4-19-2022

Systemic Stress in Mid-Century American Military Service Members: The Impact of Socioeconomic Status and Military Service Length on the Human Skeleton

Brianna L. Petersen
University of Nebraska-Lincoln, bhumphrey2@unl.edu

SYSTEMIC STRESS IN MID-CENTURY AMERICAN MILITARY SERVICE MEMBERS: THE IMPACT OF SOCIOECONOMIC STATUS AND MILITARY SERVICE LENGTH ON THE HUMAN SKELETON

BY

Brianna L. Petersen

A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Arts

Major: Anthropology

Under the Supervision of Professor William R. Belcher

Lincoln, NE

March 2022

SYSTEMIC STRESS IN MID-CENTURY AMERICAN MILITARY SERVICE MEMBERS: THE IMPACT OF SOCIOECONOMIC STATUS AND MILITARY SERVICE LENGTH ON THE HUMAN SKELETON

Brianna Lynae Petersen, M.A.

University of Nebraska, 2022

Advisor: William R. Belcher

The purpose of this study is to identify how socioeconomic status (SES) and, separately, length of military service, may affect the human skeleton. Specifically, this study considers non-specific indicators of skeletal stress such as periosteal reactions, enamel defects, and skeletal porosity in a sample of World War II decedents. The Exact Logistic Regression test was used to examine the possible association between military service length and the presence of skeletal porosity and periosteal reaction, and Fisher's Exact Test of Independence was used to evaluate the relationship between SES and presence of enamel defects, skeletal porosity, and periosteal reaction. In total, this research examined five hypotheses. The study showed evidence that greater length of military service was associated with lower presence of periosteal reaction and that lower SES was associated with greater presence of periosteal reaction in this sample. This could be due to the economic security provided by the military and it could also be due to potential nutritional deficiency associated with low SES, respectively. Conversely, the Osteological Paradox is a phenomenon that may have affected this study sample. Finally, there are several avenues for future research with regards to non-specific indicators of skeletal stress, SES, and military service length.

ACKNOWLEDGEMENTS

There are so many to acknowledge and thank who have supported me throughout this journey. First and foremost, I would like to honor and thank the service members and their families for their sacrifice. Without them, this research would not have been possible. I would like to thank Dr. Emily Streetman for being a great mentor and helping me find and develop my passion for forensic anthropology. Without being in her Human Remains class during my undergraduate career and then later interning at the DPAA, I would probably not be here today. I am eternally grateful for her mentorship in general and especially with this project. I would like to thank Dr. Bill Belcher for his mentorship during the past three years in this program. Bill has been there for me and all of his students no matter what or when and I have learned so much from him. I am so honored to be one of his students and, even though I am graduating soon, I look forward to many more years of laughs and collaboration. I would like to also thank Dr. Brittany Walter for her willingness to share her expertise and help me hone in on my skills relating to non-specific indicators of stress. She has been a phenomenol mentor for the past several years and she has helped me deepen my passion for forensic anthropology. I would like to thank my husband J. Petersen for being a great support system as I tried to balance getting a master's degree while simultaneously working full time – all in a pandemic. He has been there for me through all of the ups and downs and I'm fairly certain that, at this point, he can name every bone in the body and maybe even side the bones too. There are too many more to individually thank, so I just want to take one more moment to shout out my support system and graduate cohort. You know who you are and I cannot thank you enough for supporting me on this endeavor.

TABLE OF CONTENTS

ABSTRACT .... **ii**
ACKNOWLEDGEMENTS .... **iii**
TABLE OF CONTENTS .... **iv**
LIST OF FIGURES .... **vi**
LIST OF TABLES .... **vii**
Chapter 1: Introduction **1**
Chapter 2: Review of Current Literature **9**
Formation of the Teeth, Skull, and Long Bones 10
Non-Specific Indicators of Skeletal Stress 12
Enamel Defects 12
Skeletal Porosity 14
Periosteal Reactions 21
Socioeconomic Status in the US during the 1930s and 1940s 23
Military Practice in the early 20th Century 26
Conclusion 29
Chapter 3: Materials and Methods **31**
Materials 32
The Skeletal Sample 32
Antemortem Information 33
Methods 36
Skeletal data 36
Skeletal Porosity 37
Periosteal Reactions 40
Enamel Defects 42
Socioeconomic Status Assessment 43
Military Service Length Assessment 45
Statistical Analysis 45
Chapter 4: Results **47**
Military Service Length Results 47
Socioeconomic Status Assessment Results 50
Chapter 5: Discussion and Conclusion **55**
Military Service Length Results Analysis 56

Socioeconomic Status Results Analysis 59
Conclusions and Future Directions 63
REFERENCES 70

LIST OF FIGURES

Figure 1: Homes of record of the study sample. 5
Figure 2: SES Index Options for NCVS from Berzofsky et al. (2014). 26
Figure 3: Porosity present on the vertebrae (left) & sacrum (right; Smith-Guzmán, 2015, p. 628). 38
Figure 4: Porosity present on the humerus (Smith-Guzmán, 2015, p. 628). 38
Figure 5: Porosity present on the femur (Smith-Guzmán, 2015, p. 628). 39
Figure 6: Example of abnormal periosteal new bone formation on the diaphysis of a right lateral tibia (Klaus, 2014, p. 295). 41
Figure 7: Presence of enamel defects in sample by years of military service. 58
Figure 8: Presence of skeletal porosity in sample by years of military service. 58
Figure 9: Presence of periosteal reaction in sample by years of military service. 59
Figure 10: Presence of enamel defects in sample by assessed socioeconomic status. 62
Figure 11: Presence of skeletal porosity in sample by assessed socioeconomic status. 62
Figure 12: Presence of periosteal reactions in sample by assessed socioeconomic status. 63

LIST OF TABLES

Table 1: Description of the research sample composition. 33
Table 2: Description of antemortem information and the sources for USS *Oklahoma* decedents. 34
Table 3: Description of antemortem information and sources for non-USS *Oklahoma* decedents. 35
Table 4: Description of expression reported in data collection procedures for skeletal porosity from Buikstra and Ubelaker (1994). 39
Table 5: Description of activity reported in data collection procedures for skeletal porosity from Buikstra and Ubelaker (1994). 40
Table 6: Description of extent reported in data collection procedures for periosteal reactions from Cook (1976, p. 317-318). 41
Table 7: Description of vascularization reported in data collection procedures for periosteal reactions from Cook (1976, p. 317-318). 42
Table 8: Description of the range of enamel defects. 43
Table 9: Socioeconomic Status Index 1 (Berzofsky et al., 2014). 44
Table 10: Final results of hypothesis testing. 47
Table 11: Description of sample's military service length in full years. 48
Table 12: Results of Exact Logistic Regression tests calculated in SAS Studio (2018). 48
Table 13: Types of skeletal porosity present in the research sample (some individuals presented with more than one type of porosity). 49
Table 14: Elements exhibiting periosteal reaction in the research. 50
Table 15: Description of Socioeconomic Status assessments for sample. 51
Table 16: Results of Fisher's Exact Test of Independence conducted in RStudio (2020) for Socioeconomic Status vs. incidence of non-specific indicators of skeletal stress. 52
Table 17: Prevalence of enamel defects by type in the study sample. 53
Table 18: Specific teeth that presented with enamel defects in the study sample. 54

Chapter 1: Introduction

Utilizing the human skeletal remains at the Defense POW/MIA Accounting Agency (DPAA) Offutt Air Force Base Laboratory and antemortem data, the goals of this research are to use a selection of visual-assessment methodologies for researching non-specific indicators of skeletal stress (specifically, enamel defects, skeletal porosity, and periosteal reactions) on remains of service members from WWII. I will examine the potential relationship between known non-specific indicators of skeletal stress, socioeconomic status (SES), and military service length in a random sample of identified WWII/Pearl Harbor (USS *Oklahoma*) casualties. Because the individuals in this sample lived through the Great Depression, I hypothesize that those with lower SES may have increased presence of non-specific indicators of skeletal stress, which are known to develop mostly during childhood, on their remains. This could be due to factors including, but not limited to, financial insecurity, malnutrition, illness, lack of access to healthcare, and trauma experienced during childhood.

The research sample consisted of skeletal remains that definitively had at least two factors in common: they all were service members in the US Military during the same time period and all died in the early 1940s. Due to the type of antemortem information I had access to at the DPAA Laboratory, I wanted to explore these commonalities. There are various factors that contribute to the development and presence of non-specific indicators of skeletal stress, and those can either be alleviated or potentially exacerbated by enlistment in the military. Particularly, enlistment in the military could have provided housing, financial, and food security. Alternatively, a potential increase in exercise from training could have led to overuse injuries, and nutritional standards used by the services may not have been acceptable for the service members to maintain skeletal health. The potential stability that the military was able to offer during this period of general socioeconomic hardship in the US leads me to hypothesize additionally that greater length of military service will cause a lower presence of skeletal porosity and periosteal reactions on the skeleton.

To better understand the development and presence of non-specific indicators of stress, it is helpful to have basic knowledge of the formation and development of the human skeleton and dentition. Dental development occurs from fetal development through about the age of 18 when the third molar emerges (White *et al.*, 2011). Although bone is a living tissue that remodels over time, teeth do not, which means that the enamel defects are a result of some type of growth disruption that remains visible on permanent dentition even decades later (Xiet *et al.*, 2009). Though some enamel defects can be caused by genetic conditions, they are commonly a result of malnutrition, deasease, illness, and more during childhood (Hillson & Bond, 1997). Because a variety of causes result in the same pathological marker, enamel defects such as linear enamel hypoplasia are referred to as non-specific. Nutritional deficiency and illness, demonstrated causes of enamel hypoplasia, can be consequences of low SES. It is important to note, however, environmental effects such as military service length cannot cause enamel defects, as these growth disruptions occur during childhood. Still, the prevalence of such defects in the military population may provide information for future research on recruitment efforts and enlistment patterns during the time of the Great Depression.

Skeletal development occurs over a slightly longer period, from early in fetal development, through early adult years. Full skeletal formation is usually reached at the fusion of the clavicle, around 21-24 years, so elements of the skeleton and teeth are in various stages of formation and maturity until that point (Langley, 2016). However, unlike dental enamel, bone as a tissue remodels over time. Thus, the activity of skeletal lesions assessed in this study may also be assessed. Active lesions are unremodeled lesions while healed lesions are remodeled and present rounded margins (DeWitte, 2014). The specific types of dental and skeletal data collected for this study are presented in greater detail in Chapter 3.

Generally, non-specific indicators of skeletal stress indicate that, during life, instances of trauma or systemic stress occurred. Systemic stress differs from psychological stress (though they can accompany one another) and, in this study, consider factors such as immune system threats as illness or disease and nutritional deficiency. One example of a non-specific indicator of skeletal stress is linear enamel hypoplasia, which can be indicative of circumstances such as infection, malnutrition, or other stress or trauma that was present and affected enamel growth during formative years. Additionally, skeletal porosity and periosteal reaction are also non-specific indicators of skeletal stress. Non-specific indicators of skeletal stress do not always present during formative years; some are a result of skeletal degeneration in adulthood due to a stress-event and some non-specific indicators of stress can present in either childhood or adulthood. These indicators can be differentiated from *specific* indicators of stress, where the resulting bony pathology is a direct result of a specific, known stress-event.

Malnutrition, disease, trauma, overuse injuries, and others may have caused non-specific indicators of skeletal stress on this research sample. Specifically, food insecurity, lack of access to healthcare, disease, and more may have affected those with low SES during childhood. Additionally, enlisting in the military may have offered nutritional security to the service members but potentially could have caused overuse injuries or other traumas that led to certain non-specific indicators of skeletal stress to present. As such, there are a variety of hypotheses to examine in this research:

1. Greater length of military service will be associated with lower presence of skeletal porosity.
2. Greater length of military service will be associated with lower presence of periosteal reactions.
3. Lower SES will be associated with greater presence of enamel defects.
4. Lower SES will be associated with greater presence of skeletal porosity.
5. Lower SES will be associated with greater presence of periosteal reactions.

The entire skeletal assemblage is unique, as it consists mainly of hundreds of young adults who grew up during the Great Depression, which was a large-scale global economic downturn, and who were killed during the attack on Pearl Harbor on December 7, 1941. Specifically, the sample includes the skeletal remains of 50 individuals. Of those 50 individuals, 37 individuals have associated data indicating SES during childhood, and 44 individuals can be used to assess military service length. Known age at death is used to determine whether the individual was in their formative years during the height of the Great Depression.

With this being a young military population, the individuals in the study sample came from all over the United States (Figure 1) and they may have faced economic hardship due to the Great Depression during their formative (skeletal growth) years. According to the Bureau of Labor Statistics, the peak rate of unemployment during the Great Depression is estimated to have been around 25% in 1933 (Dunn *et al.*, 2018). The known age at death of individuals in the study sample (n = 44) ranges from 18 to 44 years (median = 22 years), which would have been a range of approximately 10-36 years in 1933 (median = 14 years). The homes of record (officially declared home state or country) for 49 identified individuals in the study sample are shown in Figure 1 (five have yet to be identified and one has a currently-unknown home of record) and the individuals' or parents' trade/occupation collected from relevant US census data was considered.

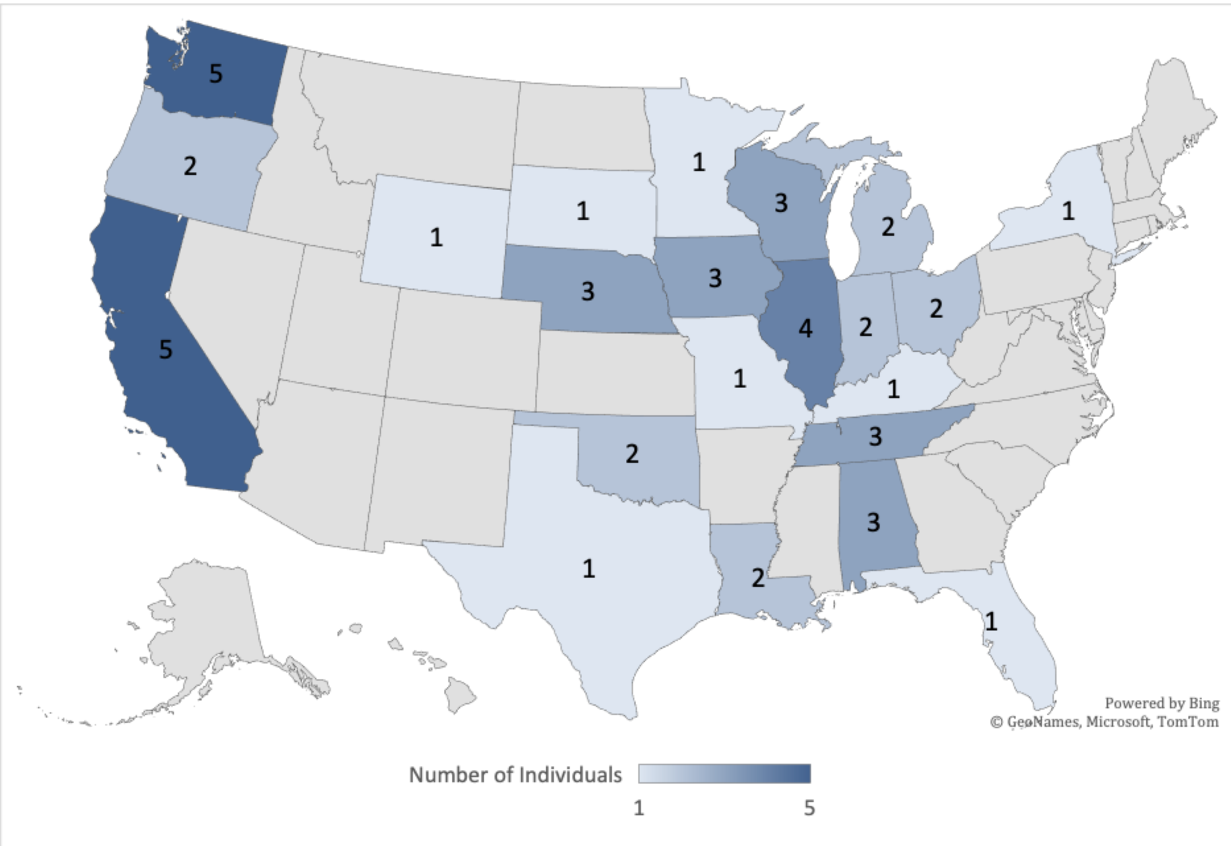

Figure 1: Homes of record of the study sample.

In addition to US census data, military records and scientific reports were used to acquire antemortem data, such as date of birth, home of record, household size, prior occupation, reason for enlistment, age at enlistment, military rank, age at death, and more. This information was collected from medical examiner reports, forensic odontology reports, historical reports of the respective fatality incidents, forensic anthropology reports, enlistment forms, DPAA case files, and other military forms. Anonymity of individuals' identities is maintained.

To make postmortem assessments, I used the scoring methods for skeletal porosity from Buikstra and Ubelaker (1994), an enamel defect data collection sheet inspired from Buikstra and Ubelaker (1994), and periosteal reaction scoring methods from Cook (1976).

