FLUCTUATING FACIAL ASYMMETRY AS A STRESS MARKER IN HISTORIC AND CONTEMPORARY AFRICAN AMERICAN POPULATIONS

by

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DEDICATION

To my family and friends. Thank you for all your support and encouragement throughout my journey.

To all Black individuals, from the start of enslavement to now. Thank you for your bravery and resilience. Thank you for paving the way for me and other Black scholars and being a constant source of motivation in hard times. I see you, I am you, and I hope this work does us all justice.

To Shelia Renee Archibald. Thank you for being my light and guardian angel. This one is for you.

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I. INTRODUCTION

Studies of the African Diaspora aid in our understanding of the experiences of Africans and African Americans in various realms of cultural, genetic, and skeletal change. These alterations transcend generations and can produce physical manifestations that display the trauma Black individuals endured through forced migration, strenuous labor, and restricted developmental mobility (Spradley 2006; DeLeon 2007; Weisensee 2013).

The purpose of this research is to expand analyses of biological profiles and life history studies concerning the bodily effects of the African Diaspora. With intentions of generational comparison, I will examine fluctuating facial asymmetry profiles from Black individuals in several documented skeletal collections to assess trends between enslavement (the 1600s–1861) and contemporary (1900–today) periods. These constructed profiles of fluctuating facial asymmetry scores will be compared with modern American White and Hispanic populations groups to position Black health within that of contemporaneous counterparts.

An additional research goal is to assess how the level of fluctuating asymmetry between mean ages at death and sex differ between historic and modern populations. The comparison of fluctuating asymmetry levels by these two categories may reveal differing stress manifestations by sex and age. My research aims to result in information concerning skeletal manifestations of historic Black health, visualization of possible generational transference of stress (via epigenetic changes), and creation of a baseline for historic and modern Black health in comparison to other population groups. The following literature review will provide a brief overview of the African Diaspora, examine black living conditions pre-and post-Civil War along with its corresponding health outcomes, explore epigenetics and transgenerational stress, and finally, discuss the skeletal indicator suite selected for this study.

Background

The African Diaspora

The African Diaspora resulted in the largest forced movement of enslaved Black individuals from their home continent to European and British colonies within the New World (Faola 2002). Estimates from The Trans-Atlantic Slave Trade Database place this number somewhere around 12.7 million enslaved Africans shipped to North America, the Caribbean, and South America - with only 10.7 million surviving the voyage (SlaveVoyages 2008). Several global European powers, such as the Portuguese, Spanish, Dutch, and British, participated in this exploitation of Black lives (Library of Congress 1998; Rawley 1981). African populations were enslaved and transported solely for "large scale manual labor that would economically benefit select European countries" (Spradley 2006, 19).

The South Atlantic trade network involved various international trade routes – one being the infamous triangle trade that directly fed the route of the Middle Passage. This involved the trading of Black individuals from the West African Coast in exchange for European goods (Rawley 1981). Ships full of human cargo would travel to European American colonies as a source of cheap labor to fuel European merchant profit (Library of Congress 1998). The cultivation of various cash crops was feasible with the amount of land provided by the American colonies but required the constant preparation and tending of the land (Rawley 1981). This lends to the regional plantation agriculture, with tobacco becoming a staple of the Chesapeake Bay area and cotton becoming a profit for the South (Spradley 2006; Northrup 2002; Curtin 1969).

Conditions of Antebellum and Reconstruction Black Populations

The enslavement of Black individuals and their transport to the Americas led to drastic changes for the population. The conditions of Antebellum and Reconstruction Black populations shifted in ways that altered the entirety of their lifeways and therefore, resulted in transgenerational trauma with corresponding effects embodied on their bodies. Although closely following one another, the Antebellum and Reconstruction periods provided different lifeways for African and African American populations. The societal shift from slavery to freedom proved to be so developmentally constrained (biologically, culturally, and politically) that the element of freedom was often overshadowed by the persisting effects of racism and enforced social inequality.

Life on plantations was a stress-ridden environment, but each greatly differed due to multiple factors such as owner temperament and state (Ball 1858; Henderson 1856). Fieldwork included extremely long days with rarely any breaks and questionable nourishment sources (Drew 1856). Housing was also minimal with small dirt floor shacks packed to the brim with people (see Stroyer 1885). Many enslaved Africans and African Americans lived by "Slave Codes," which outlined the rights and treatment of enslaved individuals (Independence Hall Association n.d.). These codes varied from state to state and often were representative of the area's view of the black community. Leading up to the war, there were instances of slave rebellions and runaways that fueled the fire toward Black emancipation. During the Civil War, however, enslaved and free populations were recruited to fight on both dueling sides.

Even after the hostilities ended, Black life after the Civil War also brought its own difficulties. While the Thirteenth Amendment of 1865 legally ended slavery and declared freedom for Africans and African Americans, it did not do much for the lasting marginalizing effect of slavery and continued White prejudice (Greer 2014; Reagan 1865; Franklin and Wilson 2020). The social status of Black individuals was extremely low due to the inhuman, subordinate characterizations placed on them during the Antebellum period. White prejudice persisted past the legal condemnation of slavery, and they transformed their racial brutalities into laws known as Black Codes (Digital History n.d.). Implemented by southern state legislation, these laws regulated the lives of free Black Americans through harsh restrictions concerning civil rights, employment, and living conditions (Constitutional Rights Foundation n.d.). For example, the South Carolina Black code provided 'persons of color' with the right "...to acquire, own and dispose of property; to make contracts; to enjoy the fruits of their labor; to sue and be sued; and to receive protection under the law in their persons and property" (Constitutional Rights Foundation n.d.), but implemented stipulations around employment (labor contracts) and living (vagrancy) during a time when many Black Americans were left with very little living structure after freedom. Other southern states followed suit, concocting new, more oppressive methods to continue the control of Black lives.

Impacts on Black Health

The explicit policing and social control resulted in biological manifestations of stress within Black American health. The group experienced health constraints from their marginalizing history of slavery and other prejudiced implementations. Among biological anthropologists, Black health on plantations is a topic of discussion (see Schuler 2011; Schuler 2005; Steckel and Rose 2002), with scholars stressing the inhumane conditions of slavery's existence and the persistence of these physiological stressors in both dental and skeletal tissues (see Marks 1993). Lambert (2006) highlights an overview of poor health for enslaved individuals through an analysis of skeletal health indices (dental caries, periosteal lesions, etc.). A collective accounting of comprising health includes elevated rates of growth instability, dental disease, and more specific diseases such as syphilis and tuberculosis (Lambert 2006; Thompson 2009). Health disparities amongst African Americans continued to persist through the years and have only expanded through generations. This is seen in the consistent, elevated rates of cardiovascular disease, hypertension, and diabetes within the Black community today, as well as the disproportionate impact of the novel 2019 Coronavirus as a result of these generational health histories (Kuzawa and Sweet 2009; Millett et al 2020; Price-Haywood et al 2020). The resulting impacts of historical enslavement and continued oppression can be understood via epigenetic inheritance and analysis of transgenerational stress within historic and modern African American populations.

Epigenetics and Transgenerational Stress

Epigenetics is defined as "somatically heritable states of gene expression…without alterations in the DNA sequence" (Choi and Fiso 2010). It is essentially the study of environmentally caused genetic changes, their transmission from the maternal to fetal environments, and the mechanism by which transgenerational stress is maintained and transmitted through descendant populations (see Choi and Fiso 2010). The mechanism and transference are of great importance because they perpetuate the effects of enslavement and societal oppression experienced by Black individuals from the historic past to today. Preserved effects can be expressed in skeletal elements, such as the cranium (see Medrano 2020).

The epigenetic changes and transgenerational stresses from enslavement and other developmentally debilitating occurrences within the Black community have been studied (see David and Collins 1991; Kuzawa and Sweet 2009). These studies present an interesting area of analysis and provide insight into the lasting physical effects of life under social and biological oppression, with researchers inferring the biological inheritance of transgenerational stress due to pervasive racism and prejudice (Sullivan 2013; Grossi 2020; Thayer and Kuzawa 2011). Thayer and Kuzawa (2011) explored the epigenetic contributions to health disparities (nutrition, psychological stress, and environmental toxicant exposure) and found that each domain presents life-long and generational effects. Sullivan (2013) demonstrated how racial, transgenerational disparities are physically adopted by the body and what racism's social role is in transgenerational biological impacts. The epigenetic impacts influence inheritance types that affect the traits of a fetus but not the DNA structure. Examples include adult psychological difficulties (i.e., PTSD, depression, etc.) in response to significant stress from elevated maternal cortisol levels during prenatal development (Sullivan 2013). Stress-inducing environments, such as enslavement in this case, induce extra cortisol from a mother and result in epigenetic marker changes in the fetus's DNA (Sullivan 2013). The stress axis of the child becomes overworked and produces more cortisol as well, therefore becoming more sensitive to events of stress. Exposure to stressful events while *in utero* or at a young age, and having this hypersensitivity to stressors can impact the skeletal manifestations of stress and preservation of transgenerational trauma.

Research concerning transgenerational stress also highlights the Developmental Origins of Health and Disease (DOHaD) hypothesis. Agarwal (2016) describes the concept as the relationship between an individual's early life factors and corresponding adult diseases. Environmental events of early childhood and pre-existing genetic disposition are crucial in the bodily response to the environment and thus, disease manifestation. The fetal environment has been identified as a vital period in respect to overall future adult disease and health (Barker et al 1989; Agarwal 2016; Mandy and Nyirenda 2018). Studies have also elaborated on the issue of maternal stress and poor nutrition that led to adaptive responses of the child to their prenatal environment (Gowland 2015). Maternal health and fetal environment directly correlate to the previous discussion of transgenerational epigenetic inheritance. Environmental stressors, such as slavery or modern poverty, experienced by the mother can directly affect the child and increase the chances of stress inheritance. Adaptive responses of the child from the mother's stress can result in skeletal manifestations, and one area of research that shows some promise is the examination of fluctuating facial asymmetry.

