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The mother-infant dyad: reconstructing maternal nutritional status at Put Dragulina cemetery

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This research investigates maternal nutritional status through the analysis of young infants (N=27) that are likely pre-weaned from two Roman occupational periods at Put Dragulina. Because young infants are solely dependent on the nutritional status of their mother while in utero and postpartum through the consumption of breast milk, the presence of skeletal pathologies positively associated to nutritional deficiencies on the remains of young infants can be analyzed to reconstruct the nutritional status of the infant's mother. This study finds that 89% (N=24) of young infants, regardless of occupational period, presented with skeletal pathologies consistent with nutritional deficiencies. These results suggest that the mothers who are absent from the Put Dragulina cemetery would have likely had poor nutritional statuses due to the high frequencies of nutritional stress indicators present on the skeletal remains of their infants.

DEDICATION

This thesis is dedicated to my paternal grandfather, Peter Paige, who passed away December 26, 2019.

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CHAPTER I

INTRODUCTION

In the archaeological absence of the maternal body, perinatal (38-40 weeks) and young infant (under 6 months) remains can be investigated as proxies for maternal nutritional status due to their sole dependency on the maternal body in utero and postpartum. Throughout development in utero, a fetus is solely dependent upon the nutritional status of the maternal body (Christian & Stewart, 2010; Kitsiou-Tzeli & Tzetis, 2017). As a result, adequate maternal nutrition is crucial to the healthy development of a fetus. If the mother's body is nutritionally deficient during her pregnancy, the lack of nutrients transmitted to the fetus via the placenta can have significant effects on the nutritional status of her offspring before and after birth (Cetin & Laoreti, 2015; Christian et al., 2015; Kitsiou-Tzeli & Tzetis, 2017; Lindsay et al., 2017; Lowensohn et al., 2016a, 2016b; Macpherson et al., 2017; Minato et al., 2019; Walsh & McAuliffe, 2015). As illustrated by numerous clinical scholars, when an infant is solely breastfed after parturition, their nutritional status remains a direct reflection of their mother's (Bravi et al., 2016; Karall et al., 2015; Landrigan et al., 2002; Lönnerdal, 2000; Oddy, 2001; Palmer, 2011; Victora et al., 2016). If the mother's body remains nutritionally deficient after the birth of her offspring, she will be unable to pass sufficient nutrients to her infant through breast milk, which may lead to the onset of nutritional deficiencies (see Background) (Bravi et al., 2016; Lönnerdal, 2000; Minato et al., 2019; Palmer, 2011).

In their recent publication on the mother-infant nexus, Gowland and Halcrow (2020) advocate that in the archaeological absence of mother/infant burials, the sole analysis of infant skeletal remains can provide valuable insight into both an infant's health and the health of its mother. Additionally, the identification and investigation of pathological lesions on the dry bone of infant remains can be used as proxies for the study of maternal health in the past (Gowland, 2015; Gowland & Halcrow, 2020; Zuckerman & Crandall, 2019). Chávez and colleagues (2000) state that because a developing fetus is prioritized during pregnancy in the face of nutritional stress, nutritional deficiencies that are present in the fetus/infant can reflect the poor health status of their mothers. As such, when the maternal body is not identifiable in a given skeletal assemblage, the skeletal remains of perinates (36-40 gestation weeks) and young infants (<6 months postpartum) that are likely pre-weaned can be used as proxies for reconstructing maternal nutritional status.

In order to explore the dyad between the nutritional status of a mother and her infant, I will apply the concept of infant proxies to a skeletal sample from the Put Dragulina cemetery. Put Dragulina was a Roman cemetery located on the Dalmatian coast of Croatia outside the present-day city of Trogir. The material grave goods, such as pottery and amphorae, were dated to between the 1st to 6th century CE (Paraman, personal communication 2018). Given the expansive temporal range, two distinct occupation periods were classified: early occupation (1st to 2nd century CE) and late occupation (3rd to 6th century CE). During the early occupation at Put Dragulina, pregnant women would have likely been impacted by the aftermath of romanization, a historical process of Roman assimilation accompanying the expansion of the Roman Empire (Forcey, 1997; Grahame, 1998; Lulić, 2015). The late occupation at Put Dragulina, however, would have likely been impacted by the subsequent decline and dissolution of the Western Roman Empire (Gibbon & Milman, 2003; Hingley, 1997).

The primary research question for this thesis aims at identifying whether there is a significant difference in the presence of nutritional deficiencies in young infants (<6 months) during the early versus the late occupation in the skeletal sample from Put Dragulina. My secondary research question aims at identifying whether there is a statistical relationship between the presence of linear enamel hypoplasia on the deciduous dentition of the early versus late occupation young infants (<6 months).

To answer my primary and secondary research questions, I examine how indicators of nutritional deficiencies can be used to reconstruct maternal nutritional health at Put Dragulina during both occupation periods. This research identifies specific skeletal pathologies that are commonly associated with nutritional deficiencies, such as porotic hyperostosis (PH), cribra orbitalia (CO), and abnormal porosity (AbPo) (Brickley, 2018; Chaparro & Suchdev, 2019; McIlvaine, 2015; Rivera & Lahr, 2017; Stuart-Macadam, 2005; Walker et al., 2009; Wang, 2016). My second research question explores the presence of linear enamel hypoplasia (LEH) as a non-specific indicator that may be suggestive of the survival of maternal nutritional stress (see Background). However, it is crucial to note that PH, CO, AbPo, and LEH are not pathognomonic of specific nutritional deficiencies (Brickley, 2018; Gamble et al., 2017; Goodman & Rose, 1990; Rivera & Lahr, 2017). This means that the presence of the aforementioned indicators cannot be definitively associated with a specific nutritional deficiency, such as scurvy or rickets. As outlined in later sections of this thesis, these pathological lesions will be investigated only as non-specific indicators that are commonly associated with nutritional deficiencies. However, if an infant does not present with a pathological lesion consistent with nutritional deficiencies, it does not mean that the individual was devoid of nutritional stress. Instead, this may suggest that the individual did not experience the nutritional stress for a long enough time to allow pathological lesions to manifest on the skeleton. For example, if the individual died while in the early stages of the condition or survived said nutritional deficiency, pathological lesions would not have manifested before death. Conversely, the absence of pathologies consistent with nutritional deficiencies may also indicate that the mother did not possess an active nutritional deficiency for a long enough period while the fetus was in utero, or that the mother did not possess an active nutritional deficiency while exclusively breastfeeding postpartum to allow skeletal manifestations to develop (DeWitte & Stojanowski, 2015; Wood et al., 1992).

Due to the nature of this research, it is important to note that when a definitive weaning age cannot be assessed, the start to the weaning process ideally could be estimated using bioarchaeological literature focused specifically in the Dalmatian region during the Roman period for this analysis. However, the start of the weaning process is not a universal occurrence and is highly variable throughout historic and prehistoric populations (see Background). Considering this dichotomy, one region within the Roman Empire may start the weaning process at a different age than another region in the Empire. Unfortunately, the age of weaning in Roman Dalmatia is inconclusive due to the scare amount of literature that focuses on weaning in the region. A definitive age at weaning cannot be established when only macroscopic analyses are conducted. Despite these limitations, the use of the aforementioned bioarchaeological literature can be employed to estimate a period prior to the start of the weaning process based on a 6-months postpartum age classification.

Ultimately, the results of this thesis can contribute to the growing body of literature that focuses on the use of infant skeletal remains as proxies for maternal nutritional health in the past (e.g., Gowland & Redfern, 2010a, 2010b; Halcrow, 2020; Redfern & DeWitte, 2011; Redfern & Gowland, 2012). The use of infant proxies can be beneficial for bioarchaeological research wherein the maternal body (for numerous potential reasons) is not available for analysis (see Discussion). Understanding the nutritional processes within the mother-infant dyad, as well as the external factors that may impact the nutritional processes, can help to reconstruct the maternal nutritional health of mothers at Put Dragulina through the macroscopic analysis of young infants over the course of both occupational periods. As a result of research in both paleopathology and bioarchaeology that focus on the dyad between the maternal body and the developing fetus/infant (see Background), my thesis can examine the skeletal remains of young infants in order to explore and reconstruct the nutritional status of mothers (Gowland, 2020; Gowland & Halcrow, 2020; Halcrow, 2020; Hodson & Gowland, 2020).

CHAPTER II

LITERATURE REVIEW

Infant Remains in Paleopathology and Bioarchaeology

The crux of this research is the understanding that perinatal infants do not merely start their nutritional status after birth; rather throughout development in utero, a fetus is exposed to biological, social, and environmental factors via the maternal body (Lowensohn et al., 2016b; Nnam, 2015). Further, Gowland and Halcrow (2020) argue that it is imperative to treat the maternal body as a conduit through which the effects of outside forces, such as nutritional stress, can impinge upon the intrauterine environment. This can be important when interpreting evidence of nutritional stress on the skeletal remains of young infants. It is also essential to recognize that evidence of nutritional deficiencies that are identified on fetal, perinatal, and young infant remains are due to calamitous cases of maternal nutritional deficiency. In order for pathologies consistent with nutritional deficiencies to manifest on the skeletal remains of infants under the age of 6 months, the maternal body would have had to have been catastrophically deficient during pregnancy (Ahmed et al., 2012; Belkacemi et al., 2010; Lowensohn et al., 2016a; Marques et al., 2013). This is because, as noted by clinical literature, fetal development in utero is directly related to the nutritional status of the maternal body during pregnancy (Cetin & Laoreti, 2015; Lindsay et al., 2017).

Dalmatian Society (1 CE-600 CE)

The presence of perinatal and young infant burials at the Put Dragulina cemetery permits the reconstruction of maternal nutritional status through the analysis of infant morbidity. Put Dragulina was a cemetery located in the present-day city of Trogir on the Dalmatian coast of Croatia. Analyses conducted by the Trogir City Museum on grave good materials—such as pottery and amphora-types—dated the use of the Put Dragulina cemetery from the 1st century CE to approximately the 6th century CE which, for the purposes of this thesis, was divided into two occupational periods of interest in order to explore possible associations between significant social events versus skeletal indicators of nutritional deficiencies: early (1st to 2nd century CE) and late (3rd to 6th century CE) (Paraman, 2018). However, it is essential to note that because the cemetery has a temporal distribution of approximately 600 years, coupled with a skeletal sample of 27 infants under the age of 6 months, the results can only offer a preliminary glimpse into the nutritional status of Put Dragulina mothers.

