orbitalia prevalence. This suggests that the underlying cause of this skeletal lesion had resolved by adulthood at Mis Island. This was not the case at Kulubnarti where cribra orbitalia persisted into adulthood resulting in a non-significant association between this pathology and age.

The severity of cribra orbitalia lesions also differed between the two sites. At the site level significant differences occurred, with Mis Island having a significant association with medium severity and Kulubnarti had a significant correlation with light severity. Again, this difference is primarily reflective of discrepancies in the adult cohorts. Over 70% of the Mis Island adults had medium severity and over 70% of the Kulubnarti adults showed light severity. These differences were also reflected on the cemetery level as 3-J-10 and 3-J-11 had significant associations with medium severity and 21-R-2 a significant association with light severity.

Within site analyses demonstrated a significant difference between the Mis Island adults and subadults, with the adults having a significant association with medium severity. At Kulubnarti, the adults and subadults were also significantly different in severity expression. The adult cohort was positively related to light severity and subadults had a significant association with severe expression. The differences by age between cemeteries, however, only showed significant results in the adult category, again characterizing 3-J-10 and 3-J-11 adults with medium expression and 21-R-2 and 21-S-46 with light expression or a negative association with medium expression. This comparison between cemeteries shows that the subadult experience of cribra orbitalia did not significantly differ by site, while adult morbidity did demonstrate significant different expressions of cribra orbitalia by site. While the Kulubnarti adults showed significantly more cribra orbitalia, the Mis Island adults had more severe expression of this lesion.

The analyses of differential experiences of cribra orbitalia by sex revealed no significant differences between males and females. The significant differences that occurred in these statistical tests reflected the difference between sites in adult expressions as outlined previously. Males and females at Kulubnarti had significantly higher frequencies of cribra orbitalia than the males and females at Mis Island. Both sexes at Mis Island, however, were significantly associated with medium severity while those at Kulubnarti were associated with light expressions of severity. There was one result that did not follow this general pattern. In cemetery

21-S-46, the males were significantly associated with severe expression (22.2%, $n = 18$), although the majority (66.7%) had only light severity.

The patterns elucidated in this analysis show that subadults at Mis Island and Kulubnarti had similar cribra orbitalia prevalence and severity. The adult experience, however, differed significantly in both prevalence and severity. The Mis Island cemeteries showed a decrease in cribra orbitalia prevalence in adulthood (46.7%, $n = 180$) compared to subadults (83.2%, $n = 161$). However, the majority of adults who did have cribra orbitalia had a medium expression (73.8%, $n = 84$). At Kulubnarti, there was no significant difference in prevalence by age, and adults actually had a slightly higher frequency than subadults (79.3%, $n = 135$; 77.5%, $n = 178$, respectively). Severity at Kulubnarti for both adults and subadults was primarily light. These results indicate that the cribra orbitalia experience at Kulubnarti was relatively similar for everyone, while at Mis Island it differed between adults and subadults. At Kulubnarti, everyone was afflicted with minor cribra orbitalia suggesting a stressor that was endemic throughout life. At Mis Island, the pattern suggests that cribra orbitalia was mainly a subadult affliction, but adults that had the lesion experienced more severe expressions. This may be a reflection of individual frailty in the adult cohorts, which could result from either inherent or culturally induced factors, including differential access to resources or exposure to stressors.

The source of this variation in adults is difficult to determine definitively. The current literature suggests that cribra orbitalia is a manifestation of subperiosteal hematoma resulting from vitamin C deficiency. The limited sources of vitamin C have been documented at Kulubnarti for both modern and ancient populations. Corkill (1949) investigated the health and nutrition of a small village in the *Batn el-Hajar* region. He found the inhabitants were generally undernourished and deficient in vitamin C, as the only sources of this nutrient were boiled for over an hour, depleting their ascorbic acid contents. In addition, village informants described seasonal peaks of scorbutic symptoms and both active and healing cases of scurvy were observed (Corkill, 1949, p 302).

An analysis of coprolite contents from Kulubnarti provides direct evidence of diet in this medieval population. Work by Cummings (1989) identified pollens, phytoliths, and floral and faunal macrofossils in coprolites from forty-nine individuals from both cemeteries at Kulubnarti. The goal of this research was to reconstruct diet and assess the nutritional value of foods regularly consumed. Results indicated that the major components of diet were sorghum and dates. These foodstuffs were present in all coprolites analyzed. This suggests that they were integral parts of the diet throughout the year, consumed both fresh while in season and after storage (Cummings, 1989, pp 188–189). Other foods contributing to diet included black-eye peas, greens, watermelon and fish. Foods observed rarely in the coprolite samples were broad beans, lentils, ground almond, okra, spinach, grapes, cantaloupe, hazelnut, pig, and crocodile (Cummings, 1989, p 189). From this data, Cummings (1989) concludes that numerous dietary deficiencies would have been common, most prominently vitamin C (p 192). In addition, Cummins (1989) found little difference in diet by cemetery, sex, or age (p 193). A finding that is consistent with the data on cribra orbitalia at Kulubnarti in this study,

