Combating frailty: application of a modified skeletal frailty index in modern military and civilian populations.

Emily M. Frazier

University of Louisville

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COMBATING FRAILTY: APPLICATION OF A MODIFIED SKELETAL FRAILTY INDEX IN MODERN MILITARY AND CIVILIAN POPULATIONS

By

Emily M. Frazier
B.A., University of Louisville, 2020

A Thesis
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Department of Anthropology
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May 2022
COMBATING FRAILTY: APLICATION OF MODIFIED SKELETAL FRAILTY INDEX IN MODERN MILITARY AND CIVILIAN POPULATIONS

By

Emily M. Frazier

A Thesis Approved on

April 13, 2022

By the following Thesis Committee:

___________________________________
Kathryn Marklein

__________________________________
Anna Browne-Ribeiro

_________________________________
Douglas Crews
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COMBATING FRAILTY: APPLICATION OF A MODIFIED SKELETAL FRAILTY INDEX IN MODERN MILITARY AND CIVILIAN POPULATIONS

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April 13, 2022

Conceptualizing, quantifying, and evaluating frailty in human skeletal remains is critical to understanding and interpreting physiological health and stress among past populations. While many researchers focus on frailty in bioarchaeological samples, developing models for mortality risk and individual- and population-specific indices of stress, no current methods directly address frailty in forensic contexts. This study considers the applicability of a modified index for assessing frailty in forensic anthropology by comparing distributions of 8 biomarkers of stress (linear enamel hypoplasia; periodontal disease; caries; osteoarthritis; intervertebral disc disease; rotator cuff disorder; antemortem fracture; and surgical procedure) using the original skeletal frailty index (SFI) to a modified skeletal frailty index (SFI+) between self-identified military veterans (n=10) and civilians (n=9) from the Bass Donated Skeletal Collection. In this forensic context, the SFI+ reflects both increased levels of skeletal preservation within modern samples and medical interventive care that may mitigate frailty. Further, it implements severity scales, rather than relying on presence/absence binaries, for evaluating frailty biomarkers as low or high. Frailty results were interpreted through a
biocultural and embodiment framework with the presence of skeletal frailty in veteran individuals reflective of embodied stressors experienced within the unique culture and lifestyle of the military. Mann-Whitney U tests showed statistically significant differences between SFI and SFI+ distributions overall ($p<0.001$), with SFI (3.79±1.40) yielding higher average distributions than SFI+ (2.34±1.12). This variation in SFI and SFI+ distributions affected subsequent differences in results comparing military and civilian subsamples, SFI ($p=0.243$) and SFI+ ($p=0.05$), with civilian individuals exhibiting higher frailty than the veteran individuals when applied to the SFI+ criterion. The SFI+ also revealed approaching significant differences in fractures, with civilians having higher instances than veterans ($p=0.065$). While the other biomarkers did not reveal significant differences between veterans and civilians using either frailty index, differences in their distributions were observed and contextually discussed. These results support the applicability of SFI+ to forensic anthropology contexts and present an effective way of quantifying frailty that highlight complexities of modern embodied experiences of military veterans.
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CHAPTER 1
INTRODUCTION

Through a lifetime of use, the human skeleton adapts and can provide valuable information regarding the lifestyle, health, and quality of life of the individual. Bioarchaeological and forensic research allows the opportunity to explore and reconstruct these complexities of a lifetime of human activity as it is portrayed on the skeletal remains of individuals. Generally, the presence of multiple macroscopic changes to the skeleton, such as those created during growth, through nutrition, or through activity, are labeled as evidence of stress and frailty (Goodman, Martin, and Armelagos 1984; Goodman 1993; McEwen and Stellar 1993; Reitsema and McIlvaine 2014; Steckel and Rose 2002; Temple and Goodman 2014). Stress and frailty research in bioarchaeology is commonly used to understand health of past contexts and populations (Boldsen 2007; DeWitte 2014; DeWitte, Boulware, and Redfern 2013; Goodman and Armelagos 1988; Klaus, Larsen, and Tam 2009; Marklein, Leahy, and Crews 2016; Paine et al. 2009; Tuggle, Marklein, and Crews 2021; Yaussy, DeWitte, and Redfern 2016), however, it can also be applied to contemporary living populations to understand how different groups of people express and embody their lifestyles on their skeletal remains (Abete et al. 2017; Bui et al. 2019; Mitnitski, Mogilner, and Rockwood 2001; Evans and Schamberg 2009; Leahy and Crews 2012; Schulkin 2004; Bollinger et al. 2015; Cheng et al. 2021; G.H. Elder, Jr., Shanahan, and Clipp 1997; Fried et al. 2001; Littman, Forsberg, and Koepsell...
This study will apply a biocultural and embodiment perspective to analyze the lifestyles of two groups of individuals: veterans who have reported serving in the military and civilians of comparable age, sex, and self-identified race who did not serve in the military. Applying a biocultural theoretical framework in this research emphasizes military cultural processes that influence the health experiences and resulting biological skeletal stress and frailty of military veterans (Cheverko, Prince-Buitenhuys, and Hubbe 2020; Knudson and Stojanowski 2008; Leatherman and Goodman 2020; Zuckerman and Armelagos 2011; Schrader and Torres-Rouff 2020). The presence of skeletal biomarkers of frailty will be interpreted through an embodiment lens as a physical representation of the multidimensional lived experience of individuals situated and interacting within their social and cultural environments (Agarwal 2016; Cheverko, Prince-Buitenhuys, and Hubbe 2020; Joyce 2005; Krieger 2005; Schrader and Torres-Rouff 2020).

Medical and interventive research has been published about the health of service members from past periods through skeletal analysis spanning from, but not limited to, the battles of Himera, Greece in 480 BCE, to the American Civil War in the 1860’s, and World War I and World War II sites across the world (Burke 2012; Danforth, Funkhouser, and Martin 2016; Gaudio et al. 2015; Gojanović and Sutlović 2007; Kyle et al. 2018; Millard et al. 2020; Stevens and Leader 2006; Viva et al. 2020; Wols and Baker 2004). There is also current research that assesses the health of living modern military service members during their time of service (Cameron et al. 2011; Chandler et al. 2017; Clark et al. 2007; S.P. Cohen et al. 2012; Dolan and Ender 2008; Groër and Burns 2009; Horn et al. 2012; Karasel, Cebeci, and Sonmez 2020; Knapik, Reynolds, and Harman 2009; McLaughlin, Nielsen, and Waller 2008; Pietrzak et al. 2014).
2004; Konitzer et al. 2008; Lane et al. 2012; McCarthy et al. 2010; Sedliak, Sedliak, and Vaara 2019; Seelig et al. 2016). Although there is considerable casework committed to the identification of military veterans from 20th century conflicts, there are currently no studies that directly compare health and stress of modern military veterans to modern civilians after their death through skeletal analysis.

Modern military experiences are unique from past contexts, impacted by differing circumstances of war, requirements to carry increasingly heavier loads of military gear such as body armor, rucksacks, ammo, food, and water, and changes in risks of injury such as improvised explosive devices (IEDs) (Carr et al. 2020; Clark et al. 2007; S.P. Cohen et al. 2012; Cornum, Matthews, and Seligman 2011; Knapik, Reynolds, and Harman 2004; Konitzer et al. 2008; T. Smith et al. 2011; Vogt et al. 2004). These experiences are influenced by the rigid and stressful lifestyle and culture of the military which emphasizes physical and mental toughness, sometimes to a fault (Barnao 2019; Dolan and Ender 2008; Hall 2011; Lane et al. 2012; Langston, Gould, and Greenberg 2007; MacLean and Elder 2007; Nindl et al. 2018; Pflanz and Ogle 2006; Schumm and Chard 2012).

This study will provide an opportunity to address the knowledge gap of skeletal stress and frailty of modern military veterans and is a first attempt to answer the question: How is modern military service embodied and reflected in the skeletal remains of veterans? More specifically, the goal of this study is to test the applicability of a modified Skeletal Frailty Index (SFI+) to quantify eight skeletal markers of stress (linear enamel hypoplasia (LEH), unfilled caries, periodontal disease (PD), osteoarthritis (OA), intervertebral disc disease (IVD), rotator cuff disorder (RCD), fractures, and surgical
procedures) using severity scales, compared to the presence-absence scoring methodology of the Skeletal Frailty Index (SFI) (Marklein and Crews 2017; Marklein, Leahy, and Crews 2016; Marklein and Crews 2022). How do SFI+ and SFI scores differ between U.S. veterans and U.S. civilians? Do military veterans exhibit more evidence of stress and frailty biomarkers on their skeletal remains than civilians, as a result of their embodied military experiences? To address these research aims and questions, the following hypotheses were generated:

**Research question 1:** How do frailty results differ between the original SFI and the modified SFI+?

**H_0:** There are no differences in frailty results between the SFI and the SFI+ (H_0: SFI = SFI+).

**H_1:** There will be significant differences in frailty results between the SFI and the SFI+ (SFI ≠ SFI+).

**Research question 2:** How do Skeletal Frailty Index+ and Skeletal Frailty Index scores differ between U.S. veterans and U.S. civilians?

**H_0:** There are no differences in Skeletal Frailty Index+ scores between U.S. veterans and U.S. civilians (H_0: F_veterans = F_civilians).

**H_1:** The U.S. veterans sample population will have higher overall Skeletal Frailty Index + scores than the U.S. civilians sample population. (H_1: F_veterans > F_civilians).

This analysis is important as it has implications beyond the bioanthropological and anthropological fields, contributing to a better understanding of veteran health and physical impacts on the body through military service by examining if there are differences in the prevalence of stress and frailty via permanent structural changes to the
skeleton. I have been enlisted in the U.S. Army for ten years, and personally have experienced, and witnessed among my leadership and peers, negative health outcomes from military service. By addressing skeletal stress and frailty from modern service members, this study will assist in illuminating the skeletally embodied outcomes of serving in the military in the late 20th and early 21st century, while also applying a modified frailty index (SFI+) that accounts for modern health interventions not evident in bioarchaeological contexts (e.g., dental fillings, joint replacements) as well as the severity of skeletal frailty biomarkers. Furthermore, the comparison of frailty outcomes from the SFI+ and SFI will determine whether the severity scales of the SFI+ uncover differences in frailty not seen the SFI methodology, and establish the applicability of the SFI+ to modern forensic skeletal samples (Marklein and Crews 2017; Marklein, Leahy, and Crews 2016; Zedda et al. 2021).

Chapter two of this study will outline the existing literature on the concepts and applications of stress and frailty, and the theoretical frameworks of the biocultural and embodiment approaches. In Chapter Three, the culture of the late 20th and early 21st century U.S. military will be discussed to provide context of the military lifestyle the veterans in this research would have experienced. Literature regarding health, stress, and frailty of veterans during and after their service, as well as service member skeletal analyses from historical contexts will be addressed. Chapter Four will outline the materials and methods used in this research by discussing donated skeletal collections and the SFI+ biomarkers and scoring methodologies. Chapters Five and Six will comprise results and discussion of results, respectively, in relation to the literature. Lastly, Chapter Seven will synthesize the major results and outcomes found with respect
to the study’s research aim and questions, discuss the study’s limitations, and recommendations for future research.
CHAPTER 2

BACKGROUND AND THEORETICAL LITERATURE

2.1. Stress and Frailty

2.1.1. Stress

Research on the health of past populations has been a focused endeavor for biological anthropologists for decades. The notion of “health” is unclear and is not universally defined, so addressing it becomes more problematic in past populations (Temple and Goodman 2014; Reitsema and McIlvaine 2014). Although agreed upon that the absence of skeletal markers of stress does not equate to a “healthy” individual or group, it is generally agreed that presence of skeletal markers related to physiological changes from stress can be determined as “unhealthy” (Reitsema and McIlvaine 2014). In attempts by anthropologists to explore health in past populations while moving away from the dichotomy of “healthy” or “not healthy” descriptions, the stress concept was initiated to account for the complex cultural, biological, and environmental processes that influence health (Reitsema and McIlvaine 2014; Temple and Goodman 2014).

The stress perspective, described as the “model for interpretation of stress indicators in paleoepidemiological research” presented a way to conceptualize the process of stress seen on skeletal remains (Temple and Goodman 2014; Goodman, Martin, and Armelagos 1984). Skeletal stress indicators have been defined as the product from processes of physiologic disruption (Goodman, Martin, and Armelagos 1984, 15;
Temple and Goodman 2014). When stress occurs, the balance of deposition or resorption of bone by osteons can be disrupted resulting in measurable indicators seen on the skeleton (Goodman et al. 1988). These disruptions are influenced by environmental constraints, cultural systems, and host experience and resilience to stress, and can occur from a variety of stressor types including nonspecific long-term cumulative stress, periodic acute events of stress, or stress by specific diseases (Goodman, Martin, and Armelagos 1984).

Concerns of using the terminology of stress in bioarchaeology have been raised because of its vague definition as well as the multifactorial etiologies of commonly used markers of stress on skeletal remains (Pilloud and Schwitalla 2020; Edinborough and Rando 2020). Discussion regarding careful consideration in the use of the term “stress” when interpreting skeletal remains was argued by Pilloud and Schwitalla (2020). Their research on periosteal reactions, porotic hyperostosis, and cribra orbitalia in an archaeological sample in central California across various time periods highlighted results that conflict with the traditional stress concept. In comparison to similar archaeological research in a different region in California, their results showed different patterns of these skeletal markers, suggesting that other variables influence their presence than purely biological responses to stress, and that the presence of these indicators vary by region, climate, and timespan (Pilloud and Schwitalla 2020).

Due to the ambiguity regarding the term’s meaning and applicability to indicators on bone, some researchers are conflicted with the use of stress terminology in bioarchaeology. Because the exact disruption that causes commonly used stress markers on bone sometimes cannot be determined due to complex etiological processes, and since
many stressors do not leave traces evident on bones, Edinborough and Rando (2020) argue that stress should only be applied when it can be specifically defined, such as mechanical stress applied to bone. However, the authors fail to provide an alternative term to stress that would be more appropriate. Instead, they suggest moving towards improved understanding of causal relationships between stressors and markers of stress on bone, improved recording and identification of diseases, and consideration of life histories rather than health reconstruction through stress (Edinborough and Rando 2020).

While the concerns regarding the ambiguity of stress raised by these researchers should be reflected upon, without an alternative it remains the best description available. The stress perspective considers the complexities of stress indicators through taking a biocultural approach and making cautious claims regarding causation of stress markers on bone. Appreciating that skeletal markers, which are often interpreted as responses from stress, have complex etiologies is an essential perspective in stress and frailty research. Simply stating that all markers seen on skeletal remains are a result of stress events would undermine the underlying theoretical basis upon which the stress perspective was built upon, which is that complex biocultural processes impact the development of skeletal stress indicators (Goodman, Martin, and Armelagos 1984; Goodman et al. 1988). By taking a biocultural approach, one that considers both the relationship between biological processes and the sociocultural contexts of the lived human experience, when interpreting skeletal markers of stress, some mitigation of these concerns can be achieved.

2.1.2. Frailty

In living populations, frailty is sometimes defined as disability, comorbidity, and
advanced old age, and associated with higher risk of poorer health, inhibited responses to stressors, and increased mortality (Fried et al. 2001; Bisset and Howlett 2019; Abete et al. 2017). Frailty studies have explored how to operationalize frailty in the living particularly focused on the aging and elderly populations. Frailty indices have been developed to quantify and describe frailty in living elderly populations (Bisset and Howlett 2019; Mitnitski, Mogilner, and Rockwood 2001). To evaluate individual aging regarding differential frailty among individuals of the same chronological age, a frailty index was used to quantify the presence of 92 variables, called deficits (Mitnitski, Mogilner, and Rockwood 2001). Each deficit was scored 0 if absent or 1 if present, summed together, and divided by the number of variables to determine the individual’s frailty index ratio (Bisset and Howlett 2019; Mitnitski, Mogilner, and Rockwood 2001). Their results show that the frailty index ratio, represented through accumulation of deficits, was a more successful predictor of risk of mortality than chronological age (Mitnitski, Mogilner, and Rockwood 2001, 332). To apply a frailty index in living elderly individuals, aged 65 years or older, within an Italian context, Abete et al. (2017) measured 40 deficits through cognitive function, depressive symptoms, comorbidity, disability, nutrition, fall risk, physical performance, physical activity, and social support evaluations. Each variable was scored using either continuous, ordinal, or binary scales, and frailty was considered as a ratio of deficits present out of the total deficits measured (Abete et al. 2017). Their results indicated that their frailty index was a good measure of frailty in living Italian populations, and a useful tool that can be applied to medical care of aging individuals to manage frailty experiences (Abete et al. 2017).

In addition to the use of indices, frailty has also been studied as a phenotypic
expression that can be measured through assessments. In a study to test operationalizing frailty as a distinct experience of aging, 5,317 individuals aged 65 to 101, participated in annual physical examinations and semiannual self-reported assessments via telephone (Fried et al. 2001, M147-M149). These assessments included taking their weight, blood vitals, cardiovascular tests, and performance tests, as well as questions regarding medical histories, physical activity, frequency of falls, and physical function in difficulty completing daily tasks (Fried et al. 2001, M147-M148). Their results found that frailty expressed was indicated by the presence of three or more of the following criteria: unintentional weight loss of more than 10 pounds in the prior year, grip strength in the lowest 10% by gender and BMI, self-reported exhaustion, the slowest 10% by gender and height in a timed walking test, and lowest 20% in physical activity by gender (Fried et al. 2001, M148). Their results found that although closely linked, frailty is an independent phenomenon distinct from disability and comorbidity (Fried et al. 2001).

2.2. Skeletal Frailty and Stress in Bioarchaeological Contexts

Frailty research in bioarchaeology has developed from the stress perspective outlined by Goodman, Martin, and Armelagos (1984). Because frailty observed and quantified in the living cannot be directly measured from skeletal data, frailty assessed in bioarchaeological research relies on the stress markers that can be observed on skeletal remains. Skeletal frailty in bioarchaeological research has been addressed through a few differing frameworks on the frailty concept.

2.2.1. Skeletal Frailty from Single Biomarkers

Frailty research can be addressed through age at death distributions of past populations (DeWitte, Boulware, and Redfern 2013; DeWitte and Wood 2008; Yaussy,
Frailty in this case is represented through the death of individuals at earlier ages in the sample, whereas individuals that die later in life are assumed to have been less frail and to have had a better quality of life. DeWitte, Boulware, and Redfern (2013) compared risk of mortality through age at death distributions between monastic and nonmonastic adult males from London using hazard models. Hazard models were used as an alternative method of analyzing health through skeletal remains that determines whether a stress marker influences risk of mortality relative to baseline mortality (DeWitte and Stojanowski 2015). Their results found that the monastic population had a reduced risk of mortality than the nonmonastic population, which was potentially caused by higher quality diets, better living conditions, hygiene, and medical care among monastic communities (DeWitte, Boulware, and Redfern 2013).

Other methods record frailty through the prevalence of individual skeletal stress markers and their impact on risk of death. In particular, linear enamel hypoplasia (LEH) is a commonly used marker identifiable on tooth enamel in mortality-focused frailty research with multiple studies reporting causal relationships between childhood stress, shown through presence of LEH and early mortality rates (Armelagos et al. 2009; Boldsen 2007; Miszkiewicz 2015; Yaussy, DeWitte, and Redfern 2016). Research of other oral pathologies such as dental calculus, periodontal disease, and dental caries have also been associated with higher frailty and elevated risk of death (DeWitte and Bekvalac 2010; Yaussy and DeWitte 2019).

Research regarding skeletal markers of stress and frailty can be used to answer questions regarding health disparities between different cultures, time periods, and sex. To determine if the Black Death killed indiscriminately, DeWitte and Wood (2008)
individually assessed the presence of periosteal lesions, porotic hyperostosis, cribra orbitalia, LEH, and femur length for individuals who died from the Black Death at East Smithfield cemetery and compared these results to individuals from a nonepidemic attritional cemetery in Denmark. They employed likelihood ratios to determine the difference in risk of death, calculated as $k_2$, between individuals with and without skeletal lesions (DeWitte and Wood 2008). They found that all lesions except for femur length were associated with higher frailty and risk of mortality in the nonepidemic Denmark and also, although less substantially, in the Black Death individuals than those without the lesions. (DeWitte and Wood 2008).

In their study investigating health of male and female individuals from Imperial Roman burials in Urbino, Italy, Paine et al. (2009) recorded rates of enamel hypoplasia, periostitis, trauma, dietary lesions, degenerative joint disease, and osteoarthritis. Applying a biocultural approach in their analysis, they found high rates of all lesions overall suggesting that these individuals experienced difficult lives and substantial levels of stress during this time period, and higher rates of degenerative joint disease periostitis in males indicating differing cultural roles between the sexes (Paine et al. 2009). The frailty research outlined thus far has provided valuable information regarding the impact of skeletal markers of stress on individual health and mortality; however, they often rely on only one or a few skeletal lesions and often rely on gross or adjusted lesion prevalence in their analysis. However, additional skeletal frailty methods exist to investigate quantifying frailty in populations in other ways.

2.2.2. Skeletal Frailty Indices

In another perspective, frailty has been considered as the deteriorated physical
state of an individual as a result of the accumulation of skeletal stress markers (Abete et al. 2017; Marklein and Crews 2017, 2022; Zedda et al. 2021). This perspective views frailty as functional impairment and the embodiment of multiple stressors resulting from various processes and etiologies that were experienced by an individual. The assessment of multiple indicators of stress in skeletal remains from archaeological contexts has been proposed as it can reveal patterns that may be overlooked when using only one indicator, and can mitigate the uncertain and overlapping etiologies of commonly used biomarkers (Goodman, Martin, and Armelagos 1984; Armelagos 2003). This conception of frailty lends itself to the creation of frailty indices that calculate an individual’s frailty based on the totality of multiple stress biomarkers.