Put Dragulina was in very close proximity to Salona, which was the capital of the Roman province of Dalmatia. Dalmatia, which was initially named Illyricum, was under the rule of the Western Roman Empire from 32 BCE to 480 CE (Paraman, 2018). This thesis aims to look at the early occupation at Put Dragulina (1st to 2nd century CE) in comparison with the late occupation at Put Dragulina (3rd to 6th century CE) in order to detect whether there are differences in the pathological patterning of lesions commonly associated with nutritional deficiencies. The two occupational periods were differentiated by Lujana Paraman with the Trogir City Museum using material grave goods associated with the skeletal material.

In relation to the early and late occupation of Put Dragulina, Lightfoot and colleagues (2012) note in their study of isotopic changes in diet, that during the early Roman period in

Dalmatia, the region was relatively protected from raiding. However, Lightfoot and colleagues (2012) also note that the later occupation in Dalmatia was a period of political instability following the overthrow of the Western Roman Empire in 476 CE. A brief historical overview of Dalmatia can help garner a better understanding of what pregnant women may have experienced. In the early occupation of Put Dragulina, pregnant women were potentially exposed to the consequences of romanization while the mothers in the late occupation of Put Dragulina may have been impacted by the nutritional stress associated with the decline of the Western Roman Empire and subsequent political instability (Gowland & Redfern, 2010a, 2010b; Lightfoot et al., 2012; Lulić, 2015; Redfern & DeWitte, 2011; Redfern & Gowland, 2012; Scheidel, 2010).

Romanization may have been a significant contributing factor to the nutritional status of the pregnant women at Put Dragulina during the early occupation. Romanization was a historical process that included the expansion of Roman cultures, such as the assimilation of cultural ideals and the integration of Roman social practices into non-Roman regions (Forcey, 1997; Freeman, 1997; Hingley, 1997; Lulić, 2015). Archaeological evidence suggests that the process of romanization would have likely been geographically selective with emphasis on areas with essential resources; however, urban centers, like Salona, would have almost been fully Romanized (Stipčević, 1977). Grahame (1998) emphasizes that subtler forms of domination would have been more likely to have been employed rather than physical violence. In his analysis of romanization in Britain, Grahame (1998) argues that subtler forms of violence would have been preferred, as the purpose of Roman domination was exploitation, primarily in the form of individuals who have power to exert and reinforce their social prowess to lesser individuals, such as the non-Roman individuals.

As illustrated by bioarchaeological studies that focus on women and children during times of conflict (e.g. Tegtmeyer & Martin, 2017), the maternal figures and therefore their fetuses/infants would have been susceptible to the onslaught of structural violence accompanying romanization. Even though Tegtmeyer and Martin (2017) focused primarily on modern cases of conflict, they advocate that although women and children may not have been involved with direct conflict, they would have still experienced stress associated with times of conflict, such as food and resource deprivation. The onset of resource deprivation that may have accompanied Romanization would have disproportionally affected pregnant women due to their high vulnerability to biological stress (Kitsiou-Tzeli & Tzetis, 2017; Marques et al., 2013), and therefore would negatively impact the nutritional development of their fetus and infant.

Despite the fact that there may have been some benefits to being a part of the Roman Empire, there are numerous case studies that outline skeletal evidence showing a decrease in stature and an increase in non-specific indicators of biological stress associated with Romanization (Gowland, 2015; Gowland & Redfern, 2010a; Redfern & DeWitte, 2011; Roberts & Cox, 2003). For example, Lewis' review of the health differences of urban and rural Roman populations illustrates that the prevalence of diseases would be higher in urban centers due to larger population sizes and poor living conditions (such as poor sanitation and resource deprivation) (Lewis, 2003). Since Put Dragulina was in close proximity to an urban center that was likely subjected to romanization, it can be extrapolated that the maternal bodies associated with the 27 infants at Put Dragulina may have been negatively impacted by the prevalence of poor conditions noted by Lewis (2003).

The complex nature between maternal and infant health was seemingly understood during the Roman period (Flemming, 2000). This is shown through medical texts that recognized the importance of the mother's behavior during pregnancy. For example, as outlined by Dunn (1995), medical texts like Gynaecology of Soranus reprimanded upper-class women for weaning too early and advocated that the use of wet nurses was detrimental to infant health. With this understanding, the onset of nutritional deficiencies in young infants may instead be attributed to factors outside the control of the mother, such as malnutrition from the consumption of nutritionally deficient food.

Specific to the region of Dalmatia, there is a scarce amount of literature that focuses on maternal nutrition before, during, and after the Roman period. Consequently, the very few bioarchaeological studies that do mention maternal nutrition are not available in English. Although there are numerous studies on the poor environment within the urban centers of the Roman Empire (Gibbon & Milman, 2003; Gowland & Redfern, 2010a; Kron, 2012; Lewis, 2009; Rawson, 2003; Redfern & DeWitte, 2011; Scheidel, 2009, 2010; Zotovic, 2003), this would not directly relate to maternal nutrition as unsanitary conditions that are more attributable to pathogen load and infectious disease. Although I focus on the reconstruction of maternal nutrition health at Put Dragulina through the use of infant skeletal proxies, it is vital to emphasize that the individuals analyzed in this sample are only associated to the nutritional status of mothers at Put Dragulina. Given the dearth of literature that focuses specifically on maternal nutrition in Dalmatia, the results of this thesis will hopefully encourage future research to explore the mother-infant nutritional dyad in more detail at surrounding cemetery sites in the region.

Maternal & Infant Nutrition

In order to better support the claim that perinatal (38-40 weeks) and young infant (under 6-months) remains can serve as proxies of maternal nutritional status in the absence of the maternal body, it is imperative to demonstrate the complexity of the relationship between maternal nutrition and fetal development. The correlation between maternal nutrition and fetal development begins with the introduction of nutrients while in utero via the placenta. Maternal nutritional status plays a crucial role in the growth and development of the fetus (Ahmed et al., 2012; Belkacemi et al., 2010; Lowensohn et al., 2016a). Maternal undernutrition, which can occur during times of nutritional stress, is the result of an insufficient intake of nutrients that are required by a specific individual (Shetty, 2006). Further, maternal undernutrition can have adverse effects on the development of the fetus, such as low birth weight and the infant's inability to respond to the intake of nutrients (Barker, 1998). Maternal dietary macronutrients are nutritional factors that aid in the healthy development of a fetus; specific deficiencies in macronutrients can result in metabolic diseases that negatively affect the fetal body, such as vitamin deficiencies like scurvy and rickets (Meyer, 2016; Purandare, 2012; Wu et al., 2012).

Clinical evidence suggests that the intrauterine environment during development can have a significant effect on both fetal and infant development (Lindsay et al., 2017; Richardson et al., 2014; Swanson et al., 2009; Wadhwa et al., 2009). It is crucial to note that the relationship between the maternal body and fetal development is a complex interaction that has a multitude of factors that may affect birth outcomes. Richardson and colleagues (2014) note that the role of the maternal body can be thought of as a vector that potentially introduces long-term adversity to the developing fetus rather than a buffer that protects from external stress. The intrauterine environment is not an impenetrable shield that protects a developing fetus (Finlay, 2013).

Therefore, as noted by Finlay (2013), a young infant is not a blank slate after birth. Thus, it can be understood that a perinate (36-44 gestational weeks) is born having been exposed to the same nutritional stress that its mother may have experienced throughout pregnancy. If nutritional stress continues postpartum, such as through the consumption of nutritionally inadequate breast milk, an infant will be more susceptible to the onset of nutritional deficiencies (Bravi et al., 2016).

The production of nutritionally rich breast milk, a vital source of nutrients that aids in the development of an infant after birth, is strongly associated with the nutritional status of its mother. According to the World Health Organization (WHO), for the first six months of an infant's life, human breast milk is the most suitable source of essential elements such as calcium, potassium, magnesium, iron, and selenium, which are all crucial to an infant's growth and development (WHO, 2019). However, the composition of human breast milk can be influenced by a number of factors that may inhibit the transfer of such nutritional elements. For example, environmental circumstances, maternal lifestyle, and dietary habits of the mother are all contributing factors to the compositional alteration of breast milk (Ballard & Morrow, 2013; Bravi et al., 2016; Hinde & Lewis, 2015; Lönnerdal, 2000).

Further, breast milk promotes immunity within the early months after birth (Lönnerdal, 2000; Minato et al., 2019; Palmer, 2011). More so, Beaumont and colleagues (2015) note that the colostrum—which is the milk produced within the first few days postpartum—is a crucial factor in the transmission of maternal immunity to the infant in order to fight against local pathogens as well as introduce crucial nutrients (Beaumont et al., 2015). In relation to nutritional value, colostrum is reported to have a higher concentration of protein, vitamin A, vitamin B^{12}, and vitamin K (Bravi et al., 2016; Emmett & Rogers, 1997; Kumar et al., 2008; Minato et al., 2019).

The composition of breast milk is essential to discuss because it further illustrates that a young infant is solely dependent on the nutritional status of its mother postpartum. As noted above, the composition of breast milk can be altered by environmental circumstances and diet (Ballard & Morrow, 2013; Bravi et al., 2016). This means that if the maternal body is nutritionally stressed due to environmental circumstances (such as inability to procure nutritionally adequate sustenance), the composition of their breast milk will not be able to facilitate healthy infant development. Based on that understanding, pathological changes most commonly associated with nutritional deficiencies that are present on the skeletal remains of young infants can be used to suggest their mother's nutritional status was poor and, therefore, may not have been producing nutritionally adequate breast milk.

When the nutritional demands of an infant exceed what can be provided through the breast milk, the process of weaning may begin. The processes of introducing complementary soft food should begin around 4 to 6 months postpartum, as an infant’s nutritional needs begins to exceed what can be provided by nutritionally rich breast milk (WHO, 2019). As evidenced in numerous clinical studies, the early diet of an infant can have a substantial effect on its health throughout childhood and adulthood (Ahmed et al., 2012; Federenko & Wadhwa, 2004; Kitsiou-Tzeli & Tzetis, 2017; Minato et al., 2019; Niewiesk, 2014; Wu et al., 2012; Yim & Wadhwa, 2004). However, Foote and Marriott (2003) note that the start of the weaning process itself can harm an infant’s health; for example, the transition to complementary foods can introduce a diarrheal disease that would impact the infant’s sensitive nutritional status. Further, with the start of the weaning process, if the infant is introduced to complementary soft foods that are nutritionally inadequate, that infant will be more susceptible to nutritional deficiencies as their diet will be nutritionally insufficient (Foote & Marriott, 2003; Palmer, 2011; Wu et al., 2012).