One of the two facets of this research is assessing how SES and economic hardship may affect the human skeleton, which is relevant in today's economic and health trends. Though many individuals experienced low SES prior to the COVID-19 pandemic, there may be parallels of human skeletal stress associated with the current economic downturn and issues related to job loss, food shortages, and food insecurity from the pandemic. The US Bureau of Labor Statistics reports that unemployment rose from 4.4% in March 2020 to 14.7% in April 2020 ("U.S. Bureau of Labor Statistics", 2020). According to the Center for Infectious Disease Research and Policy, this is a level not seen since the Great Depression and the number of jobs lost is more than double the number from the 2007-2009 Great Recession (Soucheray, 2020).

As globalization and technology have advanced, access to all kinds of food regardless of season has increased through international and domestic trade programs. As such, evidence of certain deficiency diseases, such as scurvy, is less common in modern times (Agarwal *et al.*, 2015). In addition, as nutritional science has advanced, fortified food and water products and vitamin/mineral supplements have become more prevalent (Velandia *et al.*, 2008). This broader access to most types of food year-round may have a positive effect regardless of SES, though it is important to note that food insecurity is still a large issue in developed countries such as the US; the United States Department of Agriculture reported that approximately

10.5% of the total population in the United States experienced food insecurity in 2020 (Coleman-Jensen *et al.*, 2021). Though poverty conditions and other factors affect skeletal health in any period of time, this research may provide useful information for future studies on pandemic and post-pandemic effects on skeletal and overall physiological health.

Additionally, though training methods and nutrition guidelines may be different in today's military practices, a correlation may be found between non-specific indicators of skeletal stress and length of military service in this population. This is important for two reasons. First, I may be able to identify what kind of individuals were sought out for military recruitment and investigate further in future studies. Perhaps those from lower SES were more likely to join the military due to certain securities that were offered that may have been difficult to maintain during the Great Depression (food, housing, financial, etc.). Second, this research is important so that findings can be used in efforts to maintain the continued health and well-being of service members. As one example, it is possible that greater evidence of periosteal reactions in this sample may be due to overuse or trauma injuries from their military training.

Because this sample population is of military decedents at a forensic laboratory where the primary mission is identification, there are some obstacles and limitations. The mission of the DPAA is "to provide the fullest possible accounting for our missing personnel to their families and the nation" ("About DPAA", n.d.). Specifically, the efforts of this (and any) research cannot interrupt the main mission of the DPAA: to work to account for and identify service members. Consequently, this resulted in low sample sizes for this study. This research consisted of analyzing skeletal remains prior to medicolegal identification and while they were in the later stages of the identification process. This was done so that connections to antemortem information could be done quickly. This led to a relatively short timeframe to analyze the remains and document any pathologies before they were repatriated to loved ones.

I began this study by collecting antemortem data and postmortem skeletal data separately at the DPAA Laboratory prior to the individuals' identification. This is because, once identified, remains are sent home to loved ones and that process cannot be paused for research efforts. Once the antemortem and postmortem information was gathered, I worked to associate both sets of information to the relevant individual as soon as identifications were made (however, five individuals were not identified by the time that data analysis began). Using the antemortem information and the quantitative scale presented by Berzofsky *et al.* (2014), I assessed the SES of the individuals in the study sample. Additionally, I calculated the length of active military service for each individual. Using the skeletal material, I assessed the incidence and presentation of non-specific indicators of skeletal stress. Once the antemortem and skeletal data were collected and combined, I used statistical testing methods to examine whether relationships existed as specified in the hypotheses.

Because of the types of data and to test multiple hypotheses, two statistical methods were employed. First, I used the Exact Logistic Regression test to examine the possible association between military service length and the presence of skeletal porosity and periosteal reactions. Second, I used Fisher's Exact Test of Independence to examine the association of SES and presence of non-specific indicators of skeletal stress (enamel defects, skeletal porosity, and periosteal reactions). Following the statistical analysis, I elaborate on the results, discuss the results and the information they provide about the research sample and the hypotheses, and present ideas for future research based on the findings.

Chapter 2: Review of Current Literature

Non-specific indicators of skeletal stress have been studied in multiple geographic populations, largely those from prehistoric or medieval times. These pathological markers are caused by a variety of circumstances and can manifest as growth disruption during formative years or in degenerative ways during and beyond sub-adulthood. Non-specific pathological markers are distinct from *occupational* stress markers, the latter being specifically related to one's occupation and repetitive stress. Disease states lasting as few as four days can interrupt growth and present as markers on bone, and chronic stresses can have a permanent effect on growth and development of the skeleton (Buikstra & Cook, 1980). Indicators of stress have been largely prevalent during periods of economic hardship, which can cause financial instability and food insecurity (Wood, 1996; Smith-Guzmán, 2015; Wasterlain *et al.*, 2018). Though the literature mostly supports non-specific indicators of skeletal stress being caused by nutritional deficiency, trauma due to overuse has been attributed to instances of presence of certain pathologies (Detmer, 1986; Mubarak *et al.*, 1982). Additionally, some leisure activities, such as consuming alcohol and smoking, can influence bone health (Martínez-Lavín, 2020).

To understand how growth is disrupted and how bones degenerate, one must first have a basic understanding of expected formation and structure of the human skeleton. Following this overview of human bone growth and formation, the available literature is reviewed regarding non-specific indicators of skeletal stress (specifically, enamel defects, skeletal porosity, and periosteal reactions).

Formation of the Teeth, Skull, and Long Bones

Human dentition is heterodont and diphyodont; it consists of four tooth classes (incisors, canines, premolars, and molars) and undergoes two generations: deciduous come first and are then replaced by permanent (Hovorakova, 2018). Deciduous teeth begin to form before birth and erupt during the second year of life whereas permanent dentition begins to form at around 6 months and erupts from approximately age 6 to age 18 (White *et al.*, 2011, pg. 385-386). There are three periods of eruption for permanent dentition: permanent incisors and the first molar erupt anywhere from 6-8 years, most permanent canines, premolars, and second molars erupt between 10-12 years, and the third molar erupts at around age 18 (White *et al.*, 2011, pg. 385). While slight variation of teeth eruption is common, more significant delays can occur. Delays in permanent tooth eruption may be caused by genetic disorders, chronic malnutrition, gender, pre-term birth, socioeconomic factors, body height and weight, craniofacial morphology, endocrine disorders, and systemic diseases (Almonaitiene *et al.*, 2010),

The tooth formation process, beginning at the crown from the inside out and proceeding rootward, is separated into several steps: epithelial thickening, lamina stage, bud stage, cap stage, and then bell stage. In the advanced bell stage, enamel is formed by cells called ameloblasts in a process known as amelogenesis (White *et al.*, 2011, pg. 107). Enamel hypoplasia (presenting linearly or as pits) is an enamel defect that is a decrease in enamel thickness that results from a temporary disruption during amelogenesis (Al-Shorman *et al.*, 2014). Permanent tooth formation can be delayed, and is known to be delayed in children with disorders such as cleft lip and/or palate and oligodontia (Eerens *et al.*, 2001; Van Der Weide *et al.*, 1993). A delay in permanent tooth formation may also be due to nutritional deficiency issues (Esan & Schepartz, 2020).

Once teeth formation is complete, there is no mechanism for repair as there is in bone, described below. This means that enamel cannot undergo remodeling or change (except through wear or decay), so any damage or disruption in enamel formation is a permanent defect (Xiet *et al.*, 2009). In other words, enamel defects occurring in sub-adulthood because of trauma or systemic stress will remain present in adulthood. Stresses occurring after dental formation is complete cannot affect the enamel in the same way because there is no longer any growth occuring for a stressor to disrupt. Therefore, enamel defects provide a record of childhood stresses which is useful to researchers.

The skull is composed of two main structures: the neurocranium, which surrounds and protects the brain, and the viscerocranium, which forms the anterior facial portion of the skull (Jin *et al*., 2016). While the bones of the cranial vault are present at birth, they are not fully fused and do not achieve their final developmental stage until later in life. Similarly, the long bones of humans are not fully developed at birth. The basicranium (inferior region of the skull) and long bones begin as cartilaginous models and develop into bone when osteoblasts deposit bone around the cartilage shaft (White & Folkens, 2005). During growth, the long bone grows outward at the epiphyses (the ends), stretching away from the primary growth center (the diaphysis or shaft) of the bone (White *et al.*, 2011, pg. 38). Osteoblasts secrete collagen-rich osteoid (pre-bone tissue) and then hydroxyapatite crystals are deposited into the osteoid matrix. Once osteoblasts are surrounded by bony matrix, they mature into osteocytes, which maintain bone tissue (White *et al.*, 2011, pg. 37). As growth continues during formative years, osteoclasts remove old bone, and osteoblasts in the periosteum continue to deposit new bone until the epiphyseal (or growth) plate’s cells stop dividing, signaling the halt of the growth process (White & Folkens, 2005). Even when the growth process is halted, repair and remodeling of bone continues throughout life. Additionally, it is important to note that bones in the body do not all reach complete formation at the same time.

Non-Specific Indicators of Skeletal Stress

Enamel Defects

Enamel hypoplasia, a descriptive term, is a type of enamel defect resulting from a disruption to the enamel growth that occurs during tooth development and can affect either the primary dentition or the permanent dentition (Kanchan *et al.*, 2015). As such, the living conditions and life experiences of children must be considered when making assessments on these enamel growth disruptions. They are non-specific indicators of skeletal stress that can present as various types of linear disruption (bands), plane types, or nonlinear array of pits on the enamel (Ritzman *et al*., 2008). These defects can be seen on any tooth, though the most common sites are the incisors and the first molars (Kanchan *et al.*, 2015). As described previously, enamel defects present macroscopically as a decrease in enamel thickness that is a result of a stressor during childhood causing periodic disruptions to enamel matrix secretion (Ritzman *et al.*, 2008). Linear enamel hypoplasia in particular, these horizontal bands of decreased enamel thickness across the affected tooth, are particularly helpful to research. The location of these defects and the corresponding age at which the defect occurred can be determined, allowing researchers to reconstruct the timeline of metabolically stressful events that caused such defects (Ritzman *et al.*, 2008). Since enamel defects can be seen macroscopically in both the deceased and the living, this type of research can be conducted on both living samples and archaeological populations.

Animal studies have determined a variety of causes for enamel growth disruption, including nutritional deficiency and also illness. As reported by Hillson (2009, pg. 175), medical researchers experimented on and analyzed the teeth of dogs (beagles) and found that deficiency in vitamins A or D could cause enamel hypoplasia. Additionally, fever in pregnant rats caused a variety of enamel growth disturbances in their offspring. Similarly, rats were inoculated with pathogenic viruses and bacteria, and this resulted in enamel growth disruption (Hillson, 2009, pg. 175).

Few studies of enamel hypoplasia have been conducted on modern US samples. A study of a colonial-era skeletal sample from the US (individuals born in the early 18th-century) sought to identify the frequency and chronological distribution of enamel hypoplasia in the sample (Wood, 1996). Wood (1996) found that, of 44 individuals, 35 of those had one or more cases of enamel hypoplasia. When comparing these results to the prevalence of enamel hypoplasia in the Hamman-Todd collection (individuals born in early 19th- to early 20th-century US) and the Monroe County Poorhouse collection from Rochester, New York (individuals born in late 18th- and 19th-century US), the author found that the Hamman-Todd sample had the higher prevalence. The author concluded that the low prevalence of enamel hypoplasia in the colonial sample was likely due to an abundance of land and resources in early 18th century US. The increased prevalence in the Monroe County Poorhouse sample is likely due to the transition from agricultural-based to industrial-based society. This pre-industrial era was marked by rapid population growth in the United States due mainly as a result of European immigration. Additionally, as society was becoming more stratified, immigrants, labor workers, and people of color were oftten subject to business fluctuations, depressions, and unemployment (Wood, 1996). The American economy became increasingly dependent on fluctuating international trade, which caused several bouts of major depressions in the late 19th century and regular smaller depressions. This resulted in severe unemployment issues and intense poverty (Wood, 1996). Finally, the high prevalence of enamel hypoplasia in the Hamman-Todd collection could be reflective of the living conditions and fluctuating employment market in early 20th century US (Wood, 1996).

Skeletal Porosity

Skeletal porosity is a descriptive, non-diagnostic term that refers in this study to abnormal porosity of the human skeleton. This porosity manifests as varying degrees of pores in the bone, some presenting as smaller pin-prick-looking pores while some instances show larger and potentially coalescing pores in more severe cases. They can present as either active, mixed, or healed lesions. When an individual's remains present sharp, active lesions, it shows that the bone had not yet been remodeled whereas smooth, healed lesions are evidence of bone remodeling; mixed lesions are a combination of the two (Buikstra & Ubelaker, 1994, pg. 121). There are various forms of abnormal skeletal porosity that are classified as non-specific indicators of skeletal stress. In this research, I examine porotic hyperostosis, cribra orbitalia, cribra femoris, cribra humerus, porosity of the greater wing of the sphenoid, and porosity of the internal aspect of the ascending ramus. Presence of porosity can be recorded as well as the expression of the porosity and the activity of the lesions.

Porotic hyperostosis, more rarely known as cribra cranii, is defined to be areas of pitting and pores on the external surface of the cranial vault while cribra orbitalia is the same degeneration occurring instead on the internal upper eye orbits (Walker *et al.*, 2009). These lesions result from spongy-bone expansion as a response to hypertrophy of blood-forming tissue within the cranial vault (Buikstra & Ubelaker, 1994, pg. 120; Walker, *et al.*, 2009). Active lesions are far more prevalent in younger individuals, though they have been observed in adults (Fairgrieve & Molto, 2000; Facchini *et al.*, 2004; Jacobi & Danforth, 2002). Iron deficiency anemia has been both supported (Stuart-Macadam, 1992; Walker, 1986) and rebutted as the cause of porotic hyperostosis and cribra orbitalia over the past several decades. More recent research has *not* supported the hypothesis that iron deficiency anemia is the sole cause of porotic hyporostosis and cribra orbitalia (Walker, 2009; Rothschild *et al.*, 2022; Brickley, 2018). Though it is certainly possible for anemia to result in porous lesions of the cranial vault (porotic hyperostosis) and of the orbital roof (cribra orbitalia), it must be noted that other conditions can also potentially cause this degeneration, hence its recognition as a *non-specific* indicator of skeletal stress (Brickley, 2018).

Some (Angel, 1964; Angel, 1966; Angel, 1967; Angel, 1972; Zaino, 1964) have argued that specific genetic conditions (such as thalassemia and sickle cell disorder) have influenced the presence of these skeletal lesions; however, Smith-Guzmán (2015) argues that it is much less likely to be caused by genetic conditions and is instead more likely caused by the individuals' environmental and socioeconomic factors such as poverty and diet. A deficiency of vitamin B_{12} in the diet, which is found mostly in animal products like meat, eggs, and dairy, is likely a key component in the presence of porotic hyperostosis and cribra orbitalia (Stabler, 2013; Walker *et al.*, 2009). Children can be deficient in vitamin B_{12} thorugh decreased intake, abnormal absorption, and inborn errors of transport and metabolism of the vitamin (Rasmussen *et al.*, 2001). Information about the prevalence of this deficiency in the United States is limited, however, a 2001 US study found that B_{12} deficiency may be more common than previously recognized. Normal levels range from 200 to 900 pg/mL, and their study found that out of 3766 children, three children had levels less than 100 pg/mL and 18 children (a frequency of 1 in 200) had levels less than 200 pg/mL (Rasmussen *et al.*, 2001). A higher frequency of B_{12} deficiency has been seen in countries with lower intake of animal products, and due to the food access issues caused by the Great Depression, this may have been a reality for the study sample (Rasmussen *et al.*, 2001).

Cribra (porous lesions) can also be found in the proximal humerus and femur; these pathologies are known as cribra femoris and cribra humerus. While cribra orbitalia and porotic hyperostosis have been heavily researched,the same unfortunately cannot be said regarding cribra femoris and cribra humerus. Some research has linked cribra orbitalia and these post-cranial cribrous lesions, so cribra humerus and cribra femoris will be recorded if present in this study (Schats, 2021). In Schats (2021), a study comparing the prevalence of the three types of cribra, they discovered that cribra femoris was most frequently observed. Additionally, they discovered that all cribrotic lesions are more commonly found in non-adults compared to adults (Schats, 2021). Cribra femoris and cribra humerus are associated with deficiency diseases such as iron deficiency anemia, rickets (vitamin D deficiency), and scurvy (vitamin C deficiency) in addition to non-specific infections or stresses (Wasterlain *et al.*, 2018). One must be diligent and cautious in observance of cribra femoris; some studies score cribra femoris as non-metric traits such as Allen's fossa. Cribra femoris and Allen's fossa are found on the same location of the femoral neck, but in the case of cribra femoris, the area on the femoral neck is convex without any cortical bone margins visible while Allen's fossa presents as a concave region with cortical bone margins (Göhring, 2021). Though no studies on the prevalence of cribra humerus and cribra femoris have been conducted yet on an American sample, food insecurity associated with the Great Depression may have led to vitamin deficiency, which may in turn have resulted in these lesions in the study sample.