To the best of my knowledge, The Health Index, created by Steckel, Sciulli, and Rose (2002), informed by work from Goodman and Martin (2002) and further employed by Steckel et al. (2002), is the first multi-attribute index to apply severity scales to assess health and quality of life in past populations through skeletal remains. The authors assessed health at 65 sites based on seven health attributes scored per individual between 0 and 100 percent, weighted based on severity using categorical or continuous scales, and adjusted for age and quality of life by applying attribute scores only to years that the individual’s quality of life would be impacted (Steckel, Sciulli, and Rose 2002). For example, they considered attributes that formed during childhood (stature, hypoplasias, and anemia) to influence all years of life, and all other attributes (dental, infections, degenerative joint disease, and skeletal trauma) to impact only the last 10 years of the individual’s life (Steckel, Sciulli, and Rose 2002, 71). Therefore, health is quantified at all ages within each site, with scores of 100 indicating the best health and scores of 0
indicating death.

The Health Index is a great example of a starting point and novel attempt to carefully document and quantify frailty in skeletal samples; however, as openly stated and addressed by the authors, there are limitations to their methodology. Most notably, this methodology is dependent on preservation of the skeletal elements present, and limited to contexts where sex and age estimations can be made (e.g. presence of dentition for juveniles and pubic symphysis and auricular surfaces for adults) (Steckel, Sciulli, and Rose 2002, 84). Additionally, the assumptions made regarding the time an attribute persisted before death oversimplify these skeletal lesions and the true effects these attributes had on quality of life. However, these assumptions were a necessary component in their methods to calculate quality-adjusted life years in the absence of more clearly defined etiology and timing of developing these skeletal lesions. Furthermore, the use of the term “health”, likely derived from the index’s connections to health assessments from living individuals (Steckel, Sciulli, and Rose 2002, 62), is problematic in skeletal contexts as “health” is a socially and culturally defined experience, and the use of this term in skeletal contexts often leads to oversimplified typological categories of healthy or not healthy individuals or groups (Temple and Goodman 2014).

Building upon these stress and frailty concepts, Marklein, Leahy, and Crews (2016) developed the skeletal frailty index (SFI) to operationalize a phenotypic, cumulative measure of stress in skeletal samples from monastic and nonmonastic populations in Medieval London. The authors defined frailty as a condition, or state, of being experienced by the individual rather than a risk of mortality, and assessed this through thirteen biomarkers of stress: Femoral length, femoral head diameter, and linear
enamel hypoplasia, periostitis/osteomyelitis, periodontal disease, porotic hyperostosis/cribra orbitalia, rickets/osteomalacia, neoplasms, and osteoporosis, osteoarthritis, intervertebral disc disease, rotator cuff disorder, and fracture (Marklein, Leahy, and Crews 2016). Each biomarker was given a score of 1 if the biomarker was present or fell within the highest risk quartile or given a score of 0 for all other values. These scores were the summed to result in an individual’s skeletal frailty index ranging from 0 (least frail) to 13 (most frail) (Marklein, Leahy, and Crews 2016).

Their results using their SFI revealed significant frailty index differences between the monastic and nonmonastic populations, while these results would have varied if gross prevalence or frailty index scores of single biomarkers has been used alone (Marklein, Leahy, and Crews 2016). The SFI methodology can evaluate both individual and population frailty, an attribute that gross prevalence and hazard model methods do not permit. Additionally, the quantification of the frailty concept using multiple biomarkers allows for overall health of the individual and population to be addressed rather than individual assessments of biomarkers that reflect specific events such as nutritional deficiencies or trauma. However, this SFI requires complete individuals in the archaeological record to be effective.

In a re-evaluation of their SFI, Marklein and Crews (2017) tested the SFI using fewer biomarkers and found comparable frailty results between a six biomarker SFI and the original thirteen biomarker SFI. The ability to apply the SFI using fewer biomarkers broadens its applicability towards more bioarchaeological contexts where limited skeletal elements and smaller sample sizes are present (Marklein and Crews 2017). Important limitations of the SFI addressed by the authors were that each biomarker was given equal
weight in the SFI calculation, which assumes that each biomarker equally influenced level of frailty, and biomarker frailty scores were limited to either 0 or 1 without weighing biomarkers based on severity of lesions (Marklein, Leahy, and Crews 2016). Therefore, an individual with multiple fractures was given the same score of 1 as an individual with one fracture, despite both individuals experiencing different amounts of physiological stress, impacts on quality of life, and levels of frailty as a result of their fractures.

Since its publication, the SFI has been adapted and used in further research (Tuggle, Marklein, and Crews 2021). Zedda et al. (2021) modified the SFI, which they called the BFI, and applied it to the same population as Marklein, Leahy, and Crews (2016) to address the concerns of weighing biomarkers and scoring by severity. However, their BFI regarded frailty as premature death, which contrasts with the initial intention and application of the SFI as a syndrome and not a reflection of risk of death (Marklein, Leahy, and Crews 2016; Zedda et al. 2021). Their methodology assigned severity scales to three biomarkers, cribra orbitalia, porotic hyperostosis, and periostitis, with respect to their state of healing, and applied a Logit model to estimate the risk of dying prematurely and determine the weight all biomarkers received (Zedda et al. 2021). For example, cribra orbitalia was recorded using four severity scales, and was weighted as 1 for severity 1 while severities 2-4 are weighted as 3 (Zedda et al. 2021).

Interestingly, although they were able to study 1,009 individuals using the BFI while the SFI was applied to 134 individuals, their results substantiated the significant differences found by Marklein, Leahy, and Crews (2016), with BFI results revealing significant differences in frailty between males and females (Zedda et al. 2021).
Regardless of the modifications used, the application of skeletal frailty index methodologies has advantages over other skeletal frailty methods such as gross prevalence and hazard models through the ability to quantify frailty at the individual and population level, as well as interpreting frailty through multiple biomarkers together to better understand frailty in past populations.

2.3. Allostasis, Allostatic Load, and Frailty

Allostatic load is a concept derived from Sterling and Eyer’s (1988) concept of allostasis, which means maintaining stability through change (McEwen and Seeman 1999, 32). Sterling and Eyer proposed the use allostasis in place of homeostasis as a more effective descriptor of the brain and body’s biological response to maintaining stability (1988, 637). Years later, the concept of allostatic load was introduced to measure stress as an individual’s cumulative events of allostasis over time (McEwen and Seeman 1999; McEwen and Stellar 1993). Recurring periods of allostasis leads to increased allostatic load that can cause irreversible changes to the body, which McEwen and Seeman refer to as “wear and tear” (1999, 32). These changes are influenced by an individual’s social and cultural contexts, and can include outcomes such as poorer health, inhibition of organ systems, and overactive neural, endocrine, and immune responses (McEwen and Seeman 1999, 32, 43).

An individual’s perception of stress, influenced by their social and cultural context, is informed by individual variation through genetics, developmental experiences of stress during early life, and learned stress coping behaviors from experience with previous stressors, such as smoking or exercise (McEwen and Seeman 1999). The body attempts to mediate stressors and maintain allostasis, such as activating immune
responses to fight off infection (McEwen and Seeman 1999). In this example, repeated events of infection accumulate to allostatic load from overactivity of the immune system (McEwen and Seeman 1999). McEwen and Seeman (1999) measured allostatic load within individuals through an index of ten variables that were scored into quartiles (38). For each individual, allostatic load was calculated by summing the counts of parameters whose scores fell into the highest risk quartile for that variable (1999. 38). Their results showed that social and cultural factors, such as stress experienced during childhood and socioeconomic status, play roles in individualized allostasis and allostatic load which can influence the individual’s physical and mental health (McEwen and Seeman 1999); results that have also been substantiated in many subsequent studies (Edes and Crews 2017; Boldsen 2007; Evans and Schamberg 2009; Evans and Kim 2012).

Allostasis and allostatic load cannot be directly measured based on skeletal markers (McEwen and Stellar 1993; McEwen 2004; Goodman, Martin, and Armelagos 1984). However, if we consider allostasis as a physiological response to stress that can be measured in living populations, then physiological responses that result in changes to the skeleton as stress markers can be similarly assessed. Skeletal biomarkers of stress reflect events or “disruptions to physiological homeostasis at particular points of development” (Temple and Goodman 2014, 190). By this definition, the stress concept, indicated by skeletal stress markers, is related to allostasis as physiological disruptive events, whereas allostatic load is related to the frailty concept as a representation of the accumulation of stressor events (McEwen 2004). While the SFI+ does not measure allostasis, the quantification of multiple dimensions of stress seen in skeletal remains is able to reflect
the underlying concept of allostatic load as the accumulation of embodied recurring periods of stress from the individual’s life experience.

2.4. Modern Frailty and the Osteological Paradox

In a publication that garnered widespread discussion, Wood et al. (1992) introduced the concepts of the osteological paradox, which brought to light inherent biases imbedded in the skeletal record that require consideration while interpreting health of past populations through skeletal lesions. Though unintuitive to the argument that higher frequencies of skeletal lesions results in higher frailty, the osteological paradox accordingly argues that in some cases individuals that survive long enough in order to develop skeletal lesions reflect a greater ability to withstand stressors compared to those individuals who died earlier (Wood et al. 1992). This paradox was received with much contention in the field (M.N. Cohen, Wood, and Milner 1994; Goodman 1993), and anthropologists are still grappling with the osteological paradox concepts and its application in research today (Wilson 2014; DeWitte and Stojanowski 2015).

Wood et al. (1992) outline three problems. The first is demographic nonstationarity which describes how fertility and mortality rates fluctuate and influence age at death distributions. In this problem, the authors argue that the skeletal sample present in the archaeological sample may reveal more about fertility rates, rather than the mortality patterns, of the population (Wood et al. 1992; Wright and Yoder 2003). The second problem is selective mortality which states that skeletal samples are inherently biased as they only represent individuals that died at a certain age but do not reflect all individuals who were at risk of death at that age. For example, an individual may have had just as high of a risk of mortality at the age of 35 but did not die until they were 40.
The third problem is hidden heterogeneity in risks describes the unknown factors influencing the frailty in a population, such as genetic or socioeconomic differences (Wood et al. 1992). These biases supposedly produce an unrepresentative sample of the true past population, and which can become problematic in the interpretation of skeletal data in archaeological contexts (Wood et al. 1992; DeWitte and Stojanowski 2015; M.N. Cohen, Wood, and Milner 1994).

Recent discussions on the osteological paradox are directed toward methods to counteract the problems addressed in the original publication. Improvements in sex and age estimation methodologies as well as a deeper understanding of skeletal lesions are major steps that will help alleviate these concerns (Wood et al. 1992; DeWitte and Stojanowski 2015; Wright and Yoder 2003). Analysis of DNA, stable isotopes, and histological analyses are being employed and have great potential to unlocking key etiological and healing processes and insights (Wright and Yoder 2003). When analyzing skeletal frailty data, selective mortality can be addressed by moving away from the reliance on lesion frequencies. Approaching the data through other methods such as biodistance, which can account for hidden heterogeneity such as genetic influences, and hazard models has been successful in detecting hidden heterogeneity and selective mortality through associations of skeletal lesions to risk of mortality (Wright and Yoder 2003; DeWitte and Stojanowski 2015).

As this research will explore comparative frailty in a forensic context between modern military veterans and civilians, the applicability of the osteological paradox is uncertain. While there is certainly the potential for the problems outlined in the osteological paradox that can be applied to populations today, in forensic contexts the
difference in its applicability depends on the context itself. In donated skeletal collections, documentation of the individual and their histories are common, so there is often less ambiguity regarding the individual. Additionally, the individuals in the collections often represent people from different cultural backgrounds, geographic environments, and temporal periods. Therefore, the issues of demographic nonstationarity, selective mortality, and hidden heterogeneity in risks may not apply. The SFI+ applies the frailty concept outlined by Marklein, Leahy, and Crews (2016) which addresses frailty as an individual’s state of being and quality of life through the accumulation of multiple stressors. This necessitates a biocultural perspective of frailty, while emphasizing that skeletal stress markers are expressed as embodied results from lived experiences informed by multifactorial biological, environmental, and cultural processes (Siek 2013; DeWitte and Stojanowski 2015; Goodman et al. 1988).

Some aspects of applying the SFI+ methodology overcome concerns of the osteological paradox outlined by Wood et al. (1992). First, the SFI+ includes multiple biomarkers of stress and applies severity scales to quantify overall frailty, rather than individual biomarker prevalence, at the individual level and mean frailty at population level. Additionally, it considers the complex etiologies and alternative explanations of lesion presence rather than simply attributing their presence as biological responses from stress events (Goodman 1993; Siek 2013; Wood et al. 1992; Temple and Goodman 2014; Marklein, Leahy, and Crews 2016). Furthermore, individuals included were controlled for sex (males), age (50-60 years), self-identified race (European/white), and time period of death (2001-2019) which lessens the impact of heterogeneity of risk; however, genetics and other hidden risk factors are still unknown (DeWitte and Stojanowski 2015;
Additionally, because this frailty index is applied to modern populations, the frailty results from this research can be directly compared to frailty distributions in living populations, a challenge often noted in archaeological frailty research (Wood et al. 1992, 357; Wright and Yoder 2003; Komar and Grivas 2008). Therefore, frailty variables contributing to individual SFI+ will be analyzed and interpreted in light of the osteological paradox (i.e., dentoalveolar and skeleton conditions may reflect frailty or resilience), with specific consideration of the modernity of these samples by considering the prevalence of these pathological conditions in 20th and 21st century populations.

2.5. Theoretical Background

2.5.1. Bioarchaeology and Application of Theory

Compared to other anthropological disciplines, biological anthropology was slower to apply theoretical frameworks to its research. Within early bioarchaeology and paleopathology, research focused on presence, absence, severity, and frequency of a pathology within a culture but without regard to how those cultural processes influence their results (Cheverko, Prince-Buitenhuys, and Hubbe 2020; Knudson and Stojanowski 2008; Zuckerman and Armelagos 2011). While the biocultural approach was initially introduced in the 1950’s, bioarchaeology held on to descriptive typology for a few more decades until the biocultural approach was used more frequently with a focus on individual agents and the relationship between biology and cultural processes (Cheverko, Prince-Buitenhuys, and Hubbe 2020; Leatherman and Goodman 2020; Zuckerman and Armelagos 2011). This research will apply the theoretical framework of the biocultural approach by contextualizing skeletal frailty in modern military and civilian populations,
and interpreting biomarkers of skeletal frailty as stressors experienced by and embodied in the individuals included in this study.

2.5.2. Biocultural Approach

Bioarchaeological research using a biocultural approach concentrates hypotheses less on the presence or absence of pathologies and more on patterns of the pathologies, recognizing that cultural systems and biological processes are connected within the social, political, and cultural contexts of that individual or culture that could explain their presence (Zuckerman and Armelagos 2011; Goodman et al. 1988). With the focus on cultural contexts and their relationship with biological processes, bioarchaeologists make connections regarding lifeways and skeletal markers of stress and frailty using interdisciplinary and holistic research from archaeology, ethnography, and historical and skeletal data. Skeletal data do not exist in a vacuum and are a representation of behaviors and lifestyles inherent in the population into which they are integrated. To take a biocultural approach is to analyze the data through both a biological and cultural lens and to focus research on the interconnectedness between biological stress markers and sociocultural and ecological environments.

Research has shown that both social and biological factors can influence health of an individual (Zuckerman and Armelagos 2011; Hoke and Schell 2020; Leatherman and Goodman 2020; Mitnitski, Mogilner, and Rockwood 2001; Evans and Kim 2012; Fried et al. 2001; Abete et al. 2017; Leahy and Crews 2012; Frueh et al. 2020). For example, children of low socioeconomic status face more psychological and physical risk factors; this has been correlated with increased allostatic load and decreased working memory into adulthood (Evans and Schamberg 2009; Evans and Kim 2012). These
connections can also be made within modern populations, which this research will address through military veterans and civilians. Additionally, within demanding occupations such as military special forces and firefighters, high workloads impact individuals both mentally and physically, resulting in high allostatic load, perceived stress, and burnout (Sandrin et al. 2019; Frueh et al. 2020). These vastly different examples reflect both biological and cultural processes at play that influence the health of an individual that require a biocultural approach to fully understand.

2.5.3. Embodiment

Among the theoretical frameworks that intersect the biocultural approach is the theory of embodiment. Embodiment theory in bioarchaeology recognizes that humans are both biological and social entities and incorporate our worlds physically into our bodies (Krieger 2005). Lesions seen on skeletal remains are not simply interpreted as biological responses to stressors, but reflect evidence of the contextualized entanglements and as representations of the lived experiences of the individual (Krieger 2005; Schrader and Torres-Rouff 2020; Joyce 2005; Agarwal 2016; Cheverko, Prince-Buitenhuys, and Hubbe 2020; Knudson and Stojanowski 2008). While these environments and stimuli change over an individual’s lifetime, physiological and biological vestiges of these embodied experiences and situations may nonetheless imprint indelibly on a person’s soma.

Embodiment theory has been applied to many anthropological contexts to explore the interconnectedness of biological and sociocultural experiences. Among research from both living and deceased individuals, the embodiment of racial disparities has often been addressed. Kuzawa and Sweet (2009) examined the existing research to evaluate health
disparities between U.S. African American and White individuals. They sought to
determine the relationships between genetics and maternal stress and health during
pregnancy and fetal development and their impacts on low birth weight and elevated risk
of cardiovascular disease in adulthood. They found that on average African Americans
had lower birth rates compared to White individuals, a variable that has been associated
with heightened risk of higher blood pressure, diabetes, elevated cortisol reactivity, and
cardiovascular disease later in life (Kuzawa and Sweet 2009). The differences in birth
weight between U.S. African American and White individuals, and the confounding
factors on health disparities into adulthood, were discussed through a suite of probable
causes.

While the authors recognized the potential for genetic differences impacting these
outcomes, they found no genetic evidence to substantiate the inequalities observed
(Kuzawa and Sweet 2009). Rather, the authors proposed that social and structural factors
including lower access to prenatal care, socioeconomic status, racial discrimination,
neighborhood poverty, and increased risk of depression and anxiety, affected African
American women at higher rates than White women (Kuzawa and Sweet 2009, 8). These
experiences of racial and economic stressors are passed on to their children during fetal
development and physically embodied through low birth weight, resulting in perpetual
transgenerational stressors (Kuzawa and Sweet 2009, 9). This research exemplifies the
embodiment concept by demonstrating how lived social experiences traverses into
biological outcomes.

Within a bioarchaeological context, Dent (2017) explored how the
marginalization, racial discrimination, and low socioeconomic status of the enslaved life
are embodied through analysis of 17 enslaved individuals from the Eaton Ferry Cemetery, North Carolina. While enslavement perhaps demonstrates one of the most extreme acts of discrimination, experiences of an enslaved life likely varied across individuals (Dent 2017). With this in consideration, they collected data regarding skeletal lesions indicative of disease, infection, nutrition, dental pathologies such as enamel defects, carious lesions, antemortem tooth loss, and abscesses, and stable isotopes for diet reconstruction (Dent 2017).

In comparison to other contemporary samples, their results showed similarly revealed high rates of all dental and skeletal lesions recorded. Evidence of childhood stress from nutritional deficiencies were seen from cranial porosis and new bone formation, aligning with historical accounts which documented that enslaved children received less nutritious food than the adults (Dent 2017). Periosteal lesions, new bone formation, and erosive lesions across multiple skeletal elements suggested potential exposure to disease and infection such as tuberculosis and congenital syphilis; however, the author noted the limitations of differential diagnoses (Dent 2017). Stable isotope results suggested that each individual’s diet differed, with a high C₄ based diet from consumption of maize, pork, and/or chicken (Dent 2017). Overall, the embodiment of enslavement and exposure to harm varied by individual in this sample (Dent 2017), highlighting the subtleties of embodiment even within the same social and environmental context.

Embodiment theory has been applied to other bioarchaeological contexts. To explore the effects of the decline of the Egyptian New Kingdom Empire, Schrader and Buzon (2017) examined activity patterns through entheseal changes and instances of
accidental trauma in post-colonial Nubia from a funerary sample of individuals from Tombos during the Third Intermediate Napatan period. Cultural changes that occurred between these two periods reflect the shift from dependence on the colonial powers of the New Kingdom Empire towards self-sufficiency requiring adjustments in agricultural practices and labor intensification (Schrader and Buzon 2017). Higher entheseal scores and similar frequencies of accidental trauma within the post-colonial Third Intermediate Napatan population were attributed to more frequent and demanding forms of labor requirements during this period (Schrader and Buzon 2017). The authors suggested that without the governed support from The New Kingdom, residents of Tombos participated in quarrying efforts for statue production, agricultural and animal husbandry food production activities, and frequent cemetery tumuli construction (Schrader and Buzon 2017). The similar rates of accidental trauma between the two periods suggest that the higher level of physical activity in the Third Intermediate Napatan population may have created a more robust and resilient population embodied by stronger musculoskeletal systems (Schrader and Buzon 2017). The major political and structural shift that occurred in Nubia between The New Kingdom and Third Intermediate Napatan periods showed changes in the skeletal remains between the two populations that reflect embodied cultural change. Humans interact with their social and cultural environments psychologically, behaviorally, and biologically in a myriad of ways that result in embodied changes some of which can be seen on skeletal remains.

Modern military service members are also situated in, interacting, and contributing to a specific social and cultural context both socially and physically. This context has certain sets of rules, values, beliefs, and behaviors which influence an
individual’s rate of allostasis and allostatic load, while certainly affecting the embodied consequences of the lifestyle. Therefore, when understanding patterns of stress and frailty within a modern military context, application of biocultural and embodiment theories requires understanding how bodies respond biologically within their social environments. These theories will be explored in the subsequent chapter within previous stress and frailty research of military populations and contextualized by illuminating aspects of the military culture which are embodied by the individuals situated within it.
CHAPTER 3

MILITARY CULTURE, STRESS, AND FRAILTY

As previously addressed, there is an abundance of research regarding stress in living and past military veteran populations. However, there is a gap in knowledge regarding skeletal stress and frailty of military populations from the late 20\textsuperscript{th} and early 21\textsuperscript{st} centuries. This research will address this knowledge gap through the comparison of two skeletal frailty indices (SFI and SFI+) that quantify stress markers in contemporary military veteran and civilian individuals. I will be using the term stress to discuss the permanent embodied physiological changes to skeletal remains as a response to events and experiences lived by an individual. Concurrently, the term frailty will be used to discuss the overall prevalence of stress per individual using the SFI and SFI+ score as proxies. The interpretation of stress requires a biocultural perspective, as skeletal stress is the embodied biological result of socially and culturally experienced events that dysregulated the individual’s ability to adapt (Temple and Goodman 2014; Goodman et al. 1988). Therefore, frailty results between veterans and civilians will be evaluated through a biocultural lens as embodied accumulation of stress.