In bioarchaeological research, the analysis of infant weaning and the associated diet can help inform on a multitude of foci such as infant and maternal health, infant feeding practices, subsistence change, and food choice (Halcrow et al., 2017). Investigating weaning processes in past populations, as argued by Halcrow and colleagues (2017), is crucial because it can have substantial implications for early and later life health, mortality patterns, fertility, and growth. However, among human populations, the age of onset for the weaning process is highly variable.

Katzenberg and colleagues (1996) note that weaning must be recognized as a process and does not occur as a singular event at a specific age. Therefore, terminology must be established when investigating weaning in order to understand which stage of weaning is being investigated. Following Halcrow and colleagues (2017), the start of weaning is understood as the introduction of non-breast milk foods, the completion of weaning is the end of breastfeeding, and the entire period between those two events is the weaning process. A few bioarchaeological studies have explored physiological stress through the presence of dental enamel defects; these defects were contextualized as a marker of ‘weaning stress’ (Katzenberg et al., 1996). However, Katzenberg and colleagues (1996) point out critiques and caution against the sole use of dental enamel defects due to the non-specific etiology of such defects. More recent bioarchaeological studies seem to favor the use of chemical analyses of bone and teeth in order to investigate breastfeeding, weaning, and infant diet (Halcrow et al., 2017). The use of chemical analyses, such as stable isotope and trace element analysis, on bone and teeth at Put Dragulina would be beneficial in order to determine a more definitive age of weaning, however, it was outside the scope of this research.

As illustrated by Novak and colleagues (2018), there are few written accounts that focus on weaning in the eastern Adriatic. Nonetheless, Roman medical texts like Gynaecology by

Soranus advocated for the process of weaning to begin anywhere between three months to three years postpartum (Dunn, 1995; Rawson, 2003). Because there is so little written about a definitive age of weaning for Roman infants in the Dalmatian region, an arbitrary age classification (<6 months postpartum) was chosen to likely reflect pre-weaning.

Given the focus of this thesis, the burials at Put Dragulina were split between individuals that were over the age of 6 months and under the age of 6 months. This is because, although a definitive weaning age is not explored for the scope of this research, infants under the age of 6 months are most likely associated with pre-weaning. The justification for classifying young infants as likely being pre-weaned stems from current clinical literature, which notes that the introduction of soft foods typically begins around 6-months of age (Karall et al., 2015; Victora et al., 2016). Isotopic analysis on deciduous dentition, which was not employed for this thesis, would need to be conducted in order to estimate the start of the weaning process at Put Dragulina.

Bioarchaeology and Paleopathology of the Mother-Infant Nexus

In their recent book publication, Gowland and Halcrow (2020) outline the importance of including young infant remains into bioarchaeological research as well as illustrate how infant remains can be used to explore both infant and maternal health. Although Halcrow (2020) acknowledges that the lack of literature on fetuses and young infants in bioarchaeology may be attributed to their small bones being missed during excavation, she argues that infant remains are commonly overlooked as research foci. However, recent studies have shifted towards the interrogation of paleopathology, dental anthropology, and isotopic analyses into bioarchaeological research focusing on the mother-infant nexus (Gowland, 2015; Halcrow, 2020; Halcrow et al., 2017; King et al., 2018; Lewis, 2017).

In paleopathological studies, Halcrow (2020) notes that the exclusion of infants under the age of 2 years postpartum may be attributed to the difficulties in differentiating abnormal new bone formation from normal new bone formation. Fetal bone while in utero consists of woven (fibrous) bone that is formed quickly and is less organized than compact bone. This can make macroscopic analysis difficult as the surface of the bone may appear porous without the presence of metabolic disease (Mori et al., 2013; Snoddy et al., 2018; Snoddy et al., 2017); however, this can be addressed by meticulously detailing the region of bone that appears to have abnormal porosity. Snoddy and colleagues (2017), in their paleopathological study of a transitional site in Northern Chile, presented evidence of scurvy in perinates in the analyzed sample to illustrate the impact that vitamin C deficiency can have on the maternal and infant body. As shown with Snoddy and colleagues (2017) and other recent paleopathological studies focusing on the mother-infant connection (Beaumont et al., 2015; Brickley et al., 2019; Hodson & Gowland, 2020; King et al., 2018), clinical literature can used in order to create methodological approaches that allow for the mother-infant connection to be studied.

Alongside the macroscopic analysis of dry bone, the examination of deciduous dentition can be an additional tool for investigating developmental stress associated with the mother-infant nexus. Temple (2020) advocates for the use of dentition to inform about developmental stress, arguing that the use of dentition is one of the most valuable tools when investigating the mother-infant nexus because dentition records permanent marks of stressors. Many bioarchaeological studies dating back to the 1900s have used the presence of linear enamel hypoplasia (LEH) as a non-specific indicator of stress (e.g., Blakey et al., 1994; Goodman & Armelagos, 1985; Goodman & Rose, 1990; Skinner & Goodman, 1992). LEH, following survival and/or recovery of a stressor, constitute grooves (or furrows) of enamel insufficiency that are produced when enamel development is interrupted following underlying stress (Hillson & Bond, 1997). In relation to the maternal-infant nexus, Sandberg and colleagues (2014) explored the relationship between the presence of LEH and isotopic results in order to estimate the onset of weaning. Their study found that the majority of LEHs occurred during the process of weaning and therefore represented a significant stressor associated with the maternal-infant health dynamic (Sandberg et al., 2014).

Barker and colleagues (2012) maintain that the first 1000 days of life is the most fundamental period for developmental plasticity. Consequently, this means that fetal, perinatal, and young infant individuals are the most vulnerable to social and environmental stressors (Dancause et al., 2012; Kuzawa & Quinn, 2009; Lejarraga, 2012). This vulnerability can be explored through paleopathological and bioarchaeological approaches. With this in mind, this age cohort was chosen in order to analyze the presence of indicators commonly associated with nutritional deficiencies on the skeletal remains of perinates and young infants to hypothesize the maternal nutritional health status of mothers associated with these remains . However, given the nature of the research, two problems within the osteological paradox must first be addressed: hidden heterogeneity and selective mortality (Wood et al., 1992).

Osteological Paradox: Hidden Heterogeneity and Selective Mortality

To evaluate the effect romanization and the fall of the WRE may have had on maternal nutritional health, pathological changes consistent with nutritional deficiencies are assessed due to their association to nutritional deficiencies (Brickley, 2018; Brickley & Ives, 2008; Rivera & Lahr, 2017; Schattmann et al., 2016; Walker et al., 2009). However, the constraints of the osteological paradox must be discussed in reference to the skeletal sample of Put Dragulina.

Wood and colleagues (1992) proposed the “Osteological Paradox” in which they outlined problems with the paleopathological analysis of skeletal remains from past populations. These problems include hidden heterogeneity and selective mortality. For the purposes of this study, the third element to the Osteological Paradox, demographic nonstationarity, will not be discussed as it is outside the scope of this research.

Hidden heterogeneity is the problem with which the individuals in a skeletal sample are unequally susceptible to diseases, stressors, and the risk of death (Wood et al., 1992). Wood and colleagues (1992) argue that this means that the individuals within the skeletal sample vary in their susceptibility to disease and death and therefore it is impossible to interpret mortality on a population and age-specific level. In relation to Put Dragulina, this means that the infants analyzed in the assemblage can only inform on the nutritional health of the maternal bodies associated to the infants and not on the totality of the maternal population within the population.

Selective mortality is a problem in that the skeletal sample is biased due to the fact that the individuals studied are dead (Wood et al., 1992). As a result, Wood and colleagues (1992) note that a skeletal sample is highly selective for lesions that led to death within that age category. This understanding is crucial to the skeletal sample analyzed at Put Dragulina due to the focus on infants. As evidenced by clinical literature, infants are the most biologically vulnerable age category due to their sole dependency upon maternal health (Kitsiou-Tzeli & Tzetis, 2017; Minato et al., 2019). Therefore, the infants analyzed at Put Dragulina that show evidence of poor nutritional health represent a biased sample of those that did not survive early nutritional deprivation. Further, this means that it must be recognized that the use of infants at Put Dragulina to reconstruct maternal nutritional health is inherently biased as these infants represent a highly selective category; because these infants are dead, any suggestive patterns of maternal nutritional health must recognize the selective mortality bias inherent within the assemblage.

In his analysis of bioarchaeology's role in anthropology, Armelagos (2003) states that an essential component to bioarchaeology is the understanding that multiple indicators of stress, such as those associated with nutritional deficiencies, can be crucial to the reconstruction of past population's adaptation. However, the elements proposed within the Osteological Paradox must be considered when reconstructing the adaptation of past populations. Within Put Dragulina, instead of searching for evidence of specific nutritional deficiencies such as scurvy or rickets, it is more beneficial to examine multiple pathological indicators that may suggest a pattern of nutritional deficiencies (Armelagos, 2003). When reconstructing patterns of nutritional deficiencies at Put Dragulina, in order to examine a specific portion of a population's (maternal bodies at Put Dragulina) adaptation to stress, the Osteological Paradox must be considered and explicitly addressed.

In response to Wood and colleagues (1992), Wright and Yoder (2003) argue that since the proposal of the Osteological Paradox, it is cited often in research but is rarely directly addressed. DeWitte and Stojanowski (2015) affirm this argument twelve years later and argue that the first and second element are often overlooked in bioarchaeological and paleopathological research. However, DeWitte and Stojanowksi (2015) emphasize that the elements within the Osteological Paradox must be taken into consideration when building research designs in order to not conflate the information that can be gained from paleopathological analysis.

When constructing my research questions, I considered hidden heterogeneity and selective mortality (Wood et al., 1992), the use of multiple indicators of stress rather than a specific focus (Armelagos, 2003), and the consideration of what paleopathological research can actually say about the analyzed sample (DeWitte & Stojanowski, 2015). Armelagos (2003) emphasizes that bioarchaeological research has the capacity to provide insight into how populations interaction with their environment and the subsequent consequences that may accompany such interaction. As such, cultural events within an individual's environment has the potential to impact disease processes (Armelagos, 2003). At Put Dragulina, investigating how a culturally significant event may have impacted maternal nutritional health must consider how skeletal lesions are interpreted and must directly address the Osteological Paradox.

Through this consideration, the primary and secondary research questions in this study were constructed with the recognition of the inherent bias that would be present in this sample. This bias is due to the age cohort chosen for analysis (infants under the age of 6 months) and the focus on reconstructing maternal nutritional status through infant analyses. However, by directly addressing the elements within the Osteological Paradox to the analyzed sample, the use of infant proxies can be beneficial to building a preliminary understanding of maternal nutritional status associated to the Put Dragulina cemetery (see Discussion).

