

A STUDY OF GROWTH AND RESILIENCE AMONG HISTORIC AFRICAN  
AMERICAN POPULATIONS AT THE TURN OF  
THE TWENTIETH CENTURY

by

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## **DEDICATION**

To Mom, Dad, Gary, and Scott. Your bird is one step closer to his dream.

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## **ABSTRACT**

A child's growth rate is perhaps the best means to gauge a population's health and nutritional status. The growth and development of human populations is a direct result of genetic and non-genetic factors acting in conjunction to alter growth trajectories and developmental timing. The purpose of this study is to address the non-genetic factors of human growth and to examine the effect of structural violence in the form of environmental instability and economic disparity on human growth patterns. To do so, this study examines the growth rates of historical African American subadults from Freedman's Cemetery in Dallas, Texas, Cedar Grove Cemetery in Cedar Grove, Arkansas, and a series of two cemeteries in Chatham County, Georgia, for evidence of growth stunting compared to modern population standards. This thesis addresses the historical circumstance of these populations in relation to its biological consequence on growth and discusses these results in light of literature within structural violence, developmental health, and resilience theory. Results indicate populations of historic African Americans at the turn of the 20<sup>th</sup> Century underwent episodes of stunting early in life, followed by a stabilization of growth shortly after the weaning period, and catch-up growth that leads to adolescent and terminal adult stature similar to modern comparative populations. Given the immense burden of racism, structural violence, and demographic change, it is surprising that these populations of historic African Americans do not show increased levels of stunting throughout the growth period. These results corroborate

recent literature in human biology, economics, and skeletal biology, and expound the need for continued research into the disentanglement of the genetic, cultural, and environmental components of human growth.

## 1. INTRODUCTION

To summarize Eveleth and Tanner (1991), a child's growth rate is perhaps the best means to gauge a population's health and nutritional status. The growth and development of human populations is a direct result of genetic and non-genetic factors acting in conjunction to alter growth trajectories and developmental timing. As a result, multi-disciplinary research has led to numerous publications addressing both the genetic and non-genetic factors that may influence human growth (for review see, Bogin, 1988; Eveleth and Tanner, 1991; Hoppa and Fitzgerald, 1999). This history has led to a variety of growth studies utilized in human biology, bioarchaeology, and paleopathology, including a comparison of linear measurements of long bones as a product of age-related skeletal change and growth (e.g. Y'Edynak, 1976), growth stunting as a tool in the paleopathological assessment of health (e.g. Jantz and Owsley, 1984), subadult growth (e.g. Schillaci et al., 2011, 2012), appositional bone growth (e.g. Armelagos et al., 1972), vertebral growth (e.g. Clark et al., 1986; Watts, 2011, 2013, 2015), dental development (e.g. Seselj, 2013), and craniofacial growth (e.g. Williams and Cofran, 2016).

The current investigation utilizes an examination of femoral, statural, and relative adult growth from three temporally, geographically, and culturally analogous historic African American<sup>1</sup> cemetery samples to demonstrate the means in which the human skeleton, vis a vis skeletal growth, responds to shifting environmental landscapes. The cemetery assemblages of Cedar Grove, Arkansas (1881-1927), Freedman's Cemetery, Dallas, Texas (1869-1907), and Chatham County, Georgia (1870-1916) each represent populations developing during an unstable period in American history – a period in

<sup>1</sup> The definition of communities characterized as *African American* is often varied and historically, contextually, and individually contingent (see Mukhopadhyay and Moses, 1997; Harrison, 1998). While this thesis recognizes the broad experiences of individuals who define themselves as African American (or similar), the strict definition in this study is that of populations whose ancestors were enslaved within the United States.

which demographic and epidemiologic transitions emerge in tandem with racial animosity to define volatile growth environments that may be skeletally imprinted in the form of stunted femoral and/or statural growth. Combined with traditional paleopathological techniques and robust ethnographic research, bioarchaeological studies of growth-related patterns seek to tease out inter-population variation in childhood growth and development as a result of dynamic environmental, social, economic, and genetic influences that may lead to inadequate nutrition, growth stunting, and long-term health outcomes.

### **1.1 Research Framework**

Modern humans are unique among primates in having a particularly slow life history trajectory extending from prenatal development up through adulthood. This trajectory includes variable growth velocities and certain developmental milestones such as the eruption of deciduous and permanent dentition (Bogin, 2001). An abundance of studies show that a range of genetic and environmental factors result in population-level differences in bone size, morphology, and growth trajectory (Jantz and Owsley, 1984; Bogin, 2001; Larsen 1999; Lovejoy et al., 1990; McDade et al 2008; Pomeroy et al. 2012; Y'Ednak, 1976; Clark et al, 1986; Czerwinski et al., 2007; for review see, Bogin, 1988; Eveleth and Tanner, 1991; Hoppa and Fitzgerald, 1999). Genetic studies of skeletal growth demonstrate significant genetic control over skeletal measurements, with some studies suggesting a heritability ( $h^2$ ) of 60-80 percent (Duren et al., 2013; Bernstein and Dufour, 2017). However, numerous environmental factors (nutrition, disease, stress, socioeconomic status, and intergenerational factors) aid in the achievement of full growth potential, or may alternatively lead to growth stunting in affected populations (King and

Ulijazek, 1999). Moreover, epigenetic programming may transmit the aforementioned factors to future offspring (Bernstein and Dufour, 2017). Variability during the period of growth and development represents an interplay between biology and the environment, and reflects the human body's plastic response to environmental constraints. Therefore, the study of skeletal samples representing the period of growth and development (fetal life up through adolescence) embodies both indicators of environmental quality and the overall health of a population.

The importance of these subadult and infant remains within the bioarchaeology of growth and development has long been under intense scrutiny (Lewis, 2007; Lewis, 2017). Most research suggests that for much of human history, infant mortality remained relatively high until the most recent demographic transition (Saunders and Barrans, 1999; Zuckerman, 2014). However, global populations experienced this transition at separate intervals based on socioeconomic status, ancestry, gender, geography, job status, etc. (de la Cova, 2014). With a relatively longer childhood, human infants are born dependent on others for even the most essential nutrients. Growth velocities and resulting nutrient-load are at their highest during the first three years of childhood (Johnston et al., 1978; Beaton 1992). Thus, any fluctuation in nutrient-intake or any possible infection may result in growth stunting as the body allocates its resources away from skeletal growth to more vital functions such as immune response (Schillaci et al., 2011).

The importance of the study of growth and development cannot be overstated. While genetic adaptation underlies the growth potential of human populations, the environment plays a crucial role in determining exact growth trajectories and physiological health. With that said, it is therefore necessary to analyze the skeleton's

response to environmental perturbations that may lead to specific physiological responses that affect proximate and adult health (Mohamed, Pettifor, Norris; 2017). Moreover, populations in transition are of intrigue in studies of growth and development and bioarchaeology due to the malleability of the human skeleton in the face of shifting demographic, epidemiologic, and nutritional landscapes (Reitsma et al., 2017; Malina et al., 2017).

## **1.2 Theoretical Framework**

Bogin (1999) defines *growth* as a “quantitative increase in size or mass” (p. 7). Growth is a progressive process resulting in measurable changes in variables such as skeletal length, stature, and body mass. *Development* characterizes the progression of these measurable changes through each stage of the human life cycle (Bogin, 2001).

Combined, these concepts are firmly grounded within the paradigm of *life course theory*. At the core, life course or life history theory is a multi-disciplinary suite of concepts that treats an individual as historically contingent on social and biological experiences that work in tandem to mediate human phenotypic variation (Agarwal, 2016). Human growth then represents the dynamic nature of the human body to adapt to biological and social cues throughout the life course – the human body is not static and cannot be defined on one event alone, but instead represents the sum of the entire developmental experience up through adulthood. Once again, expounding the importance of studying childhood when examining differences in growth, development, and the underlying genetic and non-genetic components that lead to the expressed phenotype (stature, long bone length, etc.). Additional hypotheses that may define the utility of life history theory on child growth include: 1) there is an energy trade-off between skeletal

growth and brain/neurological development, or 2) the period from conception to infancy while critical in defining growth environments, varies greatly between and within populations (Said-Mohamed et al., 2017). Regardless of the mechanism, there is an emphasis on developmental plasticity as a result of a reallocation of energy to buffer brain/neurological growth at the expense of skeletal growth. In populations subject to fluctuating growth environments such as those of historic African Americans, this reallocation may have consequences related to the achievement of genetic growth potential, adult health, and mortality.

Crucial to the study of growth and development within the paradigm of life course theory is the notion of *plasticity*. That is, the “ability of an organism to change its phenotype in response to changes in the environment” (Agarwal, 2016, p.132). Given that growth and that resulting quantitative traits are highly heritable, any deviation from the presumed “normal” growth curve in populations of similar genetic ancestry would therefore represent a plastic response to outside environmental factors that serve to mediate skeletal growth up or down. These responses are most apparent during childhood due to the delicate balance struck between a highly dependent, yet fast growing organism with an increased nutrient-load. Any fluctuation in nutrient-intake and/or outside perturbation during this period could lead to growth stunting, catch-up growth, or malformation of certain skeletal elements (McDade et al., 2008).

Studies of growth within bioarchaeology are often positioned within an evolutionary framework that places emphasis on the interaction between genetic growth potential and environmental constraints (see Fuentes, 2016 for critique). This assumption

is not unfounded, and volumes within the corpus of biological anthropology highlight the worldwide variability in human growth (see Eveleth and Tanner, 1991; Cameron and Bogin, 2012, Bogin, 1988). Moreover, the skeletal response to environmental perturbation is equally well-documented (see Goodman et al., 1988; Larsen, 2015). However, the use of such an evolutionary approach takes the reallocation of energy away from growth (described above) as evidence for a selective pressure working to increase biological fitness (Smith, 2013). That is, growth stunting and/or the skeletal response to delayed growth is ultimately an adaptive (or maladaptive)<sup>2</sup> endeavor. As a result, studies of developmental stress (growth stunting being an example) within bioarchaeology tend to rely on linear causal relationships that often demonstrate a certain stressor equating to a certain physiological response (e.g. linear enamel hypoplasia and decreased mortality, Armelagos et al., 2009; stunted growth and decreased mortality, Kemkes-Grottenthaler, 2005; and the relationship of successive stress events, Temple 2014).

While adaptation (*sensu stricto*) continues to be the lynchpin of bioarchaeology regarding the study of long-term skeletal change and/or modification as a result of the broad ecological niches in which human populations may and have flourished for millennia (see Chapter 7: Martin et al., 2013), long-term, causal, linear relationships like those described above may provide an incomplete picture of human health and response over small periods of time. In other words, skeletal response or plasticity that is the result of fluctuating environments throughout the growth period are better interpreted not through the lens of long-term adaptation, but instead through the human body's *resilient* ability to “absorb [environmental] disturbance and reorganize while undergoing change so as to maintain the same function and structure” (Walker et al., 2004). Thus, African

<sup>2</sup> Adaptation here refers to the neo-Darwinian approach that assumes evolutionary processes work to increase individual reproductive success and/or fitness via environmental constraint on the genotype (Glowacki and Wrangham, 2015; see Fuentes, 2016, for critique)

American growth is examined under the notion that the human body is plastic to the external world and any noted difference in skeletal growth while inherently grounded in an individual's ability to optimize survival and reproduction long-term, is the product of the transformative effects of human agency, cultural buffering, and proximate health as opposed to later adult health and/or variable genotypic manifestation.

Borrowing literature and definitions from studies within biogeography, human behavioral ecology, and systems theory, this thesis studies the *resilience* of African American growth in the face of tumultuous growth environments. Earlier attempts to mesh human behavioral ecology and biological anthropology grapple with concepts of resilience (albeit never overtly using the term *resilience*), yet their utility is lessened as a result of an inability to discriminate between adaptation and resilience in a biological system (see Thomas et al., 1979; Martin et al., 2013). By broadening the definition of Walker et al's., (2004) description of socioecological systems, this thesis argues that the human body is itself a complex system influenced by intrinsic and extrinsic factors acting toward homeostasis – normal body function. Therefore, resilience is defined as the ability of the system to function and transform despite disturbance, while adaptation is the capacity of actors within the system (either physiological or cultural) to influence resilience. Recent work by Reitsema and colleagues (2017) presents an example demonstrating the use of resilience in bioarchaeology, specifically as it relates to fluctuating dietary practices. This work furthers the study of resilience toward an analysis of developmental stress in past populations (Hoover and Hudson, 2016).

A final addition to the theoretical framework of this thesis is the integration of structural violence theory into a bioarchaeological study of growth. Here, structural

violence is defined as the work of “social structures that suppress agency and prevent individuals, groups, and societies from reaching their social, economic, and biological potential” (Galtung, 1969, quoted in Klaus, 2012, p.32). In other words, social inequality is the result of embedded social hierarchies that work in tandem to marginalize subordinate groups or populations in the form of health disparity, access to basic resources, differing labor practices, inability to climb the social ladder, etc. In terms of bioarchaeology, this is manifested in differential morbidity patterns between social classes (see Klaus, 2012; Larsen, 1997). Historic African American populations provide a unique lens to analyze the effect of structural violence because of their contested place within American society at the turn of the 20<sup>th</sup> Century<sup>3</sup>. Therefore, an analysis of skeletal growth as compared to contemporaneous European American<sup>4</sup> populations may reveal differences between two demographically and culturally distinct populations that may speak to the marginalization of one over another. Alternatively, perhaps the resilience displayed in femoral and statural growth may equally serve to demonstrate the plasticity of the human skeleton in the face of both visible environmental and hidden structural insults.

### **1.3 Research Goals**

The purpose of this study is to address differential patterns of human growth and to examine the effect of environmental instability and economic disparity on human

<sup>3</sup> The Plessy v. Ferguson Supreme Court decision (1896) upheld the “separate but equal” law of the land. Racial segregation combined with Jim Crow era laws led to the marginalization of African American communities up through the middle of the 20<sup>th</sup> Century. See Hoffer (2012), for review.

<sup>4</sup> Like the definition of African American above, European American is equally contingent on historical, contextual, and individual preference. While this thesis recognizes the varied cultural and ethnic histories of individuals considered White, Caucasian, and European/European American, in this case European American explicitly refers to individuals of western European descent who colonized the United States post-1492 and were the majority demographic at the turn of the 20<sup>th</sup> Century (see Harrison, 1998 for a discussion regarding Race and Anthropology).

growth patterns. To do so, this study will examine the growth rates of historic African American subadults from Freedman's Cemetery in Dallas, Texas, Cedar Grove Cemetery in Cedar Grove, Arkansas, and two historic cemeteries on the grounds of Hunter Air Force Base, Chatham County, Georgia, for evidence of growth stunting compared to modern samples. Combined, the growth data will lend to a discussion about the non-genetic factors influencing growth and the long-term implication of growth stunting and environmental instability on these populations. This study will examine three prevailing research questions:

1. How does historic African American childhood growth in terms of femoral length, estimated stature, and percentage of adult height achieved compare between each site?
2. What do growth parameters in conjunction with historical evidence suggest about historical African American populations in the South?
3. How does skeletal growth data lend to a discussion of developmental plasticity, resilience, and skeletal adaptation as a result of genetic, epigenetic, and environmental pressures?