3.1. U.S. Military Culture of the 20\textsuperscript{th} and 21\textsuperscript{st} Century

The military is its own culture, structure, and institution separate from the civilian sector (Barnao 2019). Those within the military lifestyle ascribe to particular social norms, values, beliefs, attitudes, and rituals that are instilled into service members during
initial military training (Barnao 2019). During initial training, recruits are stripped of their past identities and are molded into their new common identity as warriors through rituals including cutting off their hair and being provided with uniforms (Barnao 2019). Essentially, recruits are torn down through physical and emotional exhaustion, beratement, and psychological tactics to equalize all recruits to the same level (Barnao 2019). Through education of military history, ethos, rituals, and training, recruits can be built from the ground up with a foundation of military ideology, values, morals, and ways of thinking while instilling a sense of honor, pride, and esprit de corps (Barnao 2019).

The basis of these cultural norms are set within The Soldier’s Creed and Warrior Ethos, which are memorized, repeatedly drilled, and internalized into the minds of recruits and followed by soldiers throughout their military career (Riccio et al. 2004). The principles of these codes are rules and instructions of pride and commitment to the U.S. military, the mission, and your fellow soldiers. Within the Soldier’s Creed, which encapsulates the soldier’s dedication to serving the people of the United States as a “guardian of freedom” ready to deploy and fight for all it stands, is the Warrior Ethos which states: “I will always place the mission first. I will never accept defeat. I will never quit. I will never leave a fallen comrade” (Riccio et al. 2004). To those outside of the military culture the expressions of the Soldier’s Creed and Warrior Ethos may seem extreme. However, for soldiers they form the roots of the pride, motivation, and loyalty to risk their death and fight for their country.

The military population represents a unique community of individuals from all backgrounds, and its structure builds strong relationships and forms feelings of belonging between services members. Service members often describe the members within their
unit, platoon, and squad as their “second family”, and spend the majority of their days together on and off duty (Hall 2011; Barnao 2019). In high stress and dangerous combat situations, these group bonds are especially important. The preparation and training for combat imparts a responsibility to protect and depend on the individuals to your left and right (Riccio et al. 2004; Barnao 2019; Hall 2011). These relationships can provide social support during difficult and stressful times from camaraderie through commiseration (Barnao 2019; Dolan and Ender 2008; MacLean and Elder 2007).

The structure of military life is rigid, stressful, and exhausting on service members (Pflanz and Ogle 2006; Lane et al. 2012; Dolan and Ender 2008; Seelig et al. 2016). In both deployed and nondeployed settings, service members report stressful working conditions and mental health concerns such as depression and PTSD (Dolan and Ender 2008; G.H. Elder 1987; Langston, Gould, and Greenberg 2007; Lane et al. 2012; Pflanz and Ogle 2006; MacLean and Elder 2007). Stressors experienced by service members span both physical and mental dimensions, which can accumulate over time leading to increased allostatic load and frailty, and can lead to risk of injury and mortality (Abete et al. 2017; Leahy and Crews 2012; Leatherman and Goodman 2020; McEwen and Seeman 1999; Mitnitski, Mogilner, and Rockwood 2001; Zuckerman and Armelagos 2011).

To cope with these stressors, service members often rely on external sources. In the military culture alcohol and tobacco use are commonly accepted ways of coping with stress but can lead to dependency, addiction, adverse physical and mental health outcomes, and can negatively impact careers (T. Smith et al. 2011; G.H. Elder 1987; Dolan and Ender 2008; Nindl et al. 2018; Wiener et al. 2019; Schumm and Chard 2012;
The strength of the social support a service member receives from family, peers, and leadership, directly impacts their ability to manage stress in a productive way. However, social support from family can be strained from long work days, deployments away from home, and constant moves, and additional stress from home, such as financial concerns or expecting a child, can exacerbate the perceived stress of the service member (Dolan and Ender 2008).

Furthermore, fellow soldiers and leadership should provide stable sources of social support to cope with stress; however, sometimes the opposite occurs. Stigma regarding seeking help exists in the military culture, whether it be for a physical ailment or mental health, and its rejection is predicated on the necessity to be tough and results in service members delaying or failing to seek help or minimizing their symptoms out of embarrassment or ridicule of being perceived as weak (Dolan and Ender 2008; Hall 2011; Langston, Gould, and Greenberg 2007). Service members may not seek help for mental health out of fear that they will be ostracized if their peers found out or that their careers will be at risk (Dolan and Ender 2008). If the social support structures in a service members life are weakened or unhelpful, they become an additional source of stress rather than a buffer for relief (Dolan and Ender 2008).

As part of the effort to remove the stigmas and barriers of seeking help, the U.S. Army designed the Compressive Soldier Fitness program to provide support and increase psychological strength and mental wellbeing within the Army (Cornum, Matthews, and Seligman 2011). As part of this program, service members participate in mandatory resiliency trainings which teaches strategies to identify, understand, and overcome challenges and setbacks both in the Army and in their personal lives (Cornum, Matthews,
and Seligman 2011; Nindl et al. 2018). Despite this, cultural mentalities surrounding physical injury or conditions from the “old Army” on being tough and not showing weakness are still perpetuated (Dolan and Ender 2008; Hall 2011). Being told to “Soldier up”, or “This is the Army— if you can’t take it, get out!”, among other phrases, are commonly heard which can create a toxic work environment and diminish motivation (Dolan and Ender 2008; Hall 2011). While efforts are being taken to amend these mentalities, lack of support for seeking help within a service member’s peer group or leadership in addition to fear and perceptions of weakness continue to be a problem in military social contexts. By delaying treatment and minimizing their symptoms, service members put themselves at additional risk of injury and decreased mental health over time (Karasel, Cebeci, and Sonmez 2020; Dolan and Ender 2008; Hall 2011).

Furthermore, because these cultural norms and beliefs are so integrated into the identities of service members, delaying help may be a continued behavior after their service.

3.2. Stress, Frailty, and Military Service

3.2.1. Health Effects of Military Service

Entrance into the U.S. military is dependent on the recruit meeting certain qualifications and standards that are evaluated by medical staff and professionals. Generally, these standards exist to ensure recruits are medically, physically, and mentally capable and are without conditions that will interfere with completing military training and performing required duties (U.S. Department of the Army 2019; Sackett and Mavor 2006). For example, between the years 2003 and 2005 the top disqualifying conditions were body mass index (BMI)/weight, testing positive for marijuana, psychiatric and mental health, lower extremity/musculoskeletal conditions, and chest and lung conditions
(Sackett and Mavor 2006). Once enlisted, service members must be fit for deployment at all times. Fitness level, body weight, and body fat have been associated with risk of injury and impact deployment readiness; therefore service members are required to adhere to their branch standards, which vary, through regular physical fitness tests and conducting regular height and weight assessments (U.S. Department of the Army 2020, 2021; Sackett and Mavor 2006; Sedliak, Sedliak, and Vaara 2019).

Deployment readiness includes the service member’s ability to perform tactical training, react and move through to combat situations, withstand and perform in austere climates, and endure demanding physical and psychological stressors (Sackett and Mavor 2006). To address these requirements, the U.S. Army has adapted new policy regarding the health of its soldiers called the Holistic Health and Fitness (H2F) program (U.S. Department of the Army 2020). This policy outlines how to maintain soldier readiness through five physical and nonphysical domains: physical, nutritional, mental, spiritual, and sleep readiness (U.S. Department of the Army 2020). This new policy emphasizes that while physical fitness is important, other aspects of soldier readiness are just as necessary to have a healthy military force. In a way, the H2F policy is adapting a biocultural perspective of health by including training on social and cultural aspects of life including personal character and behaviors, mutual respect of personal beliefs and values, emotional wellbeing, stress, resilience, hardships, and social awareness (U.S. Department of the Army 2020).

Combat deployments are stressful both physically and mentally. Service members wear personal protective equipment and tactical gear including, but not limited to, a helmet, body armor, ruck sack, a rifle, ammunition, food, and water, resulting in very
heavy loads carried ranging from 28 to over 100 pounds (Horn et al. 2012; Knapik, 
Reynolds, and Harman 2004; Konitzer et al. 2008). Body armor is one of the most 
important aspects of protection in a combat environment, however a full body armor set 
that includes front, back, and side plates can weigh 32 pounds alone (Horn et al. 2012). 
Modern combat risks of explosive devices (IEDs), land mines, bullet and shrapnel 
projectiles accounted for 65% of combat injuries between 2001 and 2003 (Clark et al. 
2007). The burden of wearing this equipment is necessary and vital to the safety of the 
service member, but as a result service members experience reduced bone health and 
report musculoskeletal injuries such as strains and fractures, and chronic joint and 
vertebral pain due to overuse and wear and tear of their bodies (Horn et al. 2012; Knapik, 
Reynolds, and Harman 2004; Konitzer et al. 2008; McCarthy et al. 2010).

However, not all deployments are combat related and physically demanding, and 
under the right circumstances may enhance a service member’s health. In an example 
contrasting with traditional deployments of demanding physical and psychological 
stressors, Sedliak, Sedliak, and Vaara (2019) assessed the impacts of soldier on a 6-
month deployment guarding military bases. On this deployment, soldiers had sedentary 
or light workloads while on duty and ample leisure time while off duty to relax, exercise, 
and play sports (Sedliak, Sedliak, and Vaara 2019). Their results showed that this 
deployment context allowed soldiers to increase their physical fitness, reduce their body 
fat, and show beneficial changes in concentrations of glucose, creatinine, uric acid, 
hematocrit, and hemoglobin biomarkers (Sedliak, Sedliak, and Vaara 2019). In this 
environment, service members did not have the extreme circumstances of combat and 
had enough down time to enjoy recreation, recover fully, and take care of their bodies
While physical health and fitness are often at the forefront of the military experience, multiple dimensions of the service member’s life are also influenced (U.S. Department of the Army 2020; Spiro III, Settersten, and Aldwin 2016). Veterans self-reported benefits of military service including access to health care, training and job skills, independence and self-discipline, social support, lifelong friendships, and education benefits (Sackett and Mavor 2006; G.H. Elder 1987; Wilmoth, London, and Parker 2010; U.S. Department of the Army 2020). Research on World War II veterans found that military service provided individuals who were disadvantaged youth an opportunity to leave their current circumstances, start fresh, and discover themselves outside from their upbringings (Sampson and Laub 1996). By joining the military, they are able to gain a sense of purpose and belonging (Barnao 2019; Hall 2011). Further research has substantiated these results and found that these benefits extended after their service through increased physical and psychological health, stable marriages, and higher occupational attainment and socioeconomic status compared to nonveterans (Bound and Turner 2002; G.H. Elder 1986; Sampson and Laub 1996; Wilmoth, London, and Parker 2010). Additionally, some veterans reflect positively on their service through the strong bonds and lifelong friendships they attained (Barnao 2019; Dolan and Ender 2008; Langston, Gould, and Greenberg 2007; MacLean and Elder 2007).

Results from the literature highlight the complexities of assessing the impact of military service on soldier health, as deployments, soldier duties, and social support can influence the amount of stress soldiers experience (MacLean and Elder 2007; Sedliak, Sedliak, and Vaara 2019; Dolan and Ender 2008). The conflicting literature regarding
military experience emphasizes that not all service members have the same stressors or health outcomes with differing amounts of physical and mental challenges after their service, which consequently will reflect unequal embodiment of military service and differing expressions of the military experience on their skeletal remains.

3.2.2. Veteran Health After Service

Research on veterans can be complex, and the military background of the veterans included in research need to be contextually comparable. Experiences in the military will vary on an individual basis, and can depend on factors such as their military occupation (e.g. infantryman or human resources) (Carr et al. 2020; Phillips et al. 2022), what component they were in (e.g., active duty versus reserve) (Hoerster et al. 2012), the time period they were enlisted (e.g., World War II versus Operation Enduring Freedom and Iraqi Freedom) (Bollinger et al. 2015; Clark et al. 2007; MacLean and Elder 2007; T. Smith et al. 2011), and whether they deployed and what type of deployment they experienced (Bollinger et al. 2015; MacLean and Elder 2007; Vogt et al. 2020). For example, comparisons of health between deployed and nondeployed veterans showed that deployed veterans were more likely to have negative health outcomes and conditions than nondeployed veterans (Vogt et al. 2020; MacLean and Elder 2007), and individuals within the officer ranks (e.g., Lieutenants and Captains) are more likely to have better health outcomes than enlisted service members (e.g., Privates and Sergeants) (Vogt et al. 2020; Bollinger et al. 2015). Therefore, these factors need to be considered when evaluating service member and veteran health outcomes.

The complexities of military service experiences and health outcomes has generated conflicting results about the health status of veterans after their military
service. Due to the health criteria required to enlist in the military and the physically active nature of military life, service members are often believed to be healthier, more fit, and at less risk of mortality than the general population, a phenomenon referred as “the healthy soldier effect” (HSE) (McLaughlin, Nielsen, and Waller 2008; Littman, Forsberg, and Koepsell 2009). Research regarding physical activity and health of service members have substantiated the HSE, highlighting the role regular exercise plays in bone health, decreased risk of osteoarthritis, and better health outcomes in veterans (Berenbaum et al. 2018; Littman, Forsberg, and Koepsell 2009; Goolsby and Boniquit 2017; T. Smith et al. 2007; McLaughlin, Nielsen, and Waller 2008; MacLean and Elder 2007; Sackett and Mavor 2006; Pietrzak et al. 2014). Multiple studies have addressed this effect among veteran populations.

To determine how veterans self-assess their aging experience, Pietrzak et al. (2014) collected survey data regarding medical, psychiatric, cognitive, and psychosocial attributes from veterans aged 60 to 100 years old. Their results revealed support for the HSE with over 80% of veterans reporting successful aging, and the observed measures strongly correlated with successful aging were experiencing few physical health difficulties, sound mental health, and characteristics of resilience, gratitude, and purpose in life (Pietrzak et al. 2014). While the data presented by Pietrzak et al. (2014) provides unique insights into attributes of health that support quality of life and well-being in veterans, most research demonstrates conflicting results. Littman, Forsberg, and Koepsell (2009) found contrasting evidence regarding the HSE concept. Their results indicated that while veterans were more likely to be physically active and exhibit continued motivation to physical fitness, they were also more likely to self-report as having a disability, joint
pain, and other health conditions than civilian individuals (Littman, Forsberg, and Koepsell 2009).

Bollinger et al. (2015) also assessed the HSE from veterans of Operation Enduring Freedom (OEF), Operation Iraqi Freedom (OIF), and Operation New Dawn (OND) from 2002 to 2011. Their results indicate that the HSE hypothesis is weakened within modern warfare contexts. Older veterans had lower mortality risk than the general U.S. population, which may indicate support for the HSE in veterans with longer length of military service (Bollinger et al. 2015). However, younger veterans of these wars had higher risk of mortality than the general U.S. population, and was attributed to increased risky behaviors among younger combat veterans (Bollinger et al. 2015). Interestingly, Wilmoth, London, and Parker (2010) found opposing HSE results which indicate there could be a delayed expression of the unfavorable health impacts of military service. Their results showed that veterans had better health at retirement age than civilians, however at around age 75 the outcomes changed and veterans showed poorer health than civilians (Wilmoth, London, and Parker 2010). While conflicting with the results from Bollinger et al. (2015), a delayed expression of negative health outcomes in veterans until age 75 may present an explanation for the contrasting results regarding veteran health.

Research showing that the physical requirements, heavy loads carried, dangerous deployments, and the stressful environment of the military lifestyle can have detrimental impacts on veteran health has been highly published (G.H. Elder, Jr., Shanahan, and Clipp 1997; Vogt et al. 2004; Hoerster et al. 2012; T. Smith et al. 2011; Spiro III, Settersten, and Aldwin 2016; Wilmoth, London, and Parker 2010; Kramarow, Pastor, and National Center for Health 2012). One method of quantifying frailty in living veteran
populations has been addressed through the veteran affairs frailty index (VA-FI) (Cheng et al. 2021; Orkaby et al. 2018). This frailty index defines and quantifies frailty similarly to Mitnitski, Mogilner, and Rockwood (2001) as the cumulation of deficits that are scored as present or absent, summed together and divided by the total deficits measured to achieve an overall frailty score from 0 to 1 (Cheng et al. 2021; Orkaby et al. 2018).

The authors calculated frailty from deficits using Veterans Affairs, Medicare, and Medicaid data from 2,837,152 veterans between 2002 and 2012, making it a more meaningful index to apply to veteran populations (Cheng et al. 2021; Orkaby et al. 2018). Their results show increases in frail veterans from 2002 (32%) to 2012 (47%), with an almost 50% increase in individuals who were moderately frail (frailty scores between 0.31 and 0.40) and tripled increases in severely frail individuals (frailty scores greater than 0.4) (Cheng et al. 2021; Orkaby et al. 2018). The VA-FI was successful in measuring frailty and risk of death in veteran populations and included a substantial dataset. However, their data included only veterans that had used VA, Medicare, or Medicaid services and may not fully represent frailty due to the exclusion of veterans that are ineligible for that care.

Another method used to operationalize the unique health concerns and care needs of veterans was outlined by Frueh et al. (2020) using the “Operator Syndrome” model to address health in special operation forces veterans. Special operation forces, also known as special forces, are a highly skilled and specialized subset of individuals within the military structure that fight in nonconventional and particularly high-risk situations (Barnao 2019). The operator syndrome model reflects the models of allostatic load, the stress perspective, and biocultural approaches by viewing health as an outcome of
multiple interconnected dimensions (Frueh et al. 2020). This model highlights how the structural factors such as special operations’ culture and mission burden, and outside demands such as family and existential life perspective, impact biological dysfunction, psychological factors, injuries, and losses experienced by this population (Frueh et al. 2020). The cycle of these stressors accumulates, increases allostatic load, and negatively impacts the health outcomes in this population (Frueh et al. 2020). The variables outlined in this model are reflected in other literature, substantiating that the stress experience of military life is a multifactorial process influenced by biocultural factors (Dolan and Ender 2008; Barnao 2019; Hall 2011).

Differential health comparisons between veterans and civilians frequently find that more veterans use tobacco products, drink alcohol heavily, and experience worse overall physical and mental health, functional limitations, chronic pain, and comorbidities including high blood pressure, high cholesterol, cardiovascular disease, and cancer than civilians (Vogt et al. 2020; Hoerster et al. 2012; T. Smith et al. 2011). Veterans also tend to have poor oral health, with carious lesions and periodontal disease attributed to stress and smoking habits of service members (Shannon, Gibson, and Terry 1966; Terpenning et al. 2001; Chisick and Piotrowski 2000). Additionally, the high physical activity, physiological and mental stress, and wear and tear experienced from the military lifestyle results in high rates of musculoskeletal injuries, fractures, vertebral disc degeneration, osteoarthritis, joint replacement, and surgical procedures in veteran populations (Clark et al. 2007; T. Smith et al. 2011; Chandler et al. 2017; Wells et al. 2006; Cameron and Owens 2014; Murtha et al. 2017; Stanishewski and Zimmermann 2015; S.P. Cohen et al. 2012; Schoenfeld et al. 2011).
While these conditions are also represented in civilian populations, the veteran population represents individuals from a unique culture that are exposed to different experiences, distinct stressors, and subsequent differential health outcomes related to their service than the civilian population. Furthermore, healthcare for veterans after their service is not guaranteed. To be considered eligible for Veteran Affairs (VA) benefits, the service member must have discharge paperwork that reflects an honorable, under honorable conditions, or general discharge, have had at least 24 months of ordered active duty service and/or a service-related disease, injury, or disability (Szymendera 2015; Bernard and Selden 2016). Veterans are placed into 8 priority groups which determines the level of medical treatment they can receive, with priority groups 1-5 able to receive free care (Bernard and Selden 2016).

Disability ratings are determined by the VA and are calculated through a compounding, not cumulative, rating system, however final disability ratings are often difficult to understand (Wool 2020). The number of service-related injuries does not necessarily equate to the percentage of disability received. For example, in her ethnography research on veterans, Wool (2020) described the disability ratings from a few individuals she interviewed. One individual had a 30% disability rating from PTSD, tinnitus, and chronic back pain, while another individual received a 100% disability from a severe traumatic brain injury (Wool 2020). Many veterans are ineligible for free benefits, or report barriers to access of care such as wait times, travel distance to a VA facility, VA care reputation, lack of information regarding eligibility, and fear or stigma of receiving treatment (Bernard and Selden 2016). Eligibility for VA dental care is even more strict, and are only available to veterans who received a service-related dental
disability, those who were given a 100% disability from military service, and former prisoners of war (U.S. Department of Veterans Affairs 2019; Cothron et al. 2021). As a result, to have access to care many veterans pay out of pocket for care or need to purchase private health and dental care (Cothron et al. 2021). Access to health care needs to be considered when addressing veteran health and frailty, as health outcomes after their service may be influenced or exacerbated due to a lack of medical and dental services. The cultural attitudes about weakness, pain, and pain belief, and “Soldiering up” may also influence a veteran’s motivation to persist in overcoming obstacles to seeking care (Dolan and Ender 2008; Hall 2011; Karasel, Cebeci, and Sonmez 2020).