Paleopathological Review of Nutritional Deficiency

Metabolic Bone Disease

Following Brickley and Ives (2008), this research recognizes metabolic bone disease as processes that disrupt the modeling and remodeling of bone. More specifically, the manifestations of nutritional deficiencies, if present, are macroscopically recorded on the surface of dry bone. The presence of pathological lesions that are commonly associated with nutritional deficiencies on the bones of young infants can be indicative of maternal nutrition. However, it should be noted that the absence of evidence is not evidence of absence as micronutrient deficiencies rarely occur in isolation (Snoddy et al., 2017).

Scurvy and rickets, which are metabolic diseases associated with an inadequate intake of vitamin C and D, will be discussed below in association with the skeletal manifestations, such as AbPo, are commonly associated to each disorder. However, although anemia will also be outlined below because it is a general condition, only nutritional anemias will be reviewed as possible conditions associated with the presence of porotic hyperostosis (PH) and cribra orbitalia (CO) (Baker & Greer, 2010; Brickley, 2018; Rivera & Mirazón Lahr, 2017; Stuart-Macadam & Kent, 1992; Stuart-Macadam, 2005; Walker et al., 2009).

Scurvy

Scurvy is caused by the inadequate absorption of Vitamin C, or ascorbic acid, for an extended period of time. A deficiency of ascorbic acid significantly alters the membrane of blood vessels and aids in the bridging of the vascular epithelial wall to the endothelium (Popvich et al., 2009; Saladin, 2014). In scorbutic individuals, the compromised nature of the blood vessels can cause chronic hemorrhaging in response to standard muscular action and minor trauma which can result in perivascular edema, gingival bleeding, cutaneous bruising, and subperiosteal hematomas (Hirschmann & Raugi, 1999; Olmedo et al., 2006; Popvich et al., 2009).

In relation to maternal nutrition, vitamin C levels in a newborn infant are directly related to the level of vitamin C transmitted from the maternal body to the fetus via the placenta (Agarwal et al., 2015; Shah & Sachdev, 2012). After birth, vitamin C levels are maintained through breast milk (Bravi et al., 2016; Palmer, 2011). Although scurvy often affects children between 6 to 18 months of age (Kozłowski & Witas, 2016), some clinical scholars note that just 8-12 weeks of an inadequate intake of vitamin C can result in scorbutic symptoms (Agarwal et al., 2015; Algahtani et al., 2010; Besbes et al., 2010; Tamura et al., 2000).

Typically, the secondary effects, such as the inflammatory response of the chronic bleeding, are used in paleopathology to differentially diagnose scurvy in skeletal remains. Therefore, lesions that are a result of chronic bleeding in the subperiosteal area of long bones, the eye orbits, the cranial vault, and the alveolar bone of the mandible/maxilla are primarily classified as *probable scurvy* and manifest as abnormal porosity (AbPo) in these specific regions (Snoddy et al., 2016, 2017; Schattmann et al., 2016; Brickley & Ives, 2008; Mays, 2008; Ortner, 2003). In alignment with Snoddy and colleagues (2017, 2018), however, this thesis cautions against the definitive diagnosis of scurvy. Given the age range of the skeletal assemblage, the precise diagnosis of scurvy is difficult as some pathological lesions that are suggestive of scurvy may overlap with the associated rapid skeletal growth of young infants (Snoddy et al., 2017, 2018). However, a more detailed explanation of the paleopathological scoring classification will be outlined below (see Methods).

Rickets

A prolonged deficiency of vitamin D inhibits bone mineralization by preventing calcium from being deposited in developing cartilage and in newly grown osteoid (Pai & Shaw, 2011; Pettifor, 2003). This can lead to vitamin D deficiency, otherwise known as rickets, which results in malleable bones and bowing of the weight-bearing long bones. Vitamin D deficiency (also referred to as nutritional rickets) is typically due to dietary deficiency, a lack of ultraviolet B ray exposure, and the malabsorption of vitamin D in the gut (Pai & Shaw, 2011). Jones and colleagues (2018) note that, like scurvy, skeletal manifestations of rickets commonly involve areas of rapid growth such as long bone epiphyses and metaphyses as well as have a significant effect on the formation of bone structure. The affected cartilaginous growth plates result in the deformation of bone between the mineralized metaphyses and epiphyses (Jones et al., 2018; Özkan, 2010).

Although vitamin D deficiency can occur at any range, clinical studies have found that rickets has a tendency to develop around 3 to 18 months of age (Jaffe, 1972; Pettifor, 2003). Further, the minimum age that rickets can develop in an infant is between 3 to 6 months of age; however, infants do not have the capacity to store vitamin D. Instead, vitamin D is transmitted trans-placentally throughout pregnancy while in utero to the fetus (Wagner et al., 2012; Pettifor, 2003). As noted by Anatoliotaki and colleagues (2003), congenital rickets has been documented. Prenatal deficiencies, however, are scarce due to the fact that the mother's body will compensate by transmitting any available vitamin D to her fetus (Anatoliotaki et al., 2003; Shore, 2008). Unlike vitamin C, vitamin D can be synthesized through other means, such as exposure to sunlight. If the maternal body does not receive sufficient vitamin D through nutritionally rich foods or get enough exposure to sunlight during pregnancy, both the mother and fetus may be more susceptible to a deficiency of vitamin D. After birth, if an insufficient amount of vitamin D is transferred to the infant, such as through breast milk, a deficiency in the infant can develop (Holick, 2006; Özkan, 2010).

Pathological lesions that are commonly associated with rickets in dry bone includes the enlargement of the costochondral junction of the ribs and the metaphyseal cupping and flaring of long bones (Adams, 2011; Buckley et al., 2014; Snoddy et al., 2018; Schattmann et al., 2016). However, this is not to say that the presence of such pathological changes is pathognomonic of rickets. Instead, the presence of these two lesions will be classified as *possible rickets* following the diagnostic guideline outlined by Snoddy and colleagues (2018). (see Methods).

It is important to note that there is a significant overlap in the pathological manifestations of scurvy and rickets (Snoddy et al., 2017; Brickley & Ives, 2006; Schattmann et al., 2016). While a vitamin C deficiency will inhibit the formation of osteoids, a vitamin D deficiency will inhibit the mineralization of osteoids (Schattmann et al. 2016). Further, as noted by Schattmann and colleagues (2016), the comorbidity of rickets and scurvy can be challenging due to the effects that the deficiencies have on the bone. Although clinical interpretations of scurvy indicate that the skeletal manifestations are macroscopically observable, the skeletal features of rickets may be milder and macroscopically unobservable (Schattmann et al., 2016).

Anemia: Porotic Hyperostosis and Cribra Orbitalia

Although anemia, for the purpose of this research, is not definitively classified as a metabolic disease, it is vital to note that the skeletal manifestations associated with anemia are commonly linked to nutritional insufficiency (Brickley & Ives, 2008). As stated by Kozłowski and Witas (2012), anemia is detected either through the presence of reduced red blood cells, reduced function of red blood cells, or through a detectable difference in the hemoglobin the cells contain. However, this reduction of the number or function of red blood cells can be triggered by a variety of conditions (e.g., nutritional stress, trauma, etc.) that are not specific.

Among clinical literature, numerous scholars cite microcytic anemia due to iron deficiency (iron deficiency anemia) as the most common type of anemia in infants and children (Abu-Ouf & Jan, 2015; Camaschella, 2015; Chandyo et al., 2016; Joo et al., 2016; Subramaniam & Girish, 2015; Wang, 2016). Through pregnancy, iron storage in the maternal body decreases due to the increase in the mass of red blood cells, and the additional demands of the fetus (Letsky, 2008). Letsky (2008) notes that this may adversely affect the fetus. If the mother has an inadequate supply of iron during pregnancy, the body would be unable to fulfill the nutritional demands of the fetus, which may lead to an iron deficiency in the fetus postpartum (Letsky, 2008).

Anemia is a condition worthy of noting because the expansion of blood volume during pregnancy leads to a natural decline of hemoglobin concentration during the first and second trimesters before gradually increasing during the third trimester (Chaparro & Suchdev, 2019; Nestel, 2002). The causes of nutritional anemias in the maternal body can range anywhere from inadequate dietary intake to an impaired ability to absorb nutrients following parasitic infection. However, Chaparro and Suchdev (2019) emphasize that a multitude of micronutrient deficiencies will likely have a synergistic effect on the development of anemia. This means that multiple micronutrient deficiencies in the maternal body during pregnancy will likely equate to the presence of multiple nutritional anemias in the fetus due to the already compromised concentration of hemoglobin during pregnancy.

Anemia causes the irregular production of red blood cells (hematopoiesis) in the trabecular bone marrow, which can result in the enlargement of the cancellous bone structure (Rivera & Lahr, 2017; Martini et al., 2011). As noted by Rivera and Lahr (2017), the enlargement of the cancellous bone process may be a result of either marrow hypertrophy, wherein the tissue enlarges following the increase of cell size, or hyperplasia, in which the tissue enlarges following the increase of the number of cells. In skeletal material, these responses can potentially result in the diploë expansion on the cranium to be scored as porotic hyperostosis (PH) and cribra orbitalia (CO) (Ortner, 2003). However, as illustrated by Zuckerman and colleagues (2014), porous lesions on the crania, such as PH and CO, may be indicative of other conditions such as megaloblastic anemia, hemolytic anemia, scurvy, and rickets.

It is challenging to attribute the presence of porous cranial lesions to a specific etiology when only the macroscopic analysis of bone is employed. As illustrated throughout this subtopic, there are a multitude of anemias that may lead to the presence of porous lesions on the crania. The physiological capacity for the bone to respond to any sort of pathological stress is limited to either irregular bone formation (i.e., deformation) or remodeling (i.e., abnormal bone loss or gain) (Rivera et al., 2017; Ortner, 2003; Brickley & Ives, 2008). This can, unfortunately, make precise identifications more difficult because manifestations of porotic lesions on the crania, such as PH and CO, can be classified as non-specific pathological indicators; however, they are most likely associated with nutritional deficiencies (Brickley, 2018; Rivera & Lahr, 2017; Schattmann, 2014; Schattmann et al., 2016). As such, based on the extensive literature, PH and CO will be examined as non-specific pathological indicators likely associated to nutritional insufficiency.

Linear Enamel Hypoplasia

The markers on dentition left after the survival of a stressful event can be permanent indicators of interrupted development during that period of growth. Mineralization of the teeth begins in utero and can be intermittently affected by fluctuating maternal nutrition (AlQahtani et al., 2010; Davit-Béal et al., 2014; Lukacs, 2012). Insufficient nutrients from the maternal body during fetal development can have an adverse effect on enamel development. However, due to the focus on infants under the age of 6-months, deciduous dentition is needed for analysis, as deciduous teeth develop by 4.5 months postpartum: incisors (i^1, i_1, i^2, i_2), canines (c', c, c', c,), and molar (m^1, m_1, m^2, m_2) (AlQahtani et al., 2010).