Presence of porous lesions on the greater wing of the sphenoid bone and the internal aspect of the ascending ramus have both been associated with scurvy, which is a result of malnutrition (Pitre *et al.*, 2016). Scurvy is caused by an inadequate amount of vitamin C in the diet; vitamin C is found in foods such as citrus fruit, broccoli, cauliflower, kale, etc. (Brand *et al.*, 1982). In a modern American sample, all children with vitamin C deficiency had underlying medical conditions such as thalassemia, sickle cell anemia, neurologic disorders, and bone marrow transplants/chemotherapy; no children had scurvy from dietary deficiency alone (Golriz, 2017). Despite this recent study, a separate study of data from the late 20th century found that a considerable number of US children and adults were deficient in vitamin C at that time (Hampl *et al.*, 2004). This means that it is possible that vitamin C deficiency was prevalent during the Great Depression when access to nutritious food was affected. The porous lesions (a bone tissue reaction) are thought to be caused by chronic inflammation associated with bleeding (due to trauma in muscle contraction and the formation of abnormal blood vessels) and the "unusual anatomical relations of the branches of the maxillary artery" (Ortner & Ericksen, 1997, p. 213). While it is possible that scurvy can influence the human skeleton without the presence of porotic lesions on the greater wing of the sphenoid, it is uncommon (Ortner *et al.*, 2001). Additionally, researchers note that a classic indicator of scurvy in the skeleton is increased porosity around the temporomandibular joint, which includes regions of the mandibular ramus (Zakrzewski *et al.* (2015).

In a study of individuals from the Great Irish Famine (1845-1849), who were diagnosed with scurvy during life, the presence of active porotic lesions on the greater wings of the sphenoid was observed in 8.01% of the sample from birth to 17 years of age and only 4.64% of the sample aged 18 years and older (Geber & Murphy, 2012). Additionally, in a study of the remains of an ancient Egyptian child, authors disovered periosteal reactions and abnormal porosity of the greater wing of the sphenoid, internal aspects of the mandibular rami, eye orbits, and other regions. The authors indicated that several issues could have led to such porosity, but scurvy was the most likely cause of the skeletal lesions in this case (Pitre *et al.*, 2016).

A notable trend in the literature is the focus on skeletal manifestations (active lesions) of infantile scurvy. Ortner *et al.* (2001) state the prevalence of scurvy cannot be compared in children because of the high infant and early childhood mortality expected to be found in their archaeological cemetery sample. However, age has been stated as a factor in other studies. Other reviews of the effects of the disease have found skeletal evidence of scurvy is expected to be the highest during infancy and early childhood because of the rapid proportionate growth that happens during this time; the likelihood and rate of defective blood vessel formation (which causes the level of bleeding associated with scurvy) is higher in this age group (Brickley & Ives, 2006).

The Osteological Paradox by Wood *et al.* (1992) contests the inference of health from archaeological skeletal samples. This work discusses three fundamental conceptual problems: demographic nonstationarity, hidden heterogeneity in the risks of disease and death, and selective mortality. Demographic nonstationarity is when a population is not stationary. A stationary state would mean that migration is closed, there is constant and age-specific fertility and mortality, there is zero growth rate, and there is an equilibrium age distribution. The United States consists of an ever-changing, nonstationary population and the study sample therefore was likely derived from a population that experienced growth or decline due to migration and changes in fertility and mortality – though this may have been reduced during the Great Depression. Selective mortality and hidden heterogeneity in risks affect historical health research more directly than considerations of demographic nonstationarity (DeWitte & Stojanowski, 2015).

Hidden heterogeneity in risks means that the population from which a skeletal sample comes from consists of a mixture of individuals whose frailty, or susceptibility to disease and death, is varied (Wood *et al.*, 1992). The heterogeneity in susceptibility can be due to differences in socioeconomic factors, genetic causes, microenvironmental condition variation, and more.

When there is such variation in frailty or susceptibility to death and disease, it affects the accuracy of individual risk in analyses. DeWitte & Stojanowski (2015) claim that potential sources of heterogeneity, such as sex or social status, can be identified and controlled for in order to overcome this issue to some degree. However, *hidden* heterogeneity discussed by Wood *et al.*, (1992) adds a layer of difficulty in that there are some variations in frailty that cannot be directly observed on a skeletal sample and controlled for. In the study sample, factors such as biological sex and socioeconomic status can be assessed and estimated, respectively, there are certain factors that cannot be known or observed, such as conditions that do not present on the skeleton but affected an individual's health, and therefore contribute to this concern noted in the Osteological Paradox. Though the sample consists entirely of military service members and their health was assessed prior to their continuation in service, there may have been individuals with health issues that were mistakenly overlooked or not known due to other factors.

The third concern in the Wood *et al.*, (1992) Osteological Paradox is selective mortality. This refers to the fact that individuals who die at a specific age are not likely to represent the entire living population and, instead, individuals with higher frailty at a specific age are more likely to die at that age and therefore be selected out of the population and enter a skeletal assemblage (DeWitte & Stojanowski, 2015). This further means that frequencies of non-specific indicators of skeletal stress in skeletal assemblages cannot be used to assess the prevalence of the lesions in an entire population because it would lead to an overestimation of such conditions that led to non-specific indicators of skeletal stress. The study sample in this research were all killed as members of the US military and thus did not die prematurely as a result of high frailty. DeWitte & Stojanowski (2015) claim that skeletal samples of individuals who died under catastrophic conditions and not due to poor health cannot be assumed to provide unbiased samples of all people who were alive because they may have had conditions that impacted their ability to protect themselves or flee. However, the study sample in this research consisted of 96% of individuals who died onboard the USS *Oklahoma* during the attack on Pearl Harbor, one man (2% of the total sample) died in an aircraft crash, and one man (2% of the total sample) was killed in action in Germany during World War II. US military service members are assessed for acceptable physical condition before being allowed to proceed with their service, making this sample potentially less biased than other samples who died due to non-health-related incidences. Additionally, the majority of the study sample was onboard the USS *Oklahoma* when they died, and there were very few survivors due to the nature of the attack making it very difficult to escape even for those in great physical shape.

Porotic hyperostosis, cribra orbitalia, cribra femoris, cribra humerus, porosity of the greater wing of the sphenoid, and porosity of the internal aspect of the ascending ramus have all been associated with non-specific stresses as described. Though it is well established that each of these types of porotic lesions are unique, several studies have observed multiple lesions on a single individual and have suggested that they may share a common cause. Namely, porosity of the greater wing of the sphenoid, sphenoid body, and the internal aspect of the ascending ramus have been associated together in studies of scurvy (Ortner *et al.*, 1999; Snoddy *et al.*, 2018; Pitre *et al.*, 2016). Similarly, cribra orbitalia, cribra humeri, and cribra femora have been observed and assessed together related to malaria, nutritional deficiency, and anemia (Smith-Guzmán, 2015; Schats, 2021). Also, cribra orbitalia and porotic hyporostosis have been observed at the same time and discussed together in studies of nutritional deficiency (Brickley, 2018; Stuart-Macadam, 1985; Walker *et al.*, 2009). Though, again, they are each unique pathologies, they all share a commonality: their established association with issues relating to deficiency.

Periosteal Reactions

Periosteal reaction is generally defined as abnormal bone formation on the outer surfaces of bone (Ortner, 2003, pg. 51). The periosteum is a thin tissue that nourishes bone and it is located on the outer surfact of bones. This tissue penetrates the surface of bone in some locations and some of the fibers also interwine with tendons in order to anchor muscles to bone (White *et al.*, 2011, pg. 34). As stated previously, osteoblasts maintain their presence throughout life even past growth stages for purposes of remodeling and repairing bone. When an insult leading to a periosteal reaction occurs, the periosteum (whose inner layer retains osteoblasic capacity) reacts by forming abnormal bone. The morphology of this formation is reflective of the type of pathology that is stimulating the growth of new bone (Ortner, 2003, pg. 206).

Periosteal reaction is a descriptive term rather than a diagnosis for a disease or illness. While enamel hypoplasia and the porosities are mostly, if not entirely, associated with environmental factors such as nutrition and disease, periosteal reaction may be caused by a combination of genetic and environmental factors (Whitehouse, 2007). Periosteal reactions can be observed in a variety of ways on the bones: they can present with varying degrees of thickness and elevation, surface irregularity, reactive bone deposits, uneven hypervascularity, etc.

One of the most common sites of periosteal reaction is the diaphysis of the tibia, though it has been observed on other bones such as the skull, femur, ulna, and more (Ortner, 2003, pg. 207, 209). According to Cook (1976, pg. 317-318), periosteal reactions can be recorded by the extent and also the vascularization of the pathology. In other words, one should observe how much of the bone the periosteal reaction affects along with how much it may be elevated off of the bone and its formation, whether with striae and/or foramina. Cook (1976) refers to the small holes in a periosteal reaction as foramina, though pits may be a more appropriate term.

Additionally, the anatomical location of the pathology should be noted as well as whether it is focal or diffuse and whether it is woven, sclerotic, or mixed,

Christensen *et al.* (2011) note that a variety of potential diagnoses could be made based on observations of periosteal reactions. Hypertrophic Osteoarthropathy (HOA) is a clinical syndrome that is characterized by presence of clubbing on the fingers and toes, arthritis, and periosteal proliferation of the tubular bones in a bilateral and symmetric fashion (Christensen *et al.*, 2011). It is important to note that many cases in the modern era of HOA are a result of lung cancer due to smoking, cyanotic heart disease, or liver cirrhosis that can be caused by overconsumption of alcohol (Martínez-Lavín, 2020). These practices are stereotypically associated with leisure time in active military personnel and life overall in the early to mid-20th century. According to the Centers for Disease Control (CDC), there was a steady rise of annual adult per capita cigarette consumption from 1900 to around 1965. Cancer concerns heightened beginning in 1950 through1965 with the eventual first Surgeon General's Report publication in 1964 ("Centers for Disease Control", 1999). Additionally, scurvy has been known to lead to periosteal reaction due to the fact that the disease is accompanied by widespread subperiosteal bleeding (Ortner, 2003, pg. 89). Non-specific inflammatory processes such as periostitis and hematogenous osteomyelitis have also been known to cause periosteal reactions (Ortner, 2003, pg. 91).

Overuse injuries can also cause periosteal reactions in addition to other types of physiological stress like severe illness. Medial tibial stress syndrome (commonly referred to as shin splints) is a trauma-response injury that an individual can treat and recover from (though it can be chronic). Shin splints are an overuse injury caused by a rapid increase in exercise intensity, repetitive and strenuous physical activity, or an increase in the duration of impact activities (Detmer, 1986; Mubarak *et al.*, 1982). Being involved in military training exercises can introduce an individual to an increased rate of exercise than what they may have practiced in their lives prior to military service, therefore leading to overuse injuries such as shin splints.

Socioeconomic Status in the US during the 1930s and 1940s

The Great Depression began at the end of the 1920s and significantly impacted the United States. At the height of the depression in 1933, unemployment rose to 25% and remained above 15% for the rest of the 1930s (Temin, 1994). This job loss and insecurity caused starvation, homelessness, farm liquidation, and other economic hardships. The National Bureau of Economic Research shows that, among seven samples of classes of industry, the percent change in average per-capita weekly earnings between 1929 and 1932 was between -3.3% and -44.9% (Wolman, 1933).

In addition to the Great Depression, the Dust Bowl was a separate but also devastating event to American farmers that occurred during the 1930s (Schubert *et al.*, 2004). During this time, the southwestern Great Plains region of the United States suffered severe drought conditions, causing bare, destroyed farmlands. As a result, the winds picked up the dust from the over-farmed land and created large dust storms, sometimes darkening the skies for days and infiltrating homes with thick layers of dust. Because of the conditions and the inability to make a living farming, many families abandoned their homes and land and fled toward the western United States in hopes of finding jobs ("Library of Congress", n.d.). The Dust Bowl began in 1931 and was the first of four major drought episodes that occurred throughout the decade (one in 1930-1931, the second in 1934, the third in 1936, and the last in 1939-1940. In 1941, most affected areas of the country had began to receive near-normal rainfall, ending the Dust Bowl ("The dust bowl", n.d.)

According to the Office of Behavioral and Social Sciences Research from the National Institute of Health, there is no single agreed upon definition of socioeconomic status (SES); some have identified it as being a combination of measurable traditional factors such as education level, income, and occupation, while others have indicated the important inclusion of gender, population affinity (race/ethnicity), etc. (Oakes, 2012). Income is typically measured with reference to the official federal poverty line and sorted into low-, medium-, and high-income categories, education is considered to provide lifetime earning potential information, and occupation is another ranked consideration (like income) to measure information regarding an individual's power, income, and also educational requirements associated (Berzofsky *et al.*, 2014). These factors can be measured at the individual, family, or household level. In my research, most of the decedents entered the military from living with their family of origin. Thus, family factors will largely be measured except in a few situations where individuals were older and therefore not listed under a parent or guardian on the 1930 US census. Note that because there are limitations to the antemortem evidence available for this study, some data could not be collected. Notable factors affecting SES that cannot be considered here are accumulated wealth/assets and status in marginalized communities.

A team of statistical, sociological, and social science experts at RTI International made recommendations on how to measure socioeconomic status (SES) to the US government (by request and funded by the Bureau of Justice Statistics in the US Department of Justice). They considered well-known measures of (SES) and developed three indexes to measure SES on a range of 0-8, 0 indicating low SES and 8 indicating high SES; Index 1 (Figure 2) is used here because it allows analysts to observe a measure of assets of sample individuals. Specifically, it measures education level, income as a percentage of the Federal poverty level, employment information, and housing information (Berzofsky *et al.*, 2014) The difference between the three indexes is specifically regarding housing; Index 1 considers information on rental and ownership status, Index 2 considers information on public vs. non-public housing, and Index 3 does not include housing information at all, therefore reducing the possible SES assessment range from 0-8 to 0-7 in Index 3. Index 1 was selected for use in this study because rental or ownership status could be found from the US census. Index 2 considers public vs. nonpublic housing information, which could not be collected for this study, rendering it inappropriate for use in this case. Importantly, this model does not consider other factors that may affect one's SES. As one example, Black families experience socioeconomic disadvantages due to the adverse effects of racism, segregation, and inequality (Beck *et al.*, 2020).

In the 1930s there were socioeconomic trials that affected food accessibility. Harper (1985) reviewed dietary standards from the 1860s to just after World War I and described them as being "proposed initially as a guide for preventing scurvy, then for preventing diseases associated with starvation, then to feed the army and the nation, then to maintain health and working capacity, then to marry health and agriculture, and finally, to maintain 'perfect' health" (Harper, 1985, p. 147). This observation speaks to the economic trials of this time having an effect on nutrition statuses and diets of many American families. Because of the vastly reported economic hardship that affected food security as well as a general lack in standards for nutrition compared to what we see today, evidence of malnourishment-related non-specific indicators of skeletal stress may be observed in the study sample.

Measures	Index 1	Index 2	Index 3
Education	▪ 0: Less than high school ▪ 1: High school, some college, associate's degree ▪ 2: Bachelor's degree ▪ 3: Master's, professional, doctorate degree Possible range: 0–3	▪ 0: Less than high school ▪ 1: High school, some college, associate's degree ▪ 2: Bachelor's degree ▪ 3: Master's, professional, doctorate degree Possible range: 0–3	▪ 0: Less than high school ▪ 1: High school, some college, associate's degree ▪ 2: Bachelor's degree ▪ 3: Master's, professional, doctorate degree Possible range: 0–3
Income (percentage of Federal poverty level)	▪ 0: 100% or less ▪ 1: 101%–200% ▪ 2: 201%–400% ▪ 3: 401% or greater Possible range: 0–3	▪ 0: 100% or less ▪ 1: 101%–200% ▪ 2: 201%–400% ▪ 3: 401% or greater Possible range: 0–3	▪ 0: 100% or less ▪ 1: 101%–200% ▪ 2: 201%–400% ▪ 3: 401% or greater Possible range: 0–3
Employment	▪ 0: Unemployed past 6 months ▪ 1: Employed past 6 months Possible range: 0–1	▪ 0: Unemployed past 6 months ▪ 1: Employed past 6 months Possible range: 0–1	▪ 0: Unemployed past 6 months ▪ 1: Employed past 6 months Possible range: 0–1
Housing	▪ 0: Rent or no cash rent ▪ 1: Own Possible range: 0–1	▪ 0: Public housing ▪ 1: Non-public housing Possible range: 0–1	Not included
Possible range	0–8	0–8	0–7

Figure 2: SES Index Options for NCVS from Berzofsky et al. (2014).

Military Practice in the early 20th Century

Nutritional research for the US military was formalized in 1917 by the Food Division of the Surgeon General's Office (Murlin & Miller, 1919). Murlin & Miller (1919) conducted a nutritional survey in 385 training camp messes and found that the average consumption per man per day was 3,560 calories. They estimated that an additional 365 calories was consumed from optional canteen purchases. Their final estimation was that men in training messes consumed around 3,925 calories per day. Despite this estimation, Murlin & Miller (1919) note that more food was typically consumed during cold weather months and less food was consumed by new recruits, likely because of homesickness and initial distaste for the cooking and menu. Specifically, the authors found that new recruits consumed, on average, 3,275 calories per day, while recruits who have been in camp for three or more weeks average 3,750 calories per day. After Murlin & Miller (1919) concluded their nutritional survey, they made the recommendation that an enlisted man should consume 3,898 calories per day (Murlin & Miller, 1919). In this caloric intake, they recommended that 12.5% of the calories should be from protein, 25% should come from fat sources, and 62.5% was to come from carbohydrates.