3.3. Skeletal Stress and Frailty of Military Veterans

The unique environment, culture, and stress of the military become physically and mentally embodied within service members as they are socially and physically intersected within the lifestyle (Barnao 2019; Dolan and Ender 2008; Hall 2011; Frueh et al. 2020; Littman, Forsberg, and Koepsell 2009; Orkaby et al. 2018; Wilmoth, London, and Parker 2010). Stress and frailty research in bioarchaeology can sometimes detect these embodied stressors on skeletal remains of individuals (Dent 2017; DeWitte and Wood 2008; Kuzawa and Sweet 2009; Marklein, Leahy, and Crews 2016; Schrader and Buzon 2017). Previous bioarchaeological studies of military skeletal remains have been completed from a variety of temporal and geographical contexts. As the literature will show, assessing stress and frailty in veteran populations will produce varying results dependent on the time period, geographic location, and context (Bollinger et al. 2015; Carr et al. 2020; Clark et al. 2007; Hoerster et al. 2012; MacLean and Elder 2007; Phillips et al. 2022)
Kyle et al. (2018) and Viva et al. (2020) both studied skeletal pathology prevalence in mass graves from the 409 and 480 BCE battles, although from different perspectives, in the Greek colony of Himera (Sicily). The soldiers in the 480 BCE burial context were soldiers of their own volition, while the soldiers in the 409 BCE context were civilians conscripted to service (Kyle et al. 2018). Despite their differing research objectives and comparative samples, they found that the soldiers from these contexts experienced high rates of cribra orbitalia, porotic hyperostosis, linear enamel hypoplasia, periostitis, and trauma (Kyle et al. 2018; Viva et al. 2020), although results from Kyle et al. (2018) demonstrated that only cribra orbitalia and porotic hyperostosis rates were higher in the soldier population than the comparative civilian population.

From another perspective and temporospatial context, Millard et al. (2020) utilized a biochemical approach to collect data on strontium, oxygen, carbon, and nitrogen stable isotopes, oral microbiomes and diet from dental calculus, and vitamin C levels in collagen from Scottish soldiers from the Battle of Dunbar in 1650. Their results found the soldiers experienced nutritional stressors and vitamin deficiencies, inflammation and various diseases, and oral pathologies including periodontal disease, carious lesions, and abscesses (Millard et al. 2020). The presence of these skeletal stress markers was contextually situated within the historical record to provide potential explanations for their occurrences. For example, in the mass graves at Himera, skeletal trauma was argued to be caused by swords, spears, and arrows because they were the most common weapons in war between 480 and 409 BCE (Viva et al. 2020). Millard et al. (2020) attributed lack of sunlight exposure from the environment in Scotland leading to vitamin D deficiencies, and widespread shortages of fruits and vegetables during the
1630s and 1640s causing cases of Scurvy in this 1650 context (Millard et al. 2020). Contrasting, soldiers from World War I and World War II exhibited trauma evident of gunshot or grenade shrapnel projectiles, and the heavy loads carried during these wars resulted in high rates of degenerative pathologies (Gaudio et al. 2015; Gaudio et al. 2019; Gojanović and Sutlović 2007).

The discussion of stress markers and frailty embodied by soldiers needs to be addressed with respect to the changes in risks and occupational stressors experienced by the soldiers in these conflicts. As an example, the average loads carried by U.S. soldiers during the Civil War was about 33 pounds (15kg) and they used additional transportation equipment such as carts to carry extra equipment (Knapik, Reynolds, and Harman 2004). Eventually changes in war required soldiers to wear more body armor and carry all necessary gear on their bodies, resulting in increased carried loads to about 99 pounds (45kg) and increases in related injuries by the 1990s during Desert Shield in Kuwait (Knapik, Reynolds, and Harman 2004). This observation was also noted by Burke (2012) from skeletal remains of U.S. service members of World war II, the Korean War, and the Vietnam War through high rates of Schmorl’s nodes in the vertebrae of these veterans indicating potential disk herniation or degenerative disc disease (Burke 2012).

Within a North American context, Wols and Baker (2004) analyzed the dentition of fifty elderly Confederate Civil War veterans. Antemortem tooth loss (AMTL), dental caries, enamel hypoplasia, and abscesses were prevalent in their sample, and while these individuals were elderly and age was a likely contributor to the poor oral health seen in this sample, the authors also noted that historic and socioeconomic factors likely influenced these results (Wols and Baker 2004). During this time the diets of soldiers
relied heavily on carbohydrates, and dental hygiene in the form of teeth brushing was not widely practiced, which possibly contributed to the high rates of AMTL in this population (Wols and Baker 2004). Additionally, professional dental care was limited, and tooth extractions during the Civil War were common preventative measures against carious lesions, particularly among lower socioeconomic populations, because dental fillings were expensive (Wols and Baker 2004).

While studies of service members from past populations provide useful information, modern military service has drastically changed from previous wars and conflicts (Bollinger et al. 2015; Carr et al. 2020; Cornum, Matthews, and Seligman 2011; Dolan and Ender 2008; Karasel, Cebeci, and Sonmez 2020; Knapik, Reynolds, and Harman 2004; Langston, Gould, and Greenberg 2007; MacLean and Elder 2007). A biocultural perspective when addressing stress and frailty in veterans of the late 20th and early 21st century is necessary as it is influenced by cultural, social, and biological dimensions of the lived military experience, and are embodied psychologically and physically (Armelagos 2003; Barnao 2019; Cheverko, Prince-Buitenhuys, and Hubbe 2020; Dolan and Ender 2008; Edes and Crews 2017; Frueh et al. 2020; Goodman 1993; Hall 2011; Hoke and Schell 2020; Krieger 2005; Leahy and Crews 2012; Leatherman and Goodman 2020; McEwen and Seeman 1999; McEwen and Stellar 1993; Reitsema and McIlvaine 2014; Schrader and Torres-Rouff 2020; Zuckerman and Armelagos 2011). This research will address this knowledge gap through applying the SFI and SFI+ methodologies to quantify the embodied skeletal stress and frailty of military service members in comparison to civilians from the late 20th and early 21st century.
4.1. Materials

4.1.1. Structural Violence and Ethical Skeletal Collections

Amassed skeletal collections are prominent and important sources of research for bioarcheologists and forensic anthropologists; however, they are not all ethically equal. Skeletal collections in the United States have a troubled history, as many of them were built on the exploitation and mistreatment of deceased individuals from marginalized backgrounds and disenfranchised populations (Campanacho, Alves Cardoso, and Ubelaker 2021; de la Cova 2019; DeWitte 2015; Garment et al. 2007; Nystrom 2014). With a focus on racial classification and hierarchy cemented in biological determinism, the belief that non-white individuals were inferior to white individuals, many institutions produced their skeletal collections primarily by collecting the remains of Native American and African American individuals. Of the most famous collections in the United States, due the documentation of individuals within them, are the Chicago Field Museum, the Army Medical Museum, and the Robert J. Terry Anatomical Skeletal collection. (Campanacho, Alves Cardoso, and Ubelaker 2021; de la Cova 2019; DeWitte 2015; Lans 2018). When compared to the percentage of African Americans in the St. Louis population at the time, the Terry Anatomical Collection comprises over four times the number of African American individuals (de la Cova 2019). Additionally, individuals
from the Terry Collection born between 1800 and 1877 were individuals of low socioeconomic status, and most were immigrants into the community; in particular, of those who were born in the South, most likely participated in the Great Migration (de la Cova 2019).

Many early skeletal collections were facilitated through medical schools, often supported by anatomy laws, such as the first “Anatomy Act” in 1831 in Massachusetts, which allowed legal dissection of unclaimed individuals (Campanacho, Alves Cardoso, and Ubelaker 2021). Although this act was implemented with the belief that it would deter grave robbing for the acquisition of cadavers for medical education, it facilitated discrimination against poor individuals (Campanacho, Alves Cardoso, and Ubelaker 2021; Nystrom 2014). Further anatomy-based laws were passed such as the “Bone Bill” created in 1854 in New York that sanctioned the remittance of bodies of the poor and those that were unclaimed to medical institutions that desired cadavers for dissection education under the guise that they were repaying their debt to society (Lans 2018). Payment of debt to society through dissection had been a common practice in the 18th and 19th centuries that was viewed as a continued form of punishment for executed criminals (Garment et al. 2007). Poor individuals were often ignored by the public and often categorized as lazy and unworthy of support by their own fault due to flaws in their character (Nystrom 2014).

The proliferation and collection of individuals that were vulnerable and marginalized by their societies in early skeletal collections is now considered a form of postmortem social inequality and structural violence. Structural violence is the systematic and institutionally embedded political and economic organization of societies that
normalizes inequalities among groups of people that cause harm and injury (Farmer et al. 2006). Just as disparities in access to resources caused by structural violence can result in skeletal manifestations, structural violence also encompasses the postmortem violence and harm done to individuals (Nystrom 2014). When structural violence manifests in research settings a dichotomy exists between the living individual and the dead body that separates the researcher from the social identity of that person. In the same way a living person can experience and embody harm and disparity during life, so can the dead through misuse, mistreatment, and “disembodiment” of that person’s body and identity after death (Lans 2018; Nystrom 2014).

Due to the legalization of dissection through the passing of various anatomy acts, marginalized communities were exploited and commodified through established infrastructures and institutions. Consent for anatomization was rarely given by the individual or their descendants. To end the perpetuation of structural violence, forensic anthropologists can support and contribute to ethical scientific research by limiting their research to individuals who had full agency in their decision to donate their bodies to scientific pursuits.

4.1.2. Limitations of Donated Skeletal Collections

There are twenty-six modern donated documented skeletal collections in the United States (Campanacho, Alves Cardoso, and Ubelaker 2021). Collections with documented demographic and personal information about the donors has increased research outputs by improving accuracy of methods on sex and age at death estimations with larger sample sizes. Nonetheless, these assemblages are not without limitations and biases. Donors in these skeletal collections, particularly in taphonomy facilities studying
decomposition, are more likely to come from local and regional areas specific to that donation facility, resulting in biased collections that represent local geographic and temporal demographics rather than broader U.S. population demographics (Campanacho, Alves Cardoso, and Ubelaker 2021).

Furthermore, racial minorities are often underrepresented in donated skeletal collections which may portray hesitation of those minorities to donate their bodies to science given prior unethical treatment of minorities after death in recent history. This limits the number of individuals available for research to the point where creating statistically substantial subsamples becomes problematic. (Campanacho, Alves Cardoso, and Ubelaker 2021). However, in many modern donated skeletal collections, donors are predominately of European racial background, with variation in distributions of females and males (Garment et al. 2007; Vidoli et al. 2017). The William M. Bass Donated Skeletal Collection is composed of 64% males, 93% self-identified European racial background, with the majority of individuals between the ages of 55 and 73 years; however, this demographic distribution will likely expand as donations by females and those belonging to other demographics increase (Campanacho, Alves Cardoso, and Ubelaker 2021; FAC 2021; Vidoli et al. 2017).

4.1.3. W.M. Bass Donated Skeletal Collection

The most prominent consideration of this research methodology was grounded on the necessity of including only ethically obtained donated skeletal samples. Therefore, the skeletal data of the individuals included in this research were collected from the W.M. Bass Donated Skeletal Collection, hereafter referred to as the Bass Collection, housed in the Department of Anthropology at the University of Tennessee-Knoxville. Officially
founded in 1981, the Bass Collection was created by Dr. William M. Bass to develop a formal body donation program and better understand the process of human decomposition (Vidoli et al. 2017). Although the earliest donors to this collection were unidentified individuals received from medical examiners’ offices, current acquisition policies and standards only allow consenting (self-consenting or by family approval) individuals to be documented for and accessioned into the collection with over 1800 individuals curated in the collection today (Vidoli et al. 2017).

Prior to their death, individuals in the Bass Collection complete a body donation packet of their personal histories including demographic information such as biological sex, age, weight, and self-identified race (White, Black, Hispanic, or Other). Additionally, donors may provide historical data on past residences, occupations, socioeconomic status, education level, and medical histories (Appendix A) (Vidoli et al. 2017). One of the questions in the body donation questionnaire asks about military service. Although this question provides general information about an individual’s military status, no additional information is solicited regarding tenure of military service or military occupation specialty (MOS) while in service. Despite this limitation, the Bass Collection is currently the only donated skeletal collection which records military service in donor personal histories, making it the ideal sample for exploring military frailty patterns.

4.1.4. Military and Civilian Skeletal Samples

Due to the inherent limitations of donated skeletal collections previously discussed, the samples used in this research comprise white male individuals. To create comparative samples of military and civilian individuals with minimal confounding
variables (chronological age, sex, self-reported race), the researcher (EF) requested access to demographically similar individuals. Additionally, all donors included in this sample are modern donations from between 2001 and 2019, which ensures that all individuals willfully donated their bodies (Vidoli et al. 2017). A total of 24 male individuals between 50 and 60 years old at age-of-death were included in the original sample for this study, including twelve individuals with declared military service (veterans) and twelve individuals without military service (civilians). The donors in this study also represent individuals born in thirteen different states across the U.S. and derive from an array of self-disclosed childhood socioeconomic statuses, education levels, occupations, medical histories, and personal interests (Figure 4.1).

![Birth State Distribution of Sample](image)

**Figure 4.1** Distribution of Donor Birth States

To ensure anonymity of donors, each individual was assigned new identification numbers: V1-V12 for veterans, and C1-C12 for civilians. Five individuals were excluded
from the final analysis (V4, V8, C10, C11, and C12) due to postmortem preservation and unobservable skeletal or dentoalveolar conditions, or notably complete antemortem tooth loss: consequently, the final sample consisted of ten veteran individuals and nine civilian individuals.

4.2. Methods

4.2.1. Operationalizing Frailty: Application to Forensic Anthropology Contexts

Most research regarding skeletal frailty and stress has been focused on bioarchaeological contexts and samples to answer questions about the health of populations from the past, which often are limited in sample size by preservation and presence of skeletal elements in the archaeological record (Marklein and Crews 2017; Marklein, Leahy, and Crews 2016). This research takes a different approach by assessing the application of skeletal frailty, using a skeletal frailty index, to modern individuals in forensic anthropology contexts. Compared with bioarchaeological samples, forensic skeletal remains differ in preservation, content, and applications. First, individuals in forensic contexts tend to be well-preserved, which enables research to include more skeletal elements and observations in their analysis. Second, modern forensic skeletons reflect contemporary environments and technologies, including interventive medical procedures that aim to reduce phenotypic frailty and are otherwise absent from bioarchaeological individuals. Medical interventions observed in this research included dental procedures or enhancements, joint replacements, and surgical procedures. Modern skeletons with evidence of interventive care, consequently, provide a distinct context for operationalizing a modified skeletal frailty index.

4.2.2. The Skeletal Frailty Index+ (SFI+)
This research implements a Skeletal Frailty Index+ (SFI+), which is adapted from the original Skeletal Frailty Index (SFI) (Marklein and Crews 2017; Marklein, Leahy, and Crews 2016), for assessing frailty in military and civilian individuals. The SFI utilized quartile and presence-absence based scoring systems for its 13 biomarkers: high frailty (“1”) for a biomarker was assigned when the condition was present or a measurement was observed in the lowest quartile of its subsample. While this methodology works well in bioarchaeological contexts, with limitations such as skeletal preservation and absence of skeletal elements, the SFI does not consider the differing levels of severity in biomarker manifestations, which could potentially misrepresent the degree of frailty (Marklein and Crews 2022; Marklein, Leahy, and Crews 2016). For example, when using the original SFI, the presence of singular or multiple fractures is scored as “1”. Therefore, an individual with a wrist fracture would have a fracture frailty score (“1”) equal to fracture frailty score (“1”) in another individual with multiple bone fractures.

This research will test the application of an incremental scoring system using a modified skeletal frailty index (SFI+). Incremental scoring scales for evaluating high and low frailty in biomarkers can be applied to these skeletally complete and well-preserved individuals, and this method captures the range of potential variation in frailty biomarker scores and overall frailty scores. In effect, this incremental scoring methodology quantifies the frailty of individuals with more lesions as higher than the frailty of individuals with fewer pathological lesions. Although the SFI+ builds upon the original frailty index (SFI), this scoring methodology has its limitations and may be difficult to apply to all contexts, specifically those with poor skeletal preservation or limited skeletal elements present.
The SFI+ provides a rubric to quantify and operationalize modern skeletal frailty by scoring eight markers of frailty and stress on human skeletal remains using two severity scales and absence or presence scale criteria (Table 4.1). Severity Scale I is an ordinal 4-ranked scale based on the number of elements affected per individual. A score of 0 represents the absence of the biomarker, a score of 0.33 reflects one element affected, a score of 0.66 represents two elements affected, and a score of 1 reflects three or more elements affected per individual. Biomarkers scored according to Severity Scale I include linear enamel hypoplasia, osteoarthritis, and antemortem fractures. Severity Scale II is an ordinal 4-ranked scale based on the percentage of elements affected per person. A score of 0 represents the absence of the biomarker, a score of 0.33 reflects 1-33% of elements affected, a score of 0.66 represents 34-66% of elements affected, and a score of 1 reflects 67-100% of elements affected per individual. Carious lesions, periodontal disease, and intervertebral disk disease were scored according to Severity Scale II. The biomarkers scored by absence or presence include rotator cuff disorder and surgical procedures.

4.2.3. Biomarkers of Frailty

Eight skeletal and dentoalveolar biomarkers were assessed for frailty: linear enamel hypoplasia, periodontal disease, dental caries, osteoarthritis, intervertebral disk disease, rotator cuff disorder, fractures, and surgical procedures. All observations and measurements were recorded on Skeletal Frailty Index+ forms (Appendix B). Each biomarker was scored according to the specified scoring scale (Table 4.1) and biomarker frailty scores summed into an SFI+ score for each individual. Frailty scores ranged from 0 (lowest relative frailty) to 8 (highest relative frailty).
<table>
<thead>
<tr>
<th>Biomarkers of Frailty</th>
<th>Score Methodology</th>
<th>Definition of Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear Enamel Hypoplasia (LEH)</td>
<td>Severity Scale I</td>
<td>Present per tooth if visible macroscopically and can be felt with fingernail on maxillary and mandibular canines and incisors</td>
</tr>
<tr>
<td>Unfilled Caries</td>
<td>Severity Scale II</td>
<td>Present per tooth if carious lesion is unfilled and can be seen macroscopically</td>
</tr>
<tr>
<td>Periodontal Disease (PD)</td>
<td>Severity Scale II</td>
<td>Present per tooth if measurement from the alveolar crest to the cemento-enamel junction is greater than 3mm</td>
</tr>
<tr>
<td>Osteoarthritis (OA)</td>
<td>Severity Scale I</td>
<td>Present if there is evidence of eburnation in the shoulder, elbow, hand, hip, knee, and foot joints</td>
</tr>
<tr>
<td>Intervertebral Disc Disease (IVD)</td>
<td>Severity Scale II</td>
<td>Present per vertebrae if there is both pitting and marginal osteophytes on the superior or inferior surfaces of the vertebrae</td>
</tr>
<tr>
<td>Rotator Cuff Disorder (RCD)</td>
<td>Absent/Present</td>
<td>Present if there is both pitting and new bone on or around insertion of the rotator cuff</td>
</tr>
<tr>
<td>Fracture</td>
<td>Severity Scale I</td>
<td>Present if there is evidence of antemortem bone breakage</td>
</tr>
<tr>
<td>Surgical Procedure</td>
<td>Absent/Present</td>
<td>Present if evidence of joint replacement, antemortem surgical cut marks, or implementation of other non-biological material on the skeleton</td>
</tr>
</tbody>
</table>

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<th>Frailty Score</th>
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<th>0.66</th>
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<tr>
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<td>2</td>
<td>3+</td>
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</tbody>
</table>

<table>
<thead>
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<th>Frailty Score</th>
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<th>0.33</th>
<th>0.66</th>
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</thead>
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<tr>
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<td>34-66%</td>
<td>67-100%</td>
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<tr>
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<td>Frailty Score</td>
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<td>1</td>
<td></td>
<td></td>
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<tr>
<td>Absence or Presence</td>
<td>Absent</td>
<td>Present</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.1 Skeletal frailty biomarkers with designated scoring methodology, definitions of presence, and defined SFI+ severity scale scoring criteria.
4.2.3.1 Linear Enamel Hypoplasia

Tooth enamel does not have the ability to remodel itself, so it is a useful variable to measure stress that occurred during crown formation between the 6th week in utero to age 8 (Goodman and Armelagos 1988; Goodman and Rose 1990). Linear enamel hypoplasia (LEH) is an enamel defect caused by the disruption of ameloblast activity which creates a deficit of enamel thickness resulting in pits, horizontal grooves, or missing enamel. The etiology of linear enamel hypoplasia is multi-faceted, but there are three most commonly referenced causes: genetic heredity, local trauma, and systemic physiological metabolic stress during childhood, such as undernutrition and disease (Goodman and Armelagos 1988; Goodman, Armelagos, and Rose 1980; Goodman and Rose 1990; Larsen 2015; Lawrence et al. 2021; Sarnat and Moss 1985; Yaussy, DeWitte, and Redfern 2016).

Cases of enamel hypoplasia caused by heredity and traumatic events are rare in both archaeological and modern contexts, but new evidence suggests that heritability of LEH may be more common than previously believed (Lawrence et al. 2021). LEH caused by genetic heritability will often affect all teeth in the set, whereas local trauma that causes enamel hypoplasia will often only result in single events of enamel hypoplasia on one tooth (Goodman and Rose 1990). Linear enamel hypoplasia caused by systemic physiological stressors, such as an infection, are likely to affect teeth that are developing at the same time and result in a uniform linear pattern across multiple teeth (Goodman and Armelagos 1988; Goodman and Rose 1990). Linear enamel hypoplasias are included in this research because their presence is reflective of childhood stress and is often associated with an increased predisposition for adult stress and frailty (Agarwal 2016;
Amoroso, Garcia, and Cardoso 2014), notably shorter lifespans, and chronic conditions such as cardiovascular disease (Amoroso, Garcia, and Cardoso 2014; Yaussy, DeWitte, and Redfern 2016). In individuals who survived childhood stressors, as indicated by LEH present on permanent teeth and older age at death, their presence is associated with long-term compromised allostatic responses, known as the Developmental Origins of Health and Disease (DOHaD) hypothesis, leading to negative outcomes in adulthood responses and resilience to stress and frailty (Cook and Buikstra 1979; Edes and Crews 2017; Evans and Kim 2012; Evans and Schamberg 2009; McEwen and Seeman 1999). Biological and social stress experienced during development, both in utero and early childhood, has also been associated with health conditions (e.g., cardiovascular disease, respiratory disease, type 2 diabetes, osteoporosis, effects on inflammatory responses, compromised immunity (e.g., higher cortisol levels), and increased mortality (Amoroso, Garcia, and Cardoso 2014; Armelagos et al. 2009; Boldsen 2007; Cook and Buikstra 1979; Edes and Crews 2017; Evans and Schamberg 2009; Garland 2020; Crespo, White, and Roberts 2019). Bioarchaeological research has shown that individuals with LEH have higher mortality and are predisposed to an earlier age at death than individuals without LEH (Armelagos et al. 2009; Boldsen 2007; Goodman and Armelagos 1988).