#### **1.4 Purpose and Significance of Study**

The archaeology of historic African American communities throughout the Americas lends to a burgeoning field of study with a culmination of work in history, anthropology, sociology, and Africana studies. Bioarchaeological techniques lend significant insight into the complex interactions between these population groups and their social and physical world (Blakey, 2011). The approach taken within this thesis

aims to connect human growth, development, and resilience to factors outside of genetic control.

The cemetery assemblages under question in this study have been subject to extensive analyses with respect to archaeological, cultural, and other skeletal/dental parameters (Condon et al., 1998; Matternes et al., 2010; Rose, 1985; Davidson et al., 2002). While subadult growth in these studies is mentioned in conjunction with other markers related to childhood health, little to no research exists that explicitly analyzes the totality of the growth curve considering life history theory, developmental plasticity, and resilience. Moreover, recent theoretical turns in the field expound the need to reframe previous analyses in light of a broad evolutionary synthesis that encompasses the entanglement of the physiological and cultural world (Fuentes, 2016; Goodman and Leatherman, 1998; Klaus, 2012).

To that end, this thesis seeks to add to the corpus of literature established regarding historic African American populations at the turn of the 20<sup>th</sup> Century. It does this through an analysis of femoral and statural growth in relation to broader environmental constraints acting to mold and transform the human skeleton in three historic African American skeletal assemblages. This skeletal response is placed within a broader life history theory that delves into the plastic and resilient nature of the human body in the face of both invisible structural barriers and tangible environmental landscapes working in conjunction to mediate somatic skeletal growth. Altogether, the growth of past populations, while important in defining historical backgrounds, provides more evidence of human environmental adaptation and the length to which the social and biological world entangle both in the past and looking toward the present.

## 1.5 Outline

Over a century of research in biological anthropology has been dedicated to the study of growth in both living and deceased populations. This early work provides the foundation for this thesis. Chapter 2 presents a brief history of the study of growth within anthropology and provides a survey of the most relevant literature to the current project. This will include a more in-depth discussion about the interpretative errors of extending growth research to bioarchaeological specimens and examples of studies that tackle this issue head-on.

Chapter 3 discusses the more recent developments leading to a body of research that directly addresses the history of diasporic African populations and African American populations in both anthropology and more directly, bioarchaeology. This includes an in-depth look at each study site.

Chapter 4 describes the materials and methods employed in this thesis including protocols for determining sample size, comparative sample descriptions, and the limitations of each. Moreover, there will be a detailed description of the statistical methods utilized in order to account for the error in age estimation.

Chapter 5 will present the results of the statistical models described above. First, inter-site comparisons will be made based on the regression of femur length, estimated stature, and achieved adult height by age. These will be plotted against a modern dataset of “healthy” subadults for comparison. Next, a pooled sample of historic African American growth will be plotted against that of the modern comparative dataset in order to look at growth between two distinct time periods with varying genetic and/or

environmental constraints. A discussion of these findings and conclusions to be made regarding both growth and development in the past and implications for future research will occur in Chapter 7 and Chapter 8.

## 2. GROWTH AND DEVELOPMENT RESEARCH IN BIOLOGICAL ANTHROPOLOGY

### 2.1 Origins

Since its inception, the discipline of anthropology has dedicated immense study to the analysis of growth and development in modern humans and their ancestors. Franz Boas' seminal work on body form, plasticity, and the environment represents some of the earliest research on the effect of the environment on body size, form, and development (1912; cf. Sparks and Jantz 2002). Even still, the process of development fascinated scientists for centuries from Da Vinci's early anatomical works, Montebellard and Quetelet's longitudinal study of growth in children, and Bowditch's extensive look at growth in New England schoolchildren (Bogin, 1988). However, the work of D'Arcy Thompson in *On Growth and Form* (1917; 1942) signifies the most important early work on growth and development. It was Thompson who first demonstrated growth was a progressive change through time – with that, future scientists now had an avenue to form research questions that compare, model, and describe fluctuations in the human growth trajectory.

Thompson's work led to increased visibility and public support for longitudinal growth research. This culminated in the creation of the Committee on Child Development in 1923, the creation of the journals *Child Development* and *Growth*, and numerous long-term studies on childhood growth and development (Bogin, 1988). These studies include the longstanding Fels Longitudinal Study (Garn, 1955; Garn et al., 1967; Roche, 1992), the University of Iowa Child Welfare Station Study (Meredith, 1935), the Harvard Growth Study (Shuttleworth, 1937; Dearborn et al., 1938), the University of Colorado Child Research Council Study (Maresh, 1943; 1955; 1959; 1972), the Brush Foundation

Study at Case Western Reserve University (Todd, 1937; Simmons and Greulich. 1943), and the Berkley Growth Study (Jones and Bayley, 1941). The importance of these early studies cannot be overstated. Much of these studies provided foundational support for later worldwide endeavors (Tanner, 1962; INCAP, 1969). Researchers and medical professionals soon realized the immense variability in growth across the globe. More importantly, studies began to push Boas' work forward in analyzing the effect of poor growth environments on childhood health through time. This led to the large-scale distribution and usage of early growth curves to monitor a child's growth and by proxy, their health through time. The culmination of this work includes the National Center for Health Statistics' Growth Charts (NCHS, 1977; NHANES, 2000) and eventually, the World Health Organization's Multicenter Growth Reference Study (WHO & UNICEF, 2009).

## **2.2 Literature Defining the Stage of the Human Life Cycle**

With the study of growth and development in full swing, researchers throughout the subdisciplines took to characterizing the individual stages that define the trajectory of human development (Table 2.1).

### **Prenatal Life**

This period is defined with initial fertilization of the ovum and extending up through intrauterine life. This period is under intense scrutiny by medical professionals and human biologists alike. Prenatal growth literature focuses both on the fetal environment and the maternal-fetal nexus that may be crucial to later development. Several studies demonstrate the association between prenatal exposure to environmental

stressors and postnatal development. Some examples include early life predictors of increased body mass (Thurber et al. 2015), early life origins of health disparity (Thayer & Kuzawa, 2014; Gowland 2015; for a more in-depth description of the Developmental Origins of Health and Disease hypothesis, see below), and the prenatal origins of body size and morphology (Workman et al., 2016; Li et al., 2007).

Table 2.1. Stages in the human life cycle

Stage	Duration
<i>Prenatal Life</i>	
Fertilization	
First Trimester	fertilization to 12th week
Second Trimester	4th-6th lunar month
Third Trimester	7th lunar month to birth
<i>Birth</i>	
<i>Postnatal Life</i>	
Neonatal Period	birth-28 days
Infancy	second month to end of lactation, ~24 months
<i>Childhood</i>	
Early	deciduous dentition erupts, 2-6 years old
Middle	permanent dentition erupts, 7-10 years old
Late	immediately prior to puberty, 12-15 in girls and 13-16 in boys
Adolescence	the onset of puberty up until the start of adulthood
<i>Adulthood</i>	
Prime and transition	~20 years old to end of reproductive years
Old age and senescence	end of reproductive years to death
<i>Death</i>	

Adapted from Bogin (1988).

Recently, a significant amount of research is dedicated to the epigenetics of growth and development and provides a description of the hypothesized link between maternal prenatal nutrition, offspring, and the “nested” intergenerational life courses that

make up individual bodies (Gowland, 2015; Susser et al., 2012). The use of osseous tissue to study prenatal growth is limited due to the rarity in the availability and preservation of material. Regardless, the few studies that exist include the study of early dental development (Mahoney, 2015), prenatal bone growth (Fazekas and Kosa, 1978), and the effect of the intrauterine environment on bone morphology (Bonneau et al., 2011). Future research within biological anthropology will continue to address the crucial period during intrauterine development up through birth – such work is central to studying the general health of a population.

#### *Early Postnatal Life: Birth to Infancy*

Like the study of prenatal growth, the period immediately following birth up through early childhood remains under intense scrutiny due to its importance in assessing adult and population-level health outcomes. Stated previously, the human infant is a dependent organism with immense nutrient need to sustain increased growth. Perhaps the best known early work studying infant growth is Barker's study demonstrating a connection between low-birth weight, childhood blood pressure, and adult cardiovascular disease in Great Britain (Barker and Osmond, 1986; Barker et al., 1989; Barker, 2012). Currently known as the Developmental Origins of Health and Disease hypothesis, studies drawing from Barker's initial work encompass any work demonstrating the connection between stunted childhood growth and development and chronic adult disease (Gluckman et al., 2010; Armelagos et al., 2009; Gowland, 2015). Such work has led to a call for increased attention on subadults within human biology, bioarchaeology, and even paleoanthropology (Saunders and Barrans, 1999; Zemel, 2017; Gowland, 2015; Frelat et al., 2017; Zollikofer and de Leon, 2010).

Regardless of the study, most agree that growth velocity is at its highest during this period. Some suggest that an infant adds nearly half its length and over 200% of its weight in the first year of life alone (Bogin, 1988). With slight variability worldwide, human growth during these early years is predictable across individuals and populations (Johnston, 1978). This predictability grants not only an ease at statistical model formation in both inter- and intra-population studies, but also means any disruption in this predictability can be studied and contextualized within environmental and genetic constraints.

### Childhood and Adolescence

Growth decelerates following the infancy period with the onset of the weaning period and the development of adult dentition. Additionally, there is a midgrowth spurt with a slight increase in velocity before adolescence. The biggest acceleration in velocity during this period occurs at the onset of adolescence. Trajectory milestones include increased hormonal activity, the development of secondary sexual characteristics, and increased sexual dimorphism in human growth parameters (height, weight, muscle mass, etc.). This is also a period in which much of the literature addresses catch-up growth. Stinson (2000) describes this as a period of faster growth that follows a period of disruption. Thus, skeletal maturation may lengthen and/or shorten depending on a certain constraint that impedes growth. For an individual to reach average adult height potential, a change must be made in the environment to allow for that “catch-up” to occur. Studies include an analysis of malnourished populations undergoing famine (Hirvonen, 2014), an examination of Aboriginal children in Australia (Floyd and Littleton, 2006), and the effect of fluctuating environments on disadvantaged populations in the United States

(Johnston and Macvean, 1995). Catch-up growth becomes a useful tool when analyzing the environmental constraints of growth in the past and present. Current initiatives in the developing world aim to minimize these constraints in order to promote both a healthy childhood and adulthood (WHO,2009).

### Adulthood

Adulthood begins with the completion of the adolescent growth spurt, cessation of skeletal growth, and attainment of adult stature. Most publications in growth and development research treat adulthood as an end stage – the achievable goal of normal childhood development. Yet, a large body of research addresses “stunted” adult growth as a sign of childhood growth disruption and in return, a sign of increased morbidity and mortality during adulthood and senescence (Gowland, 2015, Watts 2011; Cameron and Bogin, 2012). Although not addressed directly in this study, attained adult stature has become a proxy for childhood health and is utilized in many cases to infer developmental environments when juvenile specimens may be unavailable.

### **2.3 Secular Change in Growth and Development**

Outlined above, a plethora of studies exist describing growth and development throughout the life course. A key component of each of these is the diachronic influence of the environment on growth. Stinson (2000) describes this *secular change* as trends in growth in a positive or negative direction through time. These trends typically occur as a result of environmental constraints that work in conjunction with genetic disposition to improve and/or impede population-level somatic growth processes.

Secular change has a long history in the anthropological sciences. The pioneering work of Meredith (1963, 1976), Moore (1970), and Tanner (1962, 1968) gave way to Eveleth and Tanner's (1976) seminal work in growth and development – much of which explored examples of secular change and variation in growth across time and space. Eveleth et al. (1979) extended this work to an analysis of African American adolescence in Philadelphia. Here, the authors argued that the environment in Philadelphia improved over a span of two decades, leading to an increase in African American height and weight. Perhaps the best-known work in human biology studying secular trends comes from the innumerable publications put forth by R. M. Malina. While the list is endless, examples include secular change in height and weight in children from Brownsville, Texas (Malina et al., 1987), height and weight trends in Oaxaca, Mexico (Malina et al., 2004a; Malina et al., 2010; Malina et al., 2011), trends in muscle development in Oaxaca, Mexico (Malina et al., 2010), and trends in the age at menarche (Malina et al., 2004b). Studies by Malina and others all address the effect of long-term environmental trends on the somatic growth of the study populations through time. Often, these address broad topics such as globalization, capitalism, climate change, and the epidemiologic and demographic transition. While abstract, each concept may lead to real-world effects in individual communities that may serve to buffer and/or disrupt normal growth and development.

The theory and practice subsumed under studies of secular change in modern, living populations is equally applicable to skeletal populations in the past and present. Early examples include Trotter's analysis of stature and femoral diameter in American White and African American populations (Trotter and Gleser, 1951; Trotter et al., 1968).

A reappraisal of this study took place beginning in the 1990s (Meadows and Jantz, 1995; Meadows Jantz and Jantz 1999; Jantz et al., 2016) with all finding evidence of secular change on numerous elements of the body over the last two centuries. Other studies include an analysis of craniofacial secular change (Spradley et al., 2016; Godde, 2014; Weisensee and Jantz, 2011), change in bone size, morphology, and biomechanics (Cridlin, 2016; Wescott and Zephro, 2016; Boeyer and Ousley, 2017), and dental growth (Cardoso et al., 2010; Martin and Danforth, 2009). Above, each example represents modern population trends that are most applicable to the study of modern human variation and to methodology that aids in the identification of human remains in a medico-legal setting.

#### **2.4 Growth in Skeletal Populations and Related Issues**

Numerous studies within bioarchaeology utilize the concept of plasticity, constraint, and life course theory as an attempt to grapple with questions associated with developmental stress, diet, migration, and intergenerational effects on growth and development (e.g. Gowland, 2015; Agarwal, 2016; Mays et al., 2017, for review see Hoppa and Fitzgerald, 1999). However, Saunders and Hoppa (1993) describe several interpretative problems when analyzing somatic growth in the past. Konigsberg and Holman (1999) expound on these interpretative problems and lay out three fundamental issues: 1) in bioarchaeology, growth is studied cross-sectionally, not longitudinally, 2) mortality across age-cohorts and population-level aggregates may vary, and 3) ages at death are estimated rather than known. The issues of cross-sectionality and mortality bias on subadult age-at-death samples and growth data are subject to considerable attention throughout the literature (Wood et al., 1992; Saunders and Hoppa, 1993; Bogin, 1988). It

is intuitive to suggest that data derived from a single observation provides a less robust picture of an individual's life course. Moreover, it is equally intuitive to imagine that the samples under study – non-survivors – may be subject to intense bias in age estimation, sex estimation, true sample size vs. population size, preservation, etc. (Saunders and Hoppa, 1993; Wood et al., 1992). The unfortunate reality is that as bioarchaeologists, only the dead are left to study and therefore, researchers must design robust protocols that include unbiased age-estimation techniques, control over cultural context, and increased knowledge about the relationship between skeletal plasticity and environmental constraints.