The evidence from the *Batn el-Hajar* region of the Nile Valley adequately explains the high prevalence of cribra orbitalia in the Kulubnarti skeletal sample. Sources of vitamin C were not abundant and may have been boiled for long periods for preparation, draining the vitamin C content. Thus, scurvy would have been an endemic stressor impacting all of the Kulubnarti population equally. The lower prevalence in the adult segment of the Mis Island population suggests vitamin C resources may have been more abundant in the Fourth Cataract region. The prevalence of cribra orbitalia in subadults could be attributed to age-related diets or greater impact of seasonal deficiencies on the subadult skeleton. During growth and development, vitamin C deficiencies cause the production of fragile blood vessels that are prone to rupture. When this occurs, subperiosteal hematoma formation recruits additional blood vessels to the area for repair. Unfortunately, these blood vessels are also weak and may rupture, further contributing to the damage. This circular process eventually impacts the bone, and in the case of the eye orbit, manifests as cribra orbitalia. During the weaning process, foods that supplement and eventually replace breast milk were commonly cereal-based gruels, which are nutritionally poor and would not provide adequate amounts of ascorbic acid. Seasonal fluctuations in vitamin C rich fruits and vegetables would also impact the developing subadult more quickly than the mature skeleton of an adult.

The higher degree of severity in Mis Island adults compared to Kulubnarti adults is intriguing. As previously mentioned, this could reflect individual frailty in the segment of the adult population that displayed cribra orbitalia. The underlying cultural or biological processes that contributed to cribra orbitalia in these individuals also caused lesions to advance to medium severity. Another possible contributor to adult cribra orbitalia at Mis Island is differential exposure to schistosomiasis, a parasitic worm that could deplete nutrient levels in affected individuals. Schistosomiasis infection has been related to farming practices, with those utilizing irrigation techniques at higher risk of infection (Fenwick et al., 1981). Research investigating *Schistosoma mansoni* infection at two Nubian sites, Wadi Halfa and Kulubnarti, found a significantly higher prevalence in the Wadi Halfa population (Hibbs et al., 2011, p 290). The authors attributed this difference to farming practices. The inhabitants of Wadi Halfa practiced *saqia* irrigation, utilizing a water wheel and canals to irrigate crops. These shallow canals with slow moving water provided an ideal habitat for *S. mansoni* snail vectors. Kulubnarti populations practiced *seluka* agriculture, where crops were planted in the floodplain following the annual Nile flood. This latter practice is less suitable for snail hosts since there is not a constant supply of water and the land dries between annual inundations (Kabatereine et al., 2004). While the type of agriculture practiced at Mis Island is unknown, *saqia* methods commonly practiced in Sudan could contribute to cribra orbitalia morbidity.

A final hypothesis is that the ingestion of antibiotic tetracycline through consumption of soured grains at Kulubnarti offered a protection from infectious disease that would deplete vitamin C stores. Histological analyses employing fluorescent microscopy at Kulubnarti found tetracycline in bone samples indicating this antibiotic was consumed by the population (Hummert and Van Gerven, 1982). A more recent study utilizing mass spectroscopy confirmed that Nubian bone samples did contain tetracycline (Nelson et al., 2010). This substantiated that this antibiotic was ingested and incorporated into the bone rather than caused by taphonomic processes as skeptics of the earlier studies proposed. While not directly related to vitamin C levels, tetracycline in the diet would provide a protective advantage from certain bacterial infections, which can cause loss of nutrients through vomiting and diarrhea, or intestinal malabsorption. While Kulubnarti adults would not have been able to compensate for the environmental scarcity of vitamin C, they were possibly protected from its depletion. The lower prevalence of cribra orbitalia in Mis Island adults suggest vitamin C rich foods may have been available, but infection from parasites or other diseases could have contributed to its depletion and caused cribra orbitalia.

Conclusion

This analysis of cribra orbitalia comparing the sites of Mis Island and Kulubnarti provide a regional perspective on disease in medieval Nubia. Although these sites both represent small farming communities, it is clear that health experiences, especially for adults, varied significantly. Although the Kulubnarti adults had significantly higher prevalence of cribra orbitalia, the Mis Island adults had a higher severity of the skeletal lesion. Since different researchers collected this data, the possibility of interobserver error cannot be discounted. In addition, it would be helpful to compare the activity of the lesions observed to determine whether they were still active at time of death or if signs of healing were present. These are avenues of future research that should be undertaken to clarify the differences between Mis Island and Kulubnarti.