Linear enamel hypoplasias were identified macroscopically without the use of a magnifying glass and scored as present if linear depressions in the enamel could be seen and felt with a fingernail on maxillary and mandibular anterior dentition (Goodman and Rose 1990). This methodology increases reliability and is a more conservative approach by reducing risk of including false hypoplasia than viewing hypoplasias under magnification (Goodman and Rose 1990). The labial aspect of maxillary incisors and
mandibular canines are recommended for their consistency in occurrences of linear enamel hypoplasias (Goodman, Armelagos, and Rose 1980; Goodman and Rose 1990; Miszkiewicz 2015). Frailty scores for linear enamel hypoplasias were based on the Severity Scale I, thereby capturing differing severities of enamel hypoplasia (teeth affected) rather than presence-absence.

4.2.3.2. Dental Caries

Carious lesions one of the most common conditions in both modern populations as well as in bioarchaeological studies caused by acids produced during bacterial fermentation of dietary carbohydrates that irreversibly demineralize enamel and dentine (DeWitte and Bekvalac 2010; Hillson 2001; Larsen 2015; Marklein et al. 2019). Although caries are often attributed to diet, most notably diets high in sugars and carbohydrates, caries and their prevalence in populations reflect multiple and interactive environmental, biological, and cultural factors (Marklein et al. 2019). Dental caries are included in this research due to their prevalence in modern populations as well as their relationship to poor health, higher frailty, and increased risk of mortality (DeWitte and Bekvalac 2010; DeWitte and Stojanowski 2015; Marklein et al. 2019). If dental caries progress and expose the pulp chamber to exogenous bacterial infection it may spread throughout the body and cause systemic immune responses and inflammation (DeWitte and Bekvalac 2010).

In a study of older veterans, it was found that dental decay and presence of caries-causing bacteria were linked to comorbidity of illnesses such as aspiration pneumonia, a prominent cause of death in individuals over 60 years old (Terpenning et al. 2001). Research has also found that prevalence of dental caries is increasing in service member
populations, with a mean caries rate of 3.5 carious teeth for Confederate soldiers during the Civil War, but a mean rate of 6.8 carious teeth in U.S. Air Force recruits between the years 1963 and 1964 (Shannon, Gibson, and Terry 1966; Wols and Baker 2004). Due to interventive medical care, which may impact an individual’s lifetime oral health, filled cavities present a new factor when considering frailty. It is more difficult to determine the severity of caries that are filled and whether they caused an infection before being filled. Differences in presence of unfilled dental caries within veteran and civilian populations may indicate differing levels of health and frailty within these samples, but also may indicate differences in level of access to dental care if there are differences in frequency of filled caries between the two samples.

Some researchers suggest using a caries correction factor to account for antemortem tooth loss that could have resulted from caries or to correct for differential rates of caries between anterior and posterior teeth (Lukacs 1992, 1995). However, this methodology may overestimate the prevalence of caries in a sample population. For example, Wols and Baker (2004) used this methodology which resulted in 48% of teeth having caries compared to 24.4% of teeth having caries based only on observable teeth. The tooth count method of caries calculation based on observable dentition has been successfully used by researchers to determine the prevalence of dental caries in populations and is more conservative when calculating prevalence of dental caries in a sample population (Marklein et al. 2019).

All observable dentition were assessed for carious lesions and scored based on the percentage of teeth with unfilled caries using Severity Scale II. Severity Scale II will be used for this variable because it will capture the rate of teeth with unfilled caries that an
individual has. As caries can eventuate in localized and systemic infection, unfilled carious lesions are associated with higher individual stress and frailty. However, filled cavities will also be recorded out of total teeth present to facilitate comparison of unfilled and filled caries between the two samples.

4.2.3.3. Periodontal Disease

Periodontal disease (PD) is another common oral pathological lesion observed in modern and bioarchaeological populations that impacts systemic inflammatory responses and immunocompetence. PD has been linked to other chronic diseases such as cardiovascular diseases, cancer, Alzheimer’s disease, ischemic stroke, osteoporosis, and increased frailty and morbidity in populations (Bui et al. 2019; DeWitte and Bekvalac 2010, 2011; Grau et al. 2004; Johnson 2017; Kamer et al. 2008; Michaud et al. 2008; Shaddox et al. 2010; Waldron 2009; Williams et al. 2008). Periodontal disease occurs when overactive bacteria destroy gum tissue. When untreated or unmitigated, PD can lead to irreparable alveolar bone resorption and eventual antemortem tooth loss. Although bacteria are critical to PD pathogenesis, individual health, genetics, environment, and behavior impact the presence and severity of the condition (Shaddox et al. 2010; Tomczyk et al. 2017; Waldron 2009).

Smoking can alter the balance of oral bacteria, as well as inhibit the inflammatory responses to those bacteria that cause periodontal disease, increasing the risk of developing periodontal disease and tooth loss (Johnson 2017). Smoking is a common habitual activity in both veteran and civilian populations. According to the CDC, estimates of 34 million adults (14% of the US population) were currently smoking cigarettes in 2019 (CDC 2020). The U.S. Food and Drug Administration reports that in
2015 about 14% of active-duty service members were current smokers, however they also reported that 30% of veterans self-reported as current smokers (FDA 2020). In the past, smoking was promoted among U.S. service members, and many individuals started smoking during their military service (E.A. Smith and Malone 2009; Wiener et al. 2019). Under the premise that combat risks outweighed the risks of smoking and provided comfort in times of war, tobacco companies targeted the U.S. Military and provided cigarettes to service members along with their food rations beginning in World War 1 through 1975. After 1975, cigarettes continued to be given to service members for free with care packages, and today, tobacco products are still sold tax-free on military installations (E.A. Smith and Malone 2009). Periodontal disease is included as a biomarker of frailty because of its collective comorbidity with other diseases, as well as its relationship to behaviors (e.g., smoking) observed in veteran and civilian populations.

PD was observed in all in situ dentition and recorded as present if the distance from the cementoenamel junction (CEJ) and alveolar crest (AC) was greater than 3mm (Tomczyk et al. 2017; Waldron 2009). This distance is a more conservative measure that is less likely to overestimate PD prevalence (DeWitte and Bekvalac 2010). Periodontal disease will be scored based on the percentage of affected teeth using Severity Scale II. This Severity Scale will capture differing quantities of teeth impacted by periodontal disease per person, and score individuals higher if they have more teeth affected.

4.2.3.4. Osteoarthritis

Osteoarthritis (OA) is the most common form of degenerative joint disease and has been widely studied in bioarchaeological samples (Jurmain and Kilgore 1995; Ling and Bathon 1998; Waldron 2009). Although osteoarthritis prevalence in
bioarchaeological research frequently is associated with habitual and occupational activities, studies have demonstrated its multi-factorial etiology from activity, age, sex, nutrition, hormones, trauma, genetics and heredity, and mobility factors (Jurmain 1977; Jurmain and Kilgore 1995; Loughlin 2001; Musumeci et al. 2015; Reynard and Loughlin 2012; Stanishewski and Zimmermann 2015; Waldron 2009).

Osteoarthritis is frequently associated with age, increasing in prevalence among older age groups. According to the Centers for Disease Control and Prevention’s National Center for Health Statistics, in 2019 about 7% of adults age 18-44 years and 30% of adults ages 45-64 years self-disclosed that they were diagnosed with arthritis (CDC 2019). Furthermore, lifestyle factors can also contribute to osteoarthritis development and location. Sedentary individuals are more at risk of shoulder, hand, and spinal osteoarthritis due to muscle weakness and poor posture, highly active individuals place extra stress on their joints and have higher rates of osteoarthritis in their shoulders, elbows, hips, and knees, whereas obese individuals are more likely to develop hip, knee, ankle, and spinal osteoarthritis from increased weight loading on these joints (Musumeci et al. 2015). Research shows that OA prevalence is higher among military veterans than civilians. One study among U.S. active-duty service members (1999-2008) found that 26.91% of service members aged 40 years and older had osteoarthritis compared to 12.4% within the general civilian population (Cameron et al. 2011). Veterans may be more at risk for developing osteoarthritis due to regular strenuous physical activity as well as developing OA from traumatic injury (Cameron et al. 2011).

It has been widely accepted that the wear and tear resulting from increased physical activity is linked to higher rates of osteoarthritis, however, contrasting research
has argued that physical activity inhibits the development of osteoarthritis, and that individuals who are less physically active are more at risk of developing OA (Berenbaum et al. 2018; Cameron et al. 2011; Jurmain et al. 2012; Musumeci et al. 2015; Wallace et al. 2019; Wallace et al. 2022). Recent research has shown a two-fold increase in prevalence of knee osteoarthritis since the mid 1900s with increased life expectancies, higher body mass indices (BMI), and more sedentary lifestyles (Wallace et al. 2017). Obesity and higher BMI can increase risk of OA through excessive loads placed on weight-bearing joints (Berenbaum et al. 2018; Wallace et al. 2017). Because physical inactivity can lead to obesity and high BMI, it can indirectly increase one’s risk of developing OA and result in weaker joints and related tissues as a result of a lack of stimulus (Berenbaum et al. 2018; Wallace et al. 2017).

Individuals with osteoarthritis are impacted by localized pain, stiffness in their movement, and overall disability, frailty, impairment in their daily lives, decreased quality of sleep, and depression (Fried et al. 2001; Ling and Bathon 1998; Stanishewski and Zimmermann 2015; Vina and Kwoh 2018). When articular cartilage deteriorates through osteoarthritis, bone surfaces rub against each other, resulting in polished or shiny surfaces (eburnation). Although other bony changes occur with osteoarthritis (e.g., marginal osteophytes, joint deformation), eburnation is the most pathognomonic marker of the condition and represents the most severe incidents of joint deterioration (Larsen 2015; Waldron 2009). For this research, osteoarthritis is reported in observable joints (hands, feet, shoulders, elbows, hips, knees, and spinal column) when eburnation is present on at least one joint surface (e.g., glenoid fossa or humeral head). Osteoarthritis will be scored using Severity Scale I.
4.2.3.5. Rotator Cuff Disorder

Rotator cuff disorder (RCD) is a common shoulder condition that involves weakening and eventual tearing of tendons of the rotator cuff muscles (subscapularis, supraspinatus, infraspinatus, and teres minor) (Tashjian 2012; Waldron 2009). Severe cases of RCD alter shoulder position and cause joint impingement, which can be observed in the acromion and coracoid processes, the acromioclavicular joint, and the greater tubercle and bicipital groove of the humerus (Tashjian 2012; Waldron 2009; Wohlwend et al. 1998). Commonly viewed as a degenerative disorder, RCD is often associated with aging; however, RCD also correlates with trauma, genetics, repetitive use such as in certain occupations, poor blood supply, behaviors such as smoking, and calcification of tendons (Rothschild 2019; Tashjian 2012).

Hauret et al. (2010) assessed musculoskeletal injuries in military personnel and found that shoulder injuries comprised 9% of all injuries, and 63% of upper extremity injuries in their sample. Rotator cuff disorder is included as a discrete variable in this research to determine whether military occupation correlates with RCD or occurs at higher frequency among veteran than civilian samples. RCD will be assessed using a presence and absence scoring system and will be identified according to criteria outlined by Waldron (2009): present if there is both pitting and new bone growth on the insertion of the rotator cuff muscles.

4.2.3.6. Intervertebral Disc Disease

Intervertebral disk disease (IVD) characterizes the degeneration and collapse of contiguous intervertebral discs (Waldron 2009). Over time, the nucleus pulposus is unable to retain its water content, strength, and ability to maintain the compression
between the corresponding superior and inferior vertebrae and compression of the intervertebral disc results (Adams and Roughley 2006; Martirosyan et al. 2016).

Herniation of the nucleus pulposus is also possible due to compression, which leads to a depression seen on the vertebral body called “Schmorl’s nodes” which have often been associated with intervertebral disc degeneration, although the former is associated with spinal trauma, heavy stress, and age (Burke 2012; Plomp 2017). While marginal osteophytes (often associated with back pain) form to counteract this compression, severe cases known as spondylosis eventuate in ankyloses, or fusion of vertebrae, resulting in limited mobility (Plomp 2017). IVD can occur on all vertebrae, however some researchers note that it is most associated with cervical and lumbar vertebrae (Lovell 1994; Waldron 2009).

Many etiological factors contribute to disc degeneration. It has been more recently recognized that genetics play a larger role in IVD than previously known, however other variables such as biological sex, mechanical loading of the spine, and aging are also commonly associated with disc degeneration (Adams and Roughley 2006; Martirosyan et al. 2016; Klaus, Larsen, and Tam 2009; Schoenfeld et al. 2011). IVD will be used to assess whether vertebral degeneration is influenced by military service, as this condition has been observed in high frequencies among modern military populations, particularly in lumbar vertebrae due to postural changes and strain from repeatedly carrying heavy loads during tactical training (Berry et al. 2017; S.P. Cohen et al. 2012; Onodera et al. 2019; Schoenfeld et al. 2011). In observable vertebrae, IVD will be recorded as present when there is pitting on the superior or inferior surfaces of the vertebral bodies and marginal osteophytes (Adams and Roughley 2006; Waldron 2009). Overall IVD score for frailty
will be evaluated using Severity Scale II.

4.2.3.7. Fracture

Bone fractures can have a multitude of causes from occupational or activity-based accidents, falls, and interpersonal violence, and fracture risks increase with age as bone density loss increases (Larsen 2015). Musculoskeletal injuries, including open fractures, closed fractures, and stress fractures, are common injuries sustained by individuals in physically demanding or risky occupations including military service members due to physical demands of required military training (Chandler et al. 2017; Jacobs, Cameron, and Bojescul 2014). Data on injuries sustained by the UK military between 2003 and 2014 show that fractures of the limbs were the most common, particularly in the femur, tibia, fibula, and humerus (Chandler et al. 2017). Fractures in military contexts often occur in less physically fit individuals during initial entry training into the military, as well as during regularly scheduled physical readiness training (PRT) that includes calisthenics, running, and strength training that is performed on a regular basis for active duty soldiers and during recreational sports (Cameron and Owens 2014; Goolsby and Boniquit 2017).

Contrasting evidence states that physical activity, particularly weightbearing activity while individuals are in their youth, positively impacts bone mass and reduces the risk of fractures throughout their life (Goolsby and Boniquit 2017). According to Wolff’s Law, higher rates of physical activity and exercise place stressors on bone that initiate bone remodeling and formation to adapt to increased physical demand (Goolsby and Boniquit 2017; Pepper, Akuthota, and McCarty 2006). Therefore, it is possible that the physical activity required during military service may increase bone mass of service
members and result in lower risk of fractures compared to less active populations. However, if training is progressed too quickly without sufficient time for the body to rest and adapt, such as onset of intense physical activity during basic training, osteoclast and osteoblast activity during remodeling will be unbalanced and result in injury (Goolsby and Boniquit 2017; Pepper, Akuthota, and McCarty 2006).

Fractures increase morbidity and frailty of the individual, whether from infection or long-term disabilities due to malunion of the bone during healing (Jacobs, Cameron, and Bojescul 2014; Larsen 2015; Waldron 2009). In a forensic context, Komar and Grivas (2008) found that most individuals exhibited between 0 and 4 fractures. To assess whether antemortem fractures significantly differ among modern military populations compared to civilian populations, fractures will be scored in accordance to results from Komar and Grivas (2008) using Severity Scale I.

4.2.3.8. Surgical Procedure

Surgical procedures represent another variable that is particular to modern contexts and may include stabilization of fractures through internal fixation using plates and screws or external fixation using pins and bars (Griffiths and Clasper 2006). Individuals that experienced osteoarthritis may have opted to receive a joint replacement, which appears on their skeleton through joint prostheses (Ling and Bathon 1998). Indications of other surgical procedures can be determined through the presence of other surgical metals, clips, or staples (Dirkmaat 2012). In one study of modern forensic samples, common instances of surgical procedures seen on the skeleton included cranial trephination, repair of skeletal elements, joint replacements, and sternotomy (Komar and Lathrop, 2006).
Particularly in military contexts, in some cases surgeries may be associated with fractures including extremity amputations. Chandler et al. (2017) found that in the UK military in the Iraq and Afghanistan conflicts between the years of 2003 and 2014, 2,908 surgeries were performed on extremities, of which 103 individuals lost one extremity, 85 individuals lost two limbs, and 17 individuals lost three limbs to amputations. Amputation in military contexts captures a specifically traumatic event, both in terms of the physical stress—patients with at least one amputation stayed in hospital for an average of 51 days and underwent about 7 surgical procedures—and the psychological stress (Chandler et al. 2017).

However, because many surgical events do not leave traces on the skeleton, it is impossible to know the exact number of surgical procedures each individual experienced in their life. To quantify the number of surgical procedures based on skeletal evidence may underestimate actual surgeries. Additionally, it may be impossible to know how many procedures occurred for a single event requiring surgical intervention in order to quantify the stress experienced by the individual. The number of discernable surgical procedures on the skeleton may underrepresent the actual number of surgeries experienced of the individual’s lifecourse. For example, to stabilize a fracture multiple surgical procedures may be required throughout the healing process. Because of these limitations, in this study surgical procedures will be scored on a presence or absence basis, with high frailty score (“1”) if the individual exhibits evidence of at least one surgical procedure such as a joint replacement, amputation, antemortem surgical cut marks, or implementation of other non-biological material on the skeleton and a low frailty score (“0”) if there are no surgical procedures evident on their skeleton.
4.2.4. Testing SFI vs SFI+ Applications in Modern Skeletal Assemblages

To test the applicability of the SFI+, an adaptation of the SFI, in this modern forensic context, the distribution of the eight biomarkers of frailty previously outlined, as well as overall frailty scores, will be compared using the original SFI’s scoring methodology to the SFI+’s scoring methodology within the total sample (n=19) resulting in potential SFI scores between 0 and 8. To compare SFI and SFI+ indices, a Spearman’s Correlation test will be conducted to determine if the two indices correlate significantly. Wilcoxon paired signed ranks test will be performed to assess whether overall frailty scores and distributions differ significantly between SFI and SFI+. These tests will establish (1) whether the frailty indices reflect similar levels of frailty; and (2) whether the frailty scores differ between samples when SFI and SFI+ criteria are implemented. Differences were considered statistically significant at a 0.05 p-value and approaching significance at a 0.10 p-value.

4.2.5. Comparing Skeletal Frailty in Veteran and Civilian Individuals

To determine differences in overall frailty scores between each sample, veteran (n=10) and civilian (n=9), an independent Mann-Whitney U test will be performed for both original SFI and SFI+ scores. These tests will demonstrate whether SFI or SFI+ scores and sample distributions differ significantly between veteran and civilian samples. Furthermore, a multiple correspondence analysis factor map will be created and examined to visually explore potential relationships between the biomarkers of frailty.

4.2.6. Comparing Frailty Biomarkers in Veteran and Civilian Individuals

To compare frequencies of frailty biomarker between veterans and civilians, Fisher’s Exact test will be calculated using both the original SFI and the SFI+ frailty
criteria. Furthermore, a Spearman’s Correlation test will be performed to determine if there are correlations between the biomarkers of frailty and overall frailty scores using the original SFI and SFI+ methodologies. For all inferential tests, differences were considered statistically significant at a 0.05 p-value and approaching significance at a 0.10 p-value. All statistical analyses were conducted in SPSS Version 28.0.1.0 (IBM Corp. 2021) and RStudio (R Core Team 2021).
CHAPTER 5

RESULTS

5.1. Testing SFI vs SFI+ Applications in Modern Skeletal Assemblages

Raw frailty data of the individuals included in this study can be found in Appendix C. The mean score sample (n=19) using the original SFI is 3.79, while the SFI+ average was 2.34. In addition to a higher mean, the SFI range (2-7; 5) was higher than the SFI+ range (0.99-4.66; 3.67). Despite differences in SFI and SFI+ distributions, Spearman’s correlation results comparing overall SFI and SFI+ frailty scores reveal a statistically significant positive association between the original SFI and the SFI+ (rho=0.797, \( p < 0.001 \)). Although Spearman’s Correlation results show a correlation between SFI and SFI+ scores, results from Wilcoxon Paired Signed Ranks tests reveal a statistically significant difference in overall frailty scores (\( Z = -3.830, p < 0.001 \)).

![SFI Biomarker Distributions](image-url)

**Figure 5.1** SFI Total Sample Biomarker Distributions
5.2. Comparing Skeletal Frailty in Veteran and Civilian Individuals

Raw frailty data of the individuals included in this study can be found in Appendix C. Applying the original SFI, the veteran sample’s mean frailty score was 3.40, and the civilian sample’s mean frailty score was 4.22. However, Mann-Whitney U test results showed no statistically significant differences in overall frailty scores between veterans and civilians using the SFI (U=30.5, \( p=0.243 \)) (Table 5.1).

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Mean</th>
<th>St. Dev</th>
<th>Range</th>
<th>U</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFI</td>
<td>Veteran</td>
<td>10</td>
<td>3.40</td>
<td>1.17</td>
<td>3 (2-5)</td>
<td>30.5</td>
</tr>
<tr>
<td></td>
<td>Civilian</td>
<td>9</td>
<td>4.22</td>
<td>1.56</td>
<td>5 (2-7)</td>
<td></td>
</tr>
<tr>
<td>SFI+</td>
<td>Veteran</td>
<td>10</td>
<td>1.86</td>
<td>0.65</td>
<td>1.67 (0.99-2.66)</td>
<td>21.00</td>
</tr>
<tr>
<td></td>
<td>Civilian</td>
<td>9</td>
<td>2.88</td>
<td>1.29</td>
<td>3.33 (1.33-4.66)</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.1 Descriptive statistics and Mann-Whitney U test results for SFI and SFI+ between Veteran and Civilian groups. Significant values considered at \( p <0.05 \) and designated with two (***) asterisks, and approaching significant values considered at \( p<0.10 \) and designated with one (*) asterisk.