Fluctuating Facial Asymmetry

Associated with underlying developmental stress, fluctuating facial asymmetry (FFA) is understood as symmetrical deviations of the left and right sides of the craniofacial region (Rusk 2019). Fluctuating facial asymmetry is essentially a measure of non-specific developmental instability and is indicative of environmental and developmental stresses in humans (Weisensee 2013). Asymmetry has been measured in a variety of skeletal elements such as the dental arcade and, as in the focus of this proposed research, the craniofacial structure (DeLeon 2007; Weisensee and Spradley 2018; Weisensee 2013). The first few years of a child's life are most impressionable regarding the plasticity of the cranial vault, with environmental or socioeconomic stresses absorbed and potentially expressed in the skeletal makeup. Ages 0 to 5 are extremely significant for these expressions and absorption of these extrinsic factors. This is also a pivotal age period crucial for cranial vault development; however, sutures of the vault region can remain pliable until early adulthood (Beasley n.d.). Relatedly, facial development continues into adulthood, with changes occurring to the hard and soft tissue profiles of an individual's face (Sharma et. al. 2014). These various stages of development are susceptible to the effects of pre-natal and lifelong stress and can provide a skeletal record of developmental instability.

Varying levels of craniofacial asymmetry have been examined in living individuals in connection to socioeconomic status (SES) (Hope et. al. 2013; Özener and Fink 2010). SES refers to the social standing of individuals regarding education, income, and occupation. Lower SES is proposed to lead to increased causal factors for developmental instability and acquired skeletal asymmetry (Hope et. al. 2013). Due to continued racial disparities across all social realms, Black Americans often occupy lower positions in terms of education and income rankings (United States Census Bureau 2017). Medrano (2020) discusses how SES can produce pervasive environmental stress (i.e. malnutrition, inadequate health care, etc.) and therefore, manifest into asymmetry of skeletal elements such as the cranium. Craniofacial fluctuating asymmetry is therefore thought to potentially be a direct record that can serve as a proxy of childhood SES and highlights the importance of transgenerational epigenetic inheritance as well. The historic effects of enslavement and intense poverty might produce a skeletal record with craniofacial asymmetry, and therefore might shed light on the oppressive timeline of Black individuals in America. While the craniofacial region does undergo remodeling, continued exposure to stressful environments can sustain FFA and has been found in other studies to increase with age as well (Linden et al 2018). Overall, environmental and socio-economic pressures can potentially be viewed through the biological proxy of craniofacial fluctuating asymmetry.

In addition to the relationship with SES, fluctuating facial asymmetry (FFA) shows promising prospects as an indicator of developmental instability resulting from nutritional and systematic stress in humans (DeLeon 2007; Weisensee 2013). Previous work has found a possible link between poor nutrition and resulting systematic stress with the increased presence of developmental instability in the skull when viewed in the context of health transitional periods and reported episodes of developmental stress (DeLeon 2007; Weisensee 2013; Kieser et al 1997; Beary 2018). The fluctuation between the bilateral measures of the face potentially reflects an individual's developmental instability and the struggle to maintain a homeostatic constant in shifting environmental and nutritional conditions. Overall, fluctuating asymmetry may provide insight into the skeletal manifestations of developmental stress within African and African American populations.

Developmental constraints and racially fueled disparities from the African Diaspora, enslavement, and prevalent, pervasive racism have shackled the Black community into a position of social and biological oppression that continues today.

Assessing the results gathered from Weisensee and Spradley's craniofacial FFA comparison study (Weisensee and Spradley 2018), it is predicted that the lower SES of African Americans will result in higher levels of FFA within the group when compared to other groups. The resulting craniofacial FFA scores could provide insight into secular change between historic and modern Black populations and historical treatments' manifestations onto the human skeleton.

My research questions concern the comparison of craniofacial FFA scores between historic (Antebellum and Reconstruction) and modern Black populations, and this comparative approach could allow visualization of the likely positive secular change while creating a baseline health profile within the African American community as a whole. I suspect that FFA scores between enslaved and contemporary Black populations will be within similar ranges, since the transition for Black individuals was from a historic environment of enslavement to a contemporary one of ongoing racially fueled marginalization, with continued physiological and psychosocial impacts on health. An additional comparison with American Whites and Hispanics can add an interesting supplementary analysis concerning skeletal manifestations of stress and historical effects.

Goals and Research Questions

The goal of this study is to identify trends between stress profiles embodied in historic African American populations in comparison to modern Black populations, which in turn will be compared to contemporaneous White and Hispanic individuals. My research questions are as follows:

1. Are there observable trends in fluctuating facial asymmetry between enslaved and contemporary African American populations?

2. How does the stress profile (constructed from fluctuating asymmetry score) of historic African Americans compare against contemporary population groups (i.e., American Black, American White, Hispanic)?
3. How do levels of fluctuating asymmetry compare between mean ages at death and by sex within the selected period?
4. What observable differences exist between contemporary populations' fluctuating facial asymmetry scores by socioeconomic status?

The proposed research will analyze the health of marginalized historic and modern populations via FFA scores, along with the assessment of generational patterns of fluctuating facial asymmetry within historic Black populations to form stress profiles and expand the studies concerning skeletal manifestations of historic Black health, visualization of possible generational transcendence of stress, and creation of a baseline for historic and modern Black health in comparison to other affinity groups.

II. MATERIALS AND METHODS

Fluctuating facial asymmetry (FFA) scores were examined in documented historic Black skeletal collections to assess health and developmental stress during the historic periods leading up to the Civil War and through the modern era. FFA was also assessed in modern American Black individuals and was compared with modern White and Hispanic populations to evaluate differences or similarities in the degree of facial asymmetry. Score differences between mean cohorts and sex within the designated periods are evaluated to reveal if there are different stress manifestations by sex, age cohort, and SES. There are a total of 94 individuals used in this study, comprised of historic Black individuals as well as modern American Black, American Hispanic, and American White individuals. Each group is organized by period (enslavement or contemporary) and detailed in Table 1.

The coordinate data, outside of those collected from the Texas State Donated Skeletal collection, were provided by Dr. Kate Spradley from her doctoral dissertation, "Biological Anthropological Aspects of the African Diaspora; Geographic Origins, Secular Trends, and Plastic Versus Genetic Influences Utilizing Craniometric Data" (2006). Information about each of these sample groups will be discussed in the sections below.

Table 1. Sample Populations of selected historical periods.

Collection	Time Period	Ancestry	Sample Size	Status
Enslavement Period (1600s – 1861) **n= 25**				
Jamestown (Virginia)	Early Historic 1619	Black	3	Enslaved
James City County (Virginia)	Early Historic	Black	5	Not specified (Likely Enslaved)
Clift's Plantation (Virginia)	Early Historic 1705 to 1730	Black	2	Enslaved (Plantation Slaves)
Deep River (Maryland)	Early Historic ≈ 1740	Black	4	Enslaved
Catoctin Furnace (Maryland)	Antebellum 1790-1820	Black	3	Enslaved (Industrial slaves)
Fort A.P. Hill (Virginia)	Early Historic to Antebellum Between the 18^{th} and 19^{th} century	Black	1	Not specified (Likely Enslaved)
Mt. Pleasant Cemetery (Washington, DC)	Antebellum to Historic Modern 1850 to 1900	Black	7	Enslaved
Contemporary Period (1900- today) **n = 69**				
Providence Baptist Church (Tennessee)	Historic Modern 1899 to 1933	Black	14	Free
TXSTDSC (Texas)	Modern 1900s to 2000s	Black Hispanic White	12 15 28	Contemporary

Enslaved Sample Populations

Jamestown (N=3). Black individuals in Jamestown, while technically not yet enslaved (slavery being codified in 1662) were transitioned into institutionalized enslavement through a shift of indentured service to slavery. Statutory and slave laws of the colony established the societal position of Black individuals during the time. These included required documentation for movement about the land, censoring of interpersonal relationships, and general ownership.

James City County (N=5). Information about this site related to Jamestown is sparse but represents an enslaved population located further down the James River from the main colony (Spradley 2006). The site contained one of the largest plantations in the area, with additions of gardens, barns, and a river landing post (Kingsmill of the James n.d.). The head of the river contained residential areas and graves (25 total) of enslaved Black individuals, which were later excavated and curated by the Smithsonian under the name "Utopia Archaeological Site" (Kingsmill of the James n.d.).

Clift's Plantation (N= 2). The Clift's plantation is in Westmoreland County, Virginia, and was excavated from 1976 to 1979 (Neiman 1980). With the use of dating techniques and contextual evidence, it was understood that the planation was active from 1670 to 1730 (Neiman 1980). Eighteen graves were recovered in distinctive northern (5 graves) and southern sections (12 graves). Eleven of the twelve southern graves were enslaved Black individuals and were dated to the latter half of the cemetery's occupation of the 1700s.

Deep River (N= 4). Information from the site primarily comes from J. Lawrence Angel's curated data collection sheets, which is detailed in Spradley (2006). She states that the site is located along the Magothy River in Maryland's Anne Arundel County and is proposed by Angel to have contained enslaved individuals from around the middle 1700s.

Catoctin Iron Furnace Cemetery (N= 3). The unmarked cemetery within the Catoctin Furnace State Historic District of Frederick County, Maryland was excavated by Mid-Atlantic Archaeological Research (MAAR) in 1981 (Burnston 1981). A third of the cemetery was excavated, totaling 35 graves. With the use of contextual sources, such as historic documentation research, oral history, artifact analyses, and biological profile analyses, it was proposed that those interred were enslaved Black individuals associated with the late eighteenth and early nineteenth century Catoctin Furnace complex (Burnston 1981).

Fort A.P. Hill (N= 1). Forty-three graves from around the 18^{th} and 19^{th} centuries were excavated on the Fort A.P. Hill site of Caroline County, Virginia (Spradley 2006; Bruwelheide 2002). 29 individuals were identified with 7 of them having crania complete enough for measuring (Spradley 2006).

Mt. Pleasant Cemetery (N =9). The Mt. Pleasant Plains cemetery is located in Washington, D.C, and dates to 1550 - 1900. A total of 13 Black Americans were recovered from the cemetery and displayed generally good health (Blakey and Rankin-Hill 2009), which is assumed to represent either an affluent population or a more rural lifestyle during the industrial period (Blakey and Rankin-Hill 2009).

Contemporary Sample Populations

Providence Baptist Church Cemetery (N = 14). Discovered during transportation improvements in Memphis, Tennessee of 2003, the Providence Baptist Church cemetery was an unmarked plot from the early 20th century that contained little to no historical documentation. The health status of post-reconstruction Black populations is often missing from the archaeological and historical record, however, the skeletal health of those interred at this cemetery is largely discussed by Wilson (2005). She states that with the few skeletal manifestations of stress (linear enamel hypoplasia, porotic hyperostosis, etc.) present in the population, most were "predominantly mild and in the healed state" (2005, 90).