Early literature on dental defects describes the presence of linear enamel hypoplasia (LEH) as a nonspecific stress indicator during ontogeny (Lukacs, 2012; Ogden et al., 2007;

Šlaus, 2008; Wright & White, 1996). Linear enamel hypoplasia (LEH) can be used as an indicator of maternal nutrition on perinatal and infant remains following the survival of periods of stress (Blakey & Armelagos, 2005; Ogden et al., 2007; Temple, 2020; Tsutaya & Yoneda, 2015). Linear enamel hypoplasias are caused by interrupted calcium deposition during the initial phase of enamel development and occur when malnutrition or disease interferes with this development (Liversidge, 2000; Lukacs, 2012). Enamel hypoplasias commonly occur on the incisors and canines as the premolars and molars are seemingly more buffered against the formation of hypoplasia (King et al., 2002; Meyer, 2016). This helps to illustrate that dentition can be an informative tool given that deciduous teeth can provide insight about the intrauterine environment during development as well as provide a snapshot of maternal and fetal nutritional health status (Brickley et al., 2019).

It is imperative to understand that the presence of linear enamel hypoplasias are permanent indicators of an individual's survival of a nonspecific stress event. This means that while the etiology of LEH may be the result of a number of different stress factors, the remaining defects can act as a visual indicator for stress (Lukacs, 2012; Meyer, 2016). Although previous research has linked LEH to systemic metabolic stress (Goodman & Armelagos, 1985; Goodman & Rose, 1990; Hillson, 1996; Skinner & Goodman, 1992), the presence of LEH cannot be definitively ascribed to a specific etiology and instead can be recognized as an indicator of the survival of a nonspecific stress event (Kozłowski & Witas, 2016; Lukacs, 2012; Meyer, 2016). In their isotopic study of weaning and LEHs amongst the Medieval Nubian site of Kulubnarti, Sandberg and colleagues (2014) found that the majority of LEHs occurred during the weaning process. Therefore, the macroscopic presence of LEHs on the deciduous dentition at Put

Dragulina may suggest that that individual experienced nutritional stress associated with the weaning process.

CHAPTER III

RESEARCH DESIGN

The primary research question for this research is as follows: is there a difference in the evidence of nutritional deficiencies in young infants (<6 months) during the early versus the late occupation at Put Dragulina and what can these indicators of nutritional deficiencies say about maternal health during both occupation periods? My secondary research question states: is there a difference in the presence of LEHs on the deciduous dentition young infants from the early versus the late occupation?

Research Questions

1. Is there a significant correlation between the presence of pathological lesions on young infants under the age of 6 months from the early occupation (1st-2nd century CE) of Put Dragulina compared to the young infants under the age of 6 months from the late occupation (3rd-6th century CE) of Put Dragulina?
    a. Is there a relationship between PH and early (1st-2nd century CE) versus late occupation (3rd-6th century CE)?
    b. Is there a relationship between CO and early (1st-2nd century CE) versus late occupation (3rd-6th century CE)?
    c. Is there a relationship between AbPo and early (1st-2nd century CE) versus late occupation (3rd-6th century CE)?

2. Is there a significant correlation between linear enamel hypoplasia (LEH) on young infants from the early occupation (1st-2nd century CE) of Put Dragulina compared to the young infants from the late occupation (3rd-6th century CE) of Put Dragulina?

Hypotheses

Hypothesis 1

Hypothesis 1: Young infants under the age of 6 months from the late occupation of Put Dragulina will have a higher frequency of pathological lesions (healed, unhealed, or healing) associated with nutritional deficiencies (PH, CO, AbPo) than young infants from the early occupation.

Hypothesis 1 addresses the primary research question. It proposes that the presence of pathological lesions commonly associated with nutritional deficiencies on infants under the age of 6 months from the late occupation will be different than those from the early occupation. If hypothesis 1 is accepted, it would indicate that the young infants from the late occupation may have been more impacted by social change than the early occupation of young infants. In turn, if the young infants from the late occupation show higher instances of pathologies commonly associated with nutritional deficiencies, it can be interpreted that the mothers were more nutritionally deficient in the late occupation rather than the early occupation.

Hypothesis 1 will be accepted if the correlation between pathologies and the late occupation young infants are statistically significant, and the correlation between pathologies and the early occupation young infants are not significant. Hypothesis 1 will be rejected if any of the correlations between pathologies and the late occupation of infants are not significant. This would indicate that social change may not have been a significant factor in the nutritional outcomes of late occupation infants. If both the early occupation and late occupation infants are pathologically significant, hypothesis 1 will be partially accepted. This would indicate that while social change may have impacted the nutrition of the late occupation infants, and by proxy, their mothers, it was not significant enough to differentiate the late infants from the early occupation infants statistically. Lastly, hypothesis 1 will be nullified if both the early and late occupation young infants are not significant when correlated to pathological changes associated with nutritional deficiencies. The nullification of hypothesis 1 might indicate that a social stressor event may not have been a substantial factor in the nutrition of infants and, by proxy, their mothers, in the Put Dragulina cemetery.

Hypothesis 1 is divided into three sub-hypothesis that test the correlation between independent skeletal manifestations of nutritional deficiencies:

Hypothesis 1a: Young infants from the late occupation of Put Dragulina will have a higher frequency of PH present (healed, unhealed, or healing) than young infants from the early occupation of Put Dragulina.

Hypothesis 1a addresses the first research question by independently testing the presence of porotic hyperostosis in relation to the late and early-occupation young infants. If hypothesis 1a is accepted, it would be supporting evidence that the nutrition of the late occupation infants, and by proxy, their mothers were more impacted by social change than the early occupation infants. Hypothesis 1a will be accepted if the correlation between PH and the late occupation of young infants is statistically significant, while the correlation between PH and the early occupation pre-weaned infants is not. Hypothesis 1a will be rejected if the correlation between PH and the late occupation infants is not statistically significant, while the correlation between PH and early occupations infants is. Hypothesis 1a will be partially accepted if both the early and late occupation infants are both significantly correlated to PH. Lastly, hypothesis 1a will be null if both the early and late occupation young infants are not significant when correlated to PH.

Hypothesis 1b: Young infants from the late occupation of Put Dragulina will have a higher frequency of CO present (healed, unhealed, or healing) than young infants from the early occupation of Put Dragulina.

Hypothesis 1b addresses the first research question by independently testing the frequencies of cribra orbitalia in relation to the late and early occupation young infants. If hypothesis 1b is accepted, it would be supporting evidence that the nutrition of late occupation infants, and by proxy, their mothers, were more impacted by social change than the early occupation infants. Hypothesis 1b will be accepted if the correlation between CO and the late occupation pre-weaned infants is statistically significant while the correlation between CO and the early occupation pre-weaned infants is not statistically significant. Hypothesis 1b will be rejected if the correlation between CO and the late occupation infants is not statistically significant, while the correlation between CO and early occupations infants is significant. Hypothesis 1b will be partially accepted if both the early and late occupation infants are both significantly correlated to CO. Lastly, hypothesis 1b will be null if both the early and late occupation young infants are not significant when correlated to CO.

Hypothesis 1c: Young infants from the late occupation of Put Dragulina will have a higher frequency of AbPo present than young infants from the early occupation of Put Dragulina.

Again, hypothesis 1c addresses the first research question more specifically by independently testing the frequencies of abnormal porosity in relation to the late and early occupation young infants. If hypothesis 1c is accepted, it will help support the inference that the nutrition of late occupation infants, and by proxy, their mothers, were more impacted by social change than the early occupation infants. Hypothesis 1c will be accepted if the correlation between AbPo and the late-occupation young infants is statistically significant, while the correlation between AbPo and the early-occupation young infants is not significant. Hypothesis 1c will be rejected in the correlation between AbPo and the late occupation infants is not significant, while the correlation between AbPo and early occupations infants is significant. Hypothesis 1c will be partially accepted if both the early and late occupation infants are both significantly correlated to AbPo. Lastly, hypothesis 1c will be null if both the early and late occupation young infants are not significant when correlated to AbPo.

Hypothesis 2

Hypothesis 2: Young infants from the late occupation of Put Dragulina will have higher frequencies of linear enamel hypoplasia (LEH) on the deciduous incisors (i^1, i_1, i^2, i_2), canines (c’, c,, c’, c,), or molars (m^1, m_1, m^2, m_2) than young infants from the early occupation of Put Dragulina.

Hypothesis 2 addresses the second research question. Given the nature of LEHs, the presence of LEH on the deciduous teeth would indicate the survival of a stressor, such as the deprivation of nutrients. If hypothesis 2 is accepted, it would indicate that the young infants from the late occupation showed markers for the survival of a stressor, which may suggest that their mothers experienced this stressor as well. Hypothesis 2 will be accepted if the correlation between LEH and the late occupation young infants is statistically significant, while the correlation between LEH and the early occupation young infants is not significant. Conversely, hypothesis 2 will be rejected if the correlation between present LEH and the late occupation young infants is not significant, while the correlation between LEH and early occupation young infants is significant. Hypothesis 2 will be partially accepted if the early and late occupation young infants are both statistically significant. Lastly, hypothesis 2 will be null if both the early and late occupation young infants are not significant when correlated to LEH.

CHAPTER IV

METHODS AND MATERIALS

The 2011 site report for the Put Dragulina cemetery states that numerous Roman graves were recovered, including nineteen amphora graves, four tegula architecture graves, five unmarked graves, and three graves labeled as possible cremations (Bilić, 2012). Problematically, there is limited additional information on the archaeological context of these burials (Paraman, 2018). However, additional excavations in 2016 by the Trogir City Museum were completed (Paraman, 2018). Data was collected and analyzed from both the 2011 and 2016 skeletal assemblages.

Methods

All of the skeletal material used in this study is curated at the Trogir City Museum. To maximize recovery of infant remains, the material was cleaned under running water and lightly scrubbed with a soft-bristled toothbrush above a mesh strainer in order to catch any loose bone. Because infant and perinatal remains are small and fragile, the strainer was cleaned, and the contents were collected after each storage bag in order to ensure the preservation of each individual. After drying, the material was stored in tagged plastic bags (e.g., site name, specific grave association (if noted), stratigraphic unit number, find number, brief identification (e.g., '*bone,*' '*skeleton,*' or '*skull*'), and date excavated). The contents of each bag were photographed in multiple ways (e.g., contents of the bag overall, individual elements, and a close-up of pathological evidence) with a 5cm or a 10cm scale for reference (depending on fragment size).