Both archaeological and skeletal remains from Kulubnarti have been intensively studied over the last forty years, providing many lines of evidence to understand what life was like for these medieval Nubians. From this work it is evident that sources of vitamin C were lacking for this population, which would account for the high prevalence of cribra orbitalia. For the majority of individuals cribra orbitalia lesions were relatively minor, suggesting an endemic disease that affected everyone but was probably not life threatening. Histological evidence also suggests that Kulubnarti inhabitants may have benefited from ingestion of tetracycline to protect them from certain infectious diseases that could deplete vitamin C, and other essential nutrient stores.

Archaeological and skeletal evidence from Mis Island is still in early stages of analyses making it difficult to speculate as to the potential contributors to cribra orbitalia lesions. Vitamin C resources would have also been scarce in the Fourth Cataract, since food sources rich in the vitamin were only able to grow seasonally in the wet winter period. It is also likely that a weanling diet contributed to the cribra orbitalia lesions in subadults. The underlying cause of the medium severity in adults, however, can only be hypothesized. These lesions may be related to individual biological responses, differential access to resources or exposure to pathogens, deficiencies exasperated by infectious disease, or farming practices that exposed adults to schistosomiasis infection. Further investigations on Mis Island and other sites in the Fourth Cataract will help to elucidate the hardships and stressors these populations may have faced.

Through regional analyses and site comparisons, the lives and hardships of the people of medieval Nubia will become clearer. This research represents an early step toward this goal. This work also highlights the important fact that stressors influencing the health of Nubians were not equal throughout the medieval kingdoms or regions of the Nile. Further research will help elucidate the cultural, political, and environmental factors that may have contributed to these discrepancies and highlight the many ways of being Nubian.

LITERATURE CITED

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Adams WY, Adams NK, Van Gerven DP, and Greene DL. 1999. Kulubnarti III: The Cemeteries. London: SARS.

Adams WY. 1999a. Introduction. In: Kulubnarti III: The Cemeteries. Sudan Archaeological Research Society Publication Number 4. London: SARS.

Adams WY. 1999b. Part I. The Graves. In: Kulubnarti III: The Cemeteries. Sudan Archaeological Research Society Publication Number 4. London: SARS. p 7–50.

Corkill NL. 1949. A Scorbutic Diet in a Nile Cataract Community. T. Roy. Soc. Trop. Med. H. 43:293–302.

Cummings LS. 1989. Coprolites from Medieval Christian Nubia: An Interpretation of Diet and Nutritional Stress [dissertation]. [Boulder, (CO)]: University of Colorado.

Fenwick A, Cheesmond AK, and Amin MA. 1981. The Role of Field Irrigation Canals in the Transmission of Schistosoma mansoni in the Gezira Scheme, Sudan. Bull. World Health Organ. 59:777–786.

Field A. 2009. Discovering Statistics Using SPSS. 3rd ed. London: SAGE Publications Ltd.

Hibbs AC, Secor WE, Van Gerven D, and Armelagos G. 2011. Irrigation and Infection: The Immunoepidemiology of Schistosomiasis in Ancient Nubia. Am. J. Phy. Anthropol. 145:290–298.

Hummert JR, and Van Gerven DP. 1982. Tetracycline-Labeled Human Bone from a Medieval Population in Nubia's Batn el Hajar. Hum. Biol. 54:355–363.

Kabatereine NB, Brooker S, Tukahebwa EM, Kazibwe F, and Onapa AW. 2004. Epidemiology and Geography of Schistosoma mansoni in Uganda: Implications for Planning Control. Trop. Med. Int. Health 9:372–380.

Nelson ML, Dinardo A, Hochberg J, and Armelagos GJ. 2010. Brief Communication: Mass Spectroscopic Characterization of Tetracycline in the Skeletal Remains of an Ancient Population from Sudanese Nubia 350-550 CE. Am. J. Phys. Anthropol. 143:151–154.

Soler A. 2012. Life and Death in a Medieval Nubian Farming Community: The Experience at Mis Island [dissertation]. [East Lansing, (MI)]: Michigan State University.

Stuart-Macadam P. 1985. Porotic Hyperostosis: Representative of a Childhood Condition. Am. J. Phys. Anthropol. 66:391–398.

Van Gerven DP, and Greene DL. 1999. The Human Remains. In: Kulubnarti III: The Cemeteries. Sudan Archaeological Research Society Publication Number 4. London: SARS.

Van Gerven DP, Sandford MK, and Hummert JR. 1981. Mortality and Culture Change in Nubia's Batn el Hajar. J. Hum. Evol. 10:395–408.