The Texas State Donated Skeletal Collection (N = 55). The Texas State Donated Skeletal Collection (TXSTDSC) is housed in the Forensic Anthropology Center at Texas State (FACTS) and is currently comprised of 710 individuals (Gocha et al. 2022). Individuals are signed up for the whole body donation program as either living donors or by their legal next of kin. Males make up most of the collection at 58%, while 42% are females. Ages represented span from 21 weeks gestation to 103 years old at death (66 years old mean age). Ancestry of the donors is self-identified or family-identified and encompasses ancestral groups of White (90%), Hispanic (4.5%), and Black (3%). Less than 2% of the donors are of mixed ancestry and even fewer are of Asian or Native American descent. The socioeconomic status of the donors falls mostly in the middle and lower groups, with a few falling into the higher category. A portion of the modern Black population sample of this study comes from the TXSTDSC (N = 12). All of the comparative populations of American White individuals (N= 28) and Hispanic individuals (N= 15) consist of donors from the TXSTDSC as well.

Methods

Specific demographic data of the donors, such as sex and age at death, are pivotal to this study. For the enslaved sample groups, this information is collected from historical documentation of the archaeological site or skeletal analyses performed by previous researchers (Burnston 1981; Spradley 2006). The contemporary populations do have more established documentation of sex and age at death, but similar to the enslaved populations, I relied on the estimations provided by the anthropologists in cases where some lacked this information. The sex division of each collection can be viewed in Table 2. The ages at death were organized into categories of early adulthood (20- 40 years of age), middle adulthood (41-69), and late adulthood (70 years of age and older) (see Table 3).

Table 2. Populations' male and female distribution.

Collection	Ancestry	Sample Size	Sex
Jamestown	Black	3	Male: Unknown Female: Unknown
James City County, Virginia	Black	5	Male: Unknown Female: Unknown
Clift's Plantation (Virginia)	Black	2	Male: Unknown Female: Unknown
Deep River (Maryland)	Black	4	Male: Unknown Female: Unknown
Catoctin Furnace (Maryland)	Black	3	Male:1 Female:1 Unknown: 1
Fort A.P. Hill (Virginia)	Black	1	Male: Unknown Female: Unknown
Mt. Pleasant Cemetery (Washington, DC)	Black	7	Male:4 Female:3
Providence Baptist Church (Tennessee)	Black	14	Male:7 Female:6 Unknown: 1
TXSTDSC (Texas)	Black Hispanic White	12 15 28	Male:9 Female:3 Male:9 Female:6 Male:14 Female:14

Table 3. Age at death distribution amongst the contemporary sample.

Contemporary Period	
Early Adulthood (20- 40 years of age)	4
Middle Adulthood (41-69 years of age)	31
Late Adulthood (70 years of age and older)	16

Socioeconomic status, when available, was also obtained from collection documentation and used in the analysis of this research (Table 4). Most of the individuals with documented socioeconomic status come from the TXSTDSC. This information was retrieved from the donation paperwork completed by either the living donor or the next of kin with posed questions of childhood socioeconomic status. The TXSTDSC provides five options for SES level (lower, lower-middle, middle, upper-middle, and upper) but this study uses consolidated options of lower (lower+lower-middle), middle, and upper (upper-middle+upper) in the analysis.

Table 4. Socioeconomic status (SES) distribution amongst the contemporary sample.

Contemporary Period	
Lower	21
Middle	26
Upper	4

Digitized three-dimensional cranial landmark data, in the form of x, y, and z coordinates, were used as the foundational base in the creation of the fluctuating asymmetry scores. As stated above, the majority of the craniometric data was collected previously by Dr. Kate Spradley, with the data from the TXSTDSC donors collected by this author at the Grady Early Forensic Anthropology Laboratory. A MicroScribe G2LX digitizer, paired with 3Skull (Ousley n.d.) and Advantage Data Architect (ADA) software, was used to physically collect the coordinate data and organize them into databases by the ancestral group. The digitizer has a base with an attached rotating arm that allows users to maneuver around the stationary cranium of their specimen. The rotating arm has a pointed stylus at its end to ensure precise placement on cranial landmarks. Crania of select individuals are held still by being mounted on a tri-column clay stand or any other stable, non-obstructing apparatus (see Figure 1).

Select landmarks were chosen that encapsulate the full range of shape in the craniofacial region. A list of the used landmarks and their abbreviations is contained in Table 5. The accuracy and consistency of the cranial landmark placement were ensured using the definitions presented in Howell's 1973 work, "Cranial Variation in Man." Cranial landmarks can be seen in Figure 2. Proper operation of the MicroScribe digitizer was provided by the Standard Operating Procedures (SOP) document of the Harris Country Institute of Forensic Sciences, Forensic Anthropology Division (2018). The SOP described the proper orientation and usage of the machine, along with landmark descriptions and images displaying the marked locations.

Figure 1. Digitizing Set up of crania on tri-column clay stand with MicroScribe G2LX digitizer to the right.

Table 5. Cranial Landmarks used in the analysis.

Landmark Name	Abbreviation (s)	Landmark Number
Alare	alarl, alarr	1, 2
Asterion	astl, astr	3, 4
Basion	bas	5
Bregma	brg	6
Dacryon	dacl, dacr	7, 8
Ectoconchion	etcl, ectr	9,10
Frontomalare anterior	fmal, fmar	11, 12
Lambda	lam	13
Most inferior nasal border	nlhil, nlhir	14, 15
Nasion	nas	16
Nasomaxillary suture pinch	wnbl, wnbr	17, 18
Opisthion	ops	19
Porion	porl, porr	20, 21
Zygomaxillare	zygoml, zygomr	22, 23

Figure 2. Cranial Landmarks commonly collected during the digitizing process depicted on crania. Taken from Damas et al. (2020) and used with author permission. Image authored by Dr. F. Navarro.

The digitized data for each donor was transferred from the Advantage Data Architect coordinate files and organized into a text file by period chronology (enslavement and contemporary) and sex. The 23 selected landmarks (see Table 5 above) for each donor were also listed in the same fashion as the donors, with the coordinates inputted in the same order as the donors. The complete text file was imported into the Morpho J software (Klingenberg 2011) to gather the FFA scores. Morpho J is an integrated program that allows users to perform geometric morphometric analyses for either two-dimensional or three-dimensional data. The software also allows for the implementation of a Procrustes fit for data with and without object symmetry.

Classifiers of the historical period and sex were implemented into the Morpho J program to maintain the labels of the donors. Instructions for FFA score creation were followed as described in Weisensee and Spradley (2018) and Klingenberg and Monteiro (2005). The FFA score, itself, is created from a single, multivariate estimation of the symmetry deviation that is gathered from the distance between the original landmark data and symmetrical relabeled configuration. A generalized Procrustes least-squares superimposition was used when analyzing the coordinate data in the program. An example of the Procrustes superimposition process with relabeled configurations can be seen in Figure 3. Mitteroecker and Gunz (2009) note that the Procrustes least-squares superimposition "removes non-shape related variation due to the relative location, orientation, and size of the specimens, thus allowing for an examination of shape variation between specimen" (Weisensee 2013:413). Additionally, since crania are composed of bilateral symmetry, symmetric and asymmetric components can be formulated from shape variation. The mirroring of original landmark data and symmetrical relabeled landmark configuration allows for the gathering of this component data and the creation of a symmetrical consensus (Weisensee and Spradley 2018). The symmetrical consensus and initial donor data difference was used to generate Mahalanobis FFA scores, which "account for the non-isotropic variation by using a measure analogous to Mahalanobis distance" (Weisensee and Spradley 2018, 124). Klingenberg and Monteiro 2005's guidelines were utilized for the creation of these Mahalanobis FFA scores in the Morpho J software for each individual in this study.

To identify potential outliers, the Principal Component Analysis function within MorphoJ (Klingenberg 2011) was used. The function produces a graphical output (scatter plot) that plots each individual's deviation from the overall sample mean (Figure 4). One possible outlier, an American White female (#80), contained an FFA score of 8.21 while the average of the contemporary American White group was 5.55. This individual was also highlighted by the boxplot graphical function in SPSS (IBM Corp 2017; see Figure 5). The donor, however, was not flagged as an extreme outlier by the "Find Outliers" function in the MorphoJ software. To ensure all possible data was collected, the analysis was run with and without the individual.

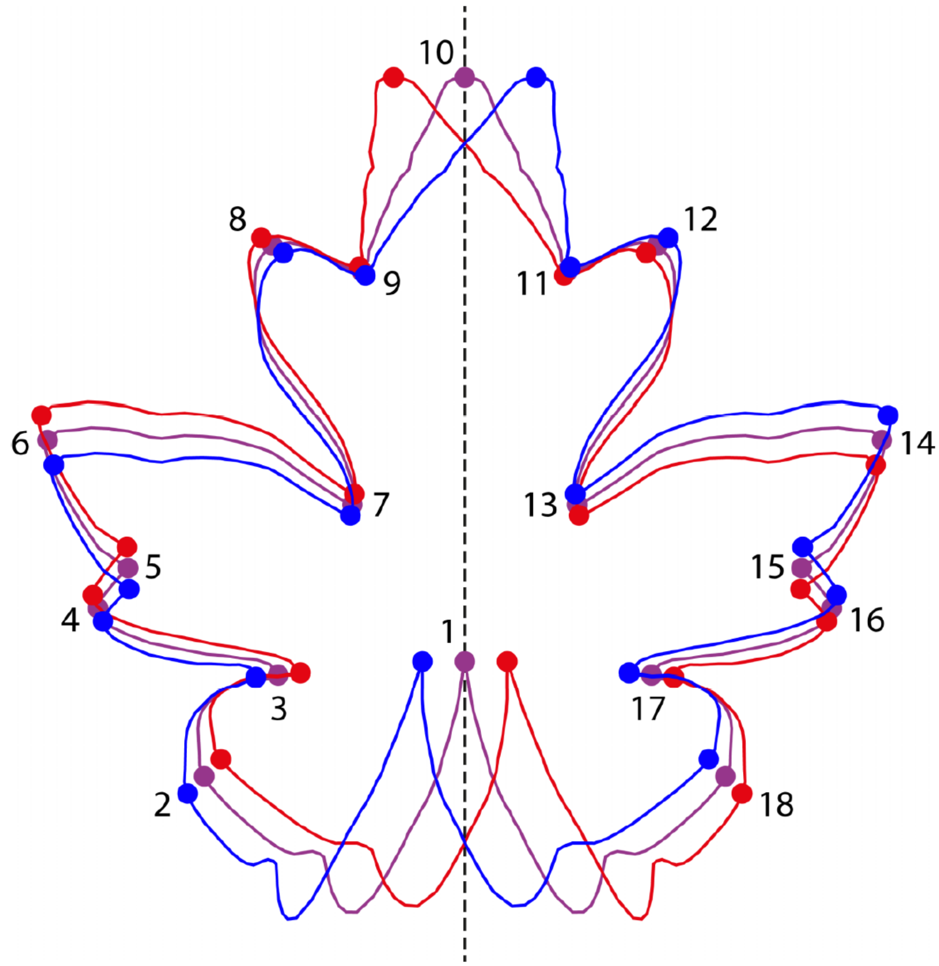

Figure 3. Depiction of a Procrustes superimposition (fit) process for a structure with object symmetry. 18 landmarks of the leaf are indicated, along with the raw point configuration (blue) and reflected and relabeled configuration (red). The symmetrical average shape of the two is depicted in purple. Taken from Klingenberg 2015 and used with author permission.