Observations of poor nutritional status of enlisting soldiers were made and deficiency diseases such as beriberi, polyneuropothy, and pellagra were reported in the Annual Reports of The Surgeon General, US Army between 1921 and 1939 (Pollack, 1963, p. 231-232). Beriberi is a deficiency disease in thiamine (vitamin B_1) which is found in whole grains, meat, and fish and is also associated with chronic alcoholism ("U.S. Department of Health", 2015; Jones Jr., 1959). Polyneuropathy is a disorder of the peripheral nervous system in adults and is caused most commonly in North America by diabetes. Additionally, among those with chronic alcoholism, 22-66% of individuals had alcohol-associated polyneuropathy (Köller *et al.*, 2005). Pellagra is a nutritional deficiency disease specifically related to insufficient levels of niacin (vitamin B_3) which is found in meat products and was mostly present in the South in the early 20th century. The disease reached its peak in 1928 and fell to a very low rate once bread, flour, and corn products were mandated to be enriched with niacin (Clay *et al.*, 2019).

Pollack (1963) also noted (from a 1944 article by the same author) that there was a failure of the military to comprehend that nutrition for troops, in order of importance other than water, was caloric supply, protein supply, and then micronutrient supply. To continue research, a series of ration tests were conducted on soldiers in 1941 to evaluate their efficiency and suitability. An increase in workload from 3,400 calories expended per day to 4,000 calories expended per day without an increase in food was commenced and results such as weight loss, muscular deterioration, dull eyes, fatigue, tremors, mood destabilization, and eventual exhaustion and collapse were reported (Pollack, 1963, p. 236). Though these observations were made, no report on the internal effects other than muscular deterioration were made.

Starting in 1919, medical professionals and high-ranking military officials reported and complained of nutritional deficiency. Finally, in 1940, the Surgeon General developed the Food and Nutrition Subdivision. From that point on, clinicians were appointed to the Food and Nutrition Subdivision. As early as January 1941, education on food and nutrition was given in the Army Medical School in Washington, D.C. (Pollack, 1963, p. 234). Despite this attention, the recommended improvements made in early 1941 may not have been implemented by late 1941, when most of the sample died. Instead, because the study sample enlisted from 1916 to 1942 with the majority enlisting in 1940, the sample was likely affected by the original, unsatisfactory nutritional standards.

In June 1940, President Franklin D. Roosevelt signed the second Naval Expansion Act into law, which increased the Navy's budget by 70% ($4 billion) and was one of the largest procurement bills in the history of the US Navy ("United States Statutes at Large", 1999). As a result, enlistment in the Navy from 1940-1941 increased by 76.5%, a considerable jump from the 1939-1940 increase of 28.6% ("World War II Museum", n.d.). Of the service members in the study sample with a known date of enlistment, 50% (17 out of 34) enlisted in 1940. An advantage to joining the military during this time in US history was economic security and stability - including nutritional needs. Additionally, Sampson & Laub (1996) argue that military service in the World War II era fostered-long term socioeconomic achievement; they showed that military service and training from the ages of 17-25 generally enhanced occupational job status, job stability, led to lower recidivism rates, and contributed to economic well-being despite potential childhood differences and socioeconomic background. This occurred mainly due to on-the-job training and further education. This article specifically discusses the positive impact of the GI Bill, but this was not put into law until 1944, after the study sample had died.

Additionally, the authors argue that overseas service was enticing to men at this time as it gave previously-sheltered men an opportunity to see the world and experience individuals different from themselves.

Conclusion

This review detailed the processes of dental and skeletal formation as well as the literature surrounding skeletal porosity, enamel defects, and periosteal reactions, which are non-specific indicators of skeletal stress. Enamel defects and skeletal porosity tend to affect children more than adults; they are associated with nutritional deficiency and other systemic stresses. Specifically, enamel defects are associated with vitamin A and vitamin D deficiency and illness. Evidence of enamel defects that formed during childhood may appear in adults because enamel cannot remodel. Therefore, enamel defects are permanent insults. Skeletal porosity has been associated with vitamin B12 deficiency, vitamin C deficiency (scurvy), vitamin D deficiency (rickets), and iron deficiency anemia. Periosteal reaction can occur in adults and is often associated with genetic conditions, vitamin C deficiency (scurvy), trauma, and illness.

Both skeletal porosity and periosteal reaction can either show as active or healed lesions on the bone. If skeletal porosity appears as healed in adults, which is most likely to be the case, it reflects that there was likely nutritional deficiency in childhood. When periosteal reaction appears healed in adults, it also shows that the insult occurred and the body was able to heal the lesion prior to death. When the lesions are active, which may result from ongoing environmental conditions following enlistment, including overuse and nutritional deficiency, it shows that the body was not able to heal the lesion before death.

Although SES is difficult to quantify, this study uses education, income, employment, and housing data, which contribute to Index 1 from Berzofsky *et al.* (2014). Individuals from the study sample were alive and some were in their formative years during the Great Depression and Dust Bowl, which affected the country at large both economically and related to food production/accessibility. Quantifying individual SES allows me to compare the presence of non-specific indicators of skeletal stress in the study sample to their respective SES and determine whether there is any association.

Finally, nutritional standards in the decades leading up to the death of the service members in the study sample were reviewed. Prior to 1941, the diet of service members was likely insufficient. Although nutritional education from the Food and Nutrition Subdivision was given to the Army Medical School in Washington, D.C., in early 1941, any recommended improvements may not have impacted the service members in the sample study before their death in late 1941.

Chapter 3: Materials and Methods

This chapter details the materials and methods used to test the following hypotheses:

1. Greater length of military service will be associated with lower presence of skeletal porosity.
2. Greater length of military service will be associated with lower presence of periosteal reactions.
3. Lower SES will be associated with greater presence of enamel defects.
4. Lower SES will be associated with greater presence of skeletal porosity.
5. Lower SES will be associated with greater presence of periosteal reactions.

The hypotheses posit relationships between non-specific indicators of skeletal stress (specifically, enamel defects, skeletal porosity, and periosteal reactions), military service length, and socioeconomic status (SES). The materials consist of skeletal remains from the Defense POW/MIA Accounting Agency (DPAA) Laboratory and the antemortem information for those individuals. Antemortem information is derived from military records, including enlistment records, and documents that shed light on service members' lives prior to enlistment in military service. The methods used for scoring methodologies for non-specific indicators of skeletal stress are detailed. Further, descriptions are provided of the index used to quantify SES and the calculation of military service length. Finally, the statistical analyses conducted for each hypothesis are presented.

Materials

The Skeletal Sample

This analysis of skeletal remains was conducted at the DPAA Laboratory at Offutt Air Force Base, Nebraska. The majority of the remains utilized are casualties from the USS *Oklahoma* (that died in 1941) while two decedents represent other WWII-related casualties (that died in 1943 & 1944). The attack on Pearl Harbor in Hawai'i occurred on December 7, 1941, where the USS *Oklahoma* was hit by Japanese torpedoes and severely damaged, eventually causing the ship to capsize. On the USS *Oklahoma*, 429 individuals (415 US Navy and 14 Marines) were killed, which was the second-largest amount of casualties after the USS *Arizona* (Brown, 2019). In 2003, when a single casket believed to hold five individuals was disinterred for identification, the immensely-commingled state of the remains of the unknowns was revealed; DNA testing concluded that the remains in the first casket to be disinterred represented a minimum of 25% of the 429 total casualties in the USS *Oklahoma* (Brown, 2019). The project was put on hold and commenced again in 2015 (Brown, 2019). In April 2020, 333 unaccounted for service members had been successfully identified (Oettel, 2021, pg. 26) and by the end of 2021, the project was completed ("USS *Oklahoma* Sailors", 2021).

For this research project, unknown individuals in the last stages of the DPAA identification process were analyzed so that they could be more quickly associated with antemortem evidence. Fifty-five total skeletons of varying degrees of completeness were analyzed. Of these, 50 were identified prior to analysis while five have no name association and are, therefore, not included in the analyses (Table 1). Availability of the relevant elements, the skull and long bones, were considered when filtering and selecting skeletons to use in this study. Additionally, stage in the identification process was a consideration, where those in the later stage were preferred for antemortem information and connection needs. Lastly, ease of acess for analysis, as to not disrupt forensic anthropologists' work, was considered.

Table 1: Description of the research sample composition.

Known skeletons from *USS Oklahoma*	48	Total Skeletons = 55
Known skeletons from other WWII casualty events	2	
Unknown skeletons (not used in analyses)	5	
Skeletons used in SES Study	37	
Skeletons used in military service length study	43	

<u>Antemortem Information</u>

Most of the antemortem data needed for this study was associated with the remains by the DPAA during the process of identification. At the time of identification of a service member, the DPAA creates and maintains a case file consisting of medical examiner reports, forensic odontology reports, historical reports, forensic anthropology reports, enlistment forms, and other relevant personnel records. These case files are compiled into a bound book referred to as the Identification Packet, which is made available to the next of kin and also kept by the DPAA.

As outlined in Table 1, some individuals in the sample were excluded from the final analyses because sufficient antemortem information could not be acquired.Tables 2 and 3 list the personal information that was gathered and the specific forms the information was gathered from. Date of birth and date of loss was used to calculate the individuals' age at death. Date of birth was also used with date of enlistment to calculate the individuals' age at first enlistment. Date of first enlistment and date of loss was used to determine total military length. The individuals' home of record, which is a military term indicating home state location, was used to find regionally accurate income estimations by referencing documents from the US Bureau of Labor Statistics. Additionally, the highest educational grade completed was used for SES consideration and next of kin information was used to verify data on the US census (described in more detail below).

Table 2: Description of antemortem information and the sources for USS Oklahoma decedents.

Form/File/Report Type:	**Information:**
NRB Form No. 24 (revised)	● Full name ● Date of birth ● Home of record ● Highest educational grade completed ● Next of kin
DPAA Service member Profile	● Military rank
N. Nav 351 (Apr. 1943) - signed commitment of service to military	● Date of first enlistment
Medical Examiner Report	● Number of articulated teeth ● Number of antemortem missing teeth
Forensic Odontology Report	● Number of articulated teeth ● Number of antemortem missing teeth

Table 3: Description of antemortem information and sources for non-USS Oklahoma decedents.

Form/File/Report Type:	**Information:**
Medical Examiner Summary Report	• Full name • Military rank • Number of articulated teeth • Number of antemortem missing teeth • Date of birth • Date of loss
Forensic Odontology Report	• Specific antemortem missing teeth
Official Report of Death	• Date of first enlistment • Home of record • Next of kin

Information gathered regarding family income and trade prior to enlistment was found on official US census documents. US census documents are maintained by the National Archives and Records Administration (NARA) and can be accessed through their website. After 72 years have passed, NARA makes the census records publicly available for viewing or purchase. If 72 years have not passed, only the named person, their heirs, or their legal representatives can request access to their individual information ("United States Census Bureau", n.d.).

The Berzofsky *et al.* (2014) method of quantifying SES uses highest education level, housing information, employment status, and income as a percentage of federal poverty level. This information was not necessarily available in the Identification Packet compiled by the DPAA. Thus, additional information was provided by US census records. Highest education level was determined by consulting the 1940 US census when this information was missing from military documents. This is because questions relating to education level were not asked on the 1930 US census. To find housing information, The US census was also utilized. This housing information included whether families rented or owned their homes, which is used to measure

SES. This question was not included in the questionnaire for the 1930 US census, but it was added in the 1940 questionnaire.

As the height of the Great Depression was reached in the early 1930s, using the 1930 US census provided the most accurate picture of employment status (vs. the 1920 or 1940 census), and was preferred where possible. However, it should be noted that employment and income information from the height of the Great Depression (1932-1933) are not reflected in either census because the census is only taken once per decade. Employment status was recorded in the 1930 US census. Income was not collected for the census, however industry/occupation was recorded. I then consulted the US Bureau of Labor Statistics to calculate income estimates for these individuals based on their industry/occupation as indicated in the 1930 US census.

Methods

Skeletal data

All the scoring methods of bone as outlined below are visual methods that do not employ the use of microscopic or photographic technology. To ensure scoring accuracy, data collection was overseen by a diplomate of the American Board of Forensic Anthropology from the DPAA Laboratory, Dr. Emily Streetman. Detailed scoring instructions are outlined in this chapter, but for the purposes of the hypotheses in this project, only presence and absence of non-specific indicators of skeletal stress were used in statistical testing. Additionally, activity of skeletal porosity and periosteal reaction describes whether the lesions were active or healed on the skeleton. In this study, I was interested in seeing what non-specific indicators of skeletal stress were present on the skeleton despite their activity. This is important to determine the overall prevalence of the lesions in the study sample. Information on the activity was recorded to be used in further research.

Skeletal Porosity

The presence, expression, and activity of skeletal porosity was documented for this research (Figures 3-5), though the statistical analyses consider presence only. Cribra orbitalia, porotic hyperostosis, porosity of the greater wing of the sphenoid, porosity of the internal aspect of the ascending ramus, cribra humerus, and cribra femoris were all scored using the Buikstra and Ubelaker (1994) method. It is important to note that Buikstra and Ubelaker (1994) do not explicitly describe cribra humerus and cribra femoris in their study, however, their porosity scoring system was used for cases of cribra humerus and cribra femoris in this study. Skeletal porosity was scored as present when it completely perforated the cortical bone. If the bone was present but the trait was not, it was scored as 0. If the bone was present, and the trait was present, it was scored as 1. If the bone was not present, it was scored as 99. Expression, which is the degree of severity of which the porosity presented, was scored on a scale from 1-4. In this scale, 1 is representative of less extreme porosity whereas 4 represents extreme expression and expansive changes, which means more coverage of the element by a lesion (Table 4). When varying degrees of expression were present in the sample, the most extreme expression was coded. Activity scores were coded on a scale from 1-3, describing whether the porosity was active, healed, or a mixed reaction, which is where both active and healed lesions are present (Table 5). Active lesions are described as exhibiting sharp and clearly defined edges and healed lesions are described as displaying a smooth lamellar texture with bone filling of the peripheral pores (Mensforth *et al.*, 1978).

Figure 3: Porosity present on the vertebrae (left) & sacrum (right; Smith-Guzmán, 2015, p. 628).

Figure 4: Porosity present on the humerus (Smith-Guzmán, 2015, p. 628).

Figure 5: Porosity present on the femur (Smith-Guzmán, 2015, p. 628).

Table 4: Description of expression reported in data collection procedures for skeletal porosity from Buikstra and Ubelaker (1994).

Expression Score	Definition
1	Barely discernible/very indistinct porosity
2	True porosity/porosity only
3	Coalescing pores
4	Coalescing pores and expansive changes

Table 5: Description of activity reported in data collection procedures for skeletal porosity from Buikstra and Ubelaker (1994).

Activity Score	Definition
1	Active
2	Healed
3	Mixed reaction

Periosteal Reactions

Periosteal reactions (Figure 6) were analyzed on the long bones and information was documented using the scoring system from Cook (1976). Importantly, statistical analyses in this research considered only the presence of periosteal reactions. This information from Cook (1976) included bone name and side, anatomical location description, focal or diffuse status, extent of surface affected, woven or sclerotic or mixed, and vascularization state, which refers in this case to the visual appearance of the bone (Cook, 1976, p. 317-318). If a long bone was not present, it was scoed as 99. Focal reactions are defined as having clear and distinct boundaries of the pathology while diffuse reactions cover a larger area and have obscured boundaries (Weston, 2008, p. 51). The extent of surface affected was coded on a scale of 1-5, where 1 represents normal bone and 5 is extreme and represents higher elevation (Table 6). Functional/vascular surface in this table refers to the surface of the bone. Woven bone is defined in Buikstra and Ubelaker (1994) as being unconsolidated, matte-surfaced new bone with a woven appearance. Sclerotic bone is dense, with a surface texture like normal bone. Vascularization of bone is scored on a scale of 1-6 (Table 7). On this table, striae refer to linear markings or grooves and foramina refer to pits or holes.

Figure 6: Example of abnormal periosteal new bone formation on the diaphysis of a right lateral tibia (Klaus, 2014, p. 295).

Table 6: Description of extent reported in data collection procedures for periosteal reactions from Cook (1976, p. 317-318).

Extent of Surface Affected	Definition
1	Normal
2	Isolated elevated plaque(s) on less than 1/3 of functional/vascular surface
3	Isolated elevated plaque(s) on 1/3 to 2/3 of functional/vascular area
4	Uniform elevation of greater than 2/3 of the area with little increase in diameter
5	Uniform elevation of more than 2-3mm

Table 7: Description of vascularization reported in data collection procedures for periosteal reactions from Cook (1976, p. 317-318).

Vascularization of Bone	**Definition**
1	Normal
2	Multiple small striae
3	Multiple small foramina
4	Multiple large striae
5	Multiple large foramina
6	Mixed abnormal vascularization

Enamel Defects

Enamel defects were documented by type and ranged from 0-5, (Table 8). However, as with previous non-specific indicators of skeletal stress, statistical analyses were done in this study based on presence alone. If the tooth was present but there was an absence of an enamel defect, a 0 was indicated. If a tooth was not present, either lost antemortem (before death), perimortem (around the time of death) or postmortem (after death), the section for that respective tooth was left blank.

Table 8: Description of the range of enamel defects.