Van Gerven DP, Sheridan SG, and Adams WY. 1995. The Health and Nutrition of a Medieval Nubian Population: The Impact of Political and Economic Change. Am. Anthropol. 97:468–480.

Welsby DA. 2002. The Medieval Kingdoms of Nubia. London: The British Museum Press.

Welsby DA. 2008. Merowe Dam Archaeological Salvage Project 1996-2006. In: Godlewski W, Łajtar A, editors. Between the Cataracts. Proceedings of the 11th Conference for Nubian Studies Warsaw University, 27 August – 2 September 2006. Part One. Main Papers. Polish Archaeology in the Mediterranean Supplement Series Volume 2.1. Warsaw: Polish Centre of Mediterranean Archaeology and Warsaw University Press. p 33–48.

CHAPTER 7 – CONCLUSION

This dissertation utilized a bioarchaeological approach to investigate the subadult individuals who were buried in the 3-J-10 and 3-J-11 cemeteries at Mis Island. The exceptional preservation of the 188 sets of skeletal remains makes this a unique and valuable sample to understand the skeletal stress experienced by the youngest members of these Mis Island communities. Further, by employing a bioarchaeological approach that combines this skeletal data with historic and archaeological evidence, it is possible to go beyond skeletal analysis to contribute to our knowledge of children and the environment in which they developed in medieval Nubia. The mortuary and skeletal evidence was compared both within and between cemeteries at Mis Island, to the adults from the same cemeteries, and to samples from the contemporary medieval Christian site of Kulubnarti. These analyses have shown that subadults at Mis Island were culturally differentiated from adults. Furthermore, this study of patterns of morbidity and mortality at different stages of life contributes to our understanding of the biological stressors present at Mis Island. The goal of this conclusion chapter is to address the results of this research as they pertain to my original research questions and hypotheses, highlight the developmental and cultural milestones and the concomitant stressors that characterize each subadult age cohort, address limitations of this work, discuss future research trajectories, and conclude with the significance and contribution of this dissertation.

Research Questions Revisited

1) Did the mortuary treatment of subadults suggest the existence of socially meaningful age classes?

Hypothesis 1: *Mortuary treatment of subadult cohorts will differ significantly from adult burial rites, especially marking a transition to adulthood.*

Results from the analysis of the mortuary treatment of subadults presented in Chapter Three supported the hypothesis that mortuary variables significantly differed for subadult cohorts, but it was found that the age of differentiation did not mark a transition to adulthood but did serve to distinguish infants. The typical mortuary treatment at Mis Island consisted of an FF03c monument marking the grave of a supine individual with legs extended, facing upward with the head at the western end of the grave protected by stones with no personal adornment or grave inclusions. At both cemeteries, however, infants were distinguished with FF03a monuments, absence of head covering, and legs either slightly flexed or both legs in different positions. At 3-J-10, there were additional distinctions with infants interred on their side, with personal adornment and in a spatially distinct cluster in the eastern portion of the cemetery. These results indicate that stage of biological development was an important organizing principle for treatment in death and that infants were most distinctly differentiated through burial rites.

2) Which subadult age cohorts were most vulnerable to morbidity and mortality?

Hypothesis 2: *Subadults of weaning age will have a statistically higher representation in the mortuary sample and will exhibit significantly higher prevalence of skeletal indicators of stress.*

The examination of paleopathology in the subadult age cohorts was presented in Chapter Four. The analyses included the prevalence of localized hypoplasias of the primary canine (LHPC), tuberculosis, periostitis, cribra orbitalia, porotic hyperostosis, and scorbutic lesions. Infants and children were equally represented as the cohorts with the greatest representation in the 3-J-10 cemetery sample, while children comprised the greatest portion of the 3-J-11 and combined group samples. In the combined Mis Island samples, the child cohort showed the highest prevalence for cribra orbitalia and scurvy and infants had the highest amounts of LHPC and periostitis. Adolescents had the highest prevalence of porotic hyperostosis and both cases of tuberculosis. Statistical analysis showed that only LHPC and porotic hyperostosis had significant associations between prevalence and age cohort. Linear enamel hypoplasias were investigated in Chapter Five and it was found that for most tooth types, the child cohort had the highest prevalence. Children also had the highest prevalence and showed a statistically significant association with multiple linear enamel hypoplasias. The linear enamel hypoplasia data does not indicate that children were more prone to affliction, but individuals that developed enamel hypoplasias before or during childhood were more likely to die before reaching adolescence. Overall, there were surprisingly few statistical differences between age cohorts for disease prevalence, reflecting the overall high incidence of skeletal lesions for all subadult cohorts. These results suggest that the physiological stressors underlying the investigated skeletal lesions began in infancy and impacted subadults through childhood and adolescence.