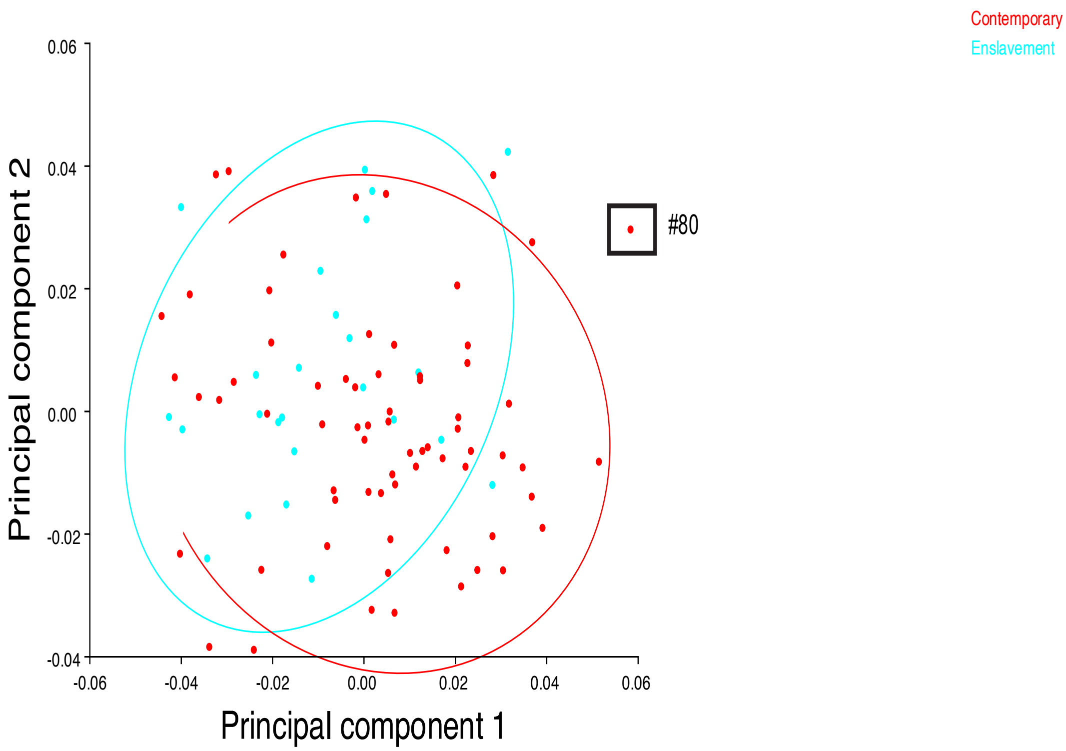

Figure 4. Principal component analysis with potential outlier (#80) indicated.

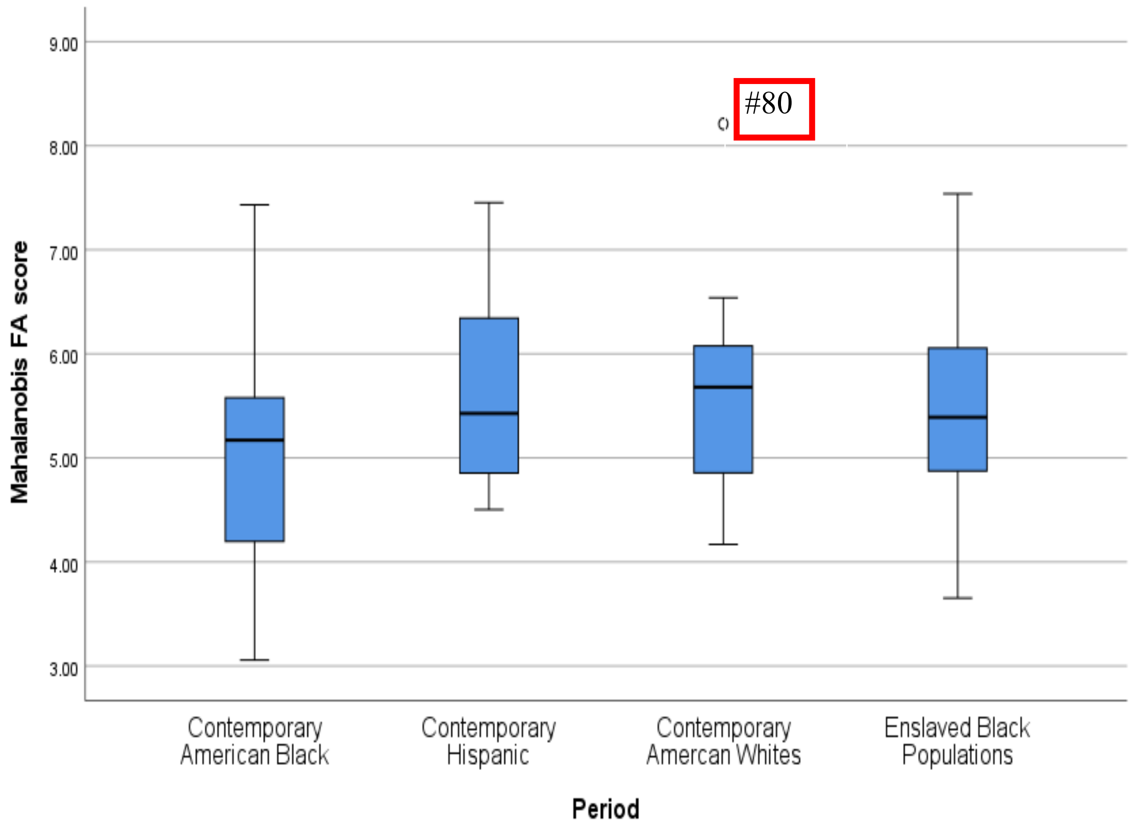

Figure 5. Boxplot that displays potential outlier in Mahalanobis FFA scores by period. The outlier is indicated by the squared-off circle.

To address the research aims of comparing the degree of FFA between the delineated historical periods and addressing the differences between mean ages at death and by sex within selected periods, analysis of variance (ANOVA) was performed using the SPSS program (IBM Corp 2017). The Mahalanobis FFA scores along with the demographic data were used for these analyses. The primary ANOVA was performed based on the period (enslavement and contemporary) and secondary analyses were conducted based on variables of sex and age at death.

III. RESULTS

Potential Outlier: Individual 80

The influence of a potential outlier, Individual #80, was assessed by completing ANOVA tests with and without the donor's FFA score. Most of the tests produced significant results and therefore it was determined that Individual #80 could remain in the analysis on the basis that their cranium was not significantly larger than the standard variation seen within the contemporary American White group. One statistically significant ANOVA was produced without the data of Individual #80 and is highlighted in Table 18.

FFA Score Comparison by Period

The descriptive statistics for the period groups by Mahalanobis FFA scores can be viewed in Table 6. A one-way ANOVA, in the form of a Univariate analysis, was performed with the dependent variable of the FFA scores by the independent variable of select period groups. It was determined that no significant difference existed between all period groups (Enslaved Black Populations, Contemporary American Blacks, Contemporary American Whites, and Contemporary Hispanics) by their Mahalanobis FFA scores. The significant p-value of 0.135 is larger than the alpha value of 0.05 (Table 7). Separate ANOVAs were completed with only the Enslaved Black Populations scores and each of the other groups within the study (see Table 8-10). These separate tests were done to address the research questions of identifying observable trends between enslaved and contemporary African American populations and comparing stress profiles (from FFA scores) of historic Blacks to other contemporary groups, outside of Black Americans. These statistical tests did not produce any significant difference of FFA scores between the selected period groups. Groupings that were approaching or potentially trending towards significance were between enslaved Black populations and contemporary American Blacks, and enslaved Blacks and contemporary Hispanics.

Table 6. Descriptive statistics of Mahalanobis FFA scores by period (enslaved and contemporary).

Period	N	Mean	Std. Dev	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Contemporary American Blacks	26	4.9942	1.02476	.20097	4.5803	5.4082	3.06	7.43
Contemporary Hispanics	15	5.6409	.90156	.23278	5.1416	6.1401	4.50	7.45
Contemporary American Whites	28	5.5035	.90695	.17140	5.1519	5.8552	4.17	8.21
Enslaved Black Populations	25	5.4162	.99984	.19997	5.0035	5.8289	3.65	7.54
Total	94	5.3614	.97909	.10099	5.1608	5.5619	3.06	8.21

Table 7. Analysis of Variance test of Mahalanobis FFA scores by period of all individuals in the study.

Tests of Between-Subjects Effects					
Dependent Variable: Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5.317[a]	3	1.772	1.903	.135
Intercept	2569.161	1	2569.161	2758.120	.000
Period	5.317	3	1.772	1.903	.135
Error	83.834	90	.931		
Total	2791.111	94			
Corrected Total	89.151	93			
a. R Squared = .060 (Adjusted R Squared = .028)					

Table 8. Analysis of Variance test of Mahalanobis FFA scores by enslaved Black Populations and contemporary American Blacks.

Tests of Between-Subjects Effects					
Dependent Variable: enslaved Black populations and contemporary Blacks Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.269[a]	1	2.269	2.213	.143
Intercept	1381.287	1	1381.287	1347.046	.000
Period	2.269	1	2.269	2.213	.143
Error	50.246	49	1.025		
Total	1432.137	51			
Corrected Total	52.515	50			
a. R Squared = .043 (Adjusted R Squared = .024)					

Table 9. Analysis of Variance test of Mahalanobis FFA scores by enslaved Black populations and contemporary Hispanics.