Data was recorded into the FileMaker Pro database created by Osterholtz (2019). Inputted data included notes, measurements of elements, and brief summaries specific to each grave tag.

Age at Death Estimation

Age at death was estimated following standards by Fazekas and Kósa (1978) and Scheuer and Black (2008). Cranial metrics and postcranial metrics were measured following landmarks developed by Fazekas and Kósa (1978) and outlined in Scheuer and Black (2008). Stages of dental formation were defined using Moorrees and colleagues, as well as Smith's modification of their dental mineralization stages (Moorrees et al., 1963a, 1963b; Smith, 1991a). For perinatal and infant remains, sliding calipers were used on any elements that were preserved enough to allow for the reference landmarks needed for measurement. For example, if preservation did not allow for the maximum length of the pars lateralis but did allow for the maximum width of the pars lateralis, the width was measured and recorded while the length was recorded as *'not scored.'* Once recorded, in order to estimate an individual's refined age at death, the measurements were compared to the dry bone fetal measurement tables established by Fazekas and Kósa (Fazekas & Kosa, 1978). For older sub-adults, methodology outlined by Scheuer and Black was used as a reference to refine the age at death estimation (Scheuer & Black, 2000). Although sparse, stages of dental mineralization were also used to refine age at death estimations further. Stages of tooth formation were noted following Moorrees, Fanning, and Hunt (1963a, 1963b) as outlined by Buikstra and Ubelaker (1994).

Pathological Analysis

Although PH, CO, AbPo, and LEH are chosen for this thesis as pathological indicators commonly associated with nutritional deficiencies (see Background), it is important to note that these skeletal manifestations are not pathognomonic of specific deficiencies. Instead, most pathological changes to bones that are commonly associated with nutritional deficiencies (PH, CO, AbPo, LEH) are non-specific and do not allow for the definitive diagnosis of specific metabolic diseases such as rickets or scurvy.

Due to the presence of faunal remains scattered throughout the assemblage, human material was first separated from faunal material. A feature-based approach was used in order to identify what elements were present for analysis in order to construct a minimum number of individuals (MNI) (Osterholtz, 2019). As outlined by Osterholtz (2019), a feature-based approach that is element-specific allows for fragmented assemblages to be recorded accurately. The corresponding database sheets for each element present was then filled out following standards outlined by Osterholtz (2019). Macroscopic analysis of the remains was then employed to identify any pathological changes to the surface of the bone. When present, dentition was also recorded into the database and scored for pathological change.

If pathological changes were macroscopically visible on the dry bone, they were described following standards established by Buikstra and Ubelaker (1994). Although all evidence of pathology was analyzed and recorded, the presence or absence of the pathologies most commonly associated with nutritional deficiencies (CO, PH, AbPo) was the specific focus during data collection. All of the pathological lesions included in the research design of this study were detailed in the database, and others observed were recorded in the summary portion of the database. All of the pathologies were photographed. CO was recorded when abnormal porosity of cortex (localized small holes) on the orbital roof was observable (Brickley & Ives, 2008). CO may also have associated expansion of diploe bone, which could result in cortical thickening (Brickley, 2018; Walker et al., 2009). PH was recorded when porous lesions—a cluster of small holes with defined margins—were observable on the cranial vault (Rivera & Lahr, 2017). AbPo was noted if there was an apparent visible increase in what would be otherwise considered normal porosity (Buikstra & Ubelaker, 1994).

CO and PH were recorded as either *present, absent,* or *NS* (not scored) following standards outlined by Buikstra and Ubelaker (1994). The location of the pathology was then scored and noted in the database. If CO, for example, was present in one or both of the orbits (*L CO*, *R CO*, *present in both*), the pathological lesions were scored independently and described in the database. If '*present,'* pathologies would be scored according to the presence of healing. Healing was determined as *unhealed* (i.e., the lesion shows no signs of healing, active lesions), *healing* (i.e., the lesion shows some signs of filling in porosity, no longer active), or *healed* (i.e., the lesion has a healed appearance, not to say that no residual porosity is present, but the porosity has an old, established appearance) (Osterholtz, 2019). Any additional observation notes for cranial pathology were recorded in the designated space within the database.

Consistent with cranial pathology, postcranial pathology such as abnormal porosity was recorded following the same guidelines in Osterholtz's (2019) database. Similar steps were employed for all aspects of the appendicular skeleton, with only the element designation being different. For instance, with a special focus of abnormal porosity, the presence of any atypical macroscopic change to the surface of a long bone (*present*) was marked as either *shaft* (all surfaces), *shaft* (anterior surface), *shaft* (lateral surface), *shaft* (medial surface), *shaft* (multiple surfaces), *proximal metaphysis, proximal epiphysis, distal metaphysis, distal epiphysis,* or *shaft* *and metaphyses.* Further, the presence of *healing* was then recorded as either *unhealed* (lesion shows no signs of healing, active lesions), *healing* (lesion shows some signs of filling in porosity, no longer active), or *healed* (lesions has a healed appearance).

Dental pathology was also recorded following standards outlined by Buikstra and Ubelaker (Buikstra & Ubelaker, 1994). The presence (and absence) of LEH, number of LEHs, and measurements (if possible) were recorded following standards by Buikstra and Ubelaker (1994). Any additional observations on dentition were recorded in the comment section of Osterholtz's database.

Materials

Sample Summary

The individuals in the 2011 assemblage were differentiated by contract archaeologists in the field through the use of grave tags that were associated with each bag of skeletal material. Although 45 grave bags were analyzed from the 2011 material, a minimum number of individuals (MNI) of 26 was established. The 2011 assemblage includes four adults (18+ years), two children (2-12 years), two indeterminates (unable to estimate age at death), eight infants (Birth-2 year), nine perinates (36-40 gestational weeks), and one fetus (0-36 gestational weeks). All entries were recorded into the Osterholtz (2019) database for the 2011 excavation, and Figure 4.1 illustrates that a total of 26 individuals were analyzed.

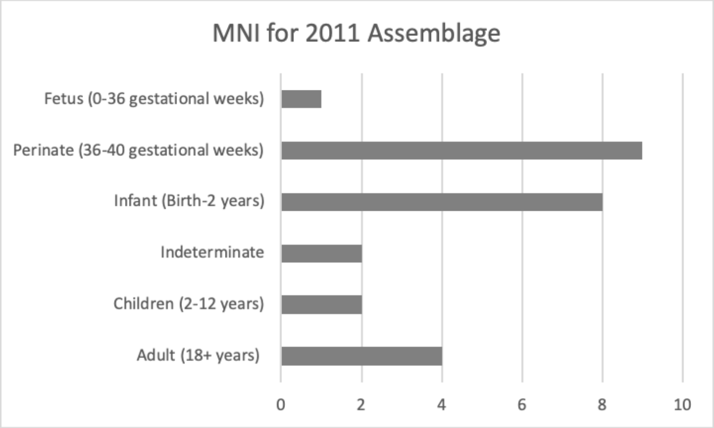

Figure 4.1 Number of Individuals analyzed from the 2011 skeletal material

Inventory and age estimation for the 2016 excavation yielded 41 individuals. As illustrated in Figure 4.2, this included ten adults (18+ years), three young adults (18-35 years), two adolescents (12-18 years), two adolescent+ (12+ years), four children (2-12 years), one indeterminate (unable to estimate age at death), 11 infants (Birth-2 years), and eight perinates (36-40 gestational weeks).

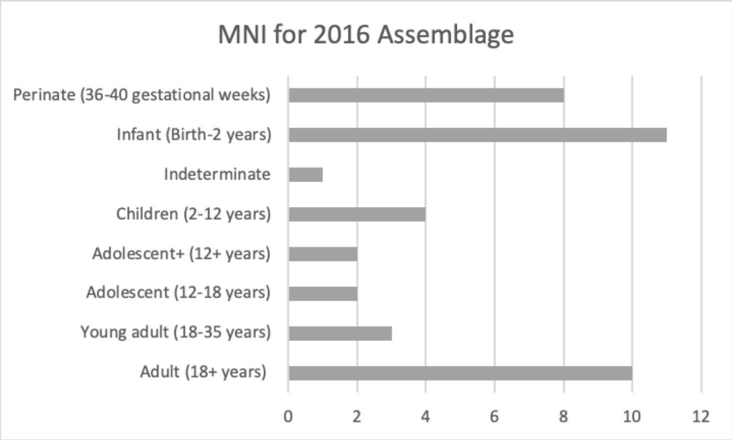

Figure 4.2 Number of Individuals analyzed from the 2016 skeletal material

Due to the uncontextualized nature of specific material, as well as the focus of the thesis questions, only eight perinates, one fetus, and five young infants were included from the 2011 material as well as five perinates and eight young infants from the 2016 material. The result is an analyzed sample of 27 individuals. This is primarily due to the lack of context and grave association with many of the bags containing human remains for the 2011 material. For example, one bag with skeletal material had a tag that was labeled '*above graves 17 & 22'* and was recorded in the database as “grave A17i22” to denote that the material was possibly associated with two graves as opposed to a single inhumation. Thus, for the purposes of this thesis, grave A17i22 will not be included in the sample as it cannot be definitively stated that the material associated with being "above graves 17 and 22" does not belong to either grave 17 or grave 22. Table 4.2 summarizes the individuals that will be included in the sample from both the 2011 and 2016 excavation material. Dating of the burials from both the 2011 and 2016 assemblages was produced by the lead archaeologist at the Trogir City Museum. The presence of specific material grave goods, such as Roman glass, pottery, and certain metals, indicated either an early or late occupation period (Paraman, 2018). Thirteen burials (48%) are associated with the early occupation at Put Dragulina, while 14 burials (51%) are associated with the late occupation.