While the two interpretative issues discussed in-depth above will ultimately be left up for critique later in this work, those related to age estimation must be dealt with up front. Simply put, several statistical issues exist when estimating the age of an unknown skeleton. These include age estimation techniques that lead to age mimicry in reference and target populations (Bocquet-Appel and Masset, 1982; Konigsberg and Frankenberg, 1992) and treating age as an exact measurement, as opposed to including the error that accompanies any statistical estimation (Konigsberg and Frankenberg, 1992; Konigsberg and Holman, 1999). Using the blunt description of Konigsberg and Holman (1999), “many of the reported significant differences in growth curves between archaeological samples probably are not actually significant” (p. 286). During an analysis of growth, the researcher would be remiss to not include an accurate representation of age because age-related change is the key component of growth and development, and life course theory in general. By not doing so, purported results are biased and may not represent the true picture of growth and the factors that intercede.

However, the method used to estimate the age distribution may also be problematic. Amongst subadults, dental development is generally considered the most accurate method of age estimation (Lewis and Gowland, 2007). This is because of the accuracy and reliability of eruption timing compared to the more plastic skeletal growth markers. Multiple methods have been quantified to determine the rate of crown and root growth and a resulting age estimate (Schour and Massler, 1940; Moorrees et al., 1963a, b; Demirjian et al., 1973, Konigsberg et al., 2016; see 2015 Age Estimation Symposium in *Annals of Human Biology*, Vol. 42, Issue 15). Although useful, many of these methods contain only graphical data with few to no numerical parameters to back up the results. Recent studies seek to correct this by generating parameters based on the previous graphical data and applying such methods in statistical software (Shackelford et al., 2012). However, these methods may not be useful for very young individuals. Perinate crowns are fragile and frequently lost leading to the creation of other age estimation techniques (Lewis and Gowland, 2007). The most common method to estimate perinate age-at-death is that of long bone diaphyseal lengths (Clement and Kosa, 1992). Although there is known error and bias, numerous regression-based and Bayesian techniques have been used to estimate age using long bone diaphyseal length (Fazekas and Kosa, 1978; Scheuer et al, 1980; Konigsberg and Frankenberg, 1994; Gowland and Chamberlain, 2002; Stull et al., 2014).

In addition to reporting an accurate representation of age, the researcher must also utilize unbiased methods to achieve an estimation and then use it appropriately in the presentation of data. Central to the issue of biased versus unbiased age estimation is the relationship between skeletal and dental growth. The relationship is a complex one, with

skeletal development lagging slightly behind dental development, as well as the more plastic nature of skeletal tissue versus that of dental tissue. Garn and colleagues were the first to explicitly study the relationship between somatic growth and dental development (Garn and Rohmann., 1959; Lewis and Garn, 1960; Garn et al., 1965). More recent studies of known age samples include Bowman et al. (1992), Saunders (2000), Cardoso (2007), and Seselj (2013). Each share a common theme, and each reaffirms the long-held belief that dental development is much less plastic to environmental insult – notwithstanding, that is not to say it is without error. Moreover, the use of skeletal age in a study examining the growth of said skeletal element is fraught with bias due to both the response variable (skeletal growth) and explanatory variable (age via skeletal growth) represented using the same parameter (Owsley and Jantz, 1985; Konigsberg and Holman, 1999; Merchant and Ubelaker, 1976).

Due to the bias introduced via similar parameterization and increased error in skeletal age estimation, dental development is the most accurate means to age an unidentified skeleton and model estimated growth. Dental age estimation can be broken up into two categories: dental development and dental emergence. Development refers to the overall growth trajectory of an individual tooth from initial bud formation to complete root closure. These methods are highly canalized and consistent throughout the life course. That is, each stage follows an order and little variability exists in the expression of each stage. However, population-specific differences may exist in the exact timing of events (Smith, 1992; Saunders, 2000; Liversidge, 2015). Examples of dental development techniques include Demirjian et al., (1973) and Moorrees et al., (1963a, b). Tooth

eruption or emergence is of equal importance to ageing subadults (Schour and Massler, 1944; Massler et al., 1941; Scheuer, et al., 2000; Ubelaker, 1989).

## **2.5 Synthesis**

The study of somatic growth in skeletal populations, while challenging, presents a unique avenue to analyze changes throughout the human life course in past populations. Using the framework of modern human biology, skeletal biologists are not only able to address questions associated with resilience, plasticity, stunting, and catch-up growth, but may also be well-equipped to better address long-term secular change and broad biological questions associated with the evolution of growth through time. The issues discussed above suggest that studies of growth using skeletal material must utilize unbiased age estimation techniques, appropriate statistical procedures to capture this estimation, and pointed research questions that demonstrate a grasp of the archaeological context. Is it possible to make meaningful comparisons of growth in the past with such error introduced? Are modern populations useful when analyzing the growth of past populations? The goal of this thesis is to answer these and other questions related to the utility of skeletal material in studying the growth and development of subadult individuals at Cedar Grove, Freedman's Cemetery, and Chatham County. With the addition of growth studies to an already bountiful skeletal and historical knowledgebase, further refinement can be undertaken to both understand past growth environments and the ability for the human body to respond, transform, and adapt to proximate and long-term insult.

### **3. THE BIOARCHEOLOGY OF AFRICAN AMERICAN POPULATIONS**

The archaeology of historic African American communities throughout the Americas lends to a burgeoning field of study with a culmination of work in history, anthropology, sociology, and Africana studies (see Blakey, 2001). With sites dating from the 18<sup>th</sup> to 20<sup>th</sup> Centuries, these studies include skeletal material from enslaved plantation laborers in the US and Caribbean (Corruccini et al. 1985; Rathbun, 1987), enslaved industrial iron-work laborers (Angel et al., 1987), enslaved urban populations in the South (Owsley et al., 1987, 1990), antebellum urban free Black African Americans in the North (Crist et al., 1997; Rankin-Hill, 1997; Blakey, 1998), reconstruction and post-reconstruction rural Black African Americans (Rose, 1985, Shogren et al., 1989, Dockall et al, 1996), and reconstruction and post-reconstruction urban Black African Americans (Beck, 1980; Blakey and Beck, 1982; Condon et al., 1998; Davidson, 1999; Hazel, 2000; Crist and Washburn, 2000; Tine, 2000; Peter et al., 2000; Davidson et al., 2002; Davidson, 2004; Wilson, 2005). Bioarchaeological techniques lend significant insight into the complex interactions between these population groups and their social and physical world.

#### **3.1 Historic African American Study Sites**

##### *Freedman's Cemetery, Dallas, Texas*

Freedman's Cemetery (41DL316) is a historic African American cemetery founded in 1869, adjacent to the community of Freedman's Town – a suburb north of greater Dallas composed of formerly enslaved individuals (Davidson et al, 2002). The cemetery saw continuous use as the primary burial ground for African American's within

all of Dallas until 1907. In fact, Freedman's was the only cemetery for any African American populations within Dallas until Woodland Cemetery opened in 1902. Because of such continuity and the limitations put forth on the remainder of the city, Freedman's supplies a rare glimpse into the life of the majority of Dallas' African American population – from the paupers and stillborn, to the more affluent elite (Davidson, 1999). Moreover, while many graves are unmarked, control of a narrow relative date range is possible due to extensive land records, diagnostic artifacts and mortuary remains, and exhaustive archival analysis.

By 1970, Dallas was the 2<sup>nd</sup> largest city in Texas with a population of over 200,000 individuals (Holmes and Saxon, 1992). While the earlier population at Freedman's most likely participated in the remnants of Dallas' agricultural industry post-Civil War, most individuals (particularly the middle-aged adults and younger), were well entrenched in Dallas' cash economy, and especially took part in physically demanding labor and domestic work (e.g. construction, early manufacturing, porter, cook, servant, etc.) (Davidson, 1999). With increased urbanization and population, African American enclaves within the city were subject to severe overcrowding, poor sanitation, and increased infectious disease as a result. Couple this with sustained racism and violence toward freed African Americans, and one would suspect to find a population increasingly stressed and stunted and in a word, unhealthy. Paradoxically, the promise of economic opportunity in a growing urban environment brought streams of individuals into the city where even today, descendants of these initial freed African Americans remain in communities throughout the city.

Due to the expansion of the North Central Expressway (U.S. Highway 75), intensive archaeological mitigation/excavation occurred between 1991 and 1994 (Condon et al, 1998; Davidson, 1999; Tine, 2000; Peter et al., 2000; Davidson et al., 2002; Davidson, 2004). Sponsored by the Texas Department of Transportation, excavation revealed approximately 25% of the cemetery with 1,157 individuals total. The current study focuses on subadult remains only (N = 486). Of this, only 65 skeletal remains are available for inclusion in this study (Table 4.1).

*Cedar Grove Cemetery, Cedar Grove, Arkansas*

Cedar Grove Cemetery (3LA97) is a rural, historic African American cemetery founded in 1881. The cemetery served the southwest Arkansas congregation of Cedar Grove Baptist Church until 1927 (Rose 1985). Cedar Grove represents a total contrast to life in urban Dallas. Here, agricultural production dominates the economic landscape with sharecropping and tenant farming the most prevalent means of income. While all freed, this way of life was not dissimilar to that of formerly enslaved individuals. This includes arduous labor in agricultural fields in often intense heat, with little relief during the cooler months where agricultural work is replaced with manual-labor dedicated to the upkeep of the industry and/or equipment. Moreover, there is even less access to public health facilities, sanitation, and upward mobility. This led to increased degenerative joint conditions, trauma, and chronic stress events (Davidson et al, 2002).

Under the authorization of the United States Army Corps of Engineers, Cedar Grove Cemetery was excavated due to the construction of a revetment along the Red River (Rose, 1985). Excavation revealed 36 adults and 44 sub-adults (Table 4.1). Of this, only 32 subadults are included in the study.

Hunter Army Airfield, Chatham County, Georgia

The skeletal remains from Hunter Army Airfield consist of two previously unrecognized cemeteries within the federal property on Hunter Army Airfield in Chatham County, Georgia. The remains are the remnants of the First Zion Baptist Church of Belmont (Area 1, 9CH1168, 1877-1932) and an unmarked burial ground located within close proximity (Area 2, 9CH875). Hunter Army Airfield is located just outside of Savannah, Georgia. Both cemeteries contain the remains of post-Emancipation African American remains dating from the late 19<sup>th</sup> to early 20<sup>th</sup> Century. Historical evidence suggests Area 1 is linked to the First Zion Baptist Church of Belmont, which draws its roots to the former Belmont Plantation (Matternes et al., 2010). Contrast this with the unnamed Area 2 that is predicted to be more aligned with the City of Savannah proper, and may have served as an informal burial ground for the city's African American population.

The Civil War devastated the economy of Savannah with significant destruction of property and infrastructure followed by a complete restructuring of the economy. A shift occurred away from large-scale plantation farming to small-scale subsistence farming and a boom in the cattle, turpentine, and timber industries (Matternes et al., 2010). Moreover, land speculation became an increasing trend in the region from northern investors, and it was this sort of development that led to the tracts of land necessary for both cemeteries. Living conditions in Chatham County led to the spread of infectious disease in various portions of the city. This is due to Savannah being a major port city in the region and being exposed to numerous pathogens as a result of the global trade (Elliot and Harrington, 1994). Like the increased urbanization seen in Dallas,

African American populations in Savannah were exposed to overcrowding, poor sanitation, and lack of a steady food supply. Nevertheless, freed African Americans in Savannah endured through systemic racism with the development of strong social institutions that persist today.

While there is no evidence to suggest Area 1 or Area 2 are related in population or structure, the sites are combined in this analysis (Table 4.1). This is due to similar ancestral affinity, contemporaneous mortuary assemblages, and geographic proximity that suggests at the very least, they shared resources within greater Savannah. Moreover, sites were combined to increase sample size for statistical procedures. At minimum, Area 1 and Area 2 represent two distinct groups of African Americans attempting to navigate the urbanization of Savannah. Excavation of both sites revealed 388 individuals, with only 42 subadults available for study.

### **3.2 Post-Bellum Environmental Instability**

The health of historic African American communities differed significantly pre- and post-Civil War. Prior to the abolition of slavery, African American health depended on the labor demanded by the slave owner. This is due to the reliance of slave owners on enslaved African American labor in a cash-crop economy. Nutritional resources and access to medical care were provided only as a means to increase labor production. Fogel and Engerman (1974) posit that post-bellum Southern African Americans underwent a 10 percent decrease in life expectancy and a 20 percent increase in illness by the turn of the 20<sup>th</sup> Century. This is simply due to the unpredictable nature of African American environments post-Reconstruction, as they sought to navigate a country still grappling with how to integrate these populations into the larger populace. Mortality and fertility

rates began to shift toward the end of the 19<sup>th</sup> Century. At that point, there is an overall increase in the African American population and a decrease in their fertility rate throughout the South (Davidson et al, 2002). Rose (1985) supports this argument and documents a significant decrease in fertility amongst African American women between 1880 and 1920. Reasons for this decrease could include venereal disease (Rose, 1985) and nutritional deficiency as a result of poor diet and sanitation (Kiple and King, 1981; Rose, 1989). Moreover, historic African American populations are especially vulnerable to physiological stress and growth disruption due to forced segregation, immense inequality, and unequal access to basic resources and healthcare (Blakey, 2001; Gravlee, 2009).

Bioarchaeological analyses of vulnerable populations tend to focus attention on several areas including growth and stature studies, nutritional studies, and demographic studies with a focus on subadult mortality. Early studies suggest that West Africans were already malnourished as a result of hunger and famine (Curtin, 1983; 1986). Enslavement exacerbated an already vulnerable population leading to immense nutritional deficiency including rickets, pellagra, anemia, among other diseases of malnutrition (Blakey and Rankin-Hill, 2009). The abolition of slavery brought no relief to the squalid conditions for African Americans. The onset of sharecropping, Jim Crow, sustained racism, and resentment, led to continued malnutrition extending up through the start of the 20<sup>th</sup> Century (Rose, 1989). While many studies demonstrate increased nutritional deficiency and enamel growth disruption, there is no clear pattern of stunted skeletal growth as a result of such poor environments. Rankin-Hill's (1990) dissertation describes four generalities borne out in the growth literature of enslaved African Americans: 1)

malnutrition is greater among individuals in large-scale plantations versus smaller-scale operations and urban slaves, 2) in general, African American height is similar to contemporaneous European counterparts, 3) Caribbean slaves tended to be shorter than mainland Africans, African Americans, and Europeans, and 4) freed and enslaved African Americans showed comparable patterns of nutritional deficiency and adult height.