Tests of Between-Subjects Effects					
Dependent Variable: enslaved Black populations and contemporary Hispanic Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.707[a]	1	.707	.754	.391
Intercept	1108.361	1	1108.361	1181.460	.000
Period	.707	1	.707	.754	.391
Error	34.711	37	.938		
Total	1222.475	39			
Corrected Total	35.418	38			
a. R Squared = .020 (Adjusted R Squared = -.007)					

Table 10. Analysis of Variance test of Mahalanobis FFA scores by enslaved Black populations and contemporary American Whites.

Tests of Between-Subjects Effects					
Dependent Variable: enslaved Black populations and contemporary American White Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.007[a]	1	.007	.007	.933
Intercept	1336.570	1	1336.570	1414.261	.000
Period	.007	1	.007	.007	.933
Error	40.638	43	.945		
Total	1431.646	45			
Corrected Total	40.645	44			
a. R Squared = .000 (Adjusted R Squared = -.023)					

FFA Score Comparison by Sex

The descriptive statistics of the Mahalanobis FFA by sex and period group can be viewed in Table 11. The univariate analysis within SPSS's Analysis function was used to generate both the descriptive statistics and one-way ANOVA of the independent variables of sex and period groups and the dependent variable of the Mahalanobis FFA scores (see Table 12). It was concluded that statistical differences of FFA scores did exist between the period groups and their corresponding sex. Sex observed within only select periods alone, however, produced significant differences in FFA scores between males and females in contemporary American whites without the outlier (see Tables 17 and 18). A lollipop graph displaying a visual of average shape variation for the sexes can be seen in figure 6. Those approaching or potentially trending towards significance were by sex between enslaved Black populations and Hispanics (Table 20). Period status also appeared to produce a significant p-value when analyzed with sex. To explore its possible significance further, a Scheffe Test was conducted, and it determined that there were no statistically significant differences present (Table 13). As detailed in the research aims, a comparison of the level of fluctuating asymmetry by sex within the selected observation period was completed (see Tables 14-18). A test between Enslaved Black populations and contemporary American Blacks sex was conducted as they are the prime comparative group in this research and differences in Mahalanobis scores were determined to be significant (see Tables 19 and 20). Lollipop graphs of each period's sex groups display the average shape and deviations (Figures 7 and 8). The differences in FFA scores by sex of other contemporary groups and Enslaved Black populations were also analyzed and did not determine a significant difference (Tables 20-21).

Table 11. Descriptive Statistics of Mahalanobis FFA Scores by sex and period (enslavement and contemporary).

Period	Sex	Mean	Std. Deviation	N
Contemporary American Blacks	F	4.2729	.77365	10
	M	5.4561	.94045	15
	Total	4.9828	1.04419	25
Contemporary Hispanics	F	5.9375	1.04309	8
	M	5.3019	.61308	7
	Total	5.6409	.90156	15
Contemporary American Whites	F	5.5782	1.11605	11
	M	5.4552	.77671	17
	Total	5.5035	.90695	28
Enslaved Black Populations	F	5.4664	.66440	4
	M	5.1665	.91975	6
	Total	5.2864	.80069	10
Total	F	5.2562	1.13856	33
	M	5.3931	.81200	45
	Total	5.3352	.95924	78

Table 12. Analysis of Variance test of Mahalanobis FFA scores by sex and period.

Tests of Between-Subjects Effects					
Dependent Variable: Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	15.548[a]	7	2.221	2.811	.012
Intercept	1816.035	1	1816.035	2298.671	.000
Period	7.335	3	2.445	3.095	.032
Sex	.016	1	.016	.020	.889
Period * Sex	9.685	3	3.228	4.086	.010
Error	55.303	70	.790		
Total	2291.079	78			
Corrected Total	70.850	77			
a. R Squared = .219 (Adjusted R Squared = .141)					

Table 13. Scheffe Test for period.

Multiple Comparisons						
Dependent Variable: Mahalanobis FFA score						
Scheffe						
					95% Confidence Interval	
(I) Period	(J) Period	Mean Diff (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Contemporary American Blacks	Contemporary Hispanics	-.6581	.29029	.172	-1.4897	.1735
	Contemporary American Whites	-.5208	.24458	.219	-1.2214	.1799
	Enslaved Black Populations	-.3036	.33257	.841	-1.2564	.6491
Contemporary Hispanics	Contemporary American Blacks	.6581	.29029	.172	-.1735	1.4897
	Contemporary American Whites	.1373	.28440	.972	-.6774	.9521
	Enslaved Black Populations	.3545	.36287	.812	-.6851	1.3940
Contemporary American Whites	Contemporary American Blacks	.5208	.24458	.219	-.1799	1.2214
	Contemporary Hispanics	-.1373	.28440	.972	-.9521	.6774
	Enslaved Black Populations	.2171	.32744	.932	-.7209	1.1552
Enslaved Black Populations	Contemporary American Blacks	.3036	.33257	.841	-.6491	1.2564
	Contemporary Hispanics	-.3545	.36287	.812	-1.3940	.6851
	Contemporary American Whites	-.2171	.32744	.932	-1.1552	.7209
Based on observed means. The error term is Mean Square(Error) = .790.						

Table 14. Analysis of variance test of Mahalanobis FFA scores by sex within enslaved Black populations.

Tests of Between-Subjects Effects					
Dependent Variable: enslaved Black populations Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.287[a]	1	.287	.349	.561
Intercept	534.808	1	534.808	652.029	.000
Sex	.287	1	.287	.349	.561
Error	17.225	21	.820		
Total	564.866	23			
Corrected Total	17.511	22			
a. R Squared = .016 (Adjusted R Squared = -.030)					

Table 15. Analysis of variance test of Mahalanobis FFA scores by sex within contemporary American Blacks.

Tests of Between-Subjects Effects					
Dependent Variable: contemporary American Black Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.342[a]	1	.342	.278	.610
Intercept	256.509	1	256.509	208.701	.000
Sex	.342	1	.342	.278	.610
Error	12.291	10	1.229		
Total	367.240	12			
Corrected Total	12.632	11			
a. R Squared = .027 (Adjusted R Squared = -.070)					

Table 16. Analysis of variance test of Mahalanobis FFA scores by sex within contemporary Hispanics.

Tests of Between-Subjects Effects					
Dependent Variable: contemporary Hispanic Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.174[a]	1	.174	.201	.661
Intercept	461.776	1	461.776	535.718	.000
Sex	.174	1	.174	.201	.661
Error	11.206	13	.862		
Total	488.672	15			
Corrected Total	11.379	14			
a. R Squared = .015 (Adjusted R Squared = -.060)					

Table 17. Analysis of variance test of Mahalanobis FFA scores by sex within contemporary American Whites.

Tests of Between-Subjects Effects					
Dependent Variable: contemporary White Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.650[a]	1	1.650	2.086	.161
Intercept	848.092	1	848.092	1072.508	.000
Sex	1.650	1	1.650	2.086	.161
Error	20.560	26	.791		
Total	870.301	28			
Corrected Total	22.209	27			
a. R Squared = .074 (Adjusted R Squared = .039)					

Table 18. Analysis of variance test of Mahalanobis FFA scores by sex within contemporary American Whites (without outlier)

Tests of Between-Subjects Effects					
Dependent Variable: contemporary White Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.421[a]	1	3.421	7.642	.011
Intercept	783.357	1	783.357	1750.243	.000
Sex	3.421	1	3.421	7.642	.011
Error	11.189	25	.448		
Total	802.887	27			
Corrected Total	14.610	26			
a. R Squared = .234 (Adjusted R Squared = .203)					

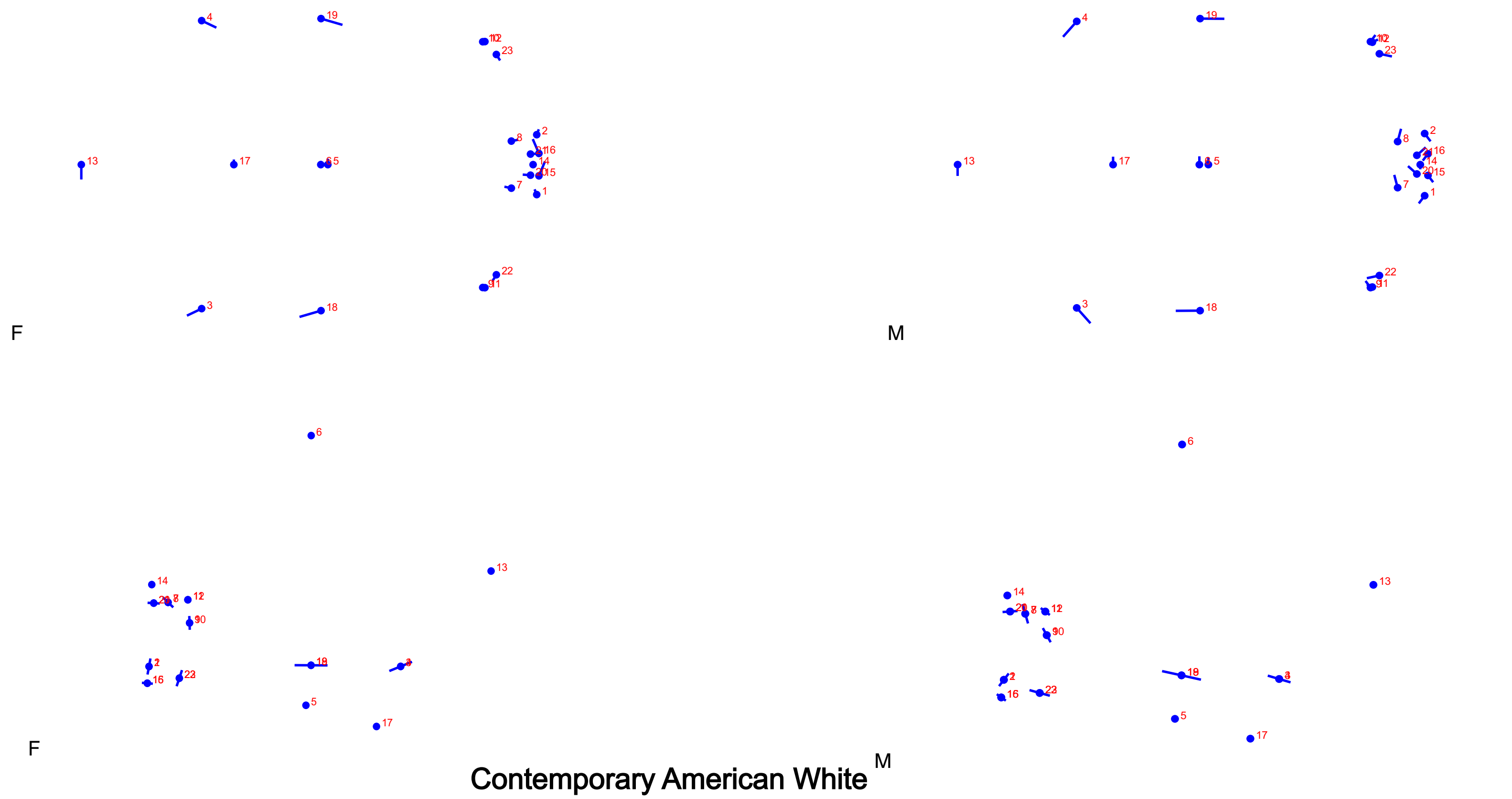

Figure 6. Lollipop graphs of average male (M) and female (F) shape within the contemporary American White group. The top image is the superior portion of the crania, and the bottom image is the left side profile of the crania. The blue dots are the centroids (average) of the landmarks and the lines are the deviations from the mean.