The activity and severity of periostitis, cribra orbitalia, and porotic hyperostosis lesions were also evaluated. There was a statistically significant association of periostitis type with age, with the child cohort showing more lamellar expressions than infant or adolescent age groups. The severity of periostitis, however, was not different between age groups to a degree that was statistically significant. Healed cribra orbitalia lesions had statistically significant association with the adolescent cohort indicating that the underlying stressor causing cribra orbitalia had resolved for some individuals in this age group. Only cemetery 3-J-10 showed a statistically significant association between cribra orbitalia severity and age, with a much higher prevalence for minor expression in the infant cohort. Lastly, both porotic hyperostosis activity and severity had statistically significant associations to age. Although infants had the lowest prevalence of porotic hyperostosis, the infant cohort was statistically correlated with active lesions and advanced severity. Thus, infants afflicted had active and relatively severe porotic hyperostosis lesions.

Overall, within the subadult cohorts investigated, there was not a particular age that demonstrated higher rates of morbidity or mortality. Thus, the hypothesis that weaning aged children were more susceptible to disease and death must be rejected.

3) Were there detectable differences in subadult morbidity and mortality between cemeteries 3-J-10 and 3-J-11?

Hypothesis 3: *The cemeteries of 3-J-10 and 3-J-11 will not differ significantly in subadult mortality or morbidity.*

The only pathology that showed a statistically significant difference in prevalence between cemeteries was cribra orbitalia. Subadults at 3-J-11 had a much higher incidence of orbital lesions than individuals at 3-J-10. Furthermore, significant differences between cemeteries were also apparent for each subadult age cohort. While the hypothesis of no significant differences between cemeteries held true for the majority of pathological lesions, subadults at 3-J-11 showed a statistically significant higher burden of cribra orbitalia. While it is difficult to pinpoint the cause of such a difference, higher amounts of cribra orbitalia morbidity could potentially be related to periods of low Nile levels before cemetery 3-J-10 came into use. Archaeological data indicates that cemetery 3-J-11 was used between AD 300 and 1100, encompassing a period of low Nile levels thought to have occurred from AD 828 to 837 and from AD 939 to 948 (Edwards, 2004, pp 213–214). As there was no archaeological evidence for irrigation agriculture recovered on Mis Island, it is likely its inhabitants relied on flood plain agriculture, utilizing the rich and moist soil deposited by the Nile and accessible after the water receded. If Nile levels were below normal, seasonal flooding may have been affected making it difficult to cultivate crops. Since cemetery 3-J-10 did not come into use until AD 1100, those buried within its confines would not have been affected by these low Niles and thus would not reflect the increased morbidity of these harsh years.

4) Did stressors impact the skeletal health of adults of Mis Island to the same extent and in the same manner as the subadults?

Hypothesis 4: *Skeletal stress markers will be more prevalent in subadult individuals than adult individuals.*

Chapter Five compared the prevalence and activity of skeletal lesions between subadult and adult cohorts to understand the impact of biological stressors on different age groups at Mis Island. Although linear enamel hypoplasias are a record of childhood stress, the prevalence of these dental lesions was studied according to age groups to explore how the development of a hypoplasia potentially affected mortality. Statistically significant differences among the age cohorts were detected for numerous teeth, including the maxillary central and lateral incisors and the mandibular central and lateral incisors. For each of these teeth, the child cohort had the highest prevalence of linear enamel hypoplasias, which reached a level of statistical significance for the maxillary lateral incisor. These results suggest that hypoplasias on incisors occurred in individuals who died in childhood, but hypoplasias on canines were common throughout the population. The canine completes crown development approximately a year after the incisors, thus it is possible that the timing of an acute stress event may have made subadults more vulnerable. However, there is substantial overlap in the timing of crown formation, with canines beginning earlier and ending later. An alternative, and perhaps more compelling, hypothesis is that a greater degree of physiological perturbation is necessary for hypoplasias to appear on incisors. It is this severe incident of stress that may predispose the individual to other disease episodes that may lead to death. In addition, there was a statistically significant association between age and the presence of multiple hypoplasias on the maxillary canine and mandibular central incisor. Similar to the presence of linear enamel hypoplasias, the child cohort had a high prevalence of multiple hypoplasias and demonstrated a statistically significant association with multiple hypoplasias on the maxillary canine.