A few assumptions can be made then about growth and environmental influence on these populations. Regardless of status, health for African Americans is poor throughout the late 19<sup>th</sup> Century and early 20<sup>th</sup> Century (Davidson et al., 2002; Steckel and Rose, 2002). Moreover, studies continue to grapple with the paradox of poor developmental growth environments, yet similar attained height to more affluent populations (Rathbun and Steckel, 2002; Davidson et al., 2002; Goode-Null et al., 2009). Steckel (1986) posits that catch-up growth commenced following early childhood when young enslaved African Americans began working. Catch-up growth, differences between freed and enslaved populations, and height comparisons with modern reference groups of European and African American children will be explored later in this work.

### **3.3 The Rural Versus Urban Environment**

Central to the discussion of historic African American health and demographics is the noted difference between rural and urban populations. Research of enslaved communities suggests differences between pathological lesion type and frequency based on a rural versus urban setting (Kelly and Angel, 1987; Owsley et al, 1987; Rathbun, 1987). Steckel (2000) notes a 132 percent increase of urbanized African American communities between 1870 and 1910. The continued redistribution of African Americans

from rural to urban environments dates long before the advent of the Civil War and endures to the present, affecting the economic, political, and social history of these groups (Baharian et al., 2016). Davidson et al. (2002) explores the relationship between rural versus urban in two of the sites of study in this work. Regardless of the environment, the two populations are very similar in health status with only subtle differences in growth and types of diseases present. The current study seeks to extend this analysis to a more in-depth picture of childhood growth throughout the life course and how this compares across populations and through time. While the continued movement of these populations from rural to urban make it difficult to pinpoint specific environments responsible for growth disruption, this thesis assumes a similar milieu experienced by the majority of African Americans developing in a tumultuous United States that had yet to accept the changing demographic landscape.

### **3.4 Historic African American Dietary Practices**

With a relatively longer childhood, human infants are born dependent on others for even the most essential nutrients. Growth velocities and resulting nutrient-load are at their highest during the first three years of childhood (Johnston et al., 1978; Beaton 1992). Thus, any fluctuation in nutrient-intake or any possible infection may result in growth stunting as the body allocates its resources away from skeletal growth to more vital functions such as immune response (Schillaci et al., 2011). The energetic expense of growth, especially during infancy, requires a robust suite of nutrients and a balanced diet high in protein, carbohydrates, and essential amino acids (Leonard, 2000). For this reason, the dietary practices of historic African American populations are important when analyzing the skeletal growth of subadult individuals.

In general, dietary practices of historic African American populations varied between a rural and urban setting. Rural sharecroppers such as that in Cedar Grove, Arkansas, typically relied on meals of salted pork, corn bread, and syrup of sorghum (Levenstein, 1993). There is evidence of increased corn usage through time, while red meat, milk products, and most vegetables were rare in rural settings (Davidson et al., 2002; Dirks and Duran, 2001). This would have led to increased metabolic and/or nutritional disorders such as pellagra, scurvy, rickets, anemia (porotic hyperostosis and cribra orbitalia), and a greater prevalence of dental caries (Davidson et al., 2002). The nutritional instability in rural environments such as Cedar Grove is equally exacerbated by the seasonal fluctuation in climate between the winter and summer months.

Urban environments such as that in Dallas (Freedman's Cemetery) and Savannah (Chatham County samples) fared significantly better as compared to rural populations regarding health and dietary practices. The diet of the African American urban poor in Philadelphia suggests a much more varied diet with the inclusion of additional resources not typically seen in the urban setting. Salt pork is still a staple, yet other meats including fish and/or red meat are more readily available. Moreover, the urban diet consisted of varied grains (wheat, oat, corn), increased milk usage, more vegetables, and fruit. The diet in an urban environment was less subject to seasonal fluctuation as compared to rural environments. In general, urban populations had greater access to the varied nutrients necessary for growth. This is borne out in the skeletal data as well. Individuals at Freedman's Cemetery and in Chatham County, displayed fewer signs of linear enamel hypoplasia, dental caries, porotic hyperostosis/cribra orbitalia, and metabolic disorders, as compared to the rural communities. Regardless, dietary evidence would suggest rural

environments may be more subject to nutritional deficiency which in turn, should lead to greater growth stunting due to the lack of important nutrients during the critical infancy period.

### **3.5 Historic African American Health in Context**

A final portion of this chapter is a comparison to the European American populations who made up a sizable majority of the American demographic at the turn of the 20<sup>th</sup> Century. In general, health levels declined for all income and ancestral groups in the United States through the middle of the 19<sup>th</sup> Century. This is most likely the result of industrialization and urbanization (Steckel, 1995; Pope, 1992). With that said, improvement began in the latter half of the 19<sup>th</sup> Century and into the 20<sup>th</sup> Century as sanitation practices increased, food availability caught-up, and modern medical techniques began to be developed. Infant mortality is high, albeit not nearly as high as that described in African American populations (Saunders et al., 2002). Moreover, European American populations most likely experienced the demographic and epidemiologic transition earlier than African American populations (Steckel and Rose, 2002).

Increased urbanization saw similar diseases of crowding and infectious agents in all populations within a city. Although, prevalence among African Americans remained higher through time as compared to European Americans. Here it seems the urban environment had an overall negative affect on all populations (Saunders et al., 2002). Skeletal markers of stress such as linear enamel hypoplasia, cribra orbitalia/ porotic hyperostosis, dental caries, infectious disease, metabolic disorder, among others, all present in greater prevalence in African American populations as compared to European

American populations (Davidson et al., 2002). However, the few cursory growth analyses present among the study sites suggests that Freedman's Cemetery and Cedar Grove Cemetery children display similar growth velocities compared to a European Canadian population from Belleville, Ontario, Canada (Saunders et al., 2002). Moreover, adult stature at Freedman's Cemetery is taller than that at Monroe County Poorhouse (an impoverished European American assemblage from Rochester, New York), and similar to middle class Canadians at Belleville and United States military members from the time (Davidson et al., 2002). Surprisingly, adult height at Cedar Grove is taller as compared to all European American assemblages described above.

When compared within the broad discussion of structural violence from chapter one, African American populations should be marginalized as compared to European American populations. This is borne out in the differences in infectious disease prevalence, developmental stress prevalence, and differences in mortality throughout the life course. However, the similar patterns of growth and stature may suggest other mechanisms at work beyond the boundaries within a segregated society that may help to explain the growth patterns present. Alternatively, perhaps the urbanization and demographic transition at the onset of the 20<sup>th</sup> Century made growth environments poor for all populations regardless of ancestry – this hypothesis, among others, will be explored to help explain the patterns of growth present at Cedar Grove, Freedman's, and Chatham County cemeteries as they compare to historic and modern populations.

### 3.6 Synthesis

Previous literature in skeletal biology present several conclusions regarding the study of African American populations in the past. There is considerable evidence exposing high subadult mortality (Steckel, 1986), individuals lived physically strenuous lives in both rural and urban environments (Davidson et al., 2002), and these populations underwent significant malnutrition and disease events (Rathbun and Steckel, 2002). Compared to European American populations, African American health, diet, and lifestyle was subject to increased turmoil and stress in a segregated United States. However, the little data on growth and development from the study sites does suggest overall growth comparable to European American populations at the time. Therefore, this thesis seeks to capture historic African American subadult growth and development as products of complex genetic and environmental variables acting upon proximate and long-term health (Wood et al., 1992; Saunders and Hoppa, 1993; DeWitte and Stojanowski, 2015). Additionally, this will include explicit efforts to address error in age estimation of these individuals, and intense scrutiny of health and growth results at both the community level (site-level) and its relationship to the greater African American experience.

#### 4. MATERIALS AND METHODS

This study focuses on femoral, statural, and relative adult growth between birth and 18 years of age in a sample of historic African American children (1869-1927) from Texas, Arkansas, and Georgia (Table 4.1). For comparison, this study utilizes data from the University of Colorado Child Research Council [Denver Growth Study] (Maresh, 1955) and from the World Health Organization’s Multicenter Growth Reference Study (MGRS) (WHO, 2009).

Table 4.1. Sample information including site name, date of cemetery usage, and sample sizes by age grouping.

<b>Site Name</b>	Freedman’s Cemetery	Cedar Grove Cemetery	Hunter Army Airfield	Totals
<b>Site Number</b>	41DL316	3LA97	9CH1168; 9CH875 <sup>a</sup>	
<b>Location</b>	Dallas, Texas	Cedar Grove, Arkansas	Chatham County, Georgia	
<b>Date</b>	1869-1907	1881-1927	1870-1916	
<b>&lt;1 year</b>	32	14	8	54
<b>1-5</b>	12	8	21	41
<b>5-10</b>	9	5	11	25
<b>10-15</b>	5	5	1	11
<b>15&lt; years</b>	7	0	1	8
<b>Study Total (n)</b>	65	32	42	139
<b>Total</b>	486	44	198	
<b>Subadults at Site</b>				
<b>% Subadult Population Studied</b>	13.37%	72.73%	21.21%	

<sup>a</sup> Chatham County sample consists of two contemporaneous sites located within close proximity, see description in previous chapter.

## 4.1 Study Samples

Freedman's Cemetery (1869-1907), Cedar Grove Cemetery (1881-1927), and the two cemeteries within Hunter Army Airfield (1870-1916), are described in-depth in the previous chapter. Each site was chosen due to the availability of subadult skeletal remains within each sample, in addition to the previous studies undertaken to define the historical, cultural, and archaeological background of each site (Rose, 1985; Condon et al., 1998; Matternes et al., 2010). The inclusion of femoral and statural growth amongst subadult individuals within each site is an addition to the growing body of literature stemming from the previous analyses that addresses African American lifeways at the onset of the 20<sup>th</sup> Century. Table 4.1 displays the demographic information related to subadults at each site and how it compares to the individuals ultimately included within the present study. Figures 4.1-4.3 show the age distribution of the study samples. Note, there is an age bias within the samples as most individuals are under the age of three. This is most likely the result of increased infant mortality and/or fertility amongst historic African American populations (Davidson et al., 2002).

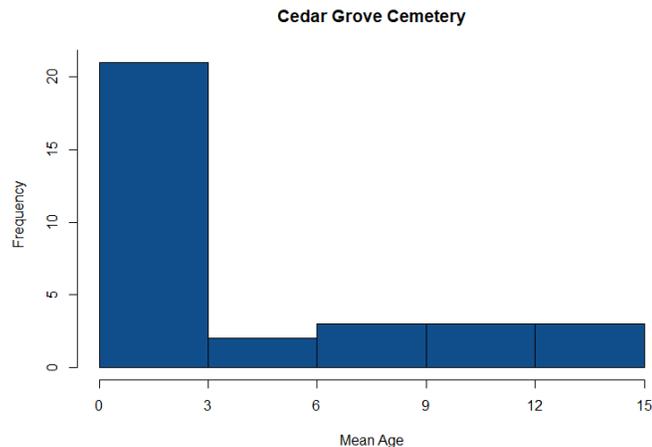


Figure 4.1. Subadult age distribution of Cedar Grove Cemetery.

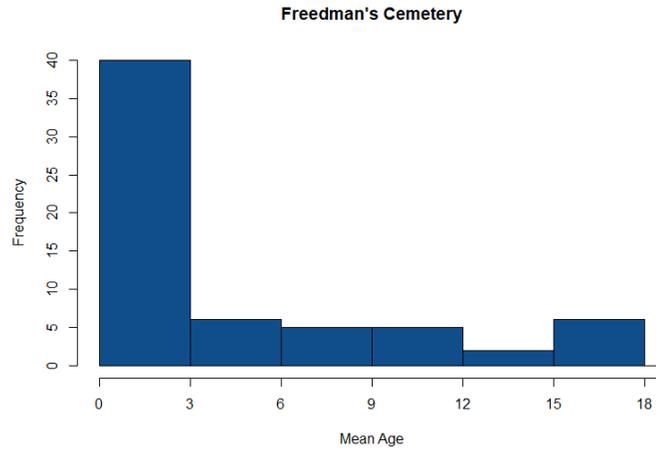


Figure 4.2. Subadult age distribution of Freedman's Cemetery.

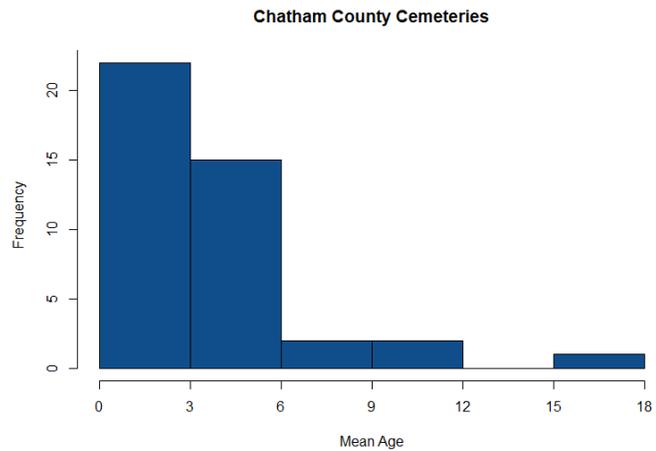


Figure 4.3. Subadult age distribution of Chatham County samples.

## 4.2 Comparative Samples

The growth analyses undertaken in this study are compared against two distinctive reference samples previously utilized in both skeletal and modern studies of childhood growth:

1. The University of Colorado Child Research Council reference sample is used because it represents the growth of healthy, well-nourished children immediately

following the end date of the study sites in this sample. That is, the Colorado reference is the closest analogue to healthy growth in the early to mid-20<sup>th</sup> Century, and has been used previously in skeletal studies of growth in the past (Schillaci et al., 2011).

2. The World Health Organization's Multicenter Growth Reference Study is the quintessential study of modern growth that most populations (including the United States) are compared against during childhood. While the use of a modern reference population in this sample may bias the results due to the long-term positive secular trend in height (Meadows Jantz and Jantz, 1999), the WHO's position is that all economically advantaged children who are breastfed will grow similarly regardless of ancestry, geography, and/or chronology (WHO, 2009). Moreover, these modern reference curves are easily applied to samples of varied research designs and provide the best means to gauge stunting and childhood health.

#### University of Colorado Child Research Council Study

The University of Colorado Child Research Council Study (Denver Growth Study) began under the auspices of a longitudinal program to detect childhood disease in 1923. It was not until the 1930s with the arrival of A.H. Washburn that the study took a turn toward an all-encompassing research program with a focus on growth, development, and childhood physiology (Tanner, 1981). Over four decades of research lead to the recruitment of 334 European American children of the Denver area to be followed throughout their period of development to adulthood. Examinations were every month until 1 year of age, every 3 months until adolescence, and every year after until

adulthood. Measurements included that of a suite of anthropometric variables (Boyd 1952, 1955) as well as blood pressure, electrocardiograms, basal metabolic rate, and blood tests (Mugrage and Andersen 1936; Lewis, Duval, and Iliff 1943). Moreover, of significance to this study are the radiographs taken of each individual at each visit.