Table 19. Descriptive Statistics of Mahalanobis FFA Scores by sex and period (enslaved Black Populations and contemporary American Blacks).

Sex	Period	Mean	Std. Deviation	N
F	Contemporary American Blacks	4.27289829980	.773648178019	10
	Enslaved Blacks Populations	5.46637963925	.664396312568	4
	Total	4.61389296821	.910653131915	14
M	Contemporary American Blacks	5.45605117947	.940447462665	15
	Enslaved Blacks Populations	5.16645220000	.919753667397	6
	Total	5.37330861390	.921177141002	21
Total	Contemporary American Blacks	4.98279002760	1.044191632528	25
	Enslaved Blacks Populations	5.28642317570	.800686993155	10
	Total	5.06954235563	.979142586824	35

Table 20. Analysis of variance test of Mahalanobis FFA scores by sex and period (enslaved Black Populations and contemporary American Blacks).

Tests of Between-Subjects Effects					
Dependent Variable: enslaved Black populations and contemporary American Blacks Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9.274[a]	3	3.091	4.109	.015
Intercept	710.747	1	710.747	944.697	.000
Sex	1.337	1	1.337	1.777	.192
Period	1.401	1	1.401	1.862	.182
Sex * Period	3.771	1	3.771	5.012	.032
Error	23.323	31	.752		
Total	932.106	35			
Corrected Total	32.596	34			
a. R Squared = .284 (Adjusted R Squared = .215)					

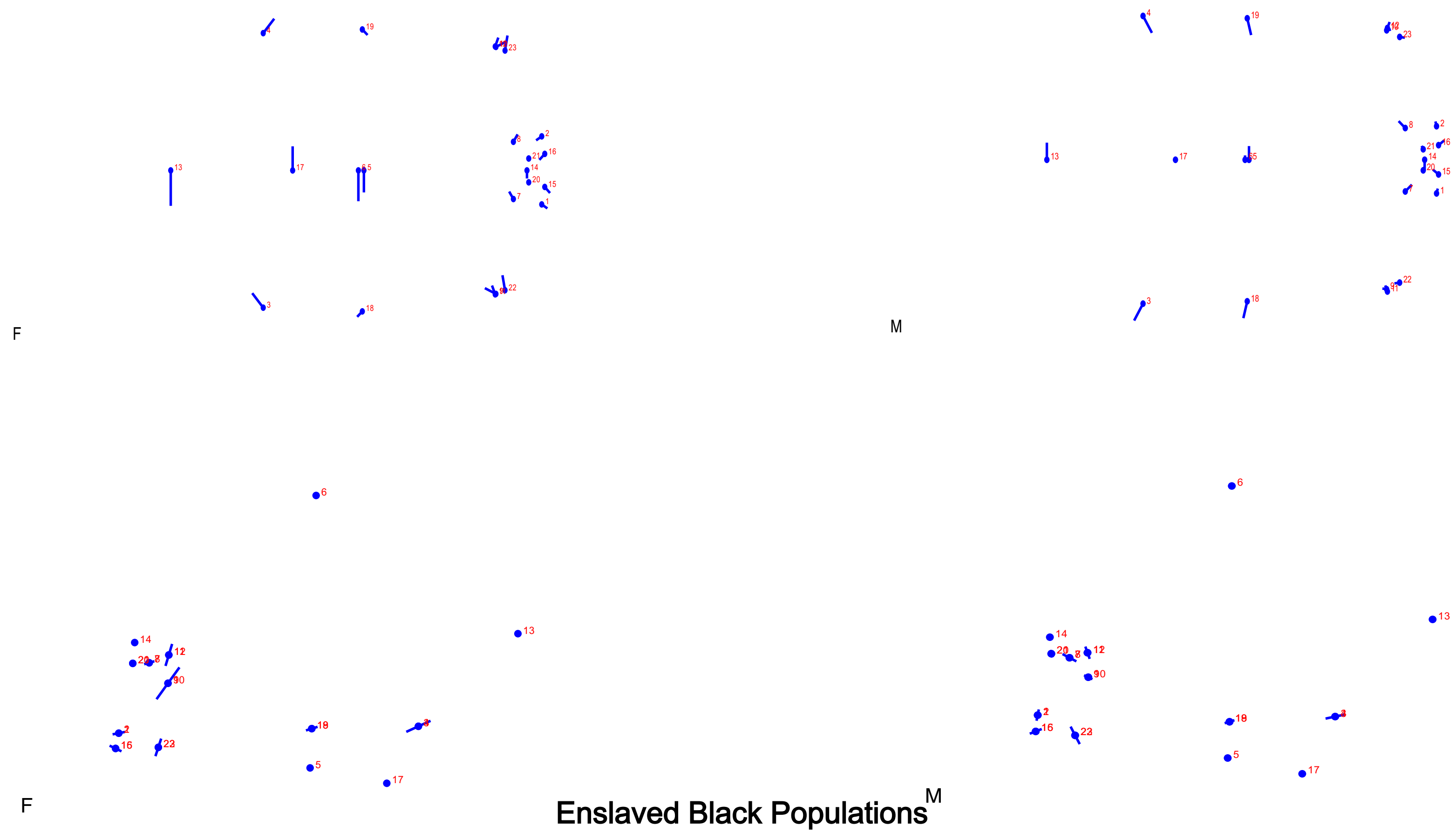

Figure 7. Lollipop graphs of average male (M) and female (F) shape within the enslaved Black populations. The top image is the superior portion of the crania, and the bottom image is the left facial side of the crania. The blue dots are the centroids (average) of the landmarks and the lines are the deviations from the mean.

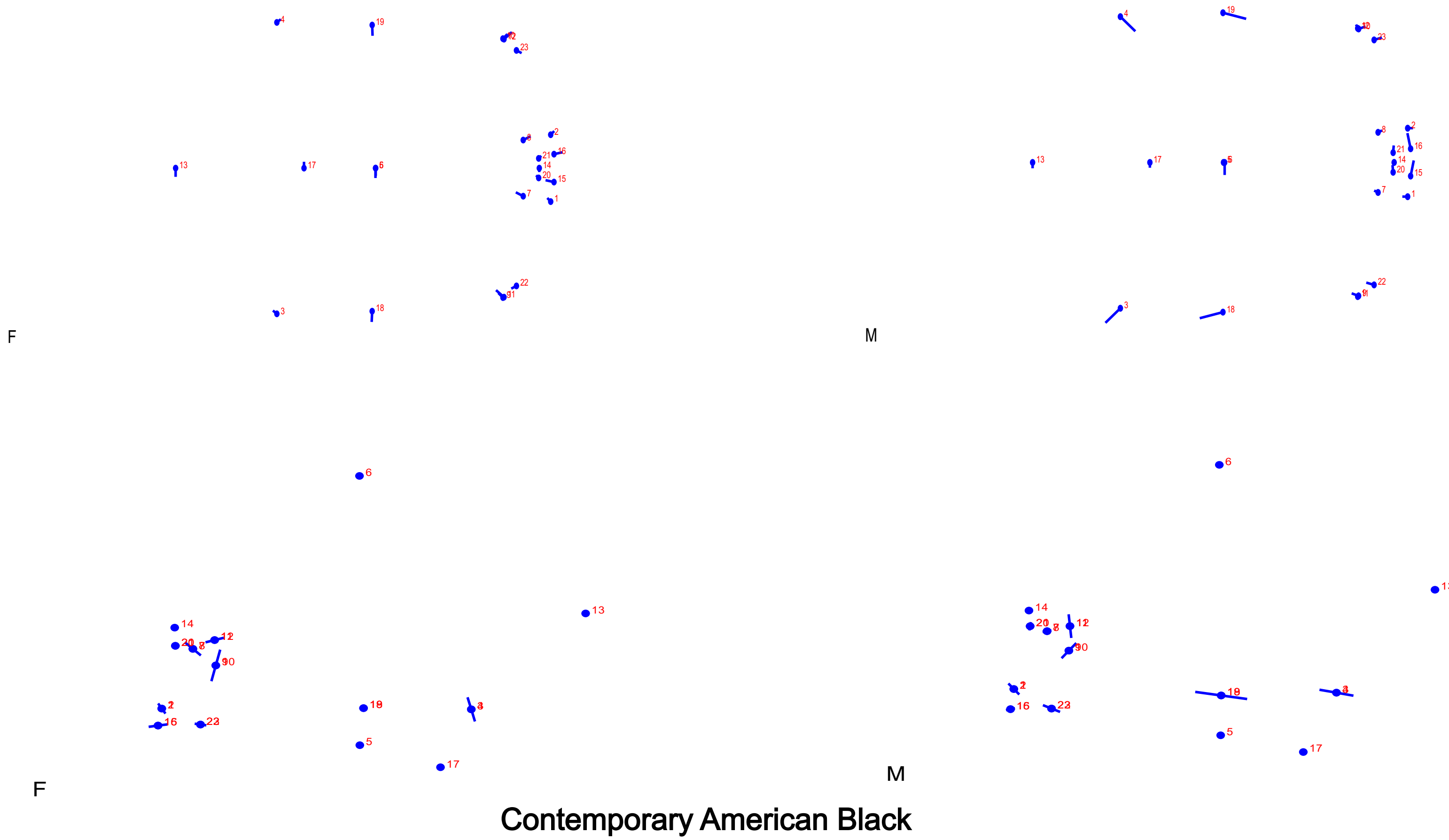

Figure 8. Lollipop graphs of average male (M) and female (F) shape within the contemporary American Black group. The top image is the superior portion of the crania, and the bottom image is the left facial side of the crania. The blue dots are the centroids (average) of the landmarks and the lines are the deviations from the mean.