Enamel Defect	Definition
1	Linear horizontal grooves
2	Linear vertical grooves
3	Linear horizontal pits
4	Nonlinear array of pits
5	Single pits

Socioeconomic Status Assessment

To assess SES in the study sample, I referred to a method created by statistical and sociological experts that was recommended to the Bureau of Justice Statistics in the US Department of Justice (Table 9; Berzofsky *et al.*, 2014). This method consist of three indices, the only difference between the three is related to housing information. Index 1 requires information on rental/ownership status, Index 2 requires information on public/non-public housing, and Index 3 does not include housing information. I chose to use Index 1 because I was able to find ownership and rental information from the 1930 US census in addition to education, income (percentage of federal poverty level), and employment information. The highest score that can be associated with an individual is 8 and is indicative of high SES.

To use estimated income to assess poverty level, I estimated the poverty threshold in 1930. This is because the federal minimum wage was not created until 1938 under the Fair Labor Standards Act and, as such, poverty thresholds were not referenced at the time ("U.S. Department of Labor", n.d.). According to the National Center for Children in Poverty, the US measures the poverty threshold by multiplying food costs by three (Cauthen & Fass, 2007). Because there is a gap in data from 1919-1934 from the US Bureau of Labor Statistics, Consumer Expenditure Survey, the 1934 Consumer Expenditure Survey was referenced and it was found that the average budget for food in the United States was $508 per year (Chae & Utgoff, 2006, p. 15). Using this information, the poverty threshold in 1930 would have been around $1,524. To calculate the percent poverty level, the estimated income was divided by the poverty threshold as outlined above and multiplied by 100. Using census data as previously described in addition to the estimated income information, I determined the highest education received for most individuals, housing information, and employment status to estimate the SES of 38 individuals (69% of total sample). For individuals whose highest education was not indicated on military documents or the US census (12 in total), a score of 0.5 was used as an estimate because the National Center for Education Statistics reports that just 22.7% of all males 25 and older in 1940 had completed high school (four or more years) in the US ("U.S. Department of Commerce", 1960). This SES assessment was compared to evidence of non-specific indicators of skeletal stress in the skeleton.

Table 9: Socioeconomic Status Index 1 (Berzofsky et al., 2014).

Measures	Index 1
Education	• 0: Less than high school • 1: High school, some college, associate's degree • 2: Bachelor's degree • 3: Master's, professional, doctorage degree
Income (percentage of federal poverty level)	• 0: 100% or less • 1: 101%-200% • 2: 201%-400% • 3: 401% or greater
Employment	• 0: Unemployed past 6 months • 1: Employed past 6 months
Housing	• 0: Rent or no cash rent • 1: Own
Total possible range: 0-8	

Military Service Length Assessment

To assess military service length in the study sample, the individual's date of loss and date of first enlistment were used. Both dates were found using military records at the DPAA Laboratory as described in Tables 2 & 3. Using this information, I used a simple date difference calculation to determine the individuals' total years of service. The military service length assessment was also compared to evidence of non-specific indicators of skeletal stress.

Statistical Analysis

Statistical analyses were done in this study to compare the presence of non-specific indicators of stress and both military service length and SES. To compare the presence of skeletal porosity and periosteal reaction and military service length, logistic regression tests were used. This testing is used to examine the association between a categorical or continuous independent variable with a two-level categorical dependent variable. The variables in these tests were military service length as a continuous independent variable and then the presence of skeletal pathology is a two-level categorical dependent variable. The Exact Logistic Regression test was used due to a small sample size (Bujang *et al.*, 2018). Exact Logistic Regression is a statistical method used to model binary outcome variables where the log-odds are then modeled as a linear combination of independent variables; it is used when the sample size is not large or complete enough for a regular logistic regression ("Exact Logistic Regression", n.d.). In this analysis, military service length was coded simply as the number of years whereas trait presence and absence were coded as 1 and 0, respectively.

To test the association of SES and the three types of non-specific indicators of skeletal stress, Fisher's Exact Test of Independence was used for each non-specific indicator of skeletal stress. Fisher's Exact Test of Independence was used due to a low sample size, precluding the use of using a Chi-square test (McHugh, 2013). Fisher's Exact Test of Independence is a non-parametric test used to examine the presence of nonrandom associations between two categorical variables (Freeman & Campbell, 2007). To satisfy the assumptions of Fisher's Exact Test of Independence , the variables must be independent (Nowacki, 2017), which is the case in this study. SES and the presence of skeletal pathology are categorical variables. In this analysis, SES was coded 0-8 as assessed using the Berzofky *et al.*, (2014) Index 1 whereas trait presence and absence were coded as "Y" and "N", respectively.

Chapter 4: Results

The results of the testing outlined in the previous chapter, Materials and Methods, are outlined below. This chapter includes the results of statistical testing conducted to analyze military service length vs. incidence of skeletol porosity and periosteal reaction as well as Socioeconomic Status (SES) vs. incidence of enamel defects, skeletal porosity, and periosteal reaction. A summary of the results can be found in Table 10.

Table 10: Final results of hypothesis testing.

Hypothesis	P-value	Result
1. Greater length of military service will be associated with lower presence of skeletal porosity.	0.4794	Failure to reject the null hypothesis
2. Greater length of military service will be associated with lower presence of periosteal reactions.	0.0621	Rejection of the null hypothesis
3. Lower SES will be associated with greater presence of enamel defects.	0.5287	Failure to reject the null hypothesis
4. Lower SES will be associated with greater presence of skeletal porosity.	0.09549	Failure to reject the null hypothesis
5. Lower SES will be associated with greater presence of periosteal reactions.	0.01053	Rejection of the null hypothesis

Military Service Length Results

The range of military service among the 43 service members analyzed for this portion of the study varied from 0 to 25 full years of active service. Table 11 shows that the vast majority (76.7%) of individuals died before completing more than 3 full years of service. of active military service, while the remainder are sparsely distributed between 4 and 25 full years of service. Individual results are discussed in more detail below, but a table of the final results can be found in Table 12.

Table 11: Description of sample's military service length in full years.

Full Years of Military Service	**n =**
0	1
1	19
2	7
3	6
4	1
5	1
6	1
12	1
18	1
19	2
21	1
24	1
25	1
Total	43

Table 12: Results of Exact Logistic Regression tests calculated in SAS Studio *(2018).*

Test	**P-value**
Military service length vs. incidence of skeletal porosity	0.4794
Military service length vs. incidence of periosteal reaction	0.0621

First, testing the presence of skeletal porosity vs. military service length was done using Exact Logistic Regression in *SAS Studio* (“SAS Institute Inc.”, 2018; n = 29). The types of skeletal porosity observed in this sample were cribra orbitalia, porotic hyperostosis, porosity of the greater wing of the sphenoid, porosity of the internal aspect of the ascending ramus, cribra humerus, and cribra femoris. The makeup of the types of porosity in the sample is shown in Table 13; the majority (86%) of the 29 individuals with porosity in the sample had porotic hyperostosis. The secondmost prominent type of porosity in this sample was porosity of the sphenoid body, where only four individuals (13.7%) had the porosity. This fact, in addition to precedent stated previously, is why multiple types of porosity were considered in this research study.In this test, the p-value (0.4794; shown in Table 12) leads to a failure to reject the null hypothesis that there is no relationship between length (years) of military service and incidence of skeletal porosity. As such, there is no significant association between years of military service and presence of skeletal porosity in this sample.

Table 13: Types of skeletal porosity present in the research sample (some individuals presented with more than one type of porosity).

Porosity	**n =**
Cribra orbitalia	1
Porotic hyperostosis	25
Porosity of the greater wing of the sphenoid	0
Porosity of the sphenoid body	4
Porosity of the internal aspect of the ascending ramus	1
Cribra humerus	2
Cribra femoris	2

Second, testing of the presence of periosteal reaction vs. military service length was done using Exact Logistic Regression in *SAS Studio* (“SAS Institute Inc.”, 2018; n = 30). Specific elements presenting with periosteal reactions can be seen in Table 14. In this test, the p-value (0.0621; shown in Table 11) leads to a failure to reject the null hypothesis that there is no relationship between length (years) of military service and incidence of periosteal reaction on the skeleton. Despite the p-value being above alpha in this case, there still may be a biological effect present between military service length and presence of periosteal reactions (i.e. 0.0621 is near 0.05), and thus I will explore these results further in Chapter 5.

Table 14: Elements exhibiting periosteal reaction in the research.

Element (Left or Right)	**n =**
Humeri	1
Radii	0
Ulnae	0
Femora	1
Tibiae	2
Fibulae	2

Socioeconomic Status Assessment Results

According to Table 9, created by Berzofsky *et al.*, (2014) for the Bureau of Justice Statistics in the US Department of Justice, the lowest SES score in Index 1, used for this study, is 0 (indicative of low SES) and the highest score is 8 (indicative of high SES). The majority of the sample (91.9%) are between scores of 1 and 3, as shown on Table 15. 100% of the sample scored at or below a score of 4, indicating that this sample skews toward the lower end of the range which means that they all experienced low to mid-level SES in life.

Table 15: Description of Socioeconomic Status assessments for sample.

Socioeconomic Status Score	**n =**
0	1
0.5	1
1	9
1.5	6
2	9
2.5	5
3	5
4	1
5	0
6	0
7	0
8	0
Total	37

Fisher's Exact Test of Independence was used instead of the chi-square test for all tests of SES vs. non-specific indicators of skeletal stress because the sample failed to meet the assumptions of the chi-square test. The goal of Fisher's Exact Test of Independence is to examine whether an association exists between two categorical variables; the null hypothesis is that there is no association between the rows and columns of the table (Freeman & Campbell, 2007). First, testing the presence of enamel defects vs. SES was done in *RStudio* (n = 37). The p-value above alpha in this case (shown in Table 16) leads to a failure to reject the null hypothesis that there is no association between SES and presence of enamel defects. The types of enamel defects and their prevalence can be seen in Table 16 and the specific teeth that presented with enamel defects can be seen in Table 18.

Second, testing of the presence of skeletal porosity vs. SES was done using Fisher's Exact Test of Independence in *RStudio* ("RStudio Team", 2020; n = 21). The makeup of the types of porosity in the sample is shown in Table 13. In this case, the p-value above 0.05 leads to a failure to reject the null hypothesis that there is no association between SES and incidence of skeletal porosity.

Finally, testing of the presence of periosteal reaction vs. SES was done using Fisher's Exact Test of Independence in *RStudio* ("RStudio Team", 2020; n = 21). In this case, the p-value below 0.05 leads to a rejection of the null hypothesis that there is no association between SES and incidence of periosteal reaction. This shows that there is significance between the presence of periosteal reaction vs SES in this sample.

Table 16: Results of Fisher's Exact Test of Independence conducted in RStudio (2020) for Socioeconomic Status vs. incidence of non-specific indicators of skeletal stress.

Test	**P-value**
SES vs. incidence of enamel defects	0.5287
SES vs. incidence of skeletal porosity	0.09549
SES vs. incidence of periosteal reaction	0.01053

Table 17: Prevalence of enamel defects by type in the study sample.

Type of Enamel Defect	**n =**
Linear horizontal grooves	48
Linear vertical grooves	2
Linear horizontal pits	3
Nonlinear array of pits	0
Single pits	0

Table 18: Specific teeth that presented with enamel defects in the study sample.

Tooth Number (Universal Numbering System)	**n =**
2	3
3	3
4	3
5	3
6	3
7	1
10	2
11	5
12	2
13	2
14	1
16	1
19	1
21	3
22	4
23	1
24	1
25	2
26	1
27	7
28	2
31	1
32	1

Chapter 5: Discussion and Conclusion

The hypotheses regarding military service length and Socioeconomic Status (SES) vs. non-specific indicators of skeletal stress (specifically, enamel defects, skeletal porosity, and periosteal reactions) were statistically tested as reported in Chapter 4. To assess the association between military service length and the presence of skeletal stress indicators, I used the Exact Logistic Regression test. The Exact Logistic Regression tests military service length vs. presence of skeletal porosity and periosteal reaction both resulted in p-values above alpha ($p = 0.1242$ and 0.06208, respectively). This indicates that there is no significant association between these skeletal stress markers and military enlistment length. It is important to note, however, that given the p-value of 0.06208, there may be a biological association present between military service length and presence of periosteal reactions.

To assess the association between SES and the presence of skeletal stress indicators, the Fisher's Exact Test of Independence was used to compare SES category and each skeletal stress indicator (enamel defects, skeletal porosity, and periosteal reaction). These results indicate that there is no significant association between SES and enamel defects ($p = 0.5287$), as well as SES and skeletal porosity ($p = 0.09549$). The association between SES and periosteal reaction, however, is statistically significant ($p = 0.01053$). In this chapter, I will analyze the results of the statistical tests used in this study and discuss their implications. Additionally, I will explore future directions for research on this topic.

While resulting p-values above alpha could certainly mean that there genuinely is no relationship, there are factors that influence p-values in statistical tests that are important to understand when conducting research in biological anthropology and interpreting statistical results, these include effect size, sample size, and data spread (Dahiru, 2008).

Although the possibility to calculate an effect size based on odds ratio in a logistic regression model has been stated, this is contested and generally not advocated for (Chinn 2000 & Uanhoro *et al*., 2019); as such, I did not calculate an effect size in the testing involving logistic regression. Aside from effect size, the sample size has the capability to affect a p-value. In this study, the sample size was quite small and could not be increased due to the historical nature of this assemblage; there was no way to increase the available number of skeletons to study. In general, the larger the sample size, the more likely it is that a significant relationship will be found if one exists (Gannon *et al.*, 2019). Small sample size can result in a higher probability of Type II errors (an error where the null hypothesis is false but it is not rejected) (Harmon & Losos, 2005). The great reliance on the p-value can be problematic in anthropological tests where the sample consists of artifacts or remains that are finite and generally represent small quantities (Gannon *et al.*, 2019). Some researchers propose that, instead of abandoning the p-value in statistical studies, a significance level should be dependent on the sample size (Gannon *et al.*, 2019). This would prevent a scenario where α (alpha) is fixed and β (beta), the probability a Type II error in a statistical test, tends to decrease with an increase in sample size and instead both error probabilities depend on the sample size (Gannon *et al.*, 2019). Lastly, spread of data can affect a p-value. The spread of data will show whether there are outliers that exist and/or whether data is skewed (McCluskey & Lalkhen, 2007). Data spread is measured commonly with standard deviation, and the bigger the standard deviation, the more the spread of observations and therefore the lower the p-value (Dahiru, 2008).

Military Service Length Results Analysis

The p-value for the test of military service length vs. presence of skeletal porosity is above alpha. Therefore, an increased length of military service is not associated with the presence of skeletal porosity. This could be due to a host of reasons. This sample was relatively small (n = 43). Further, the average length of military service in the sample was only 4.74 years with a median of 2 years (Figure 8); thus, the large majority (n = 32) of individuals had less than 3 full years of military service completed at the time of their death. This lack of data spanning more fully across the entire range of military service length could have affected the study. Continuing to take and assess data of WWII-era military personnel, when and if possible, could potentially capture a relationship between these variables if it exists.

As stated, though the p-value for the test of military service length vs. presence of periosteal reaction in this study is 0.06208, it is close enough to alpha that there still may be a biological effect present between military service length and presence of periosteal reactions. As such, these results suggest that as military service length increased, presence of periosteal reaction on the skeleton decreased. This could be due to some levels of socioeconomic security that the military was able to offer to service members, including levels of nutritional security, job and fiscal security, access to healthcare, lower recidivism rates, etc. as suggested in Chapter 2. Again, the sample size was quite small in this study, specifically in this test (n = 30) and it skews toward the lower end of military service length as described previously (Figure 9). Sample size is known to influence p-value, as is spread of the data, so one must proceed with caution when considering this interpretation.

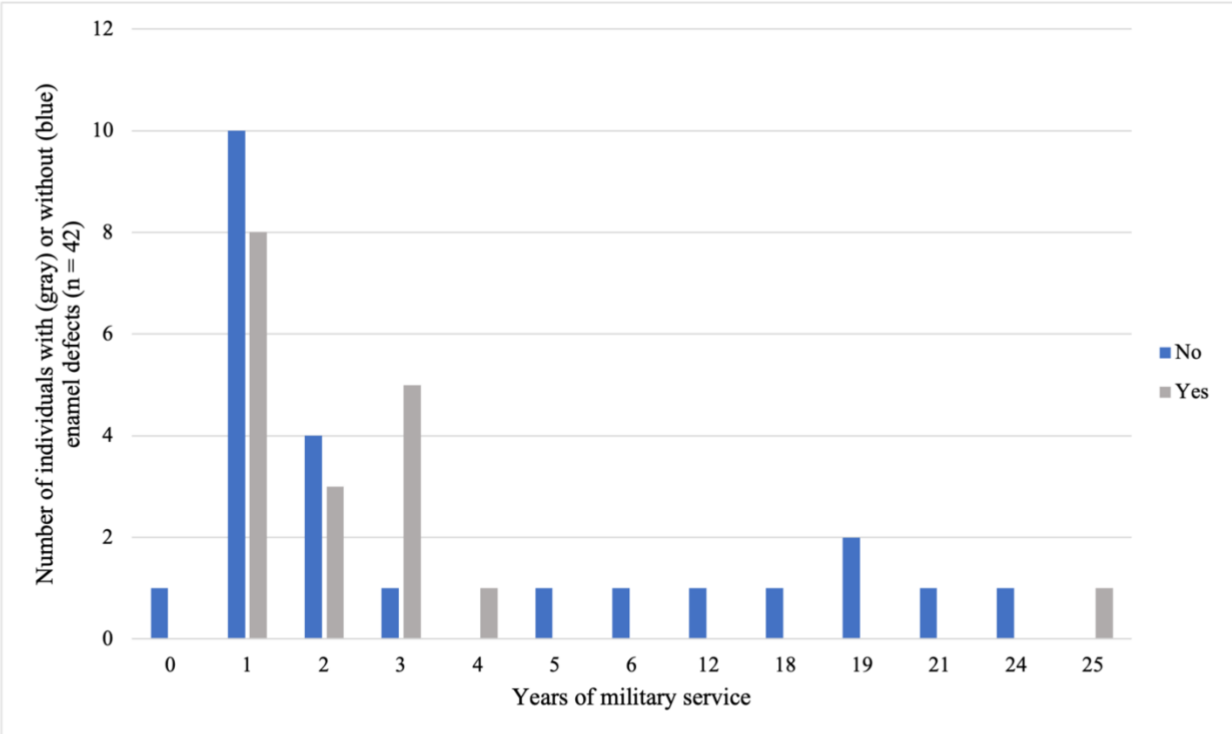

Figure 7: Presence of enamel defects in sample by years of military service.