Maresh and colleagues (1943; 1955; 1959; 1972) took radiographs of various regions of the body for measurement including the upper and lower limb. Standardized radiographs of the limb bones were taken at six months intervals throughout the developmental period and the data compiled into percentiles used to compare growth of individual elements as well as stature (Maresh 1955). Schillaci et al. (2011) expressed the utility of these measurements beyond modern growth studies, and compared them to archaeological populations from the American Southwest. Moreover, Schillaci et al. (2012) showed that while the Maresh dataset is not useful at detecting stunting events, it does serve as an appropriate reference for comparative studies of growth in the past and present. Therefore, as comparison this thesis utilizes cross-sectional data on the diaphyseal length of the femur and chronological age from a healthy, well-nourished population that slightly postdates the skeletal remains described above (Maresh, 1955).

#### *The World Health Organization's Multicenter Growth Reference Study*

The WHO Multicenter Growth Reference Study (MGRS) took place between 1997 and 2003 in order to generate new growth curves for children around the world. Based on the reconstruction of the 1977 National Center for Health Statistics (NCHS)/WHO reference sample, the MGRS is a culmination of collected growth data from approximately 8,500 children from varying ethnic and cultural backgrounds in Brazil, Ghana, India, Norway, Oman, and the United States (WHO, 2009). The results of

this program led to the growth curves commonly utilized in the medical profession to assess childhood growth and health throughout the world. Of importance to the current study are the reported length (stature)-by-age measurements for children from birth to 19. These will be plotted against the study samples in order to discern if any historic African American individuals are “stunted” according to the modern growth standard.

#### **4.3 Sampling and Data Collection**

The current study utilizes three variables of growth plotted against chronological age. These variables include maximum femoral length (millimeters), stature (centimeters), and relative adult height (percentage of childhood versus average adult height). Due to the inaccuracy and error associated with subadult sex estimation, sex was not included as a covariate in the results and no attempt is made to estimate sex in any of the samples under study. Reason for inclusion of each variable are as follows:

1. Maximum diaphyseal length of the femur: Numerous studies imply that long-bone growth is variably affected by nutritional and/or environmental constraints (see Saunders et al., 1993; Hoppa and Fitzgerald, 1999). Moreover, the linear size of long bones is often compared against age and/or maturity markers to demonstrate the described variability in long bone growth due to environmental influence. The inclusion of maximum femoral diaphyseal length is a means to measure this variability in one such long bone.
2. Estimated stature: The growth of long bones is allometrically scaled to total body size including adult stature (Ruff, 2007). Therefore, stature represents another means to measure bone growth in variable

environments. However, the inclusion of stature in the study of skeletal growth in the past introduces increased bias due to the unknown true stature. With that said, the WHO reference sample provides recumbent length and/or height only, and not femoral lengths. Therefore, a stature is estimated to compare the samples under study against the WHO reference sample.

3. Relative adult femoral length: In addition to an analysis of growth through time (e.g. femoral and or statural growth), previous studies also seek to show the rate and/or tempo of growth through time. Because the rate of growth in human populations is highly canalized and predictable (see previous chapters), any deviation compared to healthy groups who are hypothesized to grow at a “normal” rate would suggest faltering/stunting. Using previously documented methods, relative adult femoral length or the percentage of adult length achieved is a means to analyze growth rate and change in skeletal populations (Saunders et al., 1993; Schillaci et al., 2011).

Below, the sampling procedure for each variable is described in-depth. This includes where and/or how each measurement was taken, the original source, and any modifications or transformations that had to be made prior to statistical analyses. The final portion of this chapter is a description of the statistical procedures that went into a comparison of growth between all study sites and the comparative reference samples.

### Maximum Diaphyseal Femoral Length

All measurements were taken of the left femora. The right was utilized if the left element was damaged and/or missing. Both Freedman's and Cedar Grove are part of the larger Western Hemisphere Database (available at <http://global.sbs.ohio-state.edu/data.html>, accessed on November 2016) (Steckel et al., 2002). All data from Hunter Army Airfield are under the purview of the United States Army, and therefore must be accessed via governmental assistance. A Freedom of Information Act (FOIA) request to the United States Army Garrison at Fort Stewart, Georgia was submitted on September 19, 2016, requesting all reports and raw data associated with the skeletal material from the Hunter Army Airfield. By November 2016, a compact disc of all materials from Hunter Army Airfield arrived, and the data was transferred to the larger database composing this work. All metric techniques utilized to measure individual elements are derived from standards outlined in Bass (1987), Moore-Jansen, Ousley, and Jantz (1994), and Buikstra and Ubelaker (1994).

Maresh (1955) compiled cross-sectional data on both femoral measurements and stature of boys and girls, and presents the median diaphyseal length as well as the 10<sup>th</sup>, 25<sup>th</sup>, 75<sup>th</sup>, and 95<sup>th</sup> percentiles. Due to the inaccuracy of sex estimation in unknown populations of subadults, the study samples are unable to be separated by sex. Therefore, this thesis calculated the average of the male and female age-specific femoral diaphyseal length from Maresh (1955) to create the modern comparative sample. Note, all measurements after age 12 include epiphyses in the measurement as well (maximum femoral length). Due to magnification error (image parallax), a correction is necessary to

account for error because of measuring from a radiograph. The correction formula described in Ruff (2007) is as follows: for initial lengths greater than 217 mm,

$$\text{Adjusted length} = 0.949 * \text{original length} + 5.63, \quad (4.1)$$

While lengths less than 217 mm are as follows,

$$\text{Adjusted length} = 0.975 * \text{original length}. \quad (4.2)$$

### Estimated Stature

Stature is not provided in any of the sites under study. For this reason, stature must be estimated based on femoral diaphyseal length. Ruff (2007) provides age-specific stature estimation equations for individuals from 1-17 years of age. Individuals from 1-12 years of age are estimated using diaphyseal length of the femur and individuals over 12 years of age contain estimates based on maximum femoral length including epiphyses. All prediction equations were generated using ordinary least squares regression (OLS) (see Ruff, 2007 for a discussion of OLS and possible alternatives). Note, the estimation of stature confounds the analysis already fraught with error in age estimation. Even so, Sciulli and Blatt (2008) demonstrate the reliability and accuracy of Ruff's (2007) method on modern populations of African American and European American children.

To assess stunting, stature is modelled against the modern human growth curve developed from the MGRS (available at <http://www.who.int/childgrowth/mgrs/en/>) (WHO, 2009). Sex-specific tabular datasets are provided for both boys and girls ages 0-19 and are organized into average height/length in either percentiles and/or z-scores around the mean. The WHO does not provide pooled averages based on the combined male and female dataset. The initial 2007 WHO reference growth curve is fit using the

generalized additive model for locations scale and shape (GAMLSS) with the Box-Cox power exponential distribution (BCPE) (WHO, 2006). The computation of z-score and/or percentile curves are simplified using the lambda-mu-sigma (LMS) method where the Box-Cox power  $L(t) = 1$ , which transforms the initial BCPE distribution to a normal distribution (Cole and Green, 1992). Thus, this thesis models the WHO growth reference curve using the pooled stature data regardless of sex based on the methods outlined in WHO (2006). The resulting curves represent the median combined stature as well as  $\pm 3$  standard deviations from the median (see statistical techniques below).

An additional portion of the stature analysis is a comparison of standardized stature to the normal distribution assumed under the WHO growth standards. This is done via a transformation to z-scores based on the provided WHO standards, and is a means to analyze the overall sample's distribution of stature compared to the healthy, well-nourished populations within the WHO study. Moreover, this analysis will lend additional support to a discussion about community-level health as it relates to stunted (or lack thereof) stature. The WHO provides a formula for the estimation of z-scores based on the coefficient of variation ( $CV = \sigma/\mu$ , where  $\sigma$  is the standard deviation and  $\mu$  is the population mean) (available at, <http://www.who.int/growthref/computation.pdf?ua=1>) (WHO, 2017). To calculate the z-score for each individual the formula is as follows:

$$Z_{ind} = ([y/M(t)]^{L(t)} - 1) / (S(t)*L(t)), \quad (4.3)$$

Where  $y$  is the estimated stature,  $M(t)$  is the median age-specific stature from the WHO dataset,  $L(t)$  is the Box-Cox transformation power, and  $S(t)$  is the generalized coefficient of variation provided by the WHO standard. Based on the LMS method,  $L(t) =$

1 for a Box-Cox normal transformation. Z-scores were calculated for all individuals and compared against the WHO reference sample to discern prevalence of stunting.

### Relative Femoral Growth

The final variable analyzed is that of age-related change in relative growth of the femur. That is, the percent of adult length achieved for a given age. This measurement serves as a proxy for growth velocity and any deviation from the “normal” rate of growth may suggest stunting. Previous studies have used the Maresh growth curve to compare relative femoral growth in archaeological skeletal samples (Schillaci et al., 2011). The variable is an age-specific percentage based on the subadult femoral length divided by the average adult femoral length. For all three study sites, adult femoral length values are provided in the published literature (Steckel et al., 2002; Matternes et al., 2010). Male and female measurements are combined and the average adult stature per site is compared to each subadult femoral length (Cedar Grove:  $n = 33$ ,  $\bar{x} = 474.0303$ ; Freedman's:  $n = 28$ ,  $\bar{x} = 456.8969$ ; Hunter:  $n = 16$ ,  $\bar{x} = 450.8125$ ).

Maresh (1955) states that bone growth is normally completed by 17-18 years of age for males and 16-17 for females. Based on procedures outlined by Schillaci et al. (2011), average adult length is the result of the pooled femoral lengths from 18-year-old males and 16-year-old females ( $n = 85$ ,  $\bar{x} = 404.8$ ). This analysis is not a comparison of adult height between sites and recognizes that final adult height will vary according to genetic and environmental variation. The goal of studying relative growth is to analyze the tempo of change over time and pinpoint areas of faltering as compared to “normal” age-related changes in growth seen in a healthy, affluent population.

#### 4.4 Age Estimation

A problem that plagues any study of growth in past populations is an inability to account for exact, known age. Because of the statistical bias introduced through the estimation of age (regardless of technique), the independent or explanatory variable in a growth model (age) is no longer a discrete point, but instead a distribution with an upper and lower limit. Therefore, the resulting growth curve sought after in any study of growth and development is a moving target – in other words, the plotted growth curve could fall along a continuum anywhere between the upper and lower age limit of a given femoral measurement. Thus, an analysis of actual difference in femoral, statural, and relative growth is hampered by an inability to pinpoint the exact location of the growth curve in relation to individual age. The present study utilizes specific age estimation and statistical practices to grapple with the bias inherent in skeletal studies of growth.

The Maresh and WHO dataset contain known age individuals. However, all three study samples are of unknown age. In each case, age is estimated via dental development and/or dental eruption methods. For the cases of Freedman's and Cedar Grove, the Western Hemisphere Database provides dental age point estimates. In both instances, these dental ages are estimated using dental eruption (Edgar, personal communication, 2017; Rose, personal communication, 2017). However, neither site provides a true distribution of age, therefore biasing any analysis that may be a result of age. With confirmation from the researchers responsible for the initial skeletal data analysis (Rose and Edgar, see above), the author of this thesis formulated an age distribution based on the provided mean dental age and the interval that corresponds to this mean dental age in Ubelaker (1989). In other words, taking the provided mean dental age from the Western

Hemisphere skeletal database, an age interval was formed based on how this age corresponds to previously documented age ranges in dental eruption (Ubelaker, 1989). For example, if the dental age provided is 3.2 years of age, Ubelaker (1989) shows the dental eruption event leading to a 3-year-old falls within a 12-month interval – 3.2 years  $\pm$  1 year. While this most likely truncates the true age distribution of the sample, it would still provide a more accurate representation of growth because it accounts for the uncertainty introduced by estimation techniques.

The skeletal assemblage from Hunter Army Airfield does include dental development scores based on Moorrees, Fanning, and Hunt (1963a, b). Therefore, an age distribution is estimated using techniques outlined in Shackelford et al. (2012), where the input of developmental tooth scores returns a truncated normal distribution with mean, upper, and lower estimates, as well as the within-tooth variance. These results make up the age distribution used to model growth below. However, there are published issues related to the use of Moorrees, Fanning, and Hunt's method to estimate the age of certain populations of African ancestry. Specifically, this method tends to underestimate the age of South African populations (Phillips and van Wyk Kotze, 2009) and British populations of African descent (Liversidge, 2008; Liversidge et al., 2012). Broadly, the Moorrees, Fanning, and Hunt, method may lead to significant age differences between disparate populations – the limitations of this method in relation to this study are addressed in the discussion. Note, following an initial run of the dental codes in R (R Core Team, 2016), visual analysis of the age intervals and tooth plots revealed discrepancies suggesting developmentally impossible results. In some instances, the estimated eruption interval is either left- or right-skewed, indicating the misclassification of a certain tooth and

developmental code. This error may be caused by a misidentification between adult and deciduous dentition, and occurred during initial data analysis by Matternes et al. (2010). Prior to age estimation in this thesis, all individuals were examined for these biased results, and influential scores were removed to achieve a true estimate of the interval. While the manipulation itself biases the results, frequently this process removed only a single tooth score and narrowed the interval without significantly influencing the mean.

#### **4.5 Statistical Procedures**

All statistical procedures and plots were completed in the integrated development environment (IDE) of RStudio [<https://www.rstudio.com/>] using the R-Programming Language (R Core Team, 2016). Additional packages independent of the base programming model will be cited separately. In some instances, statistical procedures outside of the base programming model had to be utilized due to the specificity of such techniques as applied to the study of human growth (see discussion of maximum likelihood estimation and optimization below).

The procedures outlined below are as follows: 1) model diaphyseal growth against estimated chronological age as compared to the Maresh (1955) dataset, 2) plot the standardized estimated stature against estimated mean age as compared against the WHO reference data (WHO, 2009), and 3) model relative adult femoral growth against estimated mean chronological age as compared to the relative adult growth of the Maresh (1955) dataset. The Maresh (1955) sample is utilized in instances where only femoral growth is modelled. The WHO (WHO, 2009) reference sample is utilized in instances where stature is to be modelled. Combined, the purpose of all statistical techniques is to visualize differences in growth between contemporaneous historic African American

populations as compared to the reference groups. The nature of this comparison, and whether the skeletal sample growth falls above or below the reference populations is the main purpose of this analysis and drives the results in the next chapter. Therefore, the final goal is to display the results in a manner that best portrays the growth differences so as to facilitate later discussion about where growth stunting occurs along the developmental trajectory, why it occurs, and how does that relate to broader historic African American environments at the onset of the 20<sup>th</sup> Century.