Table 21. Analysis of variance test of Mahalanobis FFA scores by sex and period (enslaved Black populations and contemporary Hispanics).

Tests of Between-Subjects Effects					
Dependent Variable: enslaved Black Populations and Contemporary Hispanics Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.668[a]	3	.889	1.168	.347
Intercept	661.508	1	661.508	868.700	.000
SEXS	1.439	1	1.439	1.889	.185
Period	.658	1	.658	.864	.364
SEXS * Period	.090	1	.090	.119	.734
Error	15.230	20	.761		
Total	742.877	24			
Corrected Total	17.898	23			
a. R Squared = .149 (Adjusted R Squared = .021)					

Table 22. Analysis of variance test of Mahalanobis FFA scores by sex and period (enslaved Black Populations and contemporary American Whites).

Tests of Between-Subjects Effects					
Dependent Variable: enslaved Black populations and contemporary American Whites Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.844[a]	3	.281	.338	.798
Intercept	776.905	1	776.905	933.423	.000
Sex	.423	1	.423	.508	.481
Period	.386	1	.386	.464	.500
Sex * Period	.111	1	.111	.133	.718
Error	27.466	33	.832		
Total	1124.506	37			
Corrected Total	28.311	36			
a. R Squared = .030 (Adjusted R Squared = -.058)					

FFA Score Comparison by Age at Death

The one-way ANOVA and resulting descriptive statistics of age can be viewed in Tables 18 and 19. This analysis only included the contemporary groups (American Black, Hispanic, and American White) as they were the only individuals with available and accurate age assessments. Similar to the other analyses here, the dependent variable was the Mahalanobis FFA scores while the independent variables were age and period group. It was determined that significant differences of FFA scores between age groups and period groups do not exist. The p-value of 0.782 is higher than the alpha value of 0.05. The statistical test most approaching significance, however, was age at death as a singular variable between all contemporary groups (Table 24).

Table 23. Descriptive Statistics of Mahalanobis FFA Scores by age at death and period groups (contemporary only).

Period	Age at Death	Mean	Std. Deviation	N
Contemporary American Blacks	Early Adulthood	3.98128716800	.	1
	Middle Adulthood	5.57715492325	1.209467266200	8
	Late Adulthood	5.57859951200	.	1
	Total	5.41771260660	1.180030834426	10
Contemporary Hispanics	Early Adulthood	5.42740084300	.	1
	Middle Adulthood	6.12661597850	.846780006148	6
	Late Adulthood	5.30326321475	.880018029542	8
	Total	5.64088016213	.901557967595	15
Contemporary American Whites	Early Adulthood	4.92078551100	.647458551072	2
	Middle Adulthood	5.58495984435	1.025402148333	17
	Late Adulthood	5.38306878700	.803710215817	7
	Total	5.47951422635	.938010301446	26
Total	Early Adulthood	4.81256475825	.709852538952	4
	Middle Adulthood	5.68778234229	1.034104145542	31
	Late Adulthood	5.35538667119	.790512310637	16
	Total	5.51485683104	.962010474297	51

Table 24. Analysis of variance test of Mahalanobis FFA scores by age at death and period groups (contemporary only).

Tests of Between-Subjects Effects					
Dependent Variable: All contemporary groups Mahalanobis FFA Scores					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5.909[a]	8	.739	.769	.632
Intercept	556.727	1	556.727	579.292	.000
Period	.933	2	.467	.486	.619
Age at Death	3.349	2	1.674	1.742	.188
Period * Age at Death	1.673	4	.418	.435	.782
Error	40.364	42	.961		
Total	1597.369	51			
Corrected Total	46.273	50			
a. R Squared = .128 (Adjusted R Squared = -.038)					

FFA Score Comparison by Socioeconomic Status (SES)

All aspects of the Mahalanobis FFA scores organized by SES and period group are listed in the descriptive statistics detailed in Table 20. Only contemporary groups and their corresponding FFA scores were used. The one-way ANOVA of the FFA score dependent variable and the SES and period independent variables confirmed that there are no significant differences in scores between the two fixed variables. The p-value of .362 is higher than the designated alpha value of 0.05. This trend was also seen in the individual variables of SES and Period in this analysis. The statistical test most approaching significance, however, was SES and period together between all contemporary groups (Table 26).

Table 25. Descriptive Statistics of Mahalanobis FFA Scores by SES and period groups (contemporary only).

SES	Period	Mean	Std. Deviation	N
Lower	Contemporary American Blacks	5.0341	1.30716	4
	Contemporary Hispanics	5.7476	1.07562	7
	Contemporary American Whites	5.6258	.78838	10
	Total	5.5537	.97613	21
Middle	Contemporary American Blacks	5.7228	1.62530	3
	Contemporary Hispanics	5.7461	.94408	5
	Contemporary American Whites	5.3108	1.02363	15
	Total	5.4591	1.05461	23
Upper	Contemporary American Blacks	3.7505	.	1
	Contemporary Hispanics	5.4274	.	1
	Contemporary American Whites	6.2271	.39521	2
	Total	5.4080	1.18963	4
Total	Contemporary American Blacks	5.1319	1.38373	8
	Contemporary Hispanics	5.7224	.93991	13
	Contemporary American Whites	5.4953	.92345	27
	Total	5.4962	1.00956	48

Table 26. Analysis of variance test of Mahalanobis FFA scores by SES and period groups (contemporary only).

Tests of Between-Subjects Effects					
Dependent Variable: Mahalanobis FFA score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6.567[a]	8	.821	.775	.627
Intercept	657.188	1	657.188	620.053	.000
SES	.621	2	.311	.293	.748
Period	3.300	2	1.650	1.557	.224
SES * Period	4.737	4	1.184	1.117	.362
Error	41.336	39	1.060		
Total	1497.916	48			
Corrected Total	47.903	47			
a. R Squared = .137 (Adjusted R Squared = -.040)					

IV. DISCUSSION

The results of this study largely differ from previous fluctuating asymmetry research surrounding skeletal manifestations of environmental stress and inheritance, developmental instability, and other social factors (i.e., DeLeon 2007; Weisensee and Spradley 2018; Hope et. al. 2013; Özener and Fink 2010; Weisensee 2013). Variables of period, SES, and age at death did not generate any statistically significant differences of Mahalanobis scores when tested independently. The only FFA score differences that were determined as significant were the combination of independent variables sex and period and sex alone. Each of these variables will be discussed in the sub-sections below with hypothesized output and potential reasoning of test results. The role of this research in examining the state of Black health in America from the period of enslavement to the modern period, the current social and anthropological climate, and future research expansion will be explored as well.

Period Variable

Period status of either Enslavement or Contemporary was the primary exploratory variable of this study and paired with ancestral group (i.e., Black, Hispanic, and White) during analyses. Period was included in all ANOVA tests conducted and was determined as insignificant on its own as an independent variable. The variable was indicated as independently significant within the ANOVA of sex and period (Table 12), but with further analysis (Table 13), it was determined that the difference of the scores wasn't truly significant. All the analyses of period groups as a singular variable confirmed its lack of significance as a variable.

This research hypothesized that FFA scores between enslaved and contemporary Black populations would be within similar ranges and not contain any drastic difference. This was formed on the basis that the transition for Black individuals was from a historic environment of enslavement to a modern one of racially fueled marginalization with ongoing impacts on health and wellness. There was no significant difference of Mahalanobis FFA between enslaved Black populations and contemporary American Blacks, which supports the proposed hypothesis, but is made insignificant by the lack of significant differences also seen between enslaved Black populations and other contemporary populations (Hispanic and American White). This could be potentially explained by the geographical origins of the research sample. Separate research has found that migrant individuals and samples from consistent geographical locations show a higher level of FFA difference (Weisensee and Spradley 2018), which is not strongly represented here. The Jamestown sample could possibly include unadmixed African-born individuals to contrast with the American-born comparison groups, but the sample size is not large enough to be potentially represented in the data analysis. Additionally, the admixture of American populations and lessened secular change could have led to reduced variation and may account for differences viewed in contemporary FFA scores. A smaller enslaved population sample could also explain the reduced difference seen in the statistical tests.

Sex Variable

Sex assessment of Mahalanobis FFA score was an additional research aim for within and between period analyses. As an independent variable, sex only generated significant differences in Mahalanobis FFA scores within contemporary American White groups. Another statistical test that produced significant differences of scores was the fixed variables of sex and period groups.

It was hypothesized that males would exhibit significantly higher FFA scores than females due to the Female Buffering Hypothesis concept. It puts forth the notion that females experience lesser impacts of surrounding environmental factors due to the presence of social support mediation (Cohen and Wills 1985; Meehan et al 2014; Jimenez 2002). Previous fluctuating studies have also produced results of significant differences of FFA scores between males and females within their observed samples (Hope et. al. 2013; Özener and Fink 2010), which is seen within the contemporary American White populations here. Contemporary American Blacks showed differences in mean FFA scores, with males at the higher end, but they were not statistically significant. This was also observed in enslaved Black populations and Hispanics, with females having a slightly higher FFA score mean. The overall sample total of FFA scores of males was higher than females, but only in a minuscule manner (0.14 above).

The singular significance seen in sex as an independent variable within period groups can be either an indication that FFA does not adequately estimate stress between the sexes or that the samples used in this study are not large enough. The documented significant differences in sex observed in other studies may argue for the latter explanation. Additionally, only seeing a significant difference in American White males and females opens the discussion of potential developmental stress differences in sex between white populations and minority populations (American Black, Hispanic, etc.). There is likely a baseline difference between males and females for all groups (due to the complexities of environmental, cultural, and biological stressors on men versus women), but amongst minority men and women these differences aren't as apparent due to social and environmental stressors applied to both sexes. This baseline can be visualized in the contemporary American White lollipop graph (Figure 6), as the cranial vault and base of males contain more asymmetry and average deviations than females.