Using the SFI+ frailty criteria, the veteran sample’s mean frailty score (1.86±0.65) was lower than civilian frailty (2.88±1.29). Comparing overall SFI+ frailty
scores, Mann-Whitney U test results reveal significantly higher overall frailty scores among civilian than veteran individuals ($U=21, p=0.05$) (Table 5.1).

![Figure 5.3 SFI and SFI+ Individual Skeletal Frailty Scores](image)

Multiple correspondence analysis factor map displays individual frailty to visualize patterns reflected in the data. When comparing veterans and civilians, veterans seem to group into two clusters while civilians show no discernable pattern (Figure 5.4).
Figure 5.4 MCA Factor Map of Individual Frailty. Veterans indicated by purple points labeled V1-V11. Civilians indicated by orange points labeled C1-C9

5.3 Comparing Frailty Biomarkers in Veteran and Civilian Individuals

Raw prevalence and frailty data of the individuals included in this study can be found in Appendix C. Mann-Whitney U tests reveal no statistically significant or approaching statistically significant differences in individual frailty biomarker scores between veterans and civilians using the SFI ($p>0.05$) (Table 5.3). Using the SFI+ frailty scores, Mann-Whitney U tests show one biomarker of frailty, fractures, resulting in approaching significant differences between veterans and civilians ($p=0.065$), while all other frailty biomarkers were not significant. Fisher’s Exact tests show no differences in frequency distributions, using either the SFI or the SFI+, within each biomarker of frailty between veterans and civilians ($p>0.05$) (Tables 5.4, 5.5).
<table>
<thead>
<tr>
<th>Biomarkers of Frailty</th>
<th>n</th>
<th>SFI</th>
<th>SFI+</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>St. Dev</td>
</tr>
<tr>
<td>Linear Enamel Hypoplasia</td>
<td>19</td>
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<td>0.51</td>
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<td>Unfilled Caries</td>
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<td>0.63</td>
<td>0.50</td>
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<td>19</td>
<td>0.84</td>
<td>0.38</td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td>19</td>
<td>0.32</td>
<td>0.48</td>
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<tr>
<td>Intervertebral Disc Disease</td>
<td>19</td>
<td>0.63</td>
<td>0.50</td>
</tr>
<tr>
<td>Rotator Cuff Disorder</td>
<td>19</td>
<td>0.05</td>
<td>0.23</td>
</tr>
<tr>
<td>Fracture</td>
<td>19</td>
<td>0.58</td>
<td>0.51</td>
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<tr>
<td>Surgical</td>
<td>19</td>
<td>0.26</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Table 5.2 Descriptive statistics for the biomarkers of frailty for the original SFI and the SFI+

<table>
<thead>
<tr>
<th>Biomarkers of Frailty</th>
<th>SFI Veteran vs Civilian</th>
<th>SFI+ Veteran vs Civilian</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U Value</td>
<td>P Value</td>
</tr>
<tr>
<td>Linear Enamel Hypoplasia</td>
<td>61.5</td>
<td>0.182</td>
</tr>
<tr>
<td>Unfilled Caries</td>
<td>48</td>
<td>0.842</td>
</tr>
<tr>
<td>Periodontal Disease</td>
<td>39.5</td>
<td>0.661</td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td>46.5</td>
<td>0.905</td>
</tr>
<tr>
<td>Intervertebral Disk Disease</td>
<td>29</td>
<td>0.211</td>
</tr>
<tr>
<td>Rotator Cuff Disorder</td>
<td>50</td>
<td>0.720</td>
</tr>
<tr>
<td>Fracture</td>
<td>62</td>
<td>0.182</td>
</tr>
<tr>
<td>Surgical</td>
<td>60.5</td>
<td>0.243</td>
</tr>
</tbody>
</table>

Table 5.3 SFI and SFI+ Mann-Whitney U test results of biomarkers of frailty between Veterans and Civilians. Significant values considered at $p<0.05$ and designated with two (**) asterisks, and approaching significant values considered at $p<0.10$ and designated with one (*) asterisk.
<table>
<thead>
<tr>
<th>Biomarker of Frailty</th>
<th>Veteran</th>
<th>Civilian</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Absent</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>LEH</td>
<td>7</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Unfilled Caries</td>
<td>4</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Periodontal Disease</td>
<td>1</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td>7</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Intervertebral Disk Disease</td>
<td>2</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Rotator Cuff Disorder</td>
<td>10</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Fracture</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Surgical</td>
<td>9</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 5.4** SFI biomarkers of frailty frequency distributions and Fisher’s Exact results between Veterans and Civilians. Significant values considered at $p < 0.05$ and designated with two (**) asterisks, and approaching significant values considered at $p < 0.10$ and designated with one (*) asterisk.

**Figure 5.5** SFI Biomarker Distributions by Veterans and Civilians
Table 5.5 SFI+ biomarkers of frailty frequency distributions and Fisher’s Exact results between Veterans and Civilians. Significant values considered at $p<0.05$ and designated with two (**) asterisks, and approaching significant values considered at $p<0.10$ and designated with one (*) asterisk.

Figure 5.6 SFI+ Severity Scale I Biomarker Distributions by Veterans and Civilians
LEH: Linear Enamel Hypoplasia
OA: Osteoarthritis
**Figure 5.7** SFI+ Severity Scale II Biomarker Distributions by Veterans and Civilians
PD: Periodontal Disease
IVD: Intervertebral Disk Disease

**Figure 5.8** SFI+ Absent/Present Scale Biomarker Distributions by Veterans and Civilians
RCD: Rotator Cuff Disorder
Multiple correspondence analysis factor map displays veterans, civilians, and the biomarkers of frailty. Overall, patterns in frailty biomarkers show veteran individuals correspond with absence of fractures, surgical procedures, osteoarthritis, and presence of intervertebral disk disease, whereas civilians correspond with surgical procedures, fractures, osteoarthritis, linear enamel hypoplasia, and no intervertebral disk disease (Figure 5.9).

Figure 5.9 MCA Factor Map of Veterans, Civilians, and Biomarkers of Frailty

Spearman’s correlation results from the SFI resulted in statistically significant positive associations between unfilled caries and intervertebral disk disease (rho=0.548,
and between surgical procedures and overall SFI frailty scores (rho=0.754, \(p<0.001\)). Additionally, frailty scores based on SFI showed approaching significant associations between linear enamel hypoplasia and periodontal disease (rho=0.411, \(p=0.081\)), linear enamel hypoplasia and overall SFI frailty scores (rho=0.438, \(p=0.061\)), intervertebral disk disease and overall SFI frailty scores (rho=0.433, \(p=0.064\)), fractures and overall SFI frailty scores (rho=0.423, \(p=0.071\)), and an approaching statistically significant negative association between unfilled caries and osteoarthritis (rho=-0.420, \(p=0.073\)) (Appendix C).

For SFI+ frailty biomarker scores, Spearman’s correlation results show statistically significant positive associations between linear enamel hypoplasia and periodontal disease (rho=0.557, \(p=0.013\)), linear enamel hypoplasia and overall SFI+ scores (rho=0.649, \(p=0.003\)), unfilled caries and intervertebral disk disease (rho=0.543, \(p=0.016\)), and surgical procedures and overall SFI+ frailty scores (rho=0.711, \(p<0.001\)). Furthermore, approaching statistically significant associations were observed between periodontal disease and overall SFI+ frailty scores (rho=0.415, \(p=0.077\)), and osteoarthritis and surgical procedures (rho=0.398, \(p=0.091\)), and an approaching statistically significant negative association between periodontal disease and fractures (rho=-0.407, \(p=0.084\)) (Appendix C).
**Figure 5.10** Veteran distributions of intervertebral disk disorder, osteoarthritis, surgical procedures, and fractures
Figure 5.11 Civilian distributions of intervertebral disk disorder, osteoarthritis, surgical procedures, and fractures
6.1. Testing SFI vs SFI+ Applications in Modern Skeletal Assemblages

The significant positive correlation between the SFI and the SFI+ establishes that the skeletal frailty indices similarly quantify frailty, facilitating comparisons between frailty results within the total sample (n=19) as well as between veterans and civilians. However, the SFI+ biomarker severity scoring methodology enables more nuanced differences and analysis of frailty on individual and sample levels (Table 5.1; Figures 5.1, 5.2). For example, individual C1’s SFI frailty score was 7, the highest in the sample, while their SFI+ score was not the highest (3.98). Additionally, on a sample level, individuals with equivalent SFI frailty scores did not receive the same SFI+ frailty scores: SFI frailty scores for individuals V3, V10, C6, C7, and C9 were 5, but their SFI+ frailty scores ranged from 2.32 (V3) to 4.66 (C6).

Furthermore, significant differences between SFI and SFI+ frailty scores support the application the SFI+ in modern samples and demonstrates the relevance of using severity scales to weigh the biomarkers of frailty per individual. Not only does an SFI+ yield a smaller range and standard deviation (0.99-4.66;1.12) for skeletal frailty than SFI (2-7; 1.40), but SFI+ results initially seem to underestimate rather than inflate frailty compared to SFI scores. This phenomenon is evident when comparing skeletal frailty scores (SFI+ and SFI) on an individual level (Figure 5.3). In the case of individual C1,
their embodied extent of skeletal frailty did not change, however the measurement of frailty between the two methodologies resulted in differing scores of frailty. Although the relationship between SFI and SFI+ frailty results between individuals varies across the sample due to the potential range of biomarker frailty levels, at the individual level one’s SFI frailty score is commensurate to their SFI+ score.

Lower mean frailty scores using the SFI+ (2.34) than the SFI (3.79) were anticipated because many individuals did not meet the level of frailty based on SFI+ frailty criteria to receive a score of 1, whereas individuals with any extent of the biomarker present received a score of 1 under the SFI frailty criteria (Marklein, Leahy, and Crews 2016). However, rather than underestimating cumulative frailty, the severity scales in the SFI+ quantify frailty more precisely by scoring biomarker frailty based on number or percentage of skeletal elements affected. Higher frequencies of a skeletal lesion has been commonly used as a proxy for severity in stress and frailty research, under the premise that higher rates of stress markers indicates an individual that endured more stress (Goodman, Martin, and Armelagos 1984; Goodman and Martin 2002; Larsen 2015; Schaik, Vinichenko, and Rühli 2014; Steckel and Rose 2002; Steckel et al. 2002; Storey, Morfin, and Smith 2002; Zedda et al. 2021). Because all biomarkers were weighted the same, ranging from 0 to 1, when applying the SFI+ severity scales to quantify overall skeletal frailty, individuals with more occurrences of biomarkers receive higher SFI+ scores. Therefore, the SFI+ frailty methodology is well suited to quantify the embodied impact of overall individual frailty within well-preserved and skeletally complete modern skeletal collections.

Within donated skeletal collections, frailty can be assessed using all skeletal
elements of an individual, facilitating more accurate quantification of biomarkers of frailty that may be more difficult to assess in oftentimes less preserved bioarchaeological contexts (Marklein and Crews 2017; Marklein, Leahy, and Crews 2016). Additionally, because the individuals from this study were obtained from a donated skeletal collection, the Bass Collection, population variable controls were possible to lessen variables that may influence frailty results. By electing a homogenous population of individuals from the same age group (50-60 years), and demographic profiles (European/white males) results could be focused on frailty and not necessarily on age, sex, or ancestral differences. Furthermore, because the individuals in this study represent a younger population, rather than elderly, the presence of biomarkers more likely reflects embodiments of biocultural environments rather than a reflection of the aging process as the accumulation of frailty (Goodman, Martin, and Armelagos 1984; Larsen 2015; Paine et al. 2009; Steckel and Rose 2002; Steckel et al. 2002).

The positive correlation and significant results in frailty scores between the two indices support the research goals of this study and determined that the SFI+ can be used in comparison with the SFI, and that skeletal frailty between veterans and civilians differed significantly between the two indices. These results prompt further analysis and application of the SFI+ in future skeletal frailty research. The potential uses of the SFI+ are vast as this research marks an initial starting point in exploring the potential of using severity scales to score skeletal biomarkers of frailty in modern individuals. Testing various severity scale methodologies would expand the potential for severity scale-based frailty indices that may be more applicable in differing contexts, populations, and modern skeletal collections.
This study is not the first to apply severity scales to skeletal frailty biomarkers. Zedda et al. (2021) compared their frailty index (BFI), which applied both severity scales and weights to their biomarkers, to the SFI (Marklein, Leahy, and Crews 2016) between Monastic and Non-monastic individuals from Medieval England. The results from the BFI detected results similar to those observed using the SFI (Marklein, Leahy, and Crews 2016); however the BFI methodology detected differences in frailty between the two female populations that the SFI did not (Zedda et al. 2021), which the authors attributed to the BFI’s ability to use weighted biomarker means and applicability to fragmentary individuals therefore yielding larger sample sizes. The SFI+ results cannot be directly compared to the results from the BFI due to the differences in sample populations, severity scoring methodology, and SFI+ frailty biomarkers that account for modern skeletal samples. However the results from this study and from Zedda et al. (2021) signify the future potential of applying biomarker severity scales to frailty indices in both bioarchaeological and modern forensic skeletal samples.

Although the mandates of complete or near complete skeletal preservation make the SFI+ well-suited to modern skeletal collections, there may be potential for SFI+ application in bioarchaeological research. Depending on preservation and commingling limitations, severity could be attempted for quantifying frailty at more precise levels than absence or presence. For instance, a bioarchaeological context with no commingling and well-preserved joint articular surfaces could use an index to quantify osteoarthritis as “0” for absent, 0.50 for one joint affected by OA, and “1” for multiple joints affected. Severity scales may not be applicable for all biomarkers being assessed in the context, but, as the results from this study show, the use of severity scales to quantify frailty
Biomarkers bring to light frailty differences between groups that may have been missed by presence-absence (high/low) frailty criteria.

SFI+ severity scores are quantified based on number or percent of elements affected, and therefore can be immediately applied to future research. Most existing research evaluating severity of frailty biomarkers focuses on severity regarding active or healed lesions or duration of life affected (Larsen 2015; McFadden and Oxenham 2020; Schaik, Vinichenko, and Rühli 2014; Steckel et al. 2002; Steckel, Sciulli, and Rose 2002; Zedda et al. 2021). While the consideration of active or healed lesions in severity scales is informative, the complexities around the etiological circumstances of chosen biomarkers along with differing severity scale methodologies often leads to contradictions in research results. For example, McFadden and Oxenham (2020) argued that active instances of cribra orbitalia (CO) can only be seen in juvenile individuals (under 15 years of age), as it is a condition that develops only in childhood, and therefore its presence in adult individuals cannot be attributed to active lesions. Contrastingly, Zedda et al. (2021), which included individuals from 12 to over 46 years old, considered active CO lesions as possible in adult individuals, and even weighted them more severely than healing or healed instances of CO. These contradictions make applying severity scales to future research difficult; however, the SFI+ methodology can be applied with ease and modified to fit the context and the researcher’s needs.

6.2. Comparing Skeletal Frailty in Veteran and Civilian Individuals

Regardless of frailty scoring methods, the civilian individuals (n=9) always yielded higher frailty scores and a larger range in frailty distributions than veterans (n=10) (Table 5.1). The smaller range in veteran frailty scores may suggest that these
veteran individuals were similarly frail, however individual frailty differences between service members shows that military service is not equally embodied by all, a conclusion also reported by Dent (2017) whose results found unequal embodiment of enslaved individuals. When comparing overall SFI frailty, results revealed no significant differences between civilian and military individuals. Conversely, SFI+ results of overall frailty showed that civilians experienced significantly higher overall frailty than veterans (Table 5.1). Although conflicting with my second research hypothesis (H1) that veterans would have higher frailty, these results demonstrate that there were differences in skeletal frailty between veterans and civilians and therefore cannot support the null hypothesis either. Differences in skeletal frailty between veterans and civilians revealed using the SFI+ that are not seen using the SFI demonstrate that SFI+ frailty criteria expose frailty differences at the population level that can go undetected by the SFI.

The significantly higher frailty results in the civilian population compared to the veteran individuals adds to the complex and disputed conversation about the embodied experiences of military service and its effect on health and frailty. Military service is a physically rigorous and mentally stressful lifestyle characterized by strict rules and regulations, social hardships, family strain, exercise regimens, and dangerous and demanding combat training both on and off deployment status (Barnao 2019; Dolan and Ender 2008; G.H. Elder 1987; Hall 2011; Lane et al. 2012; Langston, Gould, and Greenberg 2007; MacLean and Elder 2007; Pflanz and Ogle 2006; U.S. Department of the Army 2020). Several studies show that living veterans are more likely to self-report as having poor health than civilians (Bernard and Selden 2016; Hoerster et al. 2012; Kramarow, Pastor, and National Center for Health 2012; Littman, Forsberg, and Koepsell
2009). However, these studies were based on self-reporting health in living individuals, and therefore may not be directly comparable to skeletal frailty. For example, veteran individuals may have perceived their health as poor because of high cholesterol, and smoking and drinking habits. While these variables may compound and increase the individual’s allostatic load, they do not result in permanent skeletal changes and would not be detected by skeletal frailty analyses (Goodman, Martin, and Armelagos 1984; McEwen 2004; McEwen and Stellar 1993).

Conversely, other studies show that living veterans are heathier, more physically active, and report more successful aging than the civilian population (Littman, Forsberg, and Koepsell 2009; McLaughlin, Nielsen, and Waller 2008; Pietrzak et al. 2014). A common belief about military populations, named the healthy soldier effect (HSE) views service members as more fit and healthier than civilians because of the requirements and health screens needed to enlist, maintenance of physical health standards during service, and access to health care during their service (Bollinger et al. 2015; Cornum, Matthews, and Seligman 2011; Goolsby and Boniquit 2017; Hauschild et al. 2017; McLaughlin, Nielsen, and Waller 2008; U.S. Department of the Army 2020; Sackett and Mavor 2006). Results from McLaughlin, Nielsen, and Waller (2008) supported the HSE and showed veterans displayed decreases in risk of mortality ranging from 10 to 25 percent compared to civilians. Evidence suggests that physical activity can increase bone health and reduce risks in injury and developing skeletal conditions such as osteoarthritis in service members, and that service members are more likely to continue being physically active during retirement because of their prior service (Goolsby and Boniquit 2017; Hauschild et al. 2017; Knapik, Reynolds, and Harman 2004; Littman, Forsberg, and Koepsell 2009;
McCarthy et al. 2010; Pietrzak et al. 2014; Wallace et al. 2022; Wardle and Greeves 2017).

Results from this study may add evidence to the healthy soldier effect perspective. Military service has been described as a hidden variable in aging with both positive outcomes from the variables described in the HSE (Bollinger et al. 2015; McLaughlin, Nielsen, and Waller 2008) as well as negative impacts on health as veterans age such as higher rates of disability and joint pain (Spiro III, Settersten, and Aldwin 2016; Wilmoth, London, and Parker 2010; Littman, Forsberg, and Koepsell 2009). The life-span model proposed by Spiro III, Settersten, and Aldwin (2016) proposes that effects of military service should be viewed over the life course of the veteran. Because skeletal frailty is quantified using multiple biomarkers with differing etiologies, pathogeneses, and onsets (e.g., LEH), overall skeletal frailty results of veterans reflect embodied multidimensional and multifactorial lived outcomes of military service (Spiro III, Settersten, and Aldwin 2016).

Importantly, the individuals included in this study were from the same age cohort of 50 to 60 years. Results from Wilmoth, London, and Parker (2010) and Bollinger et al. (2015) may provide a rationale as to why in this sample the veteran population had lower frailty scores than civilians in this sample. Wilmoth, London, and Parker (2010) found that at the age of 50 years, veterans were overall healthier and lived with fewer health conditions than civilians; however, by age 75, results reverse as the embodied stress from military service finally expresses itself in elderly veterans (Wilmoth, London, and Parker 2010). This change in health outcomes as the veteran ages reflects the hidden aspect of military service health outcomes (Wilmoth, London, and Parker 2010). Bollinger et al.
(2015) similarly found evidence that suggests older military veterans exhibited some of the HSE, while not as much as described by McLaughlin, Nielsen, and Waller (2008), and exhibited decreased risks in mortality compared to the general U.S. population (Bollinger et al. 2015). In this study, veterans having lower skeletal frailty than civilians may be an indication that veterans between the ages of 50 and 60 years had not yet revealed their hidden variable of military service.

6.3. Comparing Frailty Biomarkers in Veteran and Civilian Individuals

Biomarker descriptive statistics can be seen in Table 5.2. There were no differences in biomarker frailty scores or distributions between veterans and civilians when implementing the SFI (i.e., presence/absence), which is consistent with lack of difference between overall frailty scores between the two samples (Tables 5.3, 5.4). When comparing individual biomarkers based on SFI+ severity scales, only fractures were approaching significant difference, with civilians experiencing more fractures than veterans (Table 5.3). Although the frequency distributions of fractures were not significant (Table 5.5), there were differences in number and locations of fractures per individual between the samples (Figures 5.10, 5.11).

Over half of the veteran sample experienced no fractures with only one individual receiving a score within the two highest severity distributions (Figure 5.6). Conversely, nearly every civilian individual exhibited an antemortem fracture, over half of which scored within the highest two severity distributions. Civilian individuals experienced fractures throughout their body, while veteran individuals experienced fractures only in their upper body and limbs (Figures 5.10, 5.11). Interestingly, veterans experiencing fewer fractures and none in lower limbs contrast with the literature regarding fracture
rates of service members and frequencies of fractures in the lower limbs (Cameron and Owens 2014; Chandler et al. 2017; Goolsby and Boniquit 2017; Jacobs, Cameron, and Bojescul 2014). It is possible that the fractures seen in these veteran individuals were caused by other factors than those related to their military service and different to those seen in the civilian individuals (Waldron 2009). Fractures to the ulna, ribs, and vertebra may be correlated to interpersonal violence or falls, however for both of these cases additional diagnostic fractures would likely be expected, such as metacarpal fractures in the case of interpersonal violence or hip fractures in the case of falls (Waldron 2009; Estabrook and Frayer 2013).