### Femoral Growth Curve Analysis

The first step in these analyses is to form a growth curve based on femoral length and chronological age. As Konigsberg and Holman (1999) note, any analysis of growth curves on populations of unknown age must somehow account for the estimation in age (see above) in model formation. One way to do this is to fit the data based on the overall age distribution with a mean age growth curve bounded by the upper and lower limits of the age distribution. To model femoral growth, this thesis uses a simple logarithmic growth model described in Count (1943) that has been used in similar studies of error prone growth estimates (Konigsberg and Holman, 1999). The model is a three-parameter growth model where femoral length ( $y$ ) is regressed on age ( $t$ ) and the natural log of age. The model is as follows:

$$y = \beta_0 + \beta_1 * t + \beta_2 * \ln(t), \quad (4.4)$$

where  $y$  is femoral length and  $t$  is age in estimated years. Using a variation on procedures outlined in Konigsberg and Holman (1999), parameters of the preceding growth model are estimated based on maximum likelihood estimation (MLE). The robustness of MLE

estimation in human growth analysis is described in depth by Cheung (2014). At the core, MLE is an analytic maximization procedure that takes the supplied data and returns the most likely (maximum) parameter values that would explain the observed results given a likelihood function and/or the supplied logarithmic growth curve to fit the current data.

In R, the procedure runs as follows: 1) form a function based on the negative sum of the squared errors of the logarithmic growth curve, 2) run an optimization procedure that returns the maximum values for each parameter given the described function [*optimx* package, (Nash and Varadhan, 2011; Nash, 2014)], and 3) plot the resulting growth curve based on the predicted values given the maximized parameters. This process is repeated three times for each site using the minimum age estimate, mean age estimate, and maximum age estimate. A bounded curve is then modelled based on these results and compared to the Maresh growth curve. Once this procedure is run for each age distribution, a polygon is fit around the mean growth curve and is bounded by the minimum and maximum estimated growth curves. The above fit of the observed data to the given logarithmic growth curve is plotted against the Maresh dataset representing femoral diaphyseal length. The points are plotted based on chronological age with the upper 90<sup>th</sup> percentile and lower 10<sup>th</sup> percentile included. An individual is considered stunted if they fall below the 10<sup>th</sup> percentile of the Maresh dataset (Schillaci, 2012).

A final addition to the analysis of femoral diaphyseal growth is a comparison between methods commonly utilized to model human skeletal growth. This will consist of the above described maximum likelihood estimation method versus a method that utilizes local regression (LOESS). LOESS is a nonparametric regression technique that fits a flexible regression line to a series of data based on the local weighting of each point

along the curve (Cleveland, 1979). It is a generalization of locally weighted scatterplot smoothing (LOWESS) that fits smooth curves without prior assumptions about the data and can be utilized in both univariate or multivariate settings. As compared to the above described MLE approach, LOESS is fitted to a model point-by-point as opposed to a global function that is smoothed based on a set of parameters averaged across the entire distribution. In other words, LOESS may provide a more nuanced approach that highlights subtle variability between age-intervals due to its ability to fit a line point-by-point as opposed to a single average throughout. Previous studies in growth utilize LOESS or LOWESS in various forms (Schillaci et al., 2011; Cheung, 2014).

The inclusion of LOESS in these analyses is a means to spur discussion about the best ways to model human growth in the past. It does not take away from results presented through the MLE model, but instead adds a layer to highlight specific areas along the growth curve that MLE may smooth over due to its global/distributional assumptions. Alternatively, LOESS is equally subjective due to the necessity to provide a smoothing and/or weighting factor that the researcher specifies prior to model formulation and therefore, LOESS curves may highlight and/or smooth over certain points along the growth curve dependent on the factor of choice. For the purposes of this study, the span ( $\alpha$ ) value is the default supplied in R,  $\alpha = 2/3$ .

### *Estimated Stature Analysis*

Due to image parallax and measurement bias, the Maresh dataset has been shown to be useful when comparing multiple growth curves, but may not be as useful when addressing the frequency of stunting in a population. For this reason, this thesis uses the WHO dataset – values used to address stunting in modern global populations –

to discern if any of the following historic African American samples are significantly stunted. Requiring a much simpler approach compared to modelling growth based on estimated age, this procedure takes the mean estimated stature of each individual and plots it against the WHO reference curves. Individuals that fall below two standard deviations are considered stunted. Moreover, on each plot is the average adult stature of modern European American and African American populations (Fryar et al., 2016), as well as the average adult stature of the adult individuals at each cemetery. Because the ultimate outcome of growth is achieved adult stature, the inclusion of these components facilitates a discussion about where each subadult falls in relation to that target average adult stature from the period and how that compares to modern populations. A second component to the analysis of stature is to plot the density of each z-score as compared to the standard normal distribution from the Box-Cox transformation of the WHO height data. The initial hypothesis here is that the data will be far left-skewed as a result of stunting in the study samples.

#### *Relative Femoral Growth Analysis*

The final piece of this analysis is to compare the tempo of growth relative to average adult length. See above for a description of how to estimate the percent of adult length achieved. Here, the percent of adult growth achieved is plotted against mean chronological age and fit using a generalized form of the Locally Weighted Scatterplot Smoothing (LOESS, as opposed to the more specific LOWESS). If relative growth is at the same tempo as the presumed “normal” Maresh (1955) dataset, then the LOESS curve will fit similar to the logarithmic curve described above. Any deviation in this fit will lead to a curve that falls off or levels out at certain points to represent decreased growth

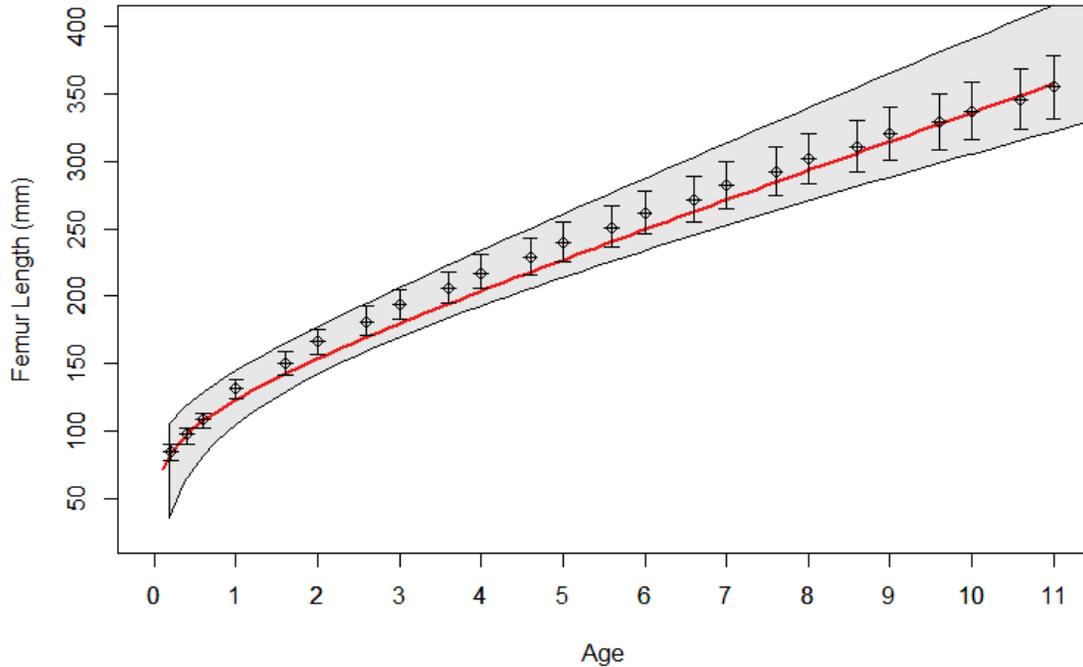
during a certain age interval. This is repeated for each site. Femoral length is used as opposed to estimated stature in order to not expound the results with more error as a result of stature estimation.

## 5. RESULTS

Results are organized based on individual study site to first elucidate patterns at the community-level. At the end, inter-site differences are modelled, followed by an analysis of broader historic African American growth compared to modern comparative populations.

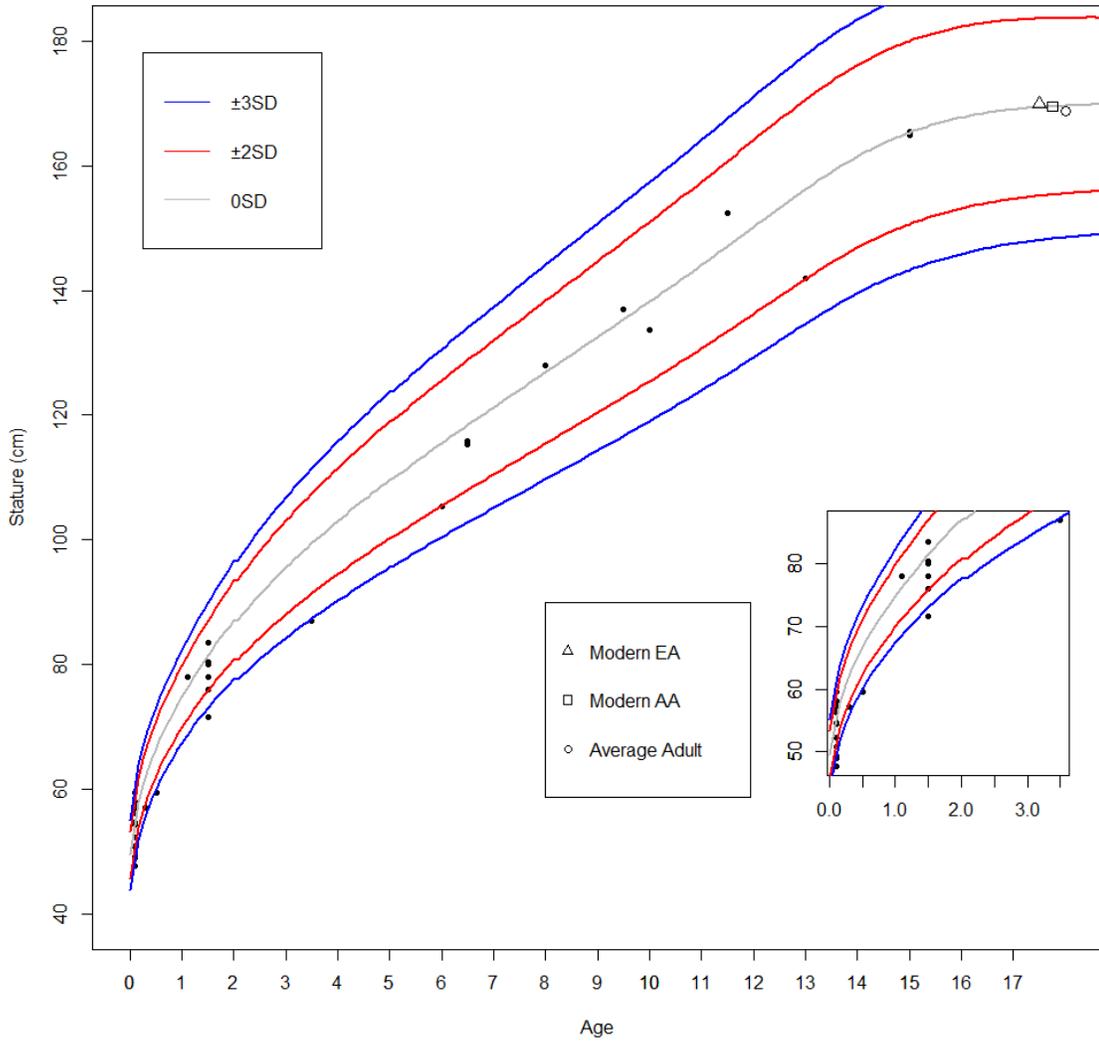
### 5.1 Subadult Growth at Cedar Grove Cemetery

Figure 5.1 models Cedar Grove subadult diaphyseal length for age as compared to the modern comparative dataset from the Denver Growth Study. The mean growth curve is represented by the fitted red curve, while the upper and lower limits of the gray polygon represent the minimum and maximum estimated age against femoral length. Growth is classified as stunted if it falls below the 10<sup>th</sup> percentile. Immediately obvious from Figure 5.1 is the wide range encompassed by the age distribution – the entire Maresh dataset falls within the estimated age range. Intuitively, the error range increases with age. Based on the mean curve, femoral length falls below the 10<sup>th</sup> percentile between the ages of 1-5 (infancy through early childhood) and may suggest a stunting event that occurs as a result of maternal stress and/or the weaning period. Moreover, the entirety of the lower limit falls below the 10<sup>th</sup> percentile. However, once the individual is approximately six or seven, growth represented by mean estimated age falls near the median height of the Maresh sample. This suggests normal growth may have commenced following the end of the weaning period and into early adolescence.

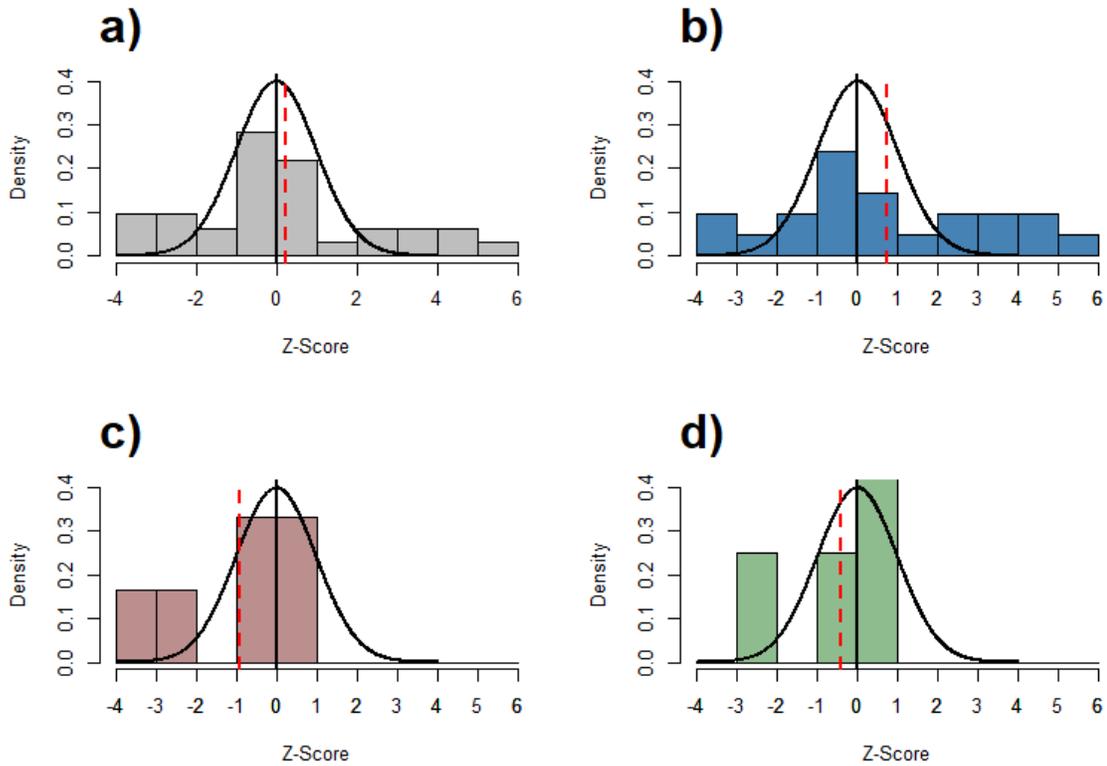


**Figure 5.1.** Plot of diaphyseal length of the femur on the estimated chronological age distribution. Subadults at Cedar Grove are represented by the red growth curve with upper and lower estimates represented by the gray polygon around the curve. The open circles and 10-90% limits represent the Maresh data set.