The significant differences of Mahalanobis FFA scores by period and sex present an interesting avenue for exploration. The environmental factors of the selected periods and societal positioning and experience of individuals in select groups could be an explanation of the significant differences of FFA scores. Different gender-based expectations and stress intake by each sex in a select period could also be an explanation of the observation. The lollipop graphs of enslaved and contemporary Blacks visually correspond to the ANOVAs, with enslaved females having more cranial vault and facial asymmetry than their male counterparts and contemporary Black males having more cranial vault and base asymmetry than corresponding females (Figures 7 and 8). These instances of asymmetry in the vault and facial area underscore the significant relation between early life craniofacial development and environmental and social stressors susceptibility.

Age at Death Variable

The observation of age at death groups between and within period analysis and their corresponding Mahalanobis FFA scores intended to address the research question of differential stress manifestations by age cohort. Due to their historic age, along with inconsistent preservation and a wide range of skeletal age estimations, age assessments were not usable for the enslaved Black populations. The contemporary groups were the only donors included in the age-FFA analyses. The age at death independent variable, when tested against the dependent variable of corresponding Mahalanobis FFA scores, did not generate any statistically significant differences.

It was hypothesized in this study that individuals of color would have higher FFA scores due to the structural discrimination and corresponding health effects (i.e., increased stress levels and the likelihood of metabolic diseases, lower SES occupation, higher epigenetic transcendence of stress, etc.) (Halloren 2019; David and Collins 1991; Sullivan 2013; Thayer and Kuzawa 2011). It was also hypothesized that younger individuals (early adulthood of 20-40 years) might show a general trend of higher scores given the pliability of the craniofacial region in early adulthood and considerations from the Developmental Origins of Health and Disease Hypothesis (DOHaD). DOHaD states that environmental events of childhood and pre-existing genetic dispositions play crucial roles in disease manifestation (Mandy and Nyirenda 2018; Agarwal 2016). Additionally, early adulthood contains a window into cranial vault and facial development manipulation. Changes can also still occur to the hard and soft tissue profiles of the face into advanced adulthood (Beasley n.d., Sharma et. al. 2014). The resulting analysis shows that the early adulthood cohort for nearly every contemporary group contains means in slightly lower values than the middle and late adulthood cohorts. Although insignificantly different, this rejects the suggested hypothesis and contrasts with the previous research discussed above.

The lack of significance in Mahalanobis FFA score difference regarding age at death cohorts and period groups could be a result of the smaller American Black (N=12) and Hispanic (N=12) contemporary groups compared to the American White group. Additionally, the number of individuals within the early adulthood cohort is extremely small (N=4). This is due to the over-representation of older adults within skeletal collections. The Texas State Donated Skeletal Collection (TXSTDSC) was used for the contemporary analysis and contains mostly older donors, with the average age being 66 years (Gocha et al. 2022). Additionally, the craniofacial region could also be an area that is not subjected to large amounts of asymmetry and manifestations of environmental stress.

Socioeconomic Status Variable

The assessment of a socioeconomic status (SES) variable and corresponding FFA scores is an additional analysis outside of the primary sex and age at death analysis. SES was evaluated because of its close ties to fluctuating asymmetry, disease manifestation, and transgenerational stress (Sullivan 2013; Medrano 2020; Weisensee and Spradley 2018). Only contemporary populations of American Blacks, Hispanics, and American Whites were used as this information was contained on their donor paperwork. Most of the donors were within SES groups of low and middle status, with only 4 donors falling into the upper-class cohort. Overall, there were no statistically significant differences of scores found in SES as a singular independent variable or when it was paired with period.

It was hypothesized that individuals of lower SES would contain higher levels of FFA from the interrelated factors of stress, social standing, and corresponding skeletal manifestations. Although not used in this particular analysis, the contextual and bio-historical evidence of enslaved Black populations would suggest a lower SES range for Black individuals during this time. The research presented here contains data that contradicts this but it is likely due to the sample size and limited availability of SES information. Additionally, next of kin can complete demographic paperwork for donors and could be unfamiliar with either the individual’s childhood and adult SES, or have a different definition for the SES groups presented to them during the donation process.

The State of Black Health in America

The generation of this research started with a consideration of modern Black health in America and the potential skeletal manifestations or indicators of developmental instability that could follow. There is a substantial body of data that points to the marginalization of Black individuals throughout time, whether it be contextual like archaeological findings or empirical like biohistory-based inferences. The trends of decreased longevity, inequity in disease load, and increased morbidity and mortality are continuous from periods of enslavement into the modern era (Franklin and Wilson 2020; Thompson 2009). Currently, Black Americans are more likely to die at early ages of disease and are exposed at higher percentages to debilitating factors such as poverty, lack of affordable medical care, and home insecurity (CDC 2017). Although different historical periods, the constraints of social positioning during enslavement and into modern-day mirror one another in the structural and deliberate violence enacted against the Black community. Fluctuating asymmetry was essentially proposed here as a potential means of quantifying stress craniofacially, although the results of this research did not bear that out. It is completely possible that FFA is not a fully encompassing measure of biological weathering (especially amongst diverse populations or over longer time periods) or that the pervasive racism and marginalization continually faced by Black Americans is not observable craniofacially in the way biological anthropologists might expect it to be.

Future Considerations

Future expansion of this research has to take into account the restrictions of historic collections, the current status of historic and contemporary Black remains in skeletal collections, and potential constraints of FFA analysis. The lack of significance in Mahalanobis FFA scores between and within the selected observation periods can be largely attributed to the very small sample size of enslaved Black individuals. Only 25 of the 94 total sample size are characterized as belonging to a period/site during enslavement (the 1600s-1860s). The fragile nature and varied preservation of historic skeletal material can also limit the amount of data, in this case, 3-D craniometric data, collected. Missing or damaged skeletal elements of the face will alter the number of landmarks available and thus, shrink the comparative numbers of individuals used in the study. The constraints of contemporary data mostly pertain to additional variables like SES. Whether this information was collected varies from skeletal collection facility and is subject to various interpretations of donor SES during the paperwork process. The number of people of color in donated skeletal collections can also pose an issue for this research. Contemporary Black Americans from the TXSTDSC are the smallest sample size contained in the analysis, and these small numbers are characteristic of the status of minorities in donated skeletal collections across the United States.

Future research should aim to expand the enslaved Black population data and assess the resulting statistical tests to fully determine if craniofacial asymmetry is a proper measure of stress and developmental instability. This should be accomplished while respecting historic black remains housed within institutions and in conjunction with calls for repatriation of remains. As modeled in this research, the use of previously collected research and building off already published work can still reveal new data for populations of interest. The addition of more people of color within donated skeletal collections can also aid in the bolstering of the sample size and depth of resulting statistical tests. The original research goal of exploring post-enslavement populations should also be explored and could contain a broader historical and transitional narrative of Black health than what is presented here.

The current social and anthropological climate around the study of Black remains also puts this research and its future expansion into an interesting predicament. The Black Lives Matter Movement has ignited the discussion of Black remains within established academic and museum collections (and institutions) around the world (Williams and Ross 2021). Additionally, recent occurrences such as the unethical use of deceased children's remains from the Move bombing in Philadelphia, as well as calls for an African American Graves Protection and Repatriation Act have pushed this topic to the forefront of anthropological spaces and have strengthened the arguments for reformative change. Historic populations, such as the enslaved Black groups used in this research, deserve to be studied and learned more about, but never at the expense of continuing the pervasive structural violence and anatomization practices that landed these individuals into institutional collections (Watkins 2018; Williams and Ross 2021). This underscores the importance of building on previously collected work and datasets and utilizing resources that may already exist in the anthropological sphere. It also highlights the importance of Willed Body donation programs and the weight of informed donor consent.

V. Conclusions

This study aimed to address the structural and physical marginalization of Black individuals in America through an assessment of the craniofacial region. The study of fluctuating facial asymmetry has been utilized by several researchers for the method's potential ability to indicate stress and developmental instability in populations (see Weisensee 2013; Weisensee and Spradley 2018; DeLeon 2007; Hope et. al. 2013). Deviations of the left and right sides of the face are suggested to correspond to environmental stressors such as social positioning as well as other demographic aspects (i.e., sex, age, etc.). The skeletal manifestation of these developmental stressors either by the individual directly or indirectly through epigenetic inheritance was also considered in this work.

The historic occurrence of enslavement and continuing constraints around modern Black lives have been documented concerning population health (Kuzawa and Sweet 2009; Schuler 2005; Schuler 2011). Fluctuating facial asymmetry was utilized here as a potential means of quantifying inequality faced by enslaved Black and contemporary American Black populations, while also creating a visual baseline of their health alongside comparative contemporary groups (Hispanic and American White). Most of the statistical tests completed in this research determined that no significant differences of FFA scores exist between and within enslaved populations and contemporary populations, but there are trends towards significance in period status, age at death, and sex for select groups.

Differences by sex of enslaved Blacks and contemporary Blacks and within contemporary American Whites were the only significant analyses. This highlights a potential limitation of FFA regarding comparisons between multiple ancestral groups. Quinto-Sánchez et. al. 2015, in their examination of individuals across Latin America, found specific patterns of FFA ancestral groups correspond to different ancestry groups. Therefore, caution should be taken with inter-sample comparison, and could be a cause for the all-around lack of significance. It also highlights potential differences in stress and developmental instability of females and males between American White population groups and minority groups.

Several additional reasons can be expanded upon for the lack of expected differences seen amongst the FFA scores. The small number of enslaved individuals compared to the contemporary sample could lead to decreased representation in the analysis, and thus produce a determination of insignificance when it may not be entirely accurate. The smaller sample size also presents a potential issue with the age at death and SES analyses, as some cohorts (i.e., early adulthood and upper SES) contain very few individuals. Secondly, the preservation and fragility of historic population samples could play a role in the statistical results through limitations placed on data collection. Missing or damaged skeletal material from enslaved individuals could eliminate potential asymmetry observed. Additionally, geographical locations and population admixtures overtime of the contemporary samples could also possibly explain the consistency of all period groups' FFA score ranges. Studies that have had success with FFA as an indicator contain much larger sample sizes within similar populations (e.g., Weisensee and Spradley 2018; Hope et. al. 2013; Quinto-Sánchez et. al. 2015). Lastly, inconsistency in collected demographic variables such as SES amongst willed body donation programs can lead to discrepancies in analysis or missed interpretative opportunities in this type of research.

The lack of FFA differences in this study underscores that the embodied experience of inequality isn't necessarily contained in an empirically identifiable way that scholars might expect, or one that fits the methods we currently use to examine differences in social positioning and how it correlates to craniofacial morphology. Increased exploration into the mechanisms and measures of developmental stress, and how it manifests on the skeleton, can aid in answering these questions.

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