Table 4.2 Summary of Individuals includes in sample

	Grave Number	**Occupation**	**Age-at-Death Estimation**	**Ref. Age-at-Death**
1	2016.31	1st - 2nd c. CE	Perinatal	~ 28-40 weeks
2	2016.23	1st - 2nd c. CE	Perinatal	~ 30-40 weeks
3	2016.30	1st - 2nd c. CE	Perinatal	~ 40 weeks
4	2016.28	1st - 2nd c. CE	Perinatal	~ 40 weeks
5	2016.02	1st - 2nd c. CE	Perinatal	~ 40 weeks
6	2016.17	1st - 2nd c. CE	Young infant	Birth-2 months
7	2016.14a	1st - 2nd c. CE	Young infant	Birth-2 months
8	2016.14b	1st - 2nd c. CE	Young infant	Birth-2 months
9	2016.24	1st - 2nd c. CE	Young infant	Birth-3 months
10	2016.21	1st - 2nd c. CE	Young infant	Birth-3 months
11	2016.35	1st - 2nd c. CE	Young infant	1-3 months
12	2016.13	1st - 2nd c. CE	Young infant	1-3 months
13	2016.25	1st - 2nd c. CE	Young infant	2-3 months
14	2011.08a	3rd - 6th c. CE	Fetal	~ 32-34 weeks
15	2011.08b	3rd - 6th c. CE	Perinatal	~ 34-40 weeks
16	2011.02	3rd - 6th c. CE	Perinatal	~ 36-40 weeks
17	2011.09	3rd - 6th c. CE	Perinatal	~ 36-40 weeks
18	2011.10b	3rd - 6th c. CE	Perinatal	~ 38-40 weeks
19	2011.11	3rd - 6th c. CE	Perinatal	~ 38-40 weeks
20	2011.18	3rd - 6th c. CE	Perinatal	~ 38-40 weeks
21	2011.26	3rd - 6th c. CE	Perinatal	~ 38-40 weeks
22	2011.19	3rd - 6th c. CE	Perinatal	~ 40 weeks
23	2011.06	3rd - 6th c. CE	Young infant	Birth-1.5 months
24	2011.13	3rd - 6th c. CE	Young infant	<6 months
25	2011.14	3rd - 6th c. CE	Young infant	<6 months
26	2011.15	3rd - 6th c. CE	Young infant	<6 months
27	2011.17	3rd - 6th c. CE	Young infant	<6 months
Total	27 graves			

(~) refers to an approximated range for the refined age at death. CE refers to “common era.”

CHAPTER V

RESULTS

Hypothesis 1

Hypothesis 1 examines the presence or absence of pathological lesions associated with nutritional deficiencies (PH, CO, AbPo) on the remains of young infants from the early and late occupation of Put Dragulina. This hypothesis is separated into three sub-hypotheses (1a, 1b, 1c). Hypothesis 1a correlates PH and early versus late occupation infants, hypothesis 1b correlates CO and early versus late occupation infants, and 1c correlates AbPo and early versus late occupation infants.

Hypothesis 1 was rejected because two of the correlations (CO and AbPo) between the occupational periods and pathological indicators were not statistically significant (Table 5.1). However, the late occupation infants exhibited higher frequencies of pathological lesions associated with nutritional deficiencies than did the early occupation infants. To determine if there was a statistically significant difference between the presence of pathological lesions associated with nutritional deficiencies on the early versus late occupation infants, a Fisher's Exact test was run. Applying Fisher's exact test, the presence of pathological changes in early versus late occupation infants is not statistically significant (p=0.5956). When comparing the frequencies of pathologies present, the early occupation infants showed a presence of 85% while the late occupation infants showed 93% presence.

Table 5.1 Fisher's Exact Test for Hypothesis 1

	Present (PH/CO/AbPo)	**Absent (PH/CO/AbPo)**	**Total**
Early Occupation	11	2	13
Late Occupation	13	1	14
Total	24	3	27

Hypothesis 1a

Hypothesis 1a was accepted as the correlation between PH and the early versus late occupation infants was statistically significant. To determine if there was a statistically significant difference between the frequencies of PH on the early versus late occupation young infants, a Fisher's Exact test was run. Applying Fisher's exact test, the presence of PH on early versus late occupation infants is significantly different. Fisher's Exact (Table 5.2) resulted in a p-value of 0.0213, which indicates that the difference between the observed and expected data was significant (Fisher, 1922). This means that there is a statistically significant difference between the frequencies of porotic hyperostosis on the early versus late occupation infants, with the late occupation infants expressing a higher number of PH.

Table 5.2 Fisher's Exact Test for Hypothesis 1a

	Present (PH)	Absent (PH)	Total
Early Occupation	4	9	13
Late Occupation	11	3	14
Total	15	12	27

Hypothesis 1b

Hypothesis 1b was rejected as the correlation between CO and the early versus late occupation infants was not statistically significant. To determine if there was a statistically significant difference between the presence of cribra orbitalia on the early versus late occupation young infants, a Fisher's Exact test was run. The Fisher's Exact (Table 5.3) resulted in a p-value of 0.5956, which indicates that the difference between the observed and expected data was not significant. This means that there is not a statistically significant difference between the frequencies of cribra orbitalia on the early versus late occupation infants.

Table 5.3 Fisher's Exact Test for Hypothesis 1b

	Present (CO)	Absent (CO)	Total
Early Occupation	1	12	13
Late Occupation	3	11	14
Total	4	23	27

Hypothesis 1c

Hypothesis 1c was rejected as the correlation between AbPo and the early versus late occupation infants was not statistically significant. To determine if there was a statistically significant difference between the presence of abnormal porosity on the early versus late occupation infants, a Fisher's Exact test was run. Fisher's Exact (Table 5.4) resulted in a p-value of 1.000, which indicates that the difference between the observed and expected data was not significant. Applying Fisher's Exact Test, the presence of AbPo on early versus late occupation infants are not different (Fisher, 1922). This means that there is not a statistically significant difference between the presence of abnormal porosity on the early versus late occupation infants.

Table 5.4 Fisher’s Exact Test for Hypothesis 1c

	Present (AbPo)	**Absent (AbPo)**	**Total**
Early Occupation	11	2	13
Late Occupation	11	3	14
Total	22	5	27

Hypothesis 2

The goal of hypothesis 2 was to examine the presence of LEH on the deciduous dentition of the early versus late occupation young infants. However, hypothesis 2 is inconclusive due to the poor preservation of the dentition. This hypothesis is neither accepted nor rejected because preservation did not allow for pathological data to be scored on the deciduous dentition and therefore did not allow for statistical testing. Although the deciduous dentition could, in some cases, be used to estimate age at death, the majority of the deciduous dentition was covered in soil concretion that did not allow for the surface of the enamel to by analyzed.

CHAPTER VI

DISCUSSION

The focus of this thesis is to reconstruct maternal nutrition at Put Dragulina via the nutritional status of young infants. The results presented in this research shows that, in totality, 89% of the young infants from Put Dragulina were nutritionally stressed to some degree. For the early occupation infants, 85% presented with skeletal indicators of nutritional deficiencies whereas 93% of the late occupation infants presented skeletal indicators of nutritional deficiencies. Although the lack of deciduous dentition did not allow for hypothesis 2 to be explored, the results of hypothesis 1 (and its corresponding sub-hypotheses) will be discussed in relation to the reconstruction of maternal nutrition via the nutritional status of young infants at Put Dragulina.

Importantly, statistically insignificant results do not necessarily mean that the results are insignificant on their own. The small sample size of this assemblage is a limitation when it comes to statistical testing. Although this assemblage of young infants is small, the results shown throughout this thesis should not be disregarded. Further, it should be recognized that the young infants included in this sample represent the worst-case scenarios of maternal nutrition. Hypothesis 1, for instance, had 24 young infant skeletons present with pathological lesions commonly associated with nutritional deficiencies, while only three young infants did not manifest observable pathologies. Thus, the results of hypothesis 1 (and its subsequent sub-hypotheses) suggests that the 27 mothers associated to the analyzed infants had poor nutritional health.

When interpreting the results, the problems outlined by the osteological paradox must be revisited for discussion. As proposed by Wood and colleagues (1992), the problems of hidden heterogeneity and selective mortality affect the interpretation of these results. It is crucial to emphasize that the results extrapolated from the 27 infants within the analyzed sample can only propose a suggestive pattern of poor maternal nutrition for the 27 mothers associated with these infants. These results cannot imply a population-level assessment of maternal nutritional status because the 27 infants in the analyzed sample do not represent the living population that was associated to Put Dragulina. Therefore, the infants in the sample can only reconstruct the maternal nutritional status of their mothers. This goes hand-in-hand with selective mortality in that the infant analyzed within this sample reflects a biased representation of maternal nutrition given they died. As covered extensively in the background chapter, infants are the most biologically vulnerable age cohort due to their dependency on maternal nutrition (Kitsiou-Tzeli & Tzetis, 2017; Minato et al., 2019) and therefore are inherently biased due to their high susceptibility to biological stress. Finally, these infants were chosen from a larger sample size in order to explore maternal nutritional status. This means that although a larger sample size was available with older infants over the age of 6 months postpartum, these 27 infants (<6 months) were chosen due to their likely association to pre-weaning and therefore represent a biased sample.

Hypotheses

When exploring whether there was a statistically significant difference between the pathologies present on the early versus late occupation young infants, Hypothesis 1 was rejected. Although the correlation was not significant statistically, the late occupation infants showed higher frequencies of pathological lesions associated with nutritional deficiencies than did the early occupation infants. However, the most notable finding from this comparison is that infants from both occupational periods showed very high instances of pathological lesions. From the early occupation, 85% of the early occupation burials presented with pathologies consistent with nutritional deficiencies. Within the late occupation, 93% of the burials presented with pathological lesions associated with nutritional deficiencies.

The rejection of hypothesis 1 proposes a question: why is maternal nutritional status not statistically different despite the occurrence of the fall of an empire during the late occupation? Hypothesis 1 being rejected proposes that there is no statistical difference between the nutritional health of the Put Dragulina mothers from both occupational periods. This may mean that the mothers at Put Dragulina were culturally buffered to some degree. As mentioned in the introduction, a plethora of material grave goods were recovered in association with certain burials. Although the material culture associated to Put Dragulina was not available for this study, future research may explore the possibility of a demarcation in social class at the cemetery given that numerous infants were noted to have seemingly wealthy grave goods.

These results positively suggest that the vast majority of young infants at Put Dragulina were nutritionally stressed. Therefore, these results also suggest that the nutritional status of the mothers before and after a significant social change may not have been differentially impacted. Instead, bioarchaeological evidence suggests that the biological mothers associated with the 27 infants at Put Dragulina had poor nutritional health during both the early occupation and the late occupation.

Further, hypothesis 1 was divided into three sub-hypotheses (Hypothesis 1a, 1b, and 1c) in order to determine whether there was a statistical correlation between a specific pathological measure and occupation status. Hypothesis 1a was accepted, while hypothesis 1b and 1c were rejected. However, each of the sub-hypotheses, regardless of statistical significance, contributed to the goal of exploring maternal nutritional status via the nutritional health of infants. For hypothesis 1a, only 30% of the young infants from the early occupation presented with PH when compared to the 79% of the young infants from the late occupation. The results of hypothesis 1a suggest that the infants in the sample, and therefore their mothers, from the late occupation, may have experienced slightly higher instances of nutritional stress. However, although hypothesis 1a is statistically significant, it is inherent to recognize that PH is only one pathological marker associated with nutritional stress. Therefore, despite hypothesis 1a being accepted, hypothesis 1 is rejected because it is important to relate these findings collectively.