Figure 5.2 plots the mean estimated subadult stature (Ruff, 2007) and mean estimated age over the WHO Multicenter Growth Reference Study curves. Any individual that falls below the lower red curve (-2 standard deviations) is considered stunted by the WHO standards. Visualized above, only 6/32 individuals analyzed (18.75%) fall below 2 standard deviations of mean subadult stature by age. Of these six individuals, five of them (83%) are under 6 years of age. Moreover, a comparison of subadults measurements to achieved adult stature plotted toward the end of the plot, suggests growth is on trajectory toward an average adult stature close to modern WHO median and modern populations from the United States (European American and African American).



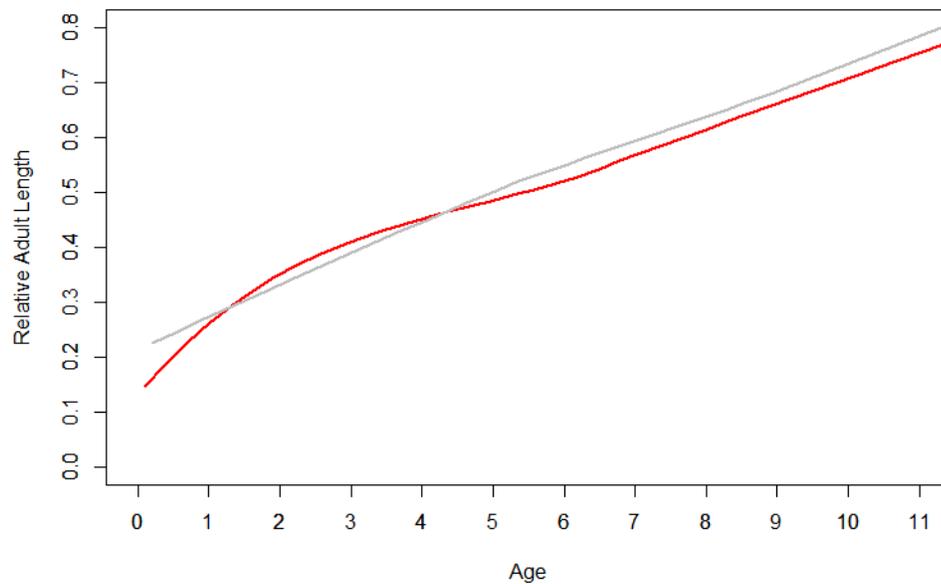
**Figure 5.2.** Plot of mean estimated stature by mean estimated age against the WHO growth reference curves. Subadults at Cedar Grove are represented by the filled circles. Median growth from the WHO is the gray curve,  $\pm 2$  standard deviations are the red curves, and  $\pm 3$  standard deviations are the blue curves. Inset is the infancy period (0-3), where most of the sample falls. Average modern European American and African American stature is in the open triangle and open square, respectively. The open circle is the average adult stature from Cedar Grove, Cemetery.



**Figure 5.3.** Histogram plot of the density of standardized stature at Cedar Grove as compared to the Box-Cox Normal Transformation. The solid black line is at 0, the red dashed line is at the group mean. A) represents the combined results, B) are individuals aged between 0-3, C) are individuals between 3-10, and D) is anyone over the age of 10.

Figure 5.3 presents another analysis of the standardized z-score for stature at Cedar Grove. Growth from the WHO reference data is assumed to follow a standard normal with mean  $\mu = 0$  and standard deviation  $\sigma = 1$ . Described above, data of an extremely stunted population is assumed to be skewed significantly left where most values fall below 2 standard deviations. Figure 5.3 plots a histogram of the standardized stature values transposed over the box-cox normal transformation with both the standard mean and sample mean represented. Plot A shows the combined sample of Cedar Grove. The distribution is unimodal, near-normal, with a mean  $\bar{x}$  equal to 0.2353. Based on the WHO standard, the population at Cedar Grove shows little evidence of stunting. Plots B-

D are broken up by age category in order to capture different periods of growth and to account for the age-bias represented by a sample with few individuals over the age of five. Individuals aged between 0-3 show a similar distribution to the sample, and equally contain a mean value taller than the standard normal distribution ( $\bar{x} = 0.7281$ ). Plots C and D suffer from small sample sizes, sample size equals seven and four respectively, but represent individuals with a slightly smaller than normal mean ( $\bar{x} = -0.9257$  and  $\bar{x} = -0.396$ , respectively). Regardless, the mean value of the population does not fall below the -2 threshold. Therefore, while a few individuals at Cedar Grove are stunted at a younger age, the population is not considered stunted per the WHO guidelines for child growth and development.



**Figure 5.4.** Plot of relative femoral growth from 0-11 years old (% adult length achieved). Cedar Grove femoral growth is represented by the red line. The Maresh comparative dataset is represented with the gray line. Data were fit using LOESS regression.

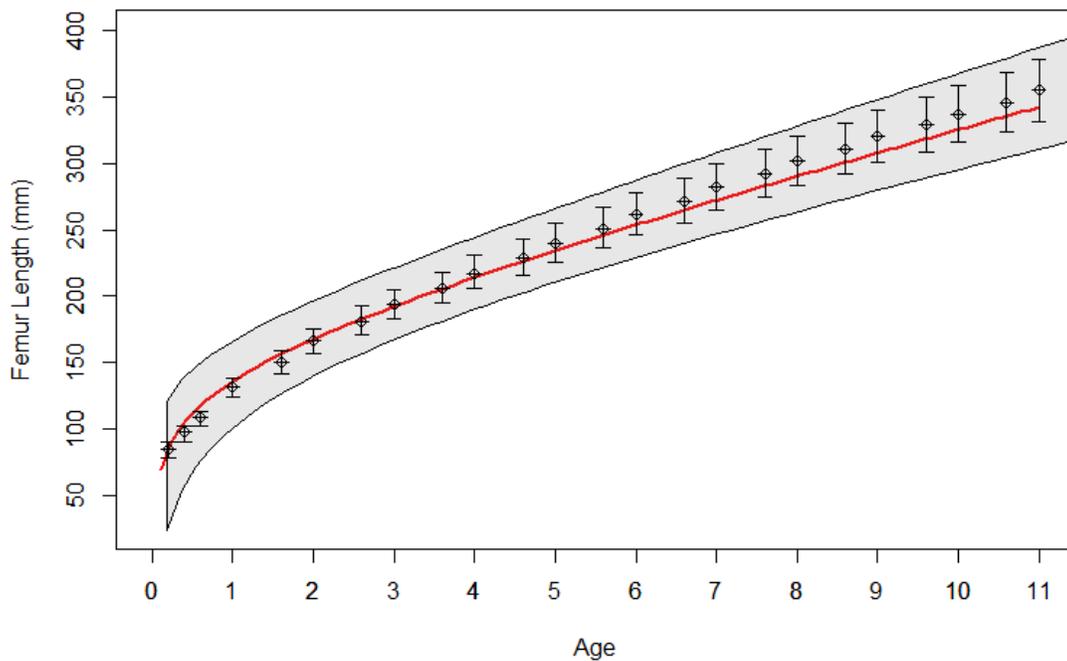
The final part of the Cedar Grove analysis is a look at change in relative femoral growth through time. If growth is normal, it is assumed that the data will follow a logarithmic curve described above. In Figure 5.4, there is a faltering of growth immediately after birth, then catch-up beyond the Denver relative growth curve at 1.5 years old, followed by a second bout of stunting that occurs between the age of 4 and 6.5. Afterwards, a gradual increase in growth occurs until relative adult potential evens out with the Maresh growth curve, albeit slightly smaller compared to the Denver curve. Again, stunting appears to occur in early childhood and continues through middle and late childhood. By adolescence, normal growth commences at the same rate, but the individuals appear to be slightly smaller compared to the Denver growth curve by age 11.

## **5.2 Subadult Growth at Freedman's Cemetery**

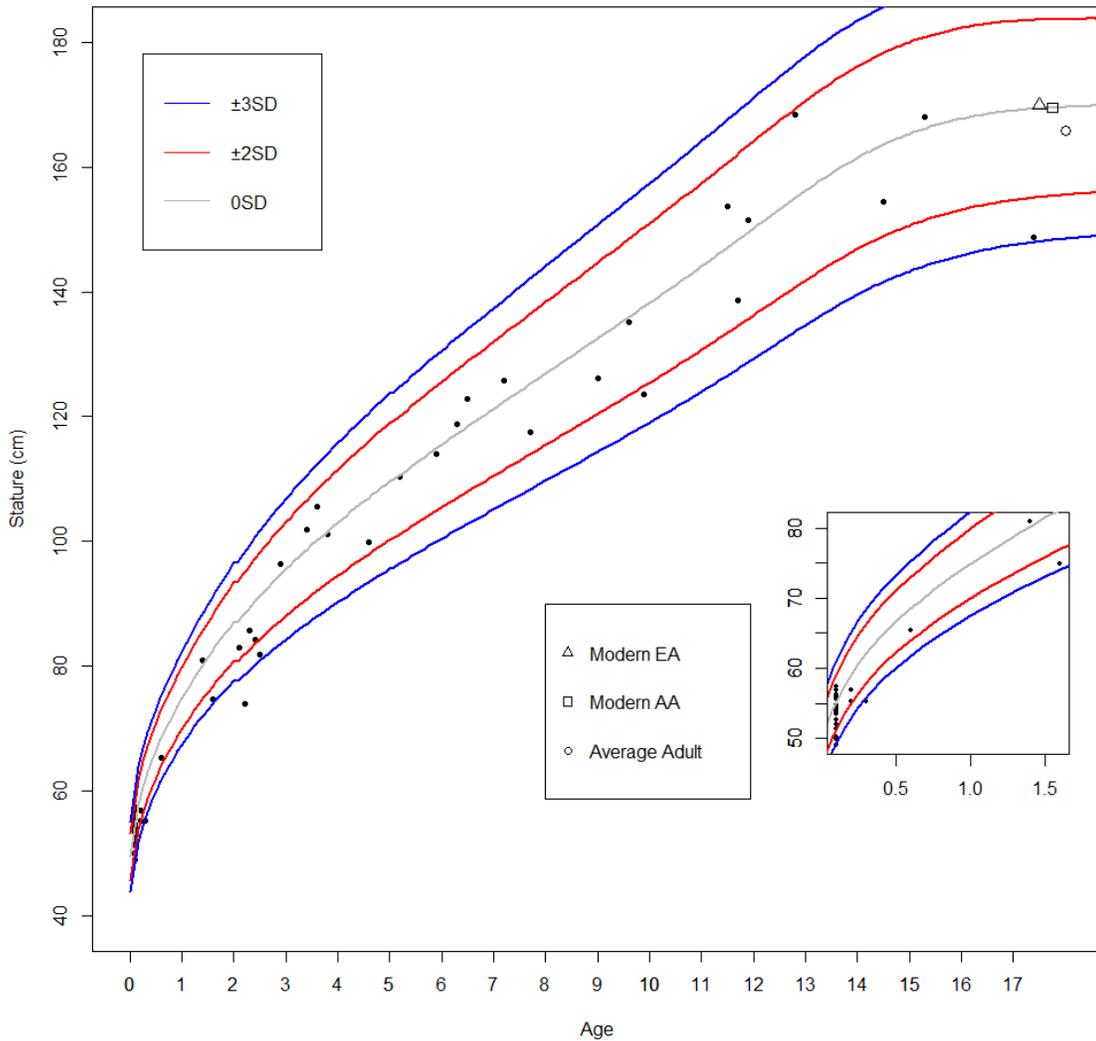
Figure 5.5 models Freedman's subadult diaphyseal length for age as compared to the modern comparative dataset from the Denver Growth Study. The mean growth curve is represented by the fitted red curve, while the upper and lower limits of the gray polygon represent the minimum and maximum estimated age against femoral length. Growth is classified as stunted if it falls below the 10<sup>th</sup> percentile. Like above, the entire age distribution encompasses the Maresh growth curve. Mean femoral growth does not fall below the 10<sup>th</sup> percentile during any point along the growth curve. On average, femoral growth at Freedman's Cemetery follows a similar trajectory and pattern to that of the modern comparative dataset. Based on the mean growth curve and wide age range, growth is either not stunted or falls just below that of Maresh's median values.

Figure 5.6 plots the Freedman's mean estimated subadult stature (Ruff, 2007) and mean estimated age over the WHO Multicenter Growth Reference Study curves. Any

individual that falls below the lower red curve (-2 standard deviations) is considered stunted by the WHO standards. Visualized below, only 10 out 65 (15.38%) fall below the two-standard deviation threshold. Of these 10, seven subadults (70%) are under a mean age of 6 years old. Like the Cedar Grove dataset, any stunting that is present tends to occur between birth and early childhood. The remainder of the dataset falls within one standard deviation of the mean. Moreover, comparison to the achieved adult statures at the end of the plot suggests that target adult height at Freedman's, while below the mean of modern global populations and modern European American and African Americans, does not fall below -2SD and therefore, while shorter than modern groups, they are not stunted in comparison.



**Figure 5.5.** Plot of diaphyseal length of the femur on the estimated chronological age distribution. Subadults at Freedman's Cemetery are represented by the red growth curve with upper and lower estimates represented by the gray polygon around the curve. The open circles and 10-90% limits represent the Maresh data set.