Civilian individuals experiencing higher rates of fractures than veterans may be partly explained by the HSE in the veteran individuals. Due to the physical training and high rates of activity military service members endure during their service, it is possible that this activity stimulated bone remodeling resulting in stronger, more resilient musculoskeletal structures and fewer lower body fractures than individuals without this level of physical activity (Goolsby and Boniquit 2017; Waldron 2009). However, it is uncertain whether the civilian individuals in this study were significantly less active in their life than the veteran population. Additionally, knowing the cause of the fracture (e.g., falling or vehicle accident) and age of the individual when their fractures occurred could shed light on whether their fractures were a result of inactivity or external circumstances such as an accident. However, only some donor information packets of the individuals in this study reported specifics regarding fractures. Despite a lack of correlation between fractures and surgical procedures in this study, the civilian individuals exhibited a broad range pattern of both fractures and surgical procedures
across the entire body, and these instances may be related (Boston 2013; Komar and Grivas 2008; Waldron 2009). Fractures can also be associated with other health conditions such as low bone mass (e.g., osteoporosis), and nutritional deficiencies (e.g., osteomalacia and vitamin D deficiency), though there was no skeletal evidence of these conditions in the civilian individuals to attribute their causes of fractures (Goolsby and Boniquit 2017; Waldron 2009).

Despite a lack of significance in all other biomarkers between veterans and civilians, there are interesting differences in prevalence and patterns in the biomarkers that warrant further exploration. As it relates to oral health, no dental frailty biomarkers (LEH, unfilled caries, and periodontal disease) were significantly different between veterans and civilians using either SFI or SFI+ criteria (Table 5.3). However, civilians exhibited over twice the number of observed teeth with LEH than veteran individuals (Figure 5.6). This could indicate that the civilian population experienced more stressors such as infections or nutritional deficiencies during their childhood, although hereditary factors may have influenced the higher civilian LEH prevalence (Amoroso, Garcia, and Cardoso 2014; Armelagos et al. 2009; Boldsen 2007; Goodman and Armelagos 1988; Goodman and Rose 1990; Miszkiewicz 2015; Yaussy, DeWitte, and Redfern 2016). Additionally, LEH was significantly correlated with periodontal disease (PD), and both LEH and PD were correlated with SFI+ skeletal frailty, which supports research stating that presence of these biomarkers leads to increased adulthood frailty (Agarwal 2016; Amoroso, Garcia, and Cardoso 2014; Armelagos et al. 2009; Bui et al. 2019; Grau et al. 2004; Kamer et al. 2008; Michaud et al. 2008; Shaddox et al. 2010; Waldron 2009; Williams et al. 2008). The significant correlation between LEH and SFI+ frailty scores
support the DOHaD and is demonstrated in the current study as higher rates of LEH and higher frailty scores in the civilian individuals than the veteran individuals.

Additionally, veterans exhibited twice the number of unfilled caries (n=36) than civilians (n=18) (Figure 5.7), and over twice the number of filled caries (n=79) than civilians (n=37), making it the first of two biomarkers exhibited in higher overall prevalence by veterans than by civilians. The higher prevalence of filled caries in the veteran population could reflect the more regular access and utilization of dental care services for veteran individuals during their service than civilians (Hyman et al. 2006).

Eligibility for Veteran Affairs (VA) health care benefits for veterans is determined from priority group status based on factors such as military separation status, disability status, and income level (Cothron et al. 2021). As dental care benefits for veterans are strict, only individuals who received a service-related dental disability upon discharge, who received a 100% disability rating upon discharge from the military, and who are former prisoners of war are eligible to receive any needed dental care (U.S. Department of Veterans Affairs 2019; Wiener et al. 2019). These restrictions result in only fifteen percent of veterans being eligible for comprehensive dental care through the VA, forcing individuals to either receive dental insurance through their employer pay or dental services out of pocket (Cothron et al. 2021). These strict eligibility requirements may contribute to the higher prevalence of unfilled caries among the veteran individuals compared to the civilian caries rates.

As with dental conditions varying between military and civilians, we also see differences in frequency and location of intervertebral disk disorder (IVD) (Figures 5.10, 5.11). While not significant when applied to the SFI+ frailty criteria, veteran individuals
exhibited over three times more vertebrae with IVD (n=31) than the civilian individuals (n=10). Most notable is the difference observed within cervical vertebrae, with IVD manifesting on 18 veteran and 5 civilian cervical vertebrae; veterans also had higher rates of IVD in thoracic and lumbar vertebrae than civilians. As IVD and back pain can reflect mechanical loading of the spine, higher rates of IVD among the veteran individuals may be explained through military occupational demands.

The discussion of stress markers and frailty embodied by soldiers needs to be addressed with respect to the changes in risks and occupational stressors experienced by the soldiers during these war contexts. Combat training and deployments are stressful both physically and mentally. Service members wear personal protective equipment and tactical gear including, but not limited to, a helmet, body armor, ruck sack, a rifle, ammunition, food, and water, resulting in very heavy loads carried ranging from 28 to over 100 pounds (Horn et al. 2012; Knapik, Reynolds, and Harman 2004; Konitzer et al. 2008). Body armor is one of the most important aspects of protection in a combat environment, however a full body armor set that includes front, back, and side plates weighs 32 pounds alone (Horn et al. 2012). Modern combat risks of explosive devices (IEDs), land mines, bullet and shrapnel projectiles accounted for 65% of combat injuries between 2001 and 2003 (Clark et al. 2007). The burden of wearing this equipment is necessary and vital to the safety of the service member. However, as a result service members experience reduced bone health and report musculoskeletal injuries such as strains and fractures, and chronic joint and vertebral pain due to overuse and wear and tear of their body (Horn et al. 2012; Knapik, Reynolds, and Harman 2004; Konitzer et al. 2008; McCarthy et al. 2010). Further research has supported that these variables are
found to increase the chances of neck, shoulder, and back pain, as well as increases in IVD (Adams and Roughley 2006; Berry et al. 2017; S.P. Cohen et al. 2012; Knapik, Reynolds, and Harman 2004; Konitzer et al. 2008; Stevenson et al. 2004), and may explain the much higher rates of IVD in this veteran sample.

Rotator cuff disorder (RCD) and osteoarthritis (OA) differences were not significant between veterans and civilians. Only one civilian manifested RCD (Figure 5.8), which may be the result of the young sample in this study as RCD often appears later in life (Henderson 2008; Roberts, Peters, and Brown 2007; Rothschild 2019; Tashjian 2012). Three individuals from both the civilian sample (n=9) and veteran sample (n=10) exhibited OA evident through eburnation of the joint surfaces (Figure 5.6). However, in civilian individuals eburnation was present in the cervical vertebrae, shoulder, hand, and knees, while in the veteran population only the temporomandibular joint (TMJ), shoulder, and hand showed eburnation (Figures 5.10, 5.11). Interestingly, OA of the TMJ was only present in the veteran population, which may reflect an observed pattern of TMJ pain and dysfunction among veteran populations associated with stress and PTSD symptoms (Mottaghi and Zamani 2014). Similar to fractures, without metadata about individuals’ activity levels, it is unclear whether the increased amount of osteoarthritis within the civilian population is due to less physical activity or due to other causes such as genetics, nutrition, or trauma events (Berenbaum et al. 2018; Jurmain et al. 2012; Jurmain 1977; Loughlin 2001; Musumeci et al. 2015; Reynard and Loughlin 2012; Stanishewski and Zimmermann 2015; Waldron 2009).

Results showed an approaching significant correlation between osteoarthritis and surgical procedures, so it is possible that civilians had higher rates of osteoarthritis due to
higher instances and more varied skeletal localities of surgical procedures compared to veterans (Figures 5.10, 5.11; Appendix C). Individual C6 experienced both a left femoral fracture as well as eburnation on their left femur and tibia that likely resulted from the femoral fracture (Berenbaum et al. 2018; Jurmain 1977; Waldron 2009). It is important to note that two of the three civilian individuals with osteoarthritis, C6 and C9, may be skewing the civilian OA data. Both individuals both exhibited eburnation at three joints, compared to the rest of the individuals with eburnation at a single joint.

Surgical procedures did not show significant differences between veterans and civilians, although they were significantly correlated with overall skeletal frailty (Appendix C). Only one veteran (10%) exhibited skeletal surgical implements compared to four civilian individuals (44%) (Figure 5.8). However, differences in surgical procedures can be seen in their locations on the bodies of veterans and civilians. The surgical procedures on the veteran individual were all on the right arm, whereas surgical locations from the civilian individuals were evident on the cranium and spine, as well as both the upper and lower limbs (Figures 5.10, 5.11). Typically associated with blast-related trauma from improvised explosive devices (IEDs), amputations accounted for 8.3 percent of traumatic injuries during the Vietnam War and 12 percent of injuries during Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF), and are often considered the symbolic hallmark disability of veterans of war (Açiksöz 2012; Clark et al. 2007; Wool 2020; Stansbury et al. 2008; Griffiths and Clasper 2006). However, not all deployments are combat related and physically demanding and under the right circumstances may enhance a service members health. The veteran individuals in this
study may have not deployed, or deployed in non-combat settings, resulting in fewer extremity trauma typically associated with combat and a lack of amputation procedures.

Despite their strong symbolic association with military combat service, amputations account for a small portion of total military injuries and physical conditions, and can also occur outside of military environments and in the general population through motor-vehicle and machinery accidents (Webster 2019; Wool 2020). Interestingly, one civilian had both lower limbs amputated but no veteran individuals experienced amputations. Documentation of individual C1 notes a car accident in their medical history, which could explain their lower limb amputations, rib fractures, femoral fracture, and consequent surgical interventions.

For joint replacements, one civilian individual had knee replacement surgery, while no veteran individuals underwent joint replacement surgeries. Injuries and degeneration of the joints are among the most common conditions in the U.S. population, including modern veterans (Wool 2020; Murtha et al. 2017; Wallace et al. 2017). Joint replacements are frequently used to relieve chronic pain and restore joint function in treatments of severe osteoarthritis (OA) and are more commonly performed on individuals over the age of 65 (Wells et al. 2006; Wallace et al. 2017). An absence of joint replacements in the veteran individuals may be due to the ages of individuals in this study being younger than 65, the fewer instances of fractures, or it may reflect tendencies within veteran individuals to postpone surgical interventions compared to civilian individuals (Açıksöz, 2012; Wells et al, 2006; Wool, 2020). Perceptions of pain, masculinity, and physical disability within military populations may also be a contributing factor. Cultural mentalities surrounding physical injury or conditions from
the “old Army” on being tough and not showing weakness are still perpetuated (Dolan and Ender 2008; Hall 2011). Being told to “Soldier up”, among other phrases, are commonly heard and create a toxic work environment and diminish motivation (Dolan and Ender 2008; Hall 2011). While efforts are being taken to amend these mentalities, lack of support for seeking help within a service member’s peer group or leadership in addition to fear and perceptions of weakness continue to be a problem in military social contexts.

These mentalities may continue after a veteran’s service, and by delaying treatment and minimizing their symptoms, service members put themselves at additional risk of injury and decreased mental health over time (Karasel, Cebeci, and Sonmez 2020; Dolan and Ender 2008; Hall 2011). Furthermore, because these cultural norms and beliefs are so integrated into the identities of service members, delaying help may be a continued behavior after their service. Chronic pain is commonly experienced in veteran populations, and many veterans may not seek help and “learn to live” with their painful conditions (Karasel, 2020; Wool, 2020). Although no veteran individuals underwent joint replacements in this study, OA was present in the sample, and they likely would have still experienced pain and impairment from less severe forms of osteoarthritis without eburnation evident on their joints.

The purpose of this study was to address how military service is embodied in the skeletal remains of veterans. To accomplish this, a biocultural approach was taken to contextualize the biological and cultural factors that influence an individual’s stress and frailty and employed an embodiment framework to interpret instances of stress and frailty biomarkers on the skeleton of modern veteran and civilian individuals. A modified
skeletal frailty index (SFI+) using severity scales to score biomarkers of frailty was applied and compared to the SFI (Marklein and Crews 2017; Marklein, Leahy, and Crews 2016) to answer the following questions: How do SFI+ and SFI scores differ between U.S. veterans and U.S. civilians? Do military veterans exhibit more evidence of stress and frailty biomarkers on their skeletal remains than civilians, as a result of their embodied lifetime experiences?

Results revealed that the SFI+ was an effective methodology to quantify skeletal frailty in this sample, revealing differences in frailty between veterans and civilians not seen in the SFI. The SFI did not reveal significant differences in frailty scores between civilians and veterans; however, the SFI+ results showed significant differences in SFI+ scores between the two samples but rejected the first hypothesis with the civilian individuals exhibiting higher frailty than the veteran individuals. The patterns in frailty biomarkers show veteran individuals correspond with absence of fractures, surgical procedures, osteoarthritis, and presence of intervertebral disk disease, whereas civilians correspond with surgical procedures, fractures, osteoarthritis, linear enamel hypoplasia, and no intervertebral disk disease. While the SFI+ biomarker severity scales revealed only fractures approaching significant difference, there were differences in the prevalence of the biomarkers between the civilian and veteran samples.

Furthermore, while not significantly different using the SFI+ criterion, civilians had higher biomarker prevalence rates in all biomarkers except for unfilled caries and IVD, and visual differences were seen between the two populations in the prevalence and patterns of distribution on the body for IVD, fractures, osteoarthritis, and surgical procedures. Although not fully recognized by the SFI+ methodology, it was demonstrated
from the results that there are differences between the embodiment of skeletal frailty in modern veterans and civilians. The controlled variables of sex, age, and race facilitated the attribution of these differences in frailty to biocultural factors affecting disparate lived experiences between these two populations. The results from this study provide additional insight into the conflicting research concerning the embodied health outcomes of military service via a new approach to this topic through the skeletal remains of modern military veterans.
CHAPTER 7

CONCLUSION, LIMITATIONS, AND FUTURE DIRECTIONS

7.1. Concluding Remarks

The goal of this study was to ascertain how modern military service is embodied and reflected in the skeletal remains of veterans. To address this goal, eight skeletal biomarkers of frailty (linear enamel hypoplasia (LEH), unfilled caries, periodontal disease (PD), osteoarthritis (OA), intervertebral disc disease (IVD), rotator cuff disorder (RCD), fractures, and surgical procedures) were analyzed and skeletal frailty of modern veterans and civilians was quantified and compared between the scoring methodologies of the SFI and SFI+. This study framed skeletal frailty results from a biocultural perspective by considering the influences of the military culture on skeletal frailty in the veteran population and viewed the presence of frailty biomarkers as the result of both cultural and biological experiences of stress.

The SFI+ revealed significant differences between the civilian and veteran individuals that were not detected by the SFI. It was hypothesized that the veteran individuals would have higher frailty scores and higher distributions of frailty biomarkers than the civilian individuals. The results from this study revealed that, in fact, the civilian population had higher frailty scores and higher distributions of most biomarkers than the veteran population. Although the results conflicted with these initial research hypotheses, this research contributes to stress and frailty research by supporting the SFI+ applicability.
in quantifying skeletal frailty in modern forensic populations. By taking a biocultural approach to skeletal frailty, social and cultural factors were considered and interpreted in relation to frailty results. Veterans lived, experienced, and embodied stressors within the unique culture of military that varies from those seen in the civilian individuals that cannot be attributed to other variables such as age, sex, and race.

Although the SFI+ only showed approaching significant differences in fractures between the two populations, the results from this analysis, in addition to the existing research regarding this matter, contributes to understanding and demonstrates the ambiguity of health outcomes from military service. In this veteran population, the embodiment of military service reflected lower frailty, fewer instances of LEH, PD, OA, RCD, fractures, and surgical procedures, but higher rates of unfilled caries and IVD. Furthermore, although the smaller range in veteran frailty scores than the civilian sample might suggest similar experiences of military service, SFI+ results demonstrated that military service is differentially embodied on an individual basis. Addressing veteran frailty needs to be considered cautiously. The differential experience of service members based on their rank, with particular emphasis on officer verses enlisted ranks, influences the physical and psychological requirements, and may reflect differential embodiment of military service. Additionally, differences in duration of service, component serviced in, and exposure to combat deployments will influence the stress experienced and embodied in veterans.

7.2. Limitations and Future Directions

Obtaining sample populations from donated skeletal collections introduces additional limitations. Furthermore, biases in this research sample based on individuals
who donated their body to the Bass Collection, as well as the limited demographic variation in the sample based on sex, age, and self-identified race may have impacted results. Widening the demographics to include differing age groups, both males and females, and individuals of differing self-identified race within the veteran and civilian individuals would explore whether these variables impact frailty results and can derive more accurate data on frailty that reflect the true demographics within these populations (Campanacho, Alves Cardoso, and Ubelaker 2021; FAC 2021; Garment et al. 2007; Vidoli et al. 2017).

The health history documentation of the individuals included in this study represent self-reported data, and there are inherent limitations regarding the quantity of information disclosed by the donor (FAC 2021; Vidoli et al. 2017). There is no certainty that the information in the donation packets of the individuals in this research presented their health information in explicit detail (e.g., smoking data, auto accidents, and habitual activities). Therefore, the use of this self-disclosed information in discussion regarding their skeletal frailty was limited by the researcher (EF) to avoid assumptions. For example, it would be ideal to attain more specific activity levels of the individuals in modern donated skeletal collections. Detailed descriptions of overall activity (e.g., sedentary, lightly active, very active) during adolescence, young adulthood, adulthood, and retirement ages, would be beneficial when answering questions of causation regarding differences in OA between populations. With the understanding that donors to donated skeletal collections have full agency in self-disclosure of their personal information and are sometimes filled out by family members of the donor, these limitations may be difficult to overcome in future research using these collections (Vidoli
Documentation of the veteran individuals in this study did not include specifics regarding their military service, such as the number of years and dates in service, military occupational specialty (MOS), rank, deployment information, or injuries sustained while in the service (Bollinger et al. 2015; Carr et al. 2020; Hoerster et al. 2012; MacLean and Elder 2007). Therefore, the frailty results of these individuals will vary and may be difficult to link directly to health outcomes due to military service. Obtaining more specific information for future veteran donors to skeletal collections of their military service history would facilitate more specific discussions regarding the embodied stress and frailty of military service. Additionally, more concrete documentation about skeletal biomarkers of frailty of all individuals in donated skeletal collections is desired such as the cause, date, and age of the individual when events (e.g., fractures, surgeries, diagnoses) occurred. The results of the SFI+ did not reveal many statistically significant differences in biomarker frailty distributions, which could reflect that the severity scale methodology could be improved upon. The two severity scales were broken down into four classifications based on either the number or percent of elements affected, and the resulting distribution of scores that fell into those groups were small. Implementation of the SFI+ in future research could address these limitations by testing different scoring methodologies that reduce the number of severity groups; however, this might smooth the distribution data resulting in fewer significant differences discovered.

Additionally, because this study included only ten veteran and nine civilian individuals, arguably the most substantial limitation in this research was the sample size of the data. In perfect circumstances without time or monetary constrains, testing the current
methodology using a larger sample size may reveal more significant differences. Although this would be dependent on the number of veterans that donate their body to modern donated skeletal collections and the inclusion of military service as part of their donor documentation packet. Despite the small sample size in this application, the significant differences in frailty scores, and differences in biomarker distributions between the veteran and civilian individuals using the SFI+ are substantial and further support future implementation of the SFI+ methodology in modern forensic contexts.
REFERENCES


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Lane, Marian E., Laurel L. Hourani, Robert M. Bray, and Jason Williams. 2012. "Prevalence of perceived stress and mental health indicators among reserve-


Szymendera, Scott D. 2015. "Who is a “Veteran”?—basic eligibility for veterans’ benefits."


APPENDIX A

Forensic Anthropology Center, University of Tennessee, Knoxville
Body Donation Program Policy

The donation of a person’s body after death is a tremendous gift. We are grateful for everyone who expresses an interest in body donation. We appreciate your attention to the following.

1. Unlike medical schools, we do not return remains to the family. The skeletal remains are a very important component to our research and teaching program. The first donation made to our program in 1981 continues to be studied by researchers today.

2. We reserve the right to decline donations of individuals who have some form of infectious disease such as HIV, tuberculosis, hepatitis of any kind, or antibiotic resistant infections such as MRSA, even if contracted after donation is arranged.

3. Donors with an infectious disease who still wish to donate may do so by choosing to have their remains cremated. We have a growing collection of cremains that provides an invaluable learning resource. People choosing this option should contact us prior to making arrangements. This allows us to work with the crematory involved to ensure the remains are not pulverized. The family must assume responsibility for the arrangement and cost of cremation.

4. We also reserve the right to decline a donation if our facility is at capacity. In case of denial by the University, alternate final arrangements should be discussed by the donor and/or the family.

5. We will arrange transportation to our facility if the deceased is located within the state of Tennessee and within 100 miles of Knoxville. Outside the state of Tennessee or more than 100 miles from Knoxville, the donor and/or the donor’s family must make arrangements for the transportation of the body to our facility and assume responsibility for any associated costs.

6. We are unable to transport from a private residence or nursing home facility. The donor’s family must arrange for transportation and assume responsibility for the cost. We will transport a body from a hospital, funeral home, forensic center, or some healthcare facilities that are within the geographic limits stated above.

7. We need to have signed donation documents or releases prior to transporting. This may be a faxed copy, but the original must be sent as soon as possible. Your donation paperwork will not be complete until originals are returned.

8. Pre-donor paperwork needs to be returned to the Forensic Anthropology Center at the time of completion in order for a file to be established. Changes of address or medical status should be sent to keep donor files up to date.

9. Pre-donor paperwork needs 2 witnesses to verify your signature, but does not need to be notarized.

10. We do not perform autopsies to determine cause of death on donations to our program.

If you have any questions or concerns that have not been addressed in this letter, please feel free to contact us at 865-974-4408 or donateinfo@utk.edu.

V9, 2017
APPENDIX A

Forensic Anthropology Center, University of Tennessee, Knoxville
Body Donation Program Instructions for Donors

This packet contains all the forms required for registering with our body donation program; policy sheet, body donation document, and body donation questionnaire. Please feel free to contact us with any questions you may have.