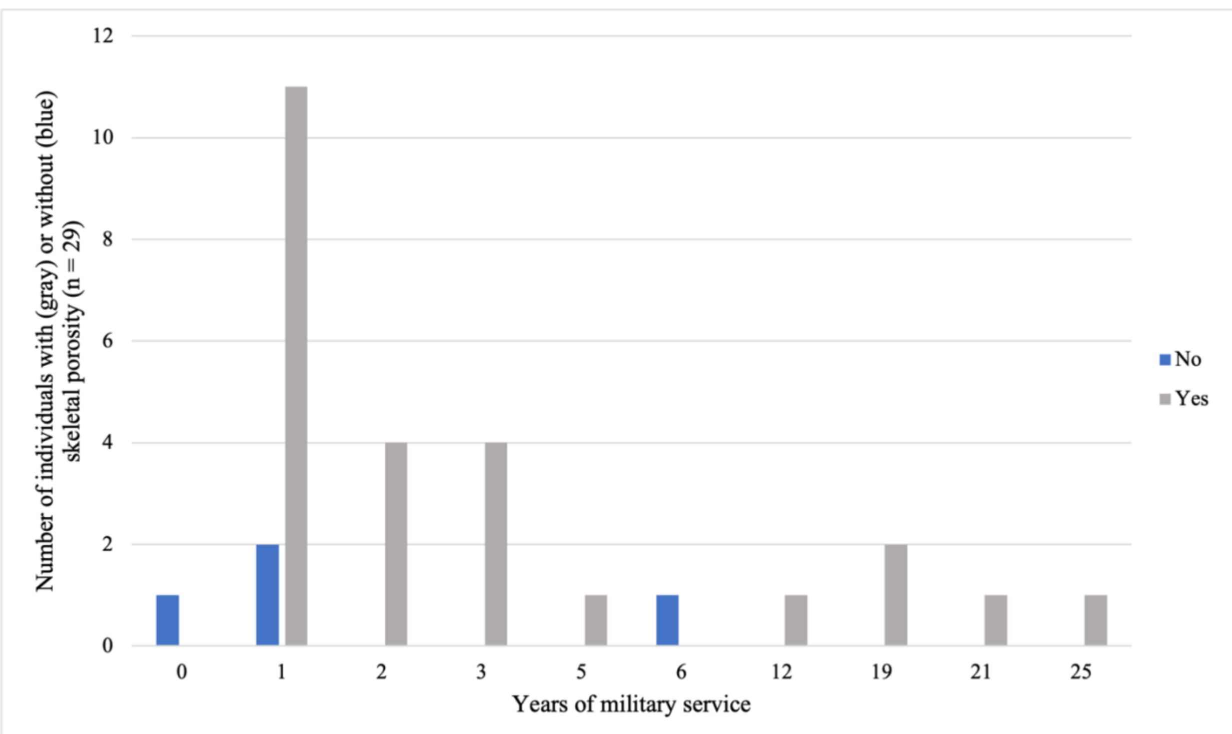

Figure 8: Presence of skeletal porosity in sample by years of military service.

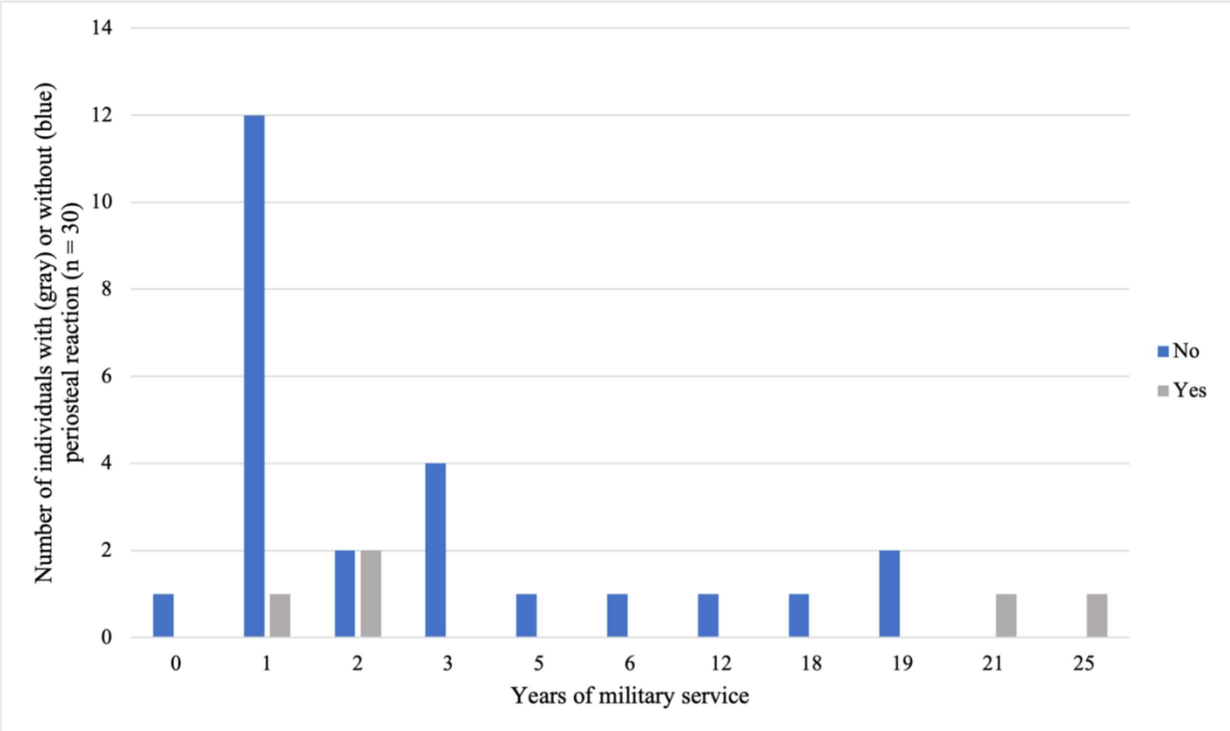

Figure 9: Presence of periosteal reaction in sample by years of military service.

Socioeconomic Status Results Analysis

Results assessing the association between SES and the presence of enamel defects indicates that there is no significant relationship between these variables. The enamel growth defects focused on in this study, as previously indicated, occur in childhood as teeth are developing. Any presence of defects would be a disruption of the growth process, not degenerative as is the case with other indicators. Figure 10 shows that about half (16 of 37) of individuals had enamel defects and the spread of those results was relatively even across SES categories. This assessment with enamel defects is imperfect as an exact assessment of SES at the time of tooth development could not be made. This is mainly due to multiple changes in the information requested on the US census between 1900-1940 and, because of the information needed to use the Berzofsky *et al.*, (2014) SES Index, the 1930 census was deemed to be the most informative and useful.

Further, results indicate that there is no relationship between SES and presence of skeletal porosity. While Figure 11 shows that there is a significantly higher prevalence of individuals with skeletal porosity than without (18 of 21), those individuals are spread relatively evenly across the SES categories represented in the sample for this test (1-3). This shows that skeletal porosity was seen in this sample despite SES category, though the categories for SES were relatively low considering the possible range was 0-8.

Although a careful attempt was made to be as accurate as possible with regard to the individual's SES using the data from the US census, it is impossible to be able to say definitively what an individual's SES was during their childhood, which is when that disruptive process would have taken place. Other studies (such as Smith-Guzmán, 2015; Walker *et al.*, 2009; Wasterlain *et al.*, 2018; Ortner *et al.*, 2001; Whitehouse, 2007) show that factors relating to lower SES (e.g., potential malnourishment or food insecurity), are associated with indicators of metabolic stress on the skeleton. These results may suggest that the individuals were not in a low SES during their developmental stage, they were in a low SES but their access to nutrition was not affected, or that there are other factors in the last 100 years that contribute to reduced deficiency of certain vitamins. The creation and prevalence of government assistance programs, supplements and additives, globalization increasing access to more types of nutritious foods, among other factors could result in less nutritional deficiency among all SES classes.

Lastly, results indicate that there is a statistically significant association between SES and presence of periosteal reactions. While skeletal porosity and enamel defects have been associated in the current literature as resulting mostly, if not entirely, from environmental factors such as nutrition and disease, periosteal reaction has been associated with both genetic and environmental factors in both childhood and adulthood (Whitehouse, 2007). Individuals with a lower SES may experience struggles with healthcare accessibility resulting in exacerbation of genetically and environmentally related health issues, however, the outcome of this study shows that those associated with higher SES have a higher prevalence of periosteal reaction (Figure 12). It must be noted that "higher SES" in that range is still not high, as the greatest level of SES in the individuals in this facet of the whole study was 3 out of a maximum of 8 possible. The traditional level of significance, 0.05, can be negatively impacted by a small sample size, so while this test shows a significance, it must be approached with caution when extending the results to a larger population.

Alternatively, The Osteological Paradox, as described in Chapter 2, may play a part in these results of higher presence of periosteal reactions in those with higher SES. In summary, it is possible that (if these lesions were healed), the individuals may have been able to fight off illness or trauma, making them potentially healthier individuals in life than others. This would show that they may have been able to fight against the cause of the periosteal reaction, surviving past the point that it left permanent defects on the bones. Additionally, it is possible that individuals with higher SES could have been better buffered from systemic stressors during their childhood, leading them to be potentially more vulnerable to these stressors in their adult lives. This is potentially why there is an increased prevalence of periosteal reaction in the study sample.

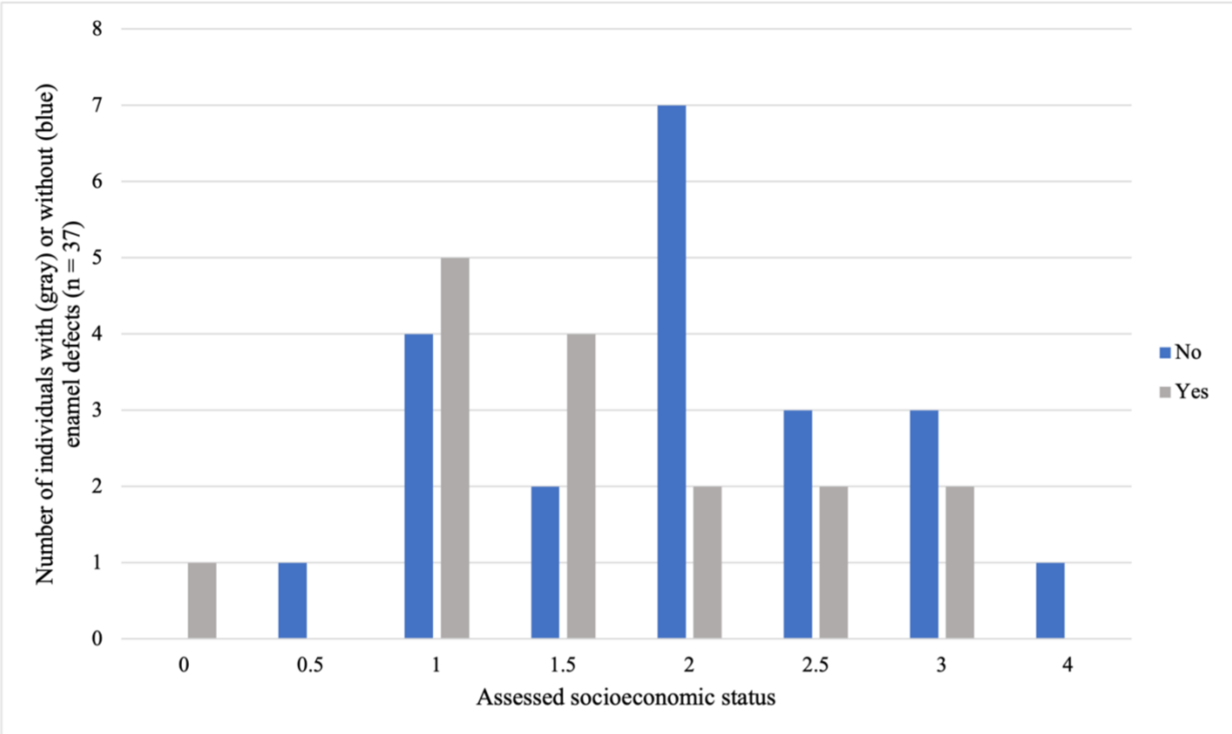

Figure 10: Presence of enamel defects in sample by assessed socioeconomic status.

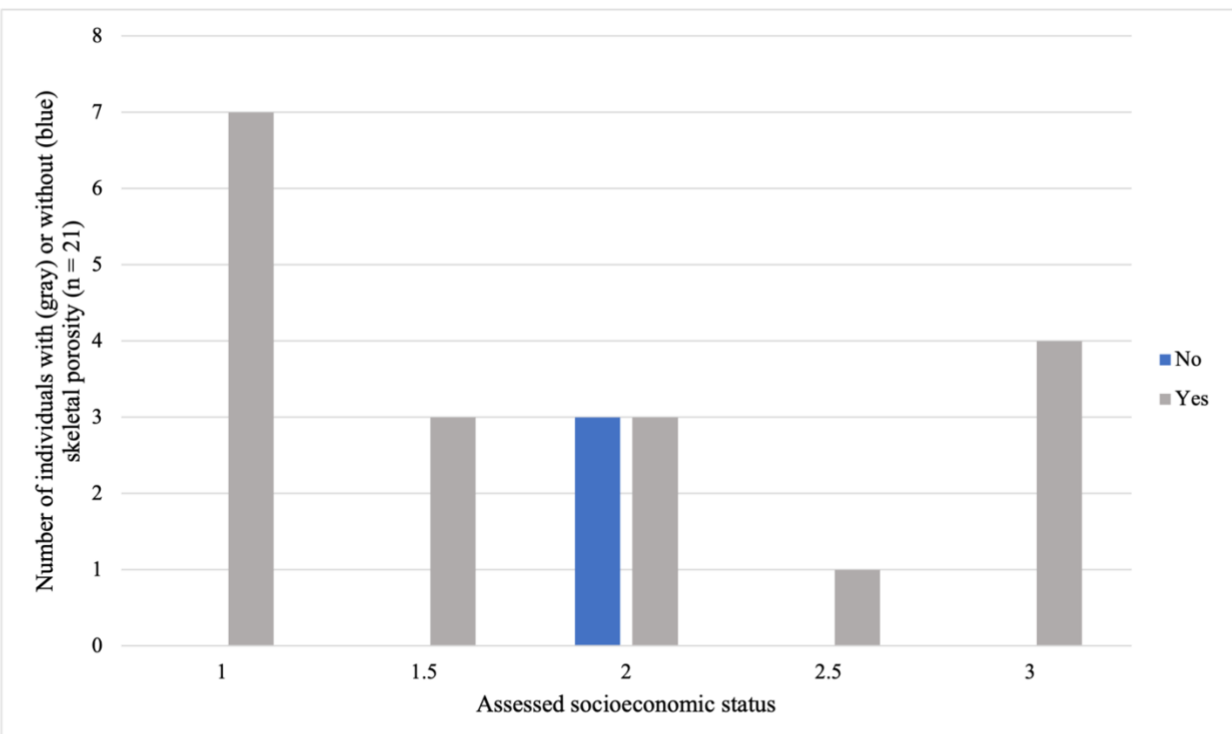

Figure 11: Presence of skeletal porosity in sample by assessed socioeconomic status.