Beyond dental pathology, statistically significant differences by age were also found for cribra orbitalia, porotic hyperostosis, scurvy, and tuberculosis. The only lesion investigated that did not show statistically significant differences by age was periostitis. Periostitis affliction was relatively stable throughout the age categories, indicating that this stressor was not biologically or culturally related to age. The same was not true for cribra orbitalia, which had statistically significant associations with age for individuals buried in 3-J-10 and 3-J-11. For both cemeteries, subadults had prevalence rates over 25% higher than the adults. Cribra orbitalia activity was also associated with age at both cemeteries. Subadult cohorts were correlated with active cribra orbitalia lesions and adult cohorts were positively associated with healed lesions. Thus, it may be the case that at Mis Island, cribra orbitalia was widespread in subadults but was able to heal during adulthood.

An opposite trend occurred for porotic hyperostosis lesions, which showed statistically significant differences in occurrence by age, but was more prevalent in the adult cohorts. Porotic hyperostosis lesion activity was also associated with age. At both the 3-J-10 and 3-J-11 cemeteries, the infant cohort had a statistically significant association with active lesions while the child cohort showed a statistically significant association with mixed lesions. In the 3-J-11 sample, adolescents were also associated with mixed lesions, and each of the adult cohorts showed a positive association to healed lesions and a negative association to active lesions. This may suggest that porotic hyperostosis lesions began in the subadult years but had begun to heal in the older cohorts. The overall high prevalence of healed lesions indicates most individuals did not die from the underlying stressors causing porotic hyperostosis. The high frequency of porotic hyperostosis in adult cohorts may indicate the presence of endemic seasonal stressors that prevented lesions from fully healing in adulthood.

Scorbutic lesions were far more prevalent in the subadult cohorts and showed highly significant associations with age. In both cemetery 3-J-10 and 3-J-11, standardized residuals showed highly significant relationships between the infant and child cohorts and the presence of scorbutic lesions. There was also an association between adult cohorts and lesion absence. While this result may indicate differences in access to vitamin C resources for adults and subadults, biological differences in the skeletal expression of scurvy cannot be discounted.

Finally, skeletal evidence of tuberculosis was relatively rare in the subadult cohorts. It is difficult to know why this may have been the case, but it is possible that overall chronic tuberculosis infection was not common on Mis Island. Alternatively, it is possible that it is difficult to diagnose skeletal tuberculosis in the infant and child cohorts due to the immature nature of the vertebrae. Another potential reason is that infants and children who contract tuberculosis do not survive long enough for lesions to appear in the skeleton. Overall, the combined cemetery sample of tuberculosis did show a statistically significant association by age. Although there were no significant standardized residuals, adolescents had the highest prevalence of affliction. It must be noted, however, that adolescents also had the smallest sample in the age cohorts with tuberculosis, so the high prevalence may be biased due to the small sample size making it difficult to interpret this pattern of affliction.

Overall, subadults did demonstrate a higher burden of skeletal lesions than the adults. This hypothesis was supported in the case of linear enamel hypoplasias, cribra orbitalia, scurvy, and tuberculosis. Periostitis showed no age-related differences and porotic hyperostosis was more prevalent in adults. Although these results seem straightforward, there are caveats that must be addressed. First of all, the subadult sample is comprised of individuals who died prior to reaching the age of average life expectancy. Although the causes of death cannot be confidently determined, it is likely that many of these deaths were related to malnutrition and disease. It may not be fair to compare adults and subadults, as it is a measure of those who did not survive to adulthood against those who did. Unfortunately, this is a bias inherent in the bioarchaeological record. Unless a sample is derived from a mass disaster event, it is possible the subadults represent the fragile or sickly individuals of a population.

Consideration must also be given to the fact that certain skeletal lesions manifest differently in subadults and adults. As discussed in Chapter Five, scurvy can be easily recognized and differentially diagnosed in subadults as weakened blood vessels and Sharpey's fibers quickly proliferate and stimulate osteoblastic responses in numerous skeletal locations. Individuals who are afflicted with scurvy in adulthood are not producing completely new blood vessels or Sharpey's fibers. Thus, vitamin C deficiency may not impact the skeleton to the same extent in adults making identification of scurvy more difficult in these individuals.

5) How did the health of Mis Islanders compare to inhabitants of other medieval Nubian sites?

Hypothesis 5: *Mis Island populations will have a lower prevalence of mortality and prevalence and severity of cribra orbitalia lesions than samples from Kulubnarti.*

The comparison of Kulubnarti and Mis Island in Chapter Six showed that at the site level, Kulubnarti did have a statistically significant higher prevalence of cribra orbitalia than Mis Island. Furthermore, the young, middle, and older adult categories at Kulubnarti and Mis Island were also statistically different, with Kulubnarti groups having higher prevalence of cribra orbitalia lesions. The subadult cohorts, however, did not show any statistical difference in prevalence between Kulubnarti and Mis Island. The severity of lesions was also statistically different between the two sites with a significant association between Mis Island and medium severity while Kulubnarti was associated with light expression of the lesion. Again, the severity of lesions among Mis Island adults was significantly different than that of the Kulubnarti adults, but the subadults showed no statistical differences for severity. These results support the first part, but negate the second portion of Hypothesis 5.