Body Donation Document

A. Copies of the Form
   a. Three copies of the body donation document are provided to you. We need an original with a valid signature returned with your donation paperwork. The other 2 copies should be retained by you and/or your family for your records.

B. Signature Completion of the Form
   a. Top portion of the form is to be completed by the donor. The donor should be of sound mind and aware of the nature of our program at the time of signing.
   b. The middle portion is to be completed by two adult witnesses. At least one witness should be someone other than a close family member, guardian, or who exhibits a special care for the donor.
   c. A notary is not required for completion of this portion of the form.

C. Trauma Research request
   a. Knowledge of how trauma occurs is of significant interest to the biomedical and anthropological communities. Understanding trauma allows us to better interpret forensic case material and help us to work towards the prevention of such trauma in living patients. This would directly benefit the legal community and aid military personnel protective equipment needs.
   b. Please initial the statement at the bottom of the form if you are interested in participating in trauma related research. A donation will only be used for this type of research when initials are present and there is a need.

D. Simulation Center training (Graduate School of Medicine)
   a. Medical residents at the UT Graduate School of Medicine use cadavers occasionally to learn new medical procedures. The FAC and the Simulation Center are partnering to provide cadavers for temporary use for this training. The remains are then returned to the FAC.
   b. Please initial the statement at the bottom of the form if you are interested in participating in trauma related research. A donation will only be used for this type of research when initials are present and there is a need.

E. Special Requests
   a. We ask that you state any special requests you may have as to how we use your remains at the bottom of this document or on an attached sheet. We will make every effort to honor any requests.

Biological Questionnaire

A. Please complete this form to the best of your ability.
B. Information provided is needed for the completion of the Certificate of Death and contributes information for our research.
C. We ask that any changes of your statistical information be forwarded to us (ex. Name change, address change, significant health changes) in order for us to keep our record updated.

Acceptance into Program

A. Acceptance into our donation program will be determined once forms are completed and mailed back to us. Please see points 2 and 4 in the Program Policy Sheet.
B. You will receive a letter of acceptance and a donor card with contact information to carry in your wallet.

V2_2017
APPENDIX A

Forensic Anthropology Center, University of Tennessee, Knoxville
Body Donation Document

I, _______________________, do hereby dispose of and give my body, after my death, to The University of Tennessee, Knoxville, for use by the Department of Anthropology or its designee, for educational and research purposes. I request, authorize, and instruct my surviving spouse, next-of-kin, executor or the physician who certifies my death to notify The University of Tennessee, Department of Anthropology (telephone: (865) 974-4408), immediately after my death of the availability of my body.

Witness my hand and seal this ______ day of ________, ______, at ______.

_____________________________________________________
Donor’s Signature

_____________________________________________________
Address

On this ______ day of ________, ______, signed this Body Donation Document in our presence and we, as attesting witnesses, at the request of the Testator and in his/her presence and in the presence of each other have also signed this document.

WITNESSES:

Name: ____________________________  (Print Name)  ____________________________  (Signature)

Address: ____________________________

________________________________________

Name: ____________________________  (Print Name)  ____________________________  (Signature)

Address: ____________________________

________________________________________

I wish for my remains to be used for trauma research/Simulation Center that will provide the foundation for training professionals in life saving techniques and in the construction of equipment that would enhance and/or prevent the need for these measures.

V9_2017
APPENDIX A

Forensic Anthropology Center, University of Tennessee, Knoxville
Body Donation Document

I, ____________________________, do hereby dispose of and give my body, after my death, to The University of Tennessee, Knoxville, for use by the Department of Anthropology or its designee, for educational and research purposes. I request, authorize, and instruct my surviving spouse, next-of-kin, executor or the physician who certifies my death to notify The University of Tennessee, Department of Anthropology (telephone: (865) 974-4408), immediately after my death of the availability of my body.

Witness my hand and seal this _____ day of _________, ________, at ________.

______________________________
Donor’s Signature

______________________________
Address

On this _____ day of _________, ________, signed this Body Donation Document in our presence and we, as attesting witnesses, at the request of the Testator and in his/her presence and in the presence of each other have also signed this document.

WITNESSES:

Name: ____________________________ (Print Name) ____________________________ (Signature)

Address: ____________________________

______________________________

Name: ____________________________ (Print Name) ____________________________ (Signature)

Address: ____________________________

______________________________

_____ I wish for my remains to be used for trauma research/Simulation Center that will provide the foundation for training professionals in life saving techniques and in the construction of equipment that would enhance and/or prevent the need for these measures.

V9_2017
APPENDIX A

Forensic Anthropology Center, University of Tennessee, Knoxville
Body Donation Document

I, ________________________________, do hereby dispose of and give my
body, after my death, to The University of Tennessee, Knoxville, for use by the Department of
Anthropology or its designee, for educational and research purposes. I request, authorize, and instruct
my surviving spouse, next-of-kin, executor or the physician who certifies my death to notify The
University of Tennessee, Department of Anthropology (telephone: (865) 974-4408), immediately after
my death of the availability of my body.

Witness my hand and seal this ___ day of ________, ______, at ______.
(day) (month) (year) (time)

________________________
Donor’s Signature

________________________
Address

On this ___ day of ________, ______, signed this Body Donation Document in
(day) (month) (year)
our presence and we, as attesting witnesses, at the request of the Testator and in his/her presence and in
the presence of each other have also signed this document.

WITNESSES:

Name: ____________________________
(Print Name) ____________________________
(Signature)

Address: ____________________________
____________________________________
____________________________________
____________________________________

Name: ____________________________
(Print Name) ____________________________
(Signature)

Address: ____________________________
____________________________________
____________________________________
____________________________________

I wish for my remains to be used for trauma research/Simulation Center that will provide the
foundation for training professionals in life saving techniques and in the construction of equipment that would
enhance and/or prevent the need for these measures.

V9, 2017
APPENDIX A

Forensic Anthropology Center
University of Tennessee
Body Donation Program

The Forensic Anthropology Center (FAC), Department of Anthropology at the University of Tennessee relies on people like you, and we are very appreciative. As you know our research focus has always been on human remains following death. However, we have been considering some research areas that could involve you as a living subject.

Examples of living subject research by faculty and students of the FAC might include such things as surveying why you are interested in donating your body at death, or taking body measurements or 3D scans of faces and fingerprints.

Each research proposal will be subject to the University of Tennessee’s Internal Review Board for use of living human subjects for approval.

(please circle your desire for this program)

Yes, I would like to be considered for living subjects related research.

No, I would not to be considered for living subjects related research.

Print Name________________________

__________________________  __________________________
Signature                      Date

VI – 1/2013
APPENDIX A

Forensic Anthropology Center  University of Tennessee, Knoxville
Body Donation Questionnaire
Please complete the following information by filling in the blank and/or circling an option. If you need more space, additional sheets may be attached. All of the information will be considered confidential.

<table>
<thead>
<tr>
<th>Name</th>
<th>/ / /</th>
<th>Sex: male __ female _</th>
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<td>Last</td>
<td>First</td>
<td>Middle</td>
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<table>
<thead>
<tr>
<th>Social Security #</th>
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<th>Race: White / Black / Hispanic / Other (circle one)</th>
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<table>
<thead>
<tr>
<th>Date of Birth / / /</th>
<th>Age</th>
<th>Place of Birth (city/state)</th>
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<tr>
<th>Home Address</th>
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<td>City</td>
<td>County</td>
<td>State _ Zip _</td>
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<tr>
<th>Phone Number</th>
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<th>Inside City Limits: yes _ no _</th>
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<th>Place of Birth</th>
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<table>
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<tr>
<th>Father's Name</th>
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<th>Place of Birth</th>
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<tr>
<th>Driver's License Height</th>
<th>Weight</th>
<th>Recent Weight Loss: yes _ no _</th>
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<th>Handedness: Right _ Left _</th>
<th>Shoe size</th>
<th>Blood Type</th>
<th>Hair Color (natural)</th>
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<tr>
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<th>Married</th>
<th>Widowed</th>
<th>Divorced</th>
<th>Unknown</th>
<th>Other</th>
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<tr>
<th>Spouse: Last (include maiden) / / /</th>
<th>First</th>
<th>Middle</th>
<th>Living _ Deceased _ Unknown</th>
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</table>

| Number of Children:                |       | |
|------------------------------------|-------||

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<thead>
<tr>
<th>Highest Education Level (indicate number of years)</th>
<th>Military Service: yes _ no _</th>
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<tr>
<td>Elem/Second (0-12):</td>
<td>College (1-4; 5+):</td>
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<thead>
<tr>
<th>Childhood Socio-Economic Status: (circle one) Lower</th>
<th>Lower Middle</th>
<th>Middle</th>
<th>Upper Middle</th>
<th>Upper</th>
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<tr>
<th>Usual (life-long) Occupation</th>
<th>Business/Industry</th>
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<tr>
<th>Residence History (list additional locations as necessary)</th>
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<tr>
<th>Childhood Hometown (0-15 years of age):</th>
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<tr>
<td>City State</td>
<td>Start Date</td>
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<td>City State</td>
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<td>City State</td>
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<tr>
<th>Location as an Adult (any place you have lived for more than 1 year):</th>
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<td>Start Date</td>
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<td>City State</td>
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APPENDIX A

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**Dental History** – Check all that apply
- ☐ Extensive Dental work
- ☐ Lower Dentures: When________
- ☐ Upper Dentures: When________
- ☐ Upper and Lower Dentures: When________
- ☐ Partial Plate
- ☐ Braces

<table>
<thead>
<tr>
<th>Teeth Missing</th>
<th>☐ Most/all teeth</th>
<th>☐ Bridge</th>
<th>☐ Gum Disease</th>
<th>☐ Few</th>
<th>☐ Many</th>
<th>☐ Dental Disease</th>
<th>☐ All</th>
</tr>
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</table>

**Medical History (please indicate the approximate year for each).** Please do not provide just a Doctor’s name.
- ☐ Surgery (general)
- ☐ Plastic Surgery (indicate type and location)

<table>
<thead>
<tr>
<th>Medical History</th>
<th>☐ Fractures</th>
<th>☐ Cancer (type)</th>
<th>☐ Auto Accident (traumatic)</th>
<th>☐ Smoker</th>
<th>☐ Spinal Injuries</th>
<th>☐ Alcoholism</th>
<th>☐ Open Heart Surgery</th>
<th>☐ Diabetes Type:</th>
<th>☐ Amputations</th>
<th>☐ Other (including childhood disorders)</th>
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<td>Treatment:</td>
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<td>Length of Illness:</td>
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**Medical History (continued)** – Please describe the above and any other information you feel may be important, including current medications, timing of injuries, the locations of traumatic injuries, or a family history of an illness, etc. Please attach additional pages as necessary.

**Habitual Activities** (i.e., jogging, repetitive motions, life-long occupation activities, etc.) -

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APPENDIX A

Name ________________________ / ________________________ / ________________________

Last First Middle

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<th>Eye Color</th>
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<td>Hazel</td>
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<td>Other _____</td>
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Next of Kin Information

Name ________________________ Relationship ________________________

Address ________________________ Phone number ________________________

City ________________________ State _____ Zipcode ______ email: ______________

Informant Information (if other than donor or Next of Kin)

Name ________________________ Relationship ________________________

Address ________________________ Phone number ________________________

City ________________________ State _____ Zipcode ______ email: ______________

DO NOT CONTINUE IF YOU ARE A LIVING DONOR

Location of death (if applicable) Date of Death ______________

Institution/Hospital ________________________

Address ________________________

City ________________________ County _______ State _____ Zip code ______

Thank you for taking the time to fill out this questionnaire. If we can be of further assistance, please feel free to contact us.

Return completed forms to:
Dr. Lee Meadows Jantz
Department of Anthropology
1621 Cumberland Avenue
Strong Hall room 502A
Knoxville, TN 37996-1525
email: donateinfo@utk.edu
phone: (865) 974-4408

Version 6/9_2017
APPENDIX B

Osteoarthritis

Collection:  
Individual:  
Recorder(s):  
Date:  

Right:  
- TMJ: Temporal
- TMJ: Mandible

Left:  
- TMJ: Temporal
- TMJ: Mandible

ACF: Acromion
ACF: Clavicle
Shoulder: Glenoid
Shoulder: Humerus
SCJ: Manubrium
SCJ: Clavicle
Elbow: Humerus
Elbow: Radius
Elbow: Ulna
Wrist: Radius
Wrist: Ulna
Wrist: Scaphoid
Wrist: Lunate
SIJ: Sacrum
SIJ: Ilium
Hip: Acetabulum
Hip: Femur
Knee: Femur
Knee: Tibia
Knee: Patella
Ankle: Tibia
Ankle: Talus
Hand: Carpals
Hand: Metacarpals
Hand: Phalanges
Foot: Tarsals
Foot: Metatarsals
Foot: Phalanges

OA Code:  
9=unobservable joint surface, 0=no eburnation, 1=eburnation

138
## APPENDIX B

### Rotator Cuff Disorder:

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SFI Spearman’s Correlation between biomarkers of frailty and overall frailty scores. Significant values considered at $p<0.05$ and designated with two (***) asterisks, and approaching significant values considered at $p=0.10$ and designated with one (*) asterisk.
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SFI = Spearman’s Correlation between biomarkers of frailty and overall frailty scores. Significant values considered at p < 0.05 and designated with two (**) asterisks, and approaching significant values considered at p<.10 and designated with one (*) asterisk.
CURRICULUM VITA

Emily Frazier

Elizabethtown, KY   (360) 936-1094   emfrac01@louisville.edu

Education

UNIVERSITY OF LOUISVILLE: LOUISVILLE, KENTUCKY
- Degree: M.A. Anthropology
- Expected Graduation Date: May, 2022
- GPA: 4.0

UNIVERSITY OF LOUISVILLE: LOUISVILLE, KENTUCKY
- Degree: B.A. Anthropology
- Date Earned: May, 2020
- GPA: 4.0

CLARK COLLEGE: VANCOUVER, WASHINGTON
- Degree: Associate in Arts
- Date Earned: December, 2017
- GPA: 3.79, With Honors

CLARK COLLEGE: VANCOUVER, WASHINGTON
- Degree: Associate in Applied Science Fitness Trainer
- Date Earned: June, 2015
- GPA: 3.71, With Honors

WASHINGTON STATE UNIVERSITY VANCOUVER: VANCOUVER, WASHINGTON
- Credits Earned: 24 Semester Hours

WESTERN WASHINGTON UNIVERSITY UNIVERSITY: BELLINGHAM, WASHINGTON
- Dates Attended: September, 2010-June, 2011
• Credits Earned: 46 Quarter Hours

Field Schools

INSTITUTE FOR FIELD RESEARCH, BONCUKLU, TURKEY: JULY 14-AUGUST 14, 2021
In the summer of 2021 I attended a field school through the Institute for Field Research at the Neolithic site of Boncuklu, Turkey, dating to c. 8500 BCE directed by Professor Douglas Baird from the University of Liverpool. Boncuklu is one of the earliest villages in central Anatolia, predecessor to Catalhoyuk, and exhibits some of the earliest evidence of the transition from hunter gatherer to sedentary farming communities. At this field school I learned applied skills such as archaeological excavation and survey methods, intellectual experience thinking critically about and interpreting contexts and data, as well as laboratory experience through artifact analysis, heavy residue sorting and cataloging, and conservation.

ANDERSON FARM SURVEY, WINCHESTER, KENTUCKY: APRIL 12-APRIL 15, 2021
This survey was conducted with Dr. Jennings and Dr. Smallwood from the University of Louisville anthropology department on privately owned farmland that had lithic evidence of Paleoindian, Archaic, and Woodland occupations. This survey included pedestrian survey as well as 50x50cm shovel unit surveying using 25cm arbitrary levels. This survey provided experience in initial site surveying including how to set up the total station, initiating shovel test units, and completing unit level documentation forms.

FIELD METHODS COURSE: FORENSIC ANTHROPOLOGY CENTER
UNIVERSITY OF TENNESSEE KNOXVILLE: MAY 27-31, 2019
At this course I learned techniques including proper excavation and pedestaling of human skeletal remains, the use of total station and ground penetrating radar, as well as mapping a site in the field. I participated in two excavations of donors including a surface recovery and a burial recovery where my team and I documented, excavated, and inventoried, from start to finish, two individual donors at the facility.

Volunteer Experience

CENTER FOR ARCHAEOLOGY AND CULTURAL HERITAGE, UNIVERSITY OF LOUISVILLE: NOVEMBER, 2019-MAY, 2021
• 5-10 hours per week
• Primary Duties: Inventory of skeletal remains from the ManSlick Road Pauper Cemetery, Collection (MRPC)

Military Service

BASIC DATA
• E-6 Staff Sergeant
Enlisted April, 2012 into U.S. Army Reserve
Currently assigned as an Observer Controller/Trainer (OC/T) with the 3-337th TSBN Fort Knox, Kentucky

12N3OC4, HORIZONTAL CONSTRUCTION SUPERVISOR | U.S. ARMY RESERVE | FEBRUARY, 2018-PRESENT
Primary duties include operation of heavy construction equipment including 230 Hydraulic Excavator, 621G Scraper, D7R Dozer, BHL Backhoe Loader, FEL Front End Loader, and 120M Caterpillar grader. Operator of the AT422T Crane. Squad leader of 4 soldiers and primary crane operator.

Additional Skill Identifier (ASI) C4 obtained June 2019

Additional Duties: Equal Opportunity Leader (EOL), Unit Prevention Leader (UPL), Army Substance Abuse Program (ASAP) Counselor, Caswell Operator, Additional Duty Safety Officer (ADSO), Suicide Prevention and Intervention Leader, Lodging in Kind (LIK) NCOIC, Inactive Duty Training (IDT) NCOIC

92A2O, AUTOMATED LOGISTICAL SERGEANT | U.S. ARMY RESERVE | APRIL, 2012-FEBRUARY, 2018
Served as the automated logistical Sergeant for 193 Soldier Multi-Role Bridge Company in Ready Force. Primary Duties included supervising and performing management or warehouse functions in order to maintain equipment records and parts as well as establish and maintain stock records and other documents such as inventory, material control, accounting, and supply report.

Additional Duties: Suicide Prevention and Intervention Leader, Army Body Composition Program (ABCP) NCOIC, Fit Team & Leader Development Mentorship Program Coordinator, ASAP Counselor, Caswell Operator, Motorpool & Unit Arms, Ammunition, and Explosives (AA&E) Key Custodian, ADSO, Unit Movement Officer (UMO), Unit Public Affairs Representative (UPAR)

Work Experience

GRADUATE TEACHING ASSISTANT | AUGUST, 2020 – MAY, 2022
Position: ANTH 207 Introduction to Biological Anthropology Graduate Teaching Assistant
Supervisors: Dr. Lisa Markowitz, Dr. Fabian Crespo, Dr. Christopher Tillquist, and Dr. Kathryn Marklein
Key Duties: Assisted professors during courses, prepared and lead lab exercises, graded student assignment submissions, entered attendance and grade data into Blackboard LMS, and supported students with course material during office hours. Worked 20 hours per week while working towards M.A. in Anthropology.

CROMWELL PLUMBING | SEPTEMBER, 2015 – OCTOBER, 2016
Position: Plumbing Laborer
Supervisor: Joy Wadsworth, Foreman
Key Duties: Worked on a crew of five alongside licensed plumbers installing plumbing in new apartment construction. Cut and assembled new pipes, operated power tools, cleaned work areas, assembled and installed lavatories, kitchen sinks, toilets, and water heaters. Worked 40 hours per week.

TARGET | FEBRUARY, 2014 – SEPTEMBER, 2015
Position: Consumables Team Member, Sales Floor Team Member
Supervisor: Meredith Stone, Executive Team Lead
Key Duties: Greeting guests, ensuring freshness of food, stocking shelves, organizing displays, taking inventory, ordering, assisting in sales, backup cashier. Worked 16 hours per week while in school.

UPS | OCTOBER, 2014 – APRIL, 2015
Position: Package Hander Twilight Sort
Key Duties: Packing items into delivery trucks for safe delivery. Worked 20 hours per week while in school.

MACY’S | FEBRUARY, 2013 – FEBRUARY, 2014
Position: Bridal Consultant, Sales Associate
Key Duties: Greeting customers, selling housewares and bedding, stocking shelves, cashier. Worked 30 hours per week while in school.

Professional Affiliations

ANTHROPOLOGY GRADUATE STUDENT ASSOCIATION
President

GOLDEN KEY INTERNATIONAL HONOUR SOCIETY
University of Louisville Chapter
2019-present

LAMBDA ALPHA ANTHROPOLOGY HONOR SOCIETY
University of Louisville Chapter
2020-present

Honors and Awards

MILITARY
ARCOM (Army Commendation Medal)
Three AAMs (Army Achievement Medal)
Three Overseas Training Ribbons (Belize, 2017; Poland, 2018 and 2019)
Three ARCAMs (Army Reserve Component Achievement Medal)
AFRM (Army Forces Reserve Medal)
NCO Professional Development Ribbon
Army Drivers Badge (Operator)
National Defense Service Medal
Army Service Ribbon
Basic Leader Course Commandant’s List

EDUCATION
- Graduate Dean’s Citation Award: Spring 2022
- Department of Anthropology Outstanding Graduate Student Award: Spring 2022
- University of Louisville Dean’s Scholar Semesters: Fall 2018, Spring 2019, Fall 2019, Spring 2020
- Graduated with honors, Associate in Arts, 2017
- Graduated with honors, Associate in Applied Science-Fitness Trainer, 2015

References

**Dr. Kathryn Marklein**
- Assistant Professor
- University of Louisville Department of Anthropology
- (502) 852-2427
- Kathryn.marklein@louisville.edu

**Dr. Douglas Baird**
- Professor
- University of Liverpool Department of Archaeology
- +44 (0)151 794 4392
- D.Baird@liverpool.ac.uk

**SFC Travis Douce**
- Platoon Sergeant
- 961st Engineer Company, U.S. Army Reserve
- (419) 979-8795
- Travis.k.douce.mil@mail.mil