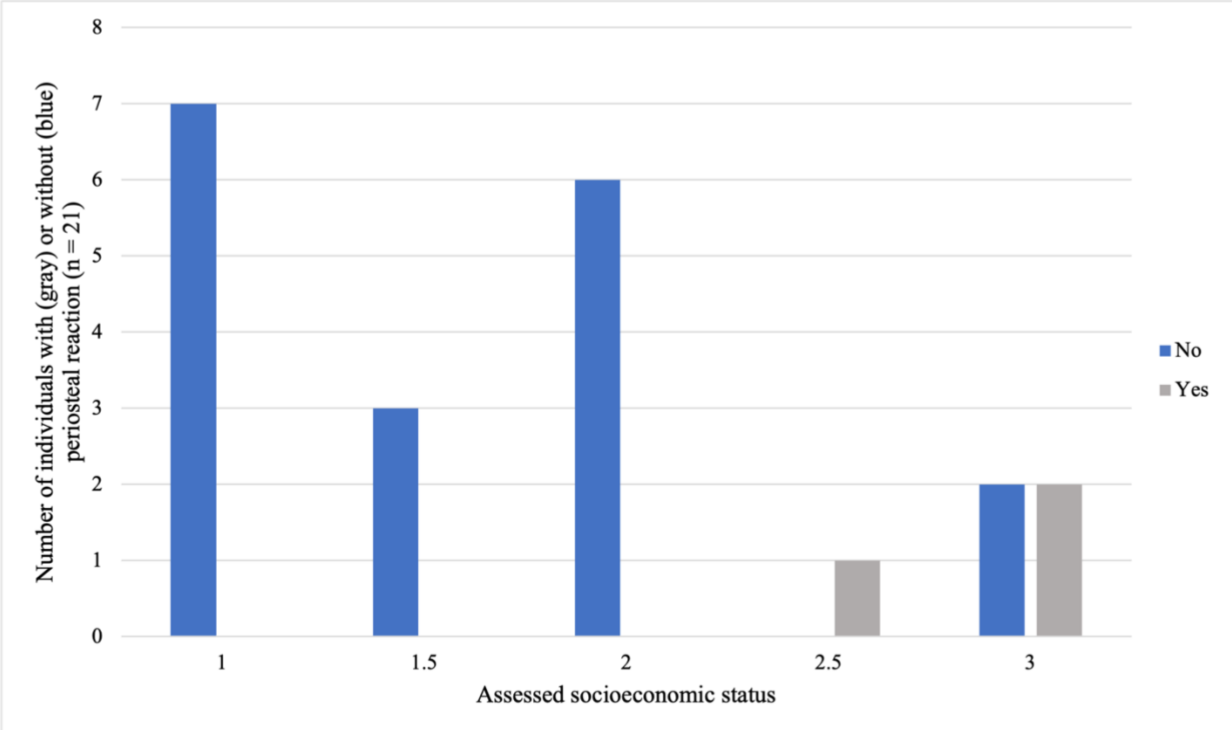

Figure 12: Presence of periosteal reactions in sample by assessed socioeconomic status.

Conclusions and Future Directions

This research sought to answer questions relating to the presence of non-specific indicators of skeletal stress on the skeleton and their relationship to length of military service and, separately, their relationship to estimated SES. The final results can be seen as a summary in Table 10.The sample consisted mainly of fallen service members from the USS *Oklahoma* and two other individuals from early 1940s WWII casualties. Due to the nature of this sample and the main mission of the DPAA where this research was conducted, outlined in Chapter 3, the sample size for this research was relatively small. The purpose of this research, as stated previously, was to assess the relationship between non-specific indicators of skeletal stress and military service length and SES. The tangential purpose was to utilize this information to be able to know more about how issues related to low SES, such as malnourishment and food insecurity, may affect the human skeleton. As the current COVID-19 pandemic has caused a surge in the unemployment rate not seen since the Great Depression (Soucheray, 2020), an event the individuals of this sample lived through, this data provides a stepping stone to further conversations about how modern socioeconomic disparities may affect the human skeleton in the United States. Further research and data are needed to make more concrete assessments on this. I hypothesize that there would not be an increased prevalence in non-specific indicators of skeletal stress due to SES in the US, but there may be increased prevalence due to Long COVID, a term used to describe lasting presence of various symptoms weeks or months after acquiring COVID-19 (Raveendran *et al.*, 2021). I would also hypothesize that there are certain areas of the world in which COVID-19 had a greater and longer-lasting economic impact, which may therefore cause a lengthy decrease in SES and potential nutritional deficiency, leading to increased prevalence of non-specific indicators of skeletal stress.

In addition to this contribution, this research shed light on potential associations between certain non-specific indicators of skeletal stress and military service length. Statistical testing was not completed to test military service length vs. presence of enamel defects in the study, though Figure 7 shows that there are several individuals with shorter length of military service possessing a greater presence of enamel defects. Again, researching military recruitment practices to discover whether those with lower SES were sought out more often for military service by recruiters, whether they are more likely to join the military due to the securities and benefits offered, or both would provide further insight to the potential relationship between enamel defects and military service members.

Though statistical testing was not completed to test military service length vs. presence of enamel defects in the study since enamel defects can *only* occur in childhood, it is interesting to observe the presence of enamel defects in the sample. Looking at enamel defects in the number of individuals that military service length could be calculated for (Figure 7), it appears that there are several individuals with fewer completed years of military service possessing a higher presence of enamel defects. It would be interesting to research military recruitment practices to discover whether those in lower socioeconomic statuses are sought out more often for military service by recruiters, whether they are more likely to join the military due to the securities and benefits offered, or both.

Figure 8 demonstrates that there seems to be a high presence of skeletal porosity in general, despite the length of military service completed at time of death. Further study to compare not only the presence as done here, but the expression or severity of skeletal porosity may provide useful information. Specifically, it would shed light on the trends in how skeletal porosity may increase or decrease in severity against length of military service in this sample. Additionally, as multiple types of skeletal porosities were observed in this study, more specific research on each type of skeletal porosity could be conducted. As most (86%) of the skeletal porosity in this sample was porotic hyperostosis (shown in Table 12), more specific research on porotic hyperostosis and military service length should be conducted. Porotic hyperostosis is associated with nutritional deficiency, namely B_{12} deficiency (outlined in Chapter 2). The literatures showed that B_{12} deficiency is more common than previously assumed, and it is usually seen in instances where lower quantities of animal products are consumed (Rasmussen *et al.*, 2001). As such, an analysis of current military nutrition and deployment rations could be conducted against evidence of porotic hyperostosis on the skeleton. I hypothesize that a lower amount of animal products are included in military deployment rations due to the reality of spoilage, and therefore there may be a heightened level of porotic hyperostosis that increases as military length increases. In this study sample, the Great Depression may have caused individuals to experience lower access to animal products for consumption in childhood, therefore contributing to an increased prevalence of porotic hyperostosis.

Figure 9 reveals that the majority (25 out of 30 total individuals) did not show signs of periosteal reactions on the skeleton. More research on the prevalence of this indicator across samples of American individuals of varying generations could shed light on any trends that may exist through time and, in turn, some hypotheses for causation. Periosteal reaction is associated with both environmental and genetic factors and can occur during childhood and adulthood. As such, there may be changes throughout the past century that contribute to an increased or decreased prevalence of periosteal reaction. For example, technological advances leading to less manual labor in certain trades may lead to less physical insults and therefore less periosteal reaction on the bones. Additionally, assessment regarding the extent of affected bone surface, the vascularization level of the periosteal reaction, and whether the periosteal reaction was woven or sclerotic could shed light on trends in how periosteal reactions tended to manifest.

Although the operations of the military are likely different now than they were during the Great Depression and WWII, further research on the effect of military service length on the human skeleton would be valuable in order to examine any current relationship between non-specific indicators of skeletal stress and military service length. Additionally, continuing to study periosteal reaction vs. military service length in modern populations could provide information on modern prevalence rates. Further studies could include not only military service length, but prevalence of non-specific indicators of skeletal stress and military rank or occupation in the military.

Figure 10 shows that about half (16 of 37) of individuals had enamel defects and the spread of those results were relatively evenly distributed across the SESes represented in this sample (0-4). Table 16 showed that the large majority of enamel defects presented as linear horizontal grooves on the teeth. Additionally, Table 17 shows that the majority of enamel defects were present on the canines (36%). Following this 19% were located on the first premolar, 9% were located on the second premolar, 9% were located on the second incisor, 9% were located on the first molar, 8% were located on the second molar, 6% were located on the first incisor, and 4% were located on the third molar. In Chapter 2 it was noted that enamel defects were most commonly found on the incisors and the first molar, which was not the case here. As this is an observation made separately to what this study examined, this phenomenon should be explored further in the future. This is important as these findings contradict what the current, published literature has indicated and may either indicate a change in how enamel defects tend to manifest or that this study sample was unique.

Regarding SES vs. skeletal porosity, considering that the SES score has a maximum of 8, indicating high SES, a range of 1-3 is relatively low, indicating that the entire sample in this test experienced low SES at this point in their lives. Having more data for individuals at the higher end of the SES score range would have more accurately captured the prevalence of skeletal porosity for those individuals with higher SES. If this is not possible because the SES for most people at this time may have tended to be lower, a larger sample size would also be helpful in making stronger associations (as low sample size can impact p-values). Because this comparison does not need a military population as a sample, that allows more flexibility for future testing and data addition. Skeletal porosity (specifically porotic hyperostosis) is the most prevalent non-specific indicator of skeletal stress in the sample, so the prevalence of this indicator should be further explored. As skeletal porosity is associated with nutritional deficiency, Chapter 2 notes changes in prevalence of certain deficiency diseases and also discusses food-enrichment mandates that were made to combat nutritional deficiency. As such, some nutritional deficiencies associated with certain non-specific indicators of stress may not be of concern today

In the study of SES vs. periosteal reaction, the majority of individuals (16 of 21; Figure 12) were associated with a SES of 1-2, so a larger sample with individuals across the full spectrum of SES score would be helpful in making more discerning assessments. Because this test focuses on SES and skeletal defects rather than military service length, it will be easier to continue this testing by adding data from a wider sample, not just those who are or have been in the military.

Though one large purpose of this study was to determine if a higher prevalence of non-specific indicators of skeletal stress is associated with reduced SES, the Osteological Paradox in Chapter 2 outlines why this may not be the case in every situation and is important to consider. For example, children with lower SES may have been better conditioned for adverse effects to health later in life through certain situations such as slight but prolonged nutritional deficiency during childhood. Conversely, children with higher SES may have been more vulnerable to stressors due to being better buffered from conditions such as nutritional deficiency. Additionally, hidden heterogeneity, another concept of the Osteological Paradox, is worth considering in these kinds of analyses as well. That is, children who made it through childhood experiencing low SES may therefore be more robust amd thus less likely to exhibit signs of non-specific indicators of skeletal stress as readily as their counterparts who experienced higher SES during childhood.

Overall, this research tested the associations of SES and military service length to non-specific indicators of skeletal stress in a WWII-era skeletal sample from the DPAA. The study showed evidence that greater length of military service was associated with lower presence of periosteal reactions and that lower SES was associated with greater presence of periosteal reactions in this sample. As nutritional deficiency, a large contributor to non-specific indicators of skeletal stress, exists and affects people in the world today, this research is important. Additionally, as the US military continues to recruit individuals, the results on how military service length can impact the human skeleton is important. The data did not support that greater length of military service was associated with lower presence of skeletal porosity, that lower SES was associated with greater presence of enamel defects, or that lower SES was associated with greater presence of skeletal porosity. Despite this, there are a variety of avenues to explore. These avenues include how COVID-19 has potentially caused socioeconomic disparity and therefore a potential increase in non-specific indicators of skeletal stress, how military recruitment practices may have led to larger representation of those in lower SES class in the military, and more.

REFERENCES

About DPAA. Defense POW/MIA Accounting Agency. (n.d.). Retrieved March 7, 2022, from https://www.dpaa.mil/Resources/Fact-Sheets/Article-View/Article/569601/defense-powmia-accounting-agency/

Almonaitiene, R., Balciuniene, I., & Tutkuviene, J. (2010). Factors influencing permanent teeth eruption. Part one–general factors. *Stomatologija*, *12*(3), 67-72.

Al-Shorman, A., Alrousan, M., & Khwaileh, A. (2014). Rate of enamel formation and hypoplasia timing. *Bulletin of the International Association for Paleodontology, 8*(1), 203-208.

Agarwal, A., Shaharyar, A., Kumar, A., Bhat, M. S., & Mishra, M. (2015). Scurvy in pediatric age group–a disease often forgotten? *Journal of Clinical Orthopaedics and Trauma*, *6*(2), 101-107.

Angel, J. L. (1964). Osteoporosis: thalassemia? *American Journal of Physical Anthropology*, *22*(3), 369-373.

Angel, J. L. (1966). Porotic hyperostosis, anemias, malarias, and marshes in the prehistoric eastern Mediterranean. *Science*, *153*(3737), 760-763.

Angel, J. L. (1967). Porotic hyperostosis or osteoporosis symmetrica. *Diseases in Antiquity*, 378-389.

Angel, J. L. (1972). Ecology and population in the eastern Mediterranean. *World Archaeology*, *4*(1), 88-105.

Beck, A. F., Edwards, E. M., Horbar, J. D., Howell, E. A., McCormick, M. C., & Pursley, D. M. (2020). The color of health: how racism, segregation, and inequality affect the health and well-being of preterm infants and their families. *Pediatric Research, 87*(2), 227-234.

Berzofsky, M., Creel, D.D., & Moore, M.A. (2014). Measuring Socioeconomic Status (SES) in the NCVS: Background, Options, and Recommendations. https://www.ojp.gov/pdffiles1/bjs/grants/248562.pdf

Brand, J. C., Cherikoff, V., Lee, A., & Truswell, A. S. (1982). An outstanding food source of vitamin C. *Lancet*, *2*(8303), 873.

Brickley, M.B. (2018). *Cribra orbitalia* and porotic hyperostosis: A biological approach to diagnosis. *American Journal of Physical Anthropology,* 167: 896– 902. https://doi.org/10.1002/ajpa.23701.

Brickley, M., & Ives, R. (2006). Skeletal manifestations of infantile scurvy. *American Journal of Physical Anthropology*, *129*(2), 163–172. https://doi.org/10.1002/ajpa.20265

Brown, C. (2019). The USS *Oklahoma* Identification Project. *Forensic Anthropology*, 2(2), 102-112. https://doi.org/10.5744/fa.2019.1013

Buikstra, J. E., & Cook, D. C. (1980). Palaeopathology: an American account. *Annual Review of Anthropology*, *9*(1), 433-470.

Buikstra, J. E., & Ubelaker, D.H., editors. (1994). Standards for data collection from human skeletal remains. *Arkansas Archaeological Survey Research Series*, *44*.

Bujang, M. A., Sa'at, N., Sidik, T., & Joo, L. C. (2018). Sample Size Guidelines for Logistic Regression from Observational Studies with Large Population: Emphasis on the Accuracy Between Statistics and Parameters Based on Real Life Clinical Data. *The Malaysian Journal of Medical Sciences: MJMS*, *25*(4), 122–130. https://doi.org/10.21315/mjms2018.25.4.12

Cauthen, N. K., & Fass, S. (2007). Measuring income and poverty in the United States. https://doi.org/10.7916/D8-ZBN1-PN47

Centers for Disease Control and Prevention. (1999). *Achievements in Public Health, 1900-1999: Tobacco Use -- United States, 1900-1999*. Centers for Disease Control and Prevention. https://www.cdc.gov/mmwr/preview/mmwrhtml/mm4843a2.htm

Chao, E. L., & Utgoff, K. P. (2006). *100 years of U.S. consumer spending data for the NATION, New York city, and Boston* (United States of America, Department of Labor, Bureau of Labor Statistics). Washington, D.C.: United States Dept. of Labor, Bureau of Labor Statistics.

Chinn, S. (2000). A simple method for converting an odds ratio to effect size for use in meta-analysis. *Statistics in Medicine*, *19*(22), 3127-3131.

Christensen, T., Martínez-Lavín, M., & Pineda, C. (2013). Periostitis and osteolysis in a medieval skeleton from South-West Hungary:(Leprosy, treponematosis, tuberculosis or hypertrophic osteoarthropathy) A diagnostic challenge!. *International Journal of Osteoarchaeology*, *23*(1), 69-82.

Clay, K., Schmick, E., & Troesken, W. (2019). The rise and fall of pellagra in the American south. *The Journal of Economic History*, *79*(1), 32-62.

Coleman-Jensen, A., Rabbitt, M. P., Gregory, C. A., & Singh, A. (2021). *Household food security in the United States in 2020*. USDA Economic Research Service. Retrieved September 30, 2021, from https://www.ers.usda.gov/publications/pub-details/?pubid=102075.

Cook D.C. (1976). Pathologic states and disease processes in Illinois Woodland Populations: an epidemiologic approach. Unpublished. Ph.D. Thesis. University of Chicago.

Cook, A.D.O. (2018). "Enamel Hypoplasia and Its Relation to Ethnicity and Socioeconomic Status in the 19th Century United States". Undergraduate Honors Capstone Projects. 460. https://digitalcommons.usu.edu/honors/460

Dahiru T. (2008). P - value, a true test of statistical significance? A cautionary note. *Annals of Ibadan Postgraduate Medicine*, *6*(1), 21–26. https://doi.org/10.4314/aipm.v6i1.64038

Detmer, D.E. (1986). Chronic Shin Splints. *Sports Medicine* 3, 436–446. https://doi.org/10.2165/00007256-198603060-00005

DeWitte, S. N. (2014). Differential survival among individuals with active and healed periosteal new bone formation. *International Journal of Paleopathology*, *7*, 38-44.

DeWitte, S. N., & Stojanowski, C. M. (2015). The osteological paradox 20 years later: past perspectives, future directions. *Journal of Archaeological Research*, *23*(4), 397-450.

Diane, P. (2012). *Brother, Can You Spare a Dime?* National Archives and Records Administration. https://www.archives.gov/publications/prologue/2012/spring/1940.html.