Evidence from Kulubnarti suggests a scarcity of vitamin C resources, which could lead to endemic levels of scurvy. This accounts for the high prevalence of minor expression of cribra orbitalia. Mis Island adults showed a much lower rate of affliction, but those with cribra orbitalia had more severe manifestations. This may be attributable to individual biological responses, differential access to resources or exposure to pathogens, deficiencies exasperated by infectious disease, and/or farming practices that exposed adults to schistosomiasis infection.

Study Limitations

As in any body of research, there are limitations to the methods, analyses, and conclusions that could be drawn. A major limitation to any bioarchaeological study is the osteological paradox, the inability to distinguish healthy individuals free of disease from those who perished before their skeleton could be impacted (Wood et al., 1992). Particularly in a subadult sample, the fragility of individuals and susceptibility to death from acute illness complicates the interpretation of biologic stressors. Furthermore, skeletal lesions and their etiologies are still poorly understood and can be difficult to differentially diagnose without destructive tests, like histological, isotopic, or genetic analyses which are not currently permitted on this sample. To further complicate matters, diseases rarely occur in isolation as is commonly seen in the interactions and co-morbidities of malnutrition, vitamin deficiencies, and infectious disease.

The salvage archaeological nature of the Mis Island Project did not allow for the investigation of all sites or the full excavation of the cemeteries that were the focus of this work. Although efforts were made to excavate graves from across the cemetery space, it is difficult to ascertain the overall representativeness of each sample. As was demonstrated by cemetery 3-J-10, there is not always equal distribution of ages and sexes throughout cemeteries. In addition, the significant agricultural disturbance of cemetery 3-J-11 considerably limits the ability to interpret spatial mortuary patterns from this site. The lack of archaeological data from habitation sites related to 3-J-10 and 3-J-11 means little is known about the artifacts of the living as clues to diet or subsistence practices. Thus, the results of this work must be discussed in the context of other medieval Nubian sites from outside the region.

Disease and nutritional deficiencies were also discussed in relation to modern populations from Sudan. While features of the natural environment may be similar across time, there are numerous factors that may differentiate these populations. Religious beliefs, for one, changed after the medieval period, and it may be argued that Christian and Muslim populations are culturally distinct and thus not comparable. Furthermore, sociocultural aspects such as gender, age categories, and weaning practices may be different, potentially affecting health experiences. Yet, the data from Sudan provides the best modern analogy for the Mis Island population and thus serves as a source of epidemiological data that is not available from archaeological populations.

Systematic mortuary analyses are thus far in their infancy for medieval Nubia. The mortuary results presented in this work are contributing to its development, but more work focusing on the towns and cities of medieval Nubia needs to be completed before the study of mortuary contexts can be applied to its fullest potential. Additional research will help identify similarities and differences in mortuary practices across the region and may reveal important mortuary variables that were used to distinguish groups of people in medieval Nubia, potentially by age, sex, or status. The interpretations of the mortuary variables at Mis Island presented are thus constrained by our still limited understanding of mortuary treatment in medieval Nubia.

Future Research

Mortuary practices in medieval Nubia utilizing a modern bioarchaeological approach are just beginning to be explored. The data from Mis Island revealed that medieval Nubians made an important distinction with respect to the burial of infants within the traditional cemetery space. A division between children and adults may also be detectable with further investigation and spatial analyses. Additional mortuary research may also help clarify other important principles of burial practice and cemetery organization. For instance, at 3-J-11 there seems to be changes in practice over time. Differentiating these early practices may illuminate the earliest graves within the cemetery and contribute to our understanding of the cemetery's development. Mitochondrial DNA studies should also be completed to test the hypothesis of family burial groups at 3-J-11 versus age-related organization at cemetery 3-J-10 and to potentially gain a better understanding of each community's familial composition and whether matrililocal or patrilocal customs were followed.

The excellent preservation and large number of individuals represented in the Mis Island skeletal sample makes it an ideal collection for continued research projects. My own interests include a study of the skeletal growth trajectory of Mis Island subadults in order to see if and how they are influenced by skeletal pathologies. I am also interested in refining the age categories of subadults to look more closely at infant and child mortality rates and the biological stressors that may be contributing to death. Further investigation into the underlying cause of porotic hyperostosis in this sample and its potential relation to neural tube defects is also planned.