Hypothesis 1b (CO) and 1c (AbPo) were both rejected as the statistical correlation was not significant. However, the results of hypothesis 1b may be attributable to a preservation bias. Cranial elements within the assemblage were underrepresented likely due to poor preservation (for both the early and late occupation) and/or poor excavation methodology (for the late occupation material excavated in 2011). Hypothesis 1c was statistically rejected but showed a suggestive pattern of abnormal porosity across both occupation periods. While 85% of the early occupation infants presented with AbPo, only 79% of the late occupation infants presented with AbPo. Overall, in terms of the frequency of presence of AbPo, 81% of the assemblage across both occupation periods showed abnormal porosity. Given the association between abnormal porosity and nutritional deficiencies, the results of hypothesis 1c contribute to a suggestive pattern of poor maternal nutritional health for those in the sample from both time periods.

It is crucial to recognize that 27 young infants from over the course of approximately 600 years are just a small snapshot of maternal nutritional status at Put Dragulina. As discussed in the background chapter, the infants within this sample, and therefore their mothers, are both biased (selective mortality) and are aged in a highly susceptible cohort (hidden heterogeneity). To recapitulate, this means that the infants analyzed in this sample are, in fact, dead. This makes them an inherently biased representation of maternal nutritional health at Put Dragulina. As illustrated extensively in clinical literature, infants are the most highly susceptible age group to biological stress. Correspondingly, the maternal body associated with the infants in the study are also highly susceptible to biological stress, specifically nutritional stress, due to the high demands of pregnancy. Therefore, with the problem of selective mortality and hidden heterogeneity in mind, the results of hypothesis 1 and its sub-hypothesis suggests a pattern of poor maternal nutritional health in the maternal bodies associated with the analyzed sample.

This thesis hypothesized that the late occupation infants would show higher frequencies of nutritional deficiencies due to the political instability that would have followed the decline and dissolution of the Western Roman Empire. Instead, however, the results of hypothesis 1 and its sub-hypotheses show that there was not a statistical difference between the two occupation periods. This means that the infants, and by proxy the mothers, from both the early and late occupation of Put Dragulina in the analyzed sample experienced similar instances of nutritional stress that manifested as pathological lesions consistent with nutritional deficiencies.

CHAPTER VII

CONCLUSION

This thesis was constructed to gain insight into the nutritional status of mothers at Put Dragulina through the bioarchaeological and paleopathological examination of fetal, perinatal, and young infant remains. In an effort to reconstruct the nutritional status of mothers at Put Dragulina, the skeletal remains of young infants that were likely pre-weaned were examined as proxies for maternal nutrition. This was employed through the analysis of pathological lesions commonly associated with nutritional deficiencies on the dry bone of infants. A sample size of 27 infants was used to explore whether there was an identifiable difference between the nutritional status of infants from the early occupation of Put Dragulina versus the late occupation. This study found that only the frequency of PH was statistically difference between the early and the late occupation. However, despite the statistically insignificant results of hypothesis 1, 1b, and 1c, this study did identify a suggestive pattern of poor maternal nutrition across both occupations in the analyzed skeletal sample.

Despite the statistically insignificant results of three out of the four testable hypotheses, a suggestive pattern is present. The goal of the hypotheses was to test whether there was a statistically significant correlation between specific pathological indicators and the two occupational periods. This would, hypothetically, demonstrate whether a momentous social change—such as romanization and/or the fall of the WRE—had a differential effect on maternal nutritional status. However, negative results can still be informative results. Despite hypothesis

1 (which correlated PH/CO/AbPo against the occupational periods) being statistically insignificant and therefore rejected, it proposes an interesting question: given that a large social event (fall of the Western Roman Empire) occurred during the late occupation of Put Dragulina, why is there not a statistical difference between maternal nutritional health at the early versus late occupation? This could be attributed to a differentiation in social-class buffers that may have been present at Put Dragulina. Additional skeletal material may be needed with greater breadth in social class representation to address this. Although this study initially intended to identify a differentiation in nutritional patterns between the occupation periods, it instead identified that the majority of infants buried at Put Dragulina were nutritionally deficient, which represents a suggestive pattern of poor maternal nutritional status. This thesis concludes that the results shown in this study demonstrate that the infants in the skeletal sample from Put Dragulina were nutritionally deficient which therefore suggests that the mothers of the Put Dragulina infants had poor nutritional health.

Limitations

The most significant limitation of this thesis was the sample size. Although common among bioarchaeological assemblages, only a small fraction of the overall population is represented in this sample. Despite the young infants at Put Dragulina being a relatively small skeletal sample, the data extrapolated from the hypotheses show a suggestive pattern that can be used to inform about the nutritional health of the mothers associated with the 27 infants. Additionally, due to the small skeletal sample, the statistical assessment of the data was limited by the tests that could be employed. For example, only a Fisher's Exact Test could be run for hypothesis 1 and its sub-hypotheses due to the small number of parameters in a statistical cell. The inclusion of future comparative data from other Roman cemetery sites, however, may be beneficial for evaluating a larger sample of infants in relation to exploring maternal nutritional health in Dalmatia. Due to the current lack of such comparative samples in the Dalmatian region, this research could not explore such comparison.

Further, another limitation of this research was the lack of deciduous dentition. In bioarchaeological assemblages, the importance of research flexibility is imperative. This research would have benefitted from the inclusion of deciduous dentition to record enamel hypoplasias and/or other dental pathologies to get a fuller picture of nutritional health as well as have the option to pursue isotopic data in order to explore a more definitive analysis of diet.

Future Research

The inclusion of surrounding Roman cemetery sites in Dalmatia would be beneficial to a broader reconstruction of maternal nutritional health. However, the inclusion of young infants into the paleopathological and bioarchaeological research of the Roman world is a relatively new focus. Although comparative analysis of Roman cemeteries in the Dalmatian region would be a rewarding, assemblages with young infants are not yet published. Within the region, the infants analyzed in this research assemblage is seemingly the largest Croatian sample of infants systematically studied (in English). It is with that understanding that the focus and results of this thesis may encourage future research focusing on young infants in surrounding Dalmatian cemetery sites.

This thesis utilizes the current understanding and associations of pathological changes associated with nutritional deficiencies. The interpretation of pathological changes continues to evolve with the introduction of new methodological approaches and testing. For example, the presence of PH and CO is no longer associated solely with an etiology of iron-deficiency anemia and is instead considered to be associated with numerous etiologies, including various nutritional anemias. Therefore, this means that future studies may identify outdated interpretations in the way in which current paleopathology views the presence of PH, CO, AbPo, and LEH. Through the advancement of paleopathological and bioarchaeological research and methodology, the inclusion of infants into the archaeological record helps to construct a broader picture of maternal nutritional health.

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APPENDIX A

RAW DATA

Table A.1 Raw data (e.g. age estimation, refined age estimation, pathological assessment) for the 27 infants analyzed in the sample

Grave Number	Find Number	SJ	Occupation Period	Age at Death Est.	Refined Age at Death Est.	PH	CO	AbPo	LEH
2016.31	X	X	1st - 2nd c. AD	Perinatal	~ 28-40 weeks	A	A	A	NS
2016.23	X	X	1st - 2nd c. AD	Perinatal	~ 30-40 weeks	A	A	P	NS
2016.30	X	X	1st - 2nd c. AD	Perinatal	~ 40 weeks	A	A	P	NS
2016.28	X	X	1st - 2nd c. AD	Perinatal	~ 40 weeks	P	A	P	NS
2016.02	X	X	1st - 2nd c. AD	Perinatal	~ 40 weeks	A	A	A	NS
2016.17	X	X	1st - 2nd c. AD	Infant (B-2 years)	Birth-2 months	P	A	P	NS
2016.14a	X	X	1st - 2nd c. AD	Infant (B-2 years)	Birth-2 months	P	A	P	NS
2016.14b	X	X	1st - 2nd c. AD	Infant (B-2 years)	Birth-2 months	A	A	P	NS
2016.24	X	X	1st - 2nd c. AD	Infant (B-2 years)	Birth-3 months	A	P	P	NS
2016.21	X	X	1st - 2nd c. AD	Infant (B-2 years)	Birth-3 months	A	A	P	NS

2016.35	X	X	1st - 2nd c. AD	Infant (B-2 years)	1-3 months	A	A	P	NS
2016.13	X	X	1st - 2nd c. AD	Infant (B-2 years)	1-3 months	A	A	P	NS
2016.25	X	X	1st - 2nd c. AD	Infant (B-2 years)	2-3 months	P	A	P	NS
2011.08a	154	14, 44	3rd - 6th c. AD	Perinatal	~ 32-34 weeks	P	P	P	NS
2011.08b	132	13, 52	3rd - 6th c. AD	Perinatal	~ 34-40 weeks	P	A	A	NS
2011.02	63	25	3rd - 6th c. AD	Perinatal	~ 36-40 weeks	A	A	P	NS
2011.09	153	60	3rd - 6th c. AD	Perinatal	~ 36-40 weeks	P	A	P	NS
2011.10b	165	62	3rd - 6th c. AD	Perinatal	~ 38-40 weeks	P	A	P	NS
2011.11	143	58	3rd - 6th c. AD	Perinatal	~ 38-40 weeks	P	A	A	NS
2011.18	173	63	3rd - 6th c. AD	Perinatal	~ 38-40 weeks	P	A	P	NS
2011.26	271	87	3rd - 6th c. AD	Perinatal	~ 38-40 weeks	P	P	P	NS
2011.19	180, 214	67, 74	3rd - 6th c. AD	Perinatal	~ 40 weeks	P	A	P	NS

2011.06	47	22	3rd - 6th c. AD	Infant (B-2 years)	Birth-1.5 months	P	A	P	NS
2011.13	141	55	3rd - 6th c. AD	Infant (B-2 years)	<6 months	A	A	A	NS
2011.14	115	45	3rd - 6th c. AD	Infant (B-2 years)	<6 months	P	P	P	NS
2011.15	140	56	3rd - 6th c. AD	Infant (B-2 years)	<6 months	P	A	P	NS
2011.17	229, 232	5, 65	3rd - 6th c. AD	Infant (B-2 years)	<6 months	A	A	P	NS

For the Pathological Assessment (PH, CO, AbPo, LEH): (A) represents that the pathology was absent, (P) represents that the pathology was present, and (NS) represents that the pathology was not scored.

For the Find Number and SJ: (X) represents that this spatial reference was not recorded for the associated grave.

Data regarding other pathological indicators are excluded from this table given that they were not included in the analysis.