Dunn, M., Haugen, S., & Kang, J. (2018). The current population survey-tracking unemployment in the United States for over 75 years. *Monthly Labor Review*, U.S. Bureau of Labor Statistics, January 2018, https://doi.org/10.21916/mlr.2018.4.

Eerens, K., Vlietinck, R., Heidbüchel, K., Van Olmen, A., Derom, C., Willems, G., & Carels, C. (2001). Hypodontia and tooth formation in groups of children with cleft, siblings without cleft, and nonrelated controls. *The Cleft Palate-Craniofacial Journal*, *38*(4), 374-378.

Esan, T. A., & Schepartz, L. A. (2020). Does nutrition have an effect on the timing of tooth formation?. *American Journal of Physical Anthropology*, *171*(3), 470–480. https://doi.org/10.1002/ajpa.23987

Exact Logistic Regression: R Data Analysis Examples. (n.d.). Retrieved September 08, 2021, from https://stats.idre.ucla.edu/r/dae/exact-logistic-regression/

Facchini, F., Rastelli, E., & Brasili, P. (2004). Cribra orbitalia and cribra cranii in Roman skeletal remains from the Ravenna area and Rimini (I–IV century AD). *International Journal of Osteoarchaeology*, *14*(2), 126-136.

Fairgrieve, S. I., & Molto, J. E. (2000). Cribra orbitalia in two temporally disjunct population samples from the Dakhleh Oasis, Egypt. *American Journal of Physical Anthropology*, *111*(3), 319-331.

Freeman, J. V., & Campbell, M. J. (2007). *The Analysis of Categorical Data: Fisher's Exact Test*. The University of Sheffield. https://www.sheffield.ac.uk/polopoly_fs/1.43998!/file/tutorial-9-fishers.pdf.

Gannon, M. A., de Bragança Pereira, C. A., & Polpo, A. (2019). Blending Bayesian and classical tools to define optimal sample-size-dependent significance levels. *The American Statistician*, *73*(sup1), 213-222. https://doi.org/10.1080/00031305.2018.1518268

Geber, J. & Murphy, E. (2012). Scurvy in the Great Irish Famine: evidence of vitamin C deficiency from a mid-19th century skeletal population. *American Journal of Physical Anthropology*, *148*(4), 512–524. https://doi.org/10.1002/ajpa.22066

Göhring, A. (2021). Allen's fossa—An attempt to dissolve the confusion of different nonmetric variants on the anterior femoral neck. *International Journal of Osteoarchaeology*, *31*(4), 513-522.

Golriz, F., Donnelly, L. F., Devaraj, S., & Krishnamurthy, R. (2017). Modern American scurvy—experience with vitamin C deficiency at a large children's hospital. *Pediatric Radiology*, *47*(2), 214-220.

Hampl, J. S., Taylor, C. A., & Johnston, C. S. (2004). Vitamin C deficiency and depletion in the United States: the third national health and nutrition examination survey, 1988 to 1994. *American Journal of Public Health*, *94*(5), 870-875.

Harmon, L. J., & Losos, J. B. (2005). The effect of intraspecific sample size on type I and type II error rates in comparative studies. *Evolution*, *59*(12), 2705-2710. https://www.jstor.org/stable/3449062

Harper, A. E. (1985). Origin of Recommended Dietary Allowances—an historic overview. *The American Journal of Clinical Nutrition*, *41*(1), 140–148. https://doi.org/10.1093/ajcn/41.1.140

Hillson, S., & Bond, S. (1997). Relationship of enamel hypoplasia to the pattern of tooth crown growth: a discussion. *American Journal of Physical Anthropology*, *104*(1), 89-103.

Hillson, S. (2005). *Teeth* (2nd ed., Cambridge Manuals in Archaeology). Cambridge: Cambridge University Press. doi:10.1017/CBO9780511614477

Hovorakova, M., Lesot, H., Peterka, M., & Peterkova, R. (2018). Early development of the human dentition revisited. *Journal of Anatomy*, *233*(2), 135–145. https://doi.org/10.1111/joa.12825

Jacobi, K. P., & Danforth, M. E. (2002). Analysis of interobserver scoring patterns in porotic hyperostosis and cribra orbitalia. *International Journal of Osteoarchaeology*, *12*(4), 248-258.

Jin, S. W., Sim, K. B., & Kim, S. D. (2016). Development and Growth of the Normal Cranial Vault : An Embryologic Review. *Journal of Korean Neurosurgical Society*, 59(3), 192–196. https://doi.org/10.3340/jkns.2016.59.3.192

Jones Jr, R. H. (1959). Beriberi heart disease. *Circulation*, *19*(2), 275-283.

Kanchan, T., Machado, M., Rao, A., Krishan, K., & Garg, A. K. (2015). Enamel hypoplasia and its role in identification of individuals: A review of literature. *Indian Journal of Dentistry*, *6*(2), 99–102. https://doi.org/10.4103/0975-962X.155887

Klaus, H.D. (2014), Frontiers in the bioarchaeology of stress and disease: Cross-disciplinary perspectives from pathophysiology, human biology, and epidemiology. *American Journal of Physical Anthropology*, 155: 294-308. https://doi.org/10.1002/ajpa.22574

Köller, H., Kieseier, B. C., Jander, S., & Hartung, H. P. (2005). Chronic inflammatory demyelinating polyneuropathy. *New England Journal of Medicine*, *352*(13), 1343-1356.

LaMorte, W. W. (2016). *The Role of Probability*. Central Limit Theorem. https://sphweb.bumc.bu.edu/otlt/mph-modules/bs/bs704_probability/BS704_Probability12.html.

Langley N. R. (2016). The lateral clavicular epiphysis: fusion timing and age estimation. *International Journal of Legal Medicine*, *130*(2), 511–517. https://doi.org/10.1007/s00414-015-1236-9

Library of Congress, The Dust Bowl (n.d.). https://www.loc.gov/classroom-materials/united-states-history-primary-source-timeline/great-depression-and-world-war-ii-1929-1945/dust-bowl/.

Martínez-Lavín, M. (2020). Hypertrophic osteoarthropathy. *Best Practice & Research Clinical Rheumatology*, *34*(3), 101507. https://doi.org/10.1016/j.berh.2020.101507

McCluskey, A., & Lalkhen, A. G. (2007). Statistics II: Central tendency and spread of data. *Continuing Education in Anaesthesia, Critical Care and Pain*, *7*(4), 127-130.

McHugh M. L. (2013). The chi-square test of independence. *Biochemia Medica*, *23*(2), 143–149. https://doi.org/10.11613/bm.2013.018

Mensforth, R. P., Lovejoy, C. O., Lallo, J. W., & Armelagos, G. J. (1978). Part Two: The role of constitutional factors, diet, and infectious disease in the etiology of porotic hyperostosis and periosteal reactions in prehistoric infants and children. *Medical Anthropology*, *2*(1), 1–59. https://doi.org/10.1080/01459740.1978.9986939

Mubarak, S. J., Gould, R. N., Fon, Y., Schmidt, D. A., & Hargens, A. R. (1982). The Medial Tibial Stress Syndrome: A Cause of Shin Splints. *The American Journal of Sports Medicine*, 10(4), 201–205. https://doi.org/10.1177/036354658201000402

Murlin, J. R., & Miller, C. W. (1919). Preliminary Results of Nutritional Surveys in United States Army Camps. *American Journal of Public Health*, *9*(6), 401–413. https://doi.org/10.2105/ajph.9.6.401-a

Nowacki, A. (2017). Chi-square and Fisher's exact tests. *Cleveland Clinic Journal of Medicine*, *84*(9 suppl 2). doi:10.3949/ccjm.84.s2.04

Oakes, J.M. (2012). The measurement of SES. NIH OBSSR Online Textbook Research Methods for Health Research. https://obssr.od.nih.gov/sites/obssr/files/Measuring-Socioeconomic-Status.pdf

Ortner, D. J., & Ericksen, M. F. (1997). Bone changes in the human skull probably resulting from scurvy in infancy and childhood. *International Journal of Osteoarchaeology*, *7*(3), 212-220.

Ortner, D. J., Butler, W., Cafarella, J., & Milligan, L. (2001). Evidence of probable scurvy in subadults from archeological sites in North America. *American Journal of Physical Anthropology*, *114*(4), 343–351. https://doi.org/10.1002/ajpa.1046

Ortner, D. J., Kimmerle, E. H., & Diez, M. (1999). Probable evidence of scurvy in subadults from archeological sites in Peru. *American Journal of Physical Anthropology*, *108*(3), 321-331.

Ortner, D. J. (2003). *Identification of pathological conditions in human skeletal remains*. Academic Press.

Pitre, M. C., Stark, R. J., & Gatto, M. C. (2016). First probable case of scurvy in ancient Egypt at Nag el-Qarmila, Aswan. *International Journal of Paleopathology*, *13*, 11-19.

Pollack, H. (1963). Nutritional Disorders. In Internal medicine in World War II (3rd ed., pp. 231–291). essay, Office of the Surgeon General, Dept. of the Army.

Rana, R. S., Wu, J. S., & Eisenberg, R. L. (2009). Periosteal Reaction. *American Journal of Roentgenology*, *193*(4), W259–W272. https://doi.org/10.2214/ajr.09.3300

Rasmussen, S. A., Fernhoff, P. M., & Scanlon, K. S. (2001). Vitamin B12 deficiency in children and adolescents. *The Journal of Pediatrics*, *138*(1), 10-17.

Raveendran, A. V., Jayadevan, R., & Sashidharan, S. (2021). Long COVID: an overview. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, *15*(3), 869-875.

RStudio Team (2020). *RStudio: Integrated Development for R*. RStudio, PBC, Boston, MA URL http://www.rstudio.com/.

Ritzman, T. B., Baker, B. J., & Schwartz, G. T. (2008). A fine line: a comparison of methods for estimating ages of linear enamel hypoplasia formation. *American Journal of Physical Anthropology*, *135*(3), 348–361. https://doi.org/10.1002/ajpa.20750

Sampson, R. J., & Laub, J. H. (1996). Socioeconomic achievement in the life course of disadvantaged men: Military service as a turning point, circa 1940-1965. *American Sociological Review*, 347-367.

SAS Institute Inc. (2018). *SAS® Studio 3.8: User’s Guide*. Cary, NC: SAS Institute Inc.

Schats, R. (2021). Cribriotic lesions in archaeological human skeletal remains. Prevalence, co-occurrence, and association in medieval and early modern Netherlands. *International Journal of Paleopathology*, *35*, 81-89.

Schubert, S. D., Suarez, M. J., Pegion, P. J., Koster, R. D., & Bacmeister, J. T. (2004). On the cause of the 1930s Dust Bowl. *Science*, *303*(5665), 1855-1859.

Smith-Guzmán, N. E. (2015). Cribra orbitalia in the ancient Nile Valley and its connection to malaria. *International Journal of Paleopathology*, *10*, 1–12. https://doi.org/10.1016/j.ijpp.2015.03.001

Snoddy, A. M. E., Buckley, H. R., Elliott, G. E., Standen, V. G., Arriaza, B. T., & Halcrow, S. E. (2018). Macroscopic features of scurvy in human skeletal remains: A literature synthesis and diagnostic guide. *American Journal of Physical Anthropology*, *167*(4), 876-895.

Soucheray, S. (2020). US job losses due to COVID-19 highest since Great Depression. Retrieved February 17, 2021, from https://www.cidrap.umn.edu/news-perspective/2020/05/us-job-losses-due-covid-19-highest-great-depression

Stabler, S. P. (2013). Vitamin B12 deficiency. *New England Journal of Medicine*, *368*(2), 149-160.

Stuart-Macadam, P. (1985). Porotic hyperostosis: representative of a childhood condition. *American journal of physical anthropology*, *66*(4), 391-398.

Stuart-Macadam, P. (1992). Porotic hyperostosis: a new perspective. *American Journal of Physical Anthropology*, *87*(1), 39-47.

Temin, P. (1994). The Great Depression. *National Bureau of Economic Research*. https://doi.org/10.3386/h0062

The dust bowl: National drought mitigation center. The Dust Bowl | National Drought Mitigation Center. (n.d.). Retrieved March 19, 2022, from https://drought.unl.edu/dustbowl/

Uanhoro, J. O., Wang, Y., & O'Connell, A. A. (2019). Problems with using odds ratios as effect sizes in binary logistic regression and alternative approaches. *The Journal of Experimental Education*, *89*(4), 670–689. https://doi.org/10.1080/00220973.2019.1693328

United States Census Bureau. (n.d.). *Census Records*. Retrieved March 20, 2022, from https://www.census.gov/history/www/genealogy/decennial_census_records/census_records_2.html

United States Statutes at Large. (1999). *Naval expansion act, 14 June 1940*. Naval History and Heritage Command. Retrieved September 30, 2021, from https://www.history.navy.mil/browse-by-topic/wars-conflicts-and-operations/world-war-ii/1941/prelude/naval-expansion-act-14-june-1940.html.

U.S. Bureau of Labor Statistics. Monthly employment situation news releases and COVID-19 impact summaries. (2020, April 3). Retrieved February 17, 2021, from https://www.bls.gov/covid19/effects-of-covid-19-pandemic-and-response-on-the-employment-situation-news-release.htm

U.S. Department of Commerce, Census Bureau, *U.S. Census of Population: 1960*, Vol. I, Part 1; J.K. Folger and C.B. Nam, *Education of the American Population* (1960 Census Monograph); *Current Population Reports*, Series P-20, various years; and Current Population Survey (CPS), Annual Social and Economic Supplement, 1970 through 2017. (This table was prepared October 2017). https://nces.ed.gov/programs/digest/d17/tables/dt17_104.20.asp

U.S. Department of Health and Human Services. (2015). *Beriberi*. Genetic and Rare Diseases Information Center. Retrieved March 20, 2022, from https://rarediseases.info.nih.gov/diseases/9948/beriberi

U.S. Department of Labor, Wage and Hour Division. (n.d.). *History of Federal Minimum Wage Rates Under the Fair Labor Standards Act, 1938-2009*. https://www.dol.gov/agencies/whd/minimum-wage/history/chart

USS *Oklahoma* Sailors Accounted For From World War II (Group ID). (2021, December 2). *Https://Www.dpaa.mil*. Retrieved March 30, 2022, from https://www.dpaa.mil/News-Stories/News-Releases/PressReleaseArticleView/Article/2859767/uss-*Oklahoma*-sailors-accounted-for-from-world-war-ii-group-id/.

Van Der Weide, Y. S., Prahl-Andersen, B., & Bosman, F. (1993). Tooth formation in patients with oligodontia. *The Angle Orthodontist*, *63*(1), 31-37.

Velandia, B., Centor, R. M., McConnell, V., & Shah, M. (2008). Scurvy is still present in developed countries. *Journal of General Internal Medicine*, *23*(8), 1281–1284. https://doi.org/10.1007/s11606-008-0577-1

Walker, P. L. (1986). Porotic hyperostosis in a marine-dependent California Indian population. *American Journal of Physical Anthropology*, *69*(3), 345-354.

Walker, P. L., Bathurst, R. R., Richman, R., Gjerdrum, T., & Andrushko, V. A. (2009). The causes of porotic hyperostosis and cribra orbitalia: A reappraisal of the iron-deficiency-anemia hypothesis. *American Journal of Physical Anthropology*, *139*(2), 109-125. https://doi.org/10.1002/ajpa.21031

Wasterlain, S. N., Costa, A., & Ferreira, M. T. (2018). Growth faltering in a skeletal sample of enslaved nonadult Africans found at Lagos, Portugal (15th–17th centuries). *International Journal of Osteoarchaeology*, *28*(2), 162-169. https://doi.org/10.1002/oa.2643

Weston, D.A. (2008), Investigating the specificity of periosteal reactions in pathology museum specimens. *American Journal of Physical Anthropology*, 137: 48-59. https://doi.org/10.1002/ajpa.20839

White, T. D., Black, M. T., & Folkens, P. A. (2011). *Human Osteology*. Academic press.

White, T. D., & Folkens, P. A. (2005). *The human bone manual*. Elsevier.

Whitehouse, M. W. (2007). Adjuvant arthritis 50 years on: The impact of the 1956 article by CM Pearson,'Development of arthritis, periarthritis and periostitis in rats given adjuvants'. *Inflammation Research*, *56*(4), 133-138.

Wolman, L. (1933). *Wages during the depression*. New York: National Bureau of Economic Research.

Wood, L. (1996), Frequency and chronological distribution of linear enamel hypoplasia in a North American colonial skeletal sample. *American Journal of Physical Anthropology*, 100: 247-259. https://doi.org/10.1002/(SICI)1096-8644(199606)100:2<247::AID-AJPA6>3.0.CO;2-U

World War II Museum. (n.d.). Research starters: US military by the numbers. Retrieved September 08, 2021, from https://www.nationalww2museum.org/students-teachers/student-resources/research-starters/research-starters-us-military-numbers

Xie, Z., Swain, M. V., & Hoffman, M. J. (2009). Structural integrity of enamel: experimental and modeling. *Journal of Dental Research*, *88*(6), 529-533.

Zaino, E. C. (1964). Paleontologic thalassemia. *Annals of the New York Academy of Sciences*, *119*(2), 402-412.

Zakrzewski, S., Shortland, A., & Rowland, J. (2015). *Science in the study of ancient Egypt*. Routledge.