Isotopic analyses are already making an impact in the study of past human populations and could greatly enhance the interpretations of nutritional deficiencies in this sample. Given the lack of archaeological information on diet or agricultural practices on Mis Island in the medieval period, isotopes could help identify the potential food sources upon which the inhabitants of Mis Island relied. Such analyses could also be utilized to assess whether diet was differentiated according to age at Mis Island. Investigation of geographic origins could also be accomplished with stable isotope analysis in order to answer questions about migration to Mis Island and the Fourth Cataract Region.

Significance of Research

This research has employed multi-faceted approach to contribute to the current understanding of life experiences in medieval Nubia. Culturally meaningful developmental stages were explored from the analysis of the mortuary treatment of children. The excellent preservation of the subadult skeletal remains provided the unique opportunity to discover the specific diseases, nutritional deficiencies, and other physiological perturbations that faced the communities on the island of Mis. Furthermore, pathological data provided evidence to support the decoupling of cribra orbitalia and porotic hyperostosis, suggesting separate etiologies for these two skeletal lesions. Comparison to the site of Kulubnarti provided a regional perspective on the life experiences of medieval populations, and highlighted the important fact that health disparities between communities existed. With the dearth of historical records from within or pertaining to medieval Christian Nubia, this study contributes to our understanding of the people inhabiting the Nile Valley, and particularly of the island of Mis. Furthermore, a focus on the subadults of this site represents a contribution to the emerging field of the bioarchaeology of children, and serves to begin an investigation on the youngest cohorts and their roles in medieval Nubian communities.

LITERATURE CITED

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Black R. 2003. Micronutrient Deficiency: An Underlying Cause of Morbidity and Mortality. B. World Health Organ. 81:79.

Borradale DC, and Kimlin MG. 2012. Folate Degradation Due to Ultraviolet Radiation: Possible Implications for Human Health and Nutrition. Nutr. Rev. 70:414–422.

Cummings LS. 1989. Coprolites from Medieval Christian Nubia: An Interpretation of Diet and Nutritional Stress [dissertation]. [Boulder, (CO)]: University of Colorado.

Fuller DQ, and Edwards DN. 2001. Medieval Plant Economy in Middle Nubia: Preliminary Archaeobotanical Evidence from Nauri. Sudan & Nubia 5:97–103.

Gadgil M, and Bossert WH. 1970. Life Historical Consequences of Natural Selection. Am. Nat. 104:1–24.

McDade TW. 2003. Life History Theory and the Immune System: Steps Toward a Human Ecological Immunology. Am. J. Phys. Anthropol. 122:100–125.

Micronutrient Initiative and UNICEF. 2004. Vitamin and Mineral Deficiency Reports - A Global Progress Report. Oxforshire, UK. Available from: http://www.micronutrient.org/english/View.asp?x=614

Office of Dietary Supplements, National Institutes of Health. 2011. Dietary Supplement Fact Sheet: Vitamin B12. Office of Dietary Supplements [Internet]. Available from: http://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/

Office of Dietary Supplements, National Institutes of Health. 2012. Dietary Supplement Fact Sheet: Folate. Office of Dietary Supplements [Internet]. Available from: http://ods.od.nih.gov/factsheets/Folate-HealthProfessional/

Sandford MK, and Kissling GE. 1994. Multivariate Analyses of Elemental Hair Concentrations from a Medieval Nubian Population. Am. J. Phys. Anthropol. 95:41–52.

Sandford MK. 1983. Elemental Hair Analysis: New Evidence on the Etiology of Cribra Orbitalia in Sudanese Nubia. Hum. Biol. 55:831–844.

Shinnie PL, and Shinnie M. 1978. Debeira West, a Medieval Nubian Town: University of Ghana Expedition to Nubia. Warminster: Aris and Phillips.

Stoltzfus RJ, and Underwood BA. 1995. Breast-milk Vitamin A as an Indicator of the Vitamin A Status of Women and Infants. Bull. World Health Organ. 73:703–711.

Turner BL, Edwards JL, Quinn EA, Kingston JD, and Van Gerven DP. 2007. Age-Related Variation in Isotopic Indicators of Diet at Medieval Kulubnarti, Sudanese Nubia. Int. J. Osteoarchaeol. 17:1–25.

Walker PL, Bathurst RR, Richman R, Gjerdrum T, and Andrushko VA. 2009. The Causes of Porotic Hyperostosis and Cribra Orbitalia: A Reappraisal of the Iron-Deficiency-Anemia Hypothesis. Am. J. Phys. Anthropol. 139:109–125.

Wood JW, Milner GR, Harpending HC, and Weiss KM. 1992. The Osteological Paradox: Problems of Inferring Prehistoric Health from Skeletal Samples. Curr. Anthropol. 33:343–370.

World Health Organization. 2013. Malaria. World Health Organization [Internet]. Available from: http://www.who.int/mediacentre/factsheets/fs094/en/index.html