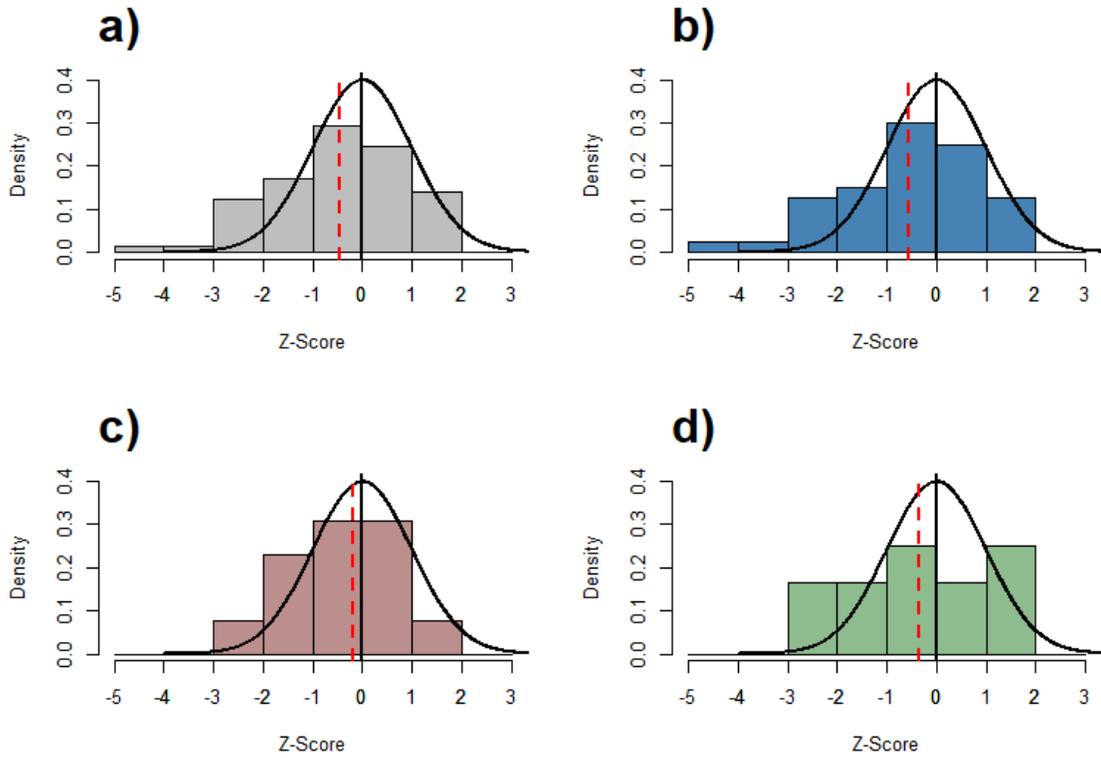


**Figure 5.6.** Plot of mean estimated stature by mean estimated age against the WHO growth reference curves. Subadults at Freedman’s Cemetery are represented by the filled circles. Median growth from the WHO is the gray curve,  $\pm 2$  standard deviations are the red curves, and  $\pm 3$  standard deviations are the blue curves. Inset is the infancy period (0-3). Average modern European American and African American stature is in the open triangle and open square, respectively. The open circle is the average adult stature from Freedman’s Cemetery.

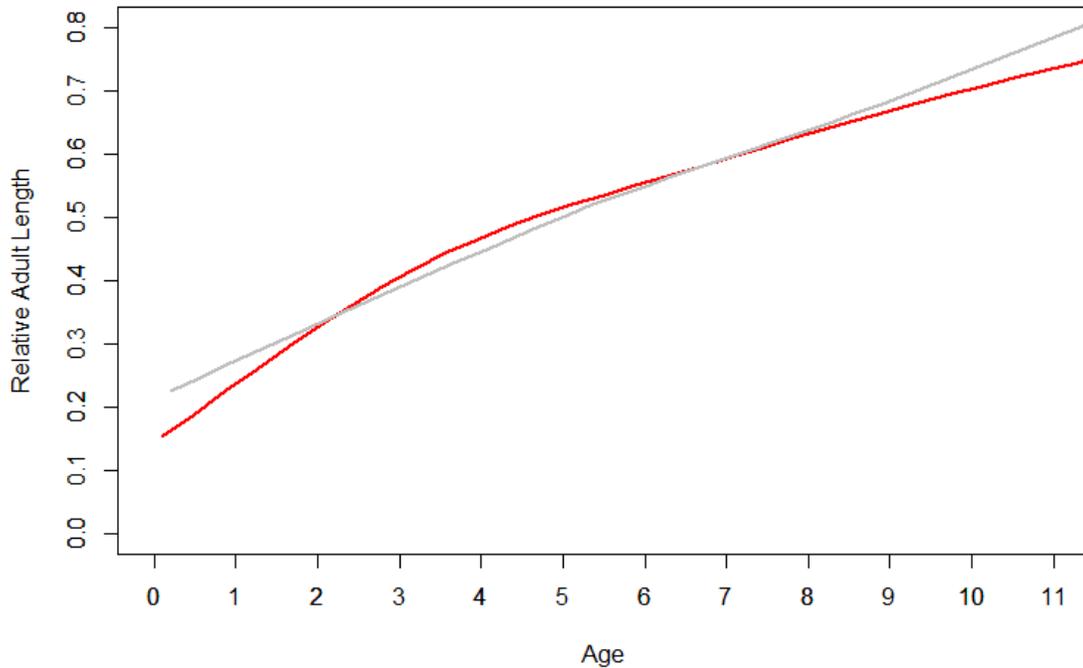
Figure 5.7 presents another analysis of the standardized z-score for stature at Freedman’s Cemetery. Growth from the WHO reference data is assumed to follow a

standard normal distribution with mean  $\mu = 0$  and standard deviation  $\sigma = 1$ . Described above, data of an extremely stunted population is assumed to be skewed significantly left where most values fall below 2 standard deviations. In Figure 5.7, histograms of standardized stature are plotted over the box-cox normal transformation with the population mean (solid black line) and sample mean (dashed red line) transposed over the plot. Plot A represents the combined population, Plot B is ages 0-3, Plot C is ages 3-10, and Plot D is ages over 10. In each case, the sample mean falls slightly below normal with A = -0.449, B = -0.56, C = -0.20, and D = -0.36. Plots A-C are similar in shape to the standard normal curve, if not skewed slight left. Like above, Freedman's Cemetery is similar in distribution to the WHO growth reference data and the sample mean does not fall below an average of the 2 standard deviations necessary to indicate a stunted population.

The last part to Freedman's analysis is a look at the change in relative femoral growth through time. If growth is normal, it is assumed that the data will follow a logarithmic curve described above. In Figure 5.8, there is a faltering of growth beginning around birth and continuing up until the age of 3. Afterwards, the tempo of growth plots near or slightly above the logarithmic curve seen in the Denver dataset. A second bout of stunting again appears to occur in late childhood around 9 years old. Although, due to the small sample sizes of any individual over the age of 5, any patterns may be masked by sampling bias. Thus, at the very least, stunting appears to occur at birth through infancy, followed by normal or slightly increased femoral growth throughout the remainder of childhood development with the possibility of a second stunting event in adolescence.



**Figure 5.7.** Histogram plot of the density of standardized stature at Freedman's as compared to the Box-Cox Normal Transformation. The solid black line is at 0, the red dashed line is at the group mean. A) represents the combined results, B) are individuals aged between 0-3, C) are individuals between 3-10, and D) is anyone over the age of



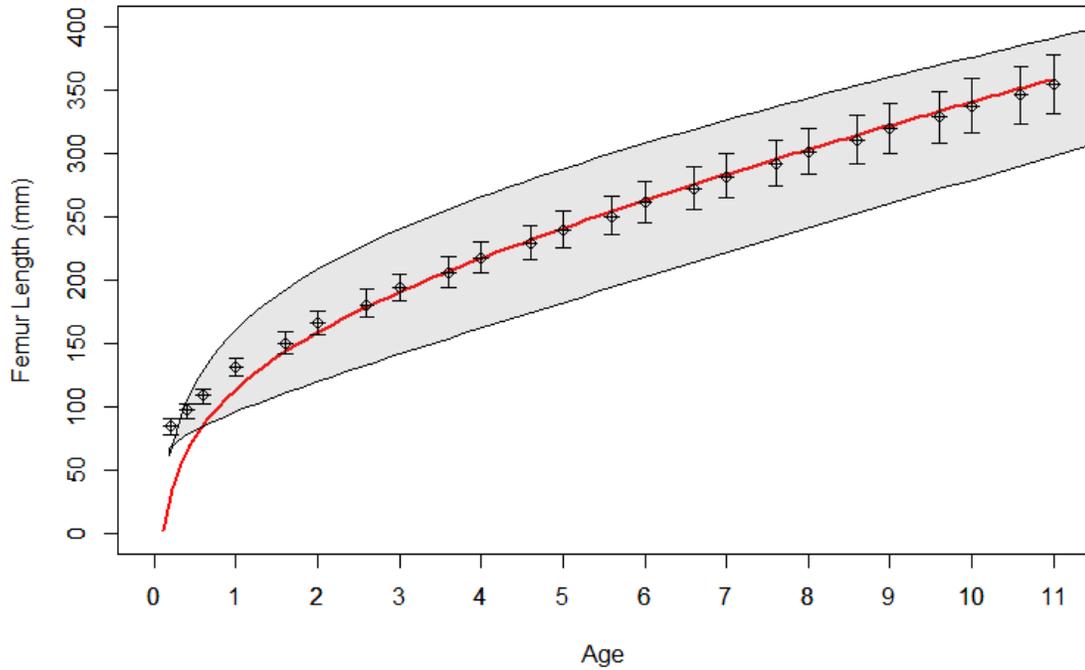
**Figure 5.8.** Plot of relative femoral growth from 0-11 years old (% adult length achieved). Freedman's femoral growth is represented by the red line. The Maresh comparative dataset is represented with the gray line. Data were fit using LOESS regression.

### 5.3 Subadult Growth in Chatham County, Georgia

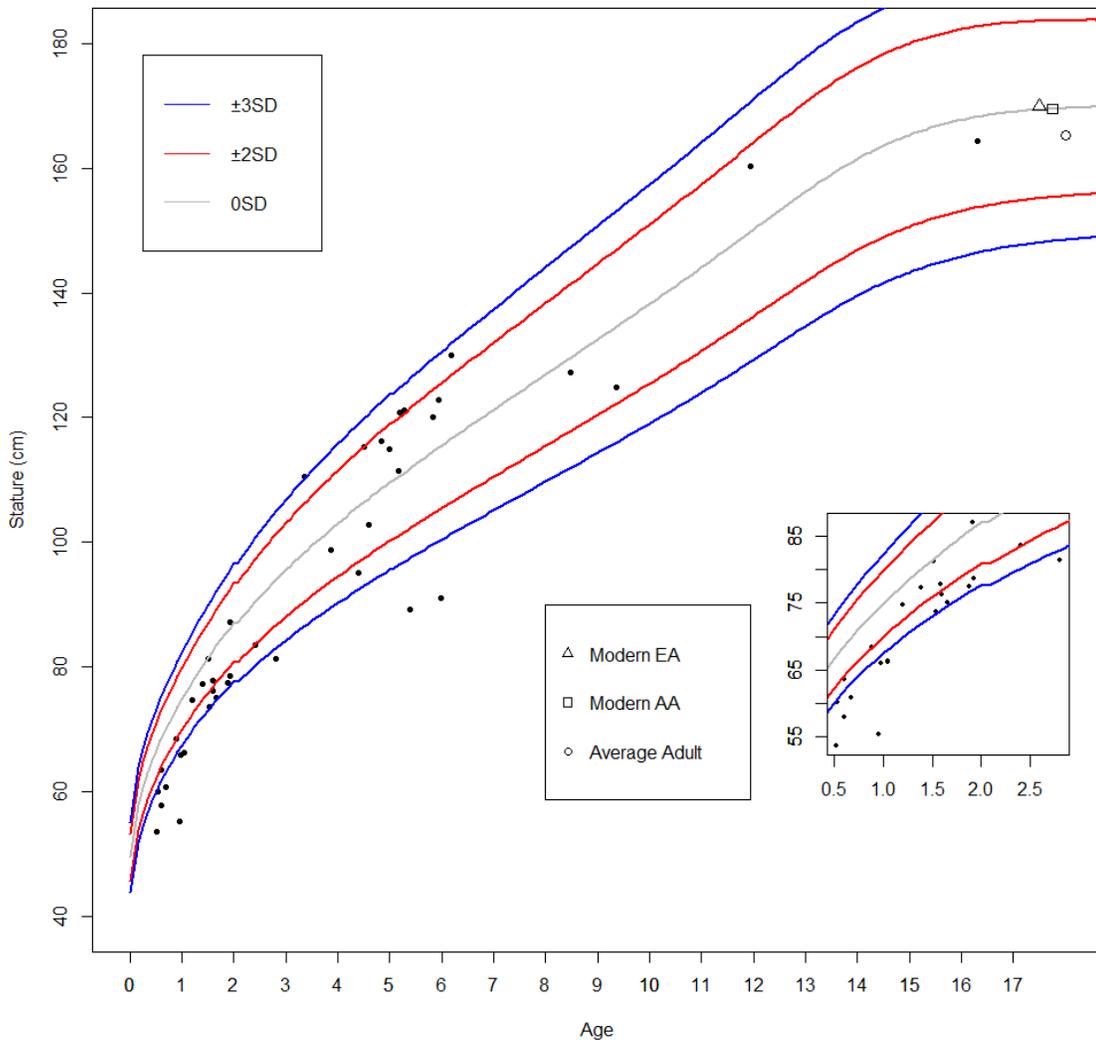
Figure 5.9 models Chatham County subadult diaphyseal length for age as compared to the modern comparative dataset from the Denver Growth Study. The mean growth curve is represented by the fitted red curve, while the upper and lower limits of the gray polygon represent the minimum and maximum estimated age against femoral length. Growth is classified as stunted if it falls below the 10<sup>th</sup> percentile. Throughout much of the growth period, the estimated distribution of ages encompasses the Maresh growth data. However, from birth to 2 years of age, both the mean and lower age range fall below the 10<sup>th</sup> percentile of the median modern growth curve. Again, indicating

possible stunting during infancy and ending by early childhood. The poor fit of the minimum and mean growth curves toward the younger age range is most likely the result of developmental tooth coding error by the initial authors. Regardless, subadult diaphyseal growth is stunted shortly after birth until the age of 2, when normal growth commences up through adolescence.

Figure 5.10 plots the Hunter Army Airfield mean estimated subadult stature (Ruff, 2007) and mean estimated age over the WHO Multicenter Growth Reference Study curves. Any individual that falls below the lower red curve (-2 standard deviations) is considered stunted by the WHO standards. Visualized below, 20 out of 42 (47.62%) subadults analyzed fall below the WHO's 2 standard deviation threshold. All stunted individuals are under the age of 6 years old. Therefore, subadults exhumed from Hunter Army Airfield in Chatham County, Georgia are significantly stunted from birth up through middle childhood – the most of any of the study sites analyzed. Moreover, when comparing the target adult stature at the end of the plot, individuals from Chatham County are shorter than modern European American and African American individuals – albeit not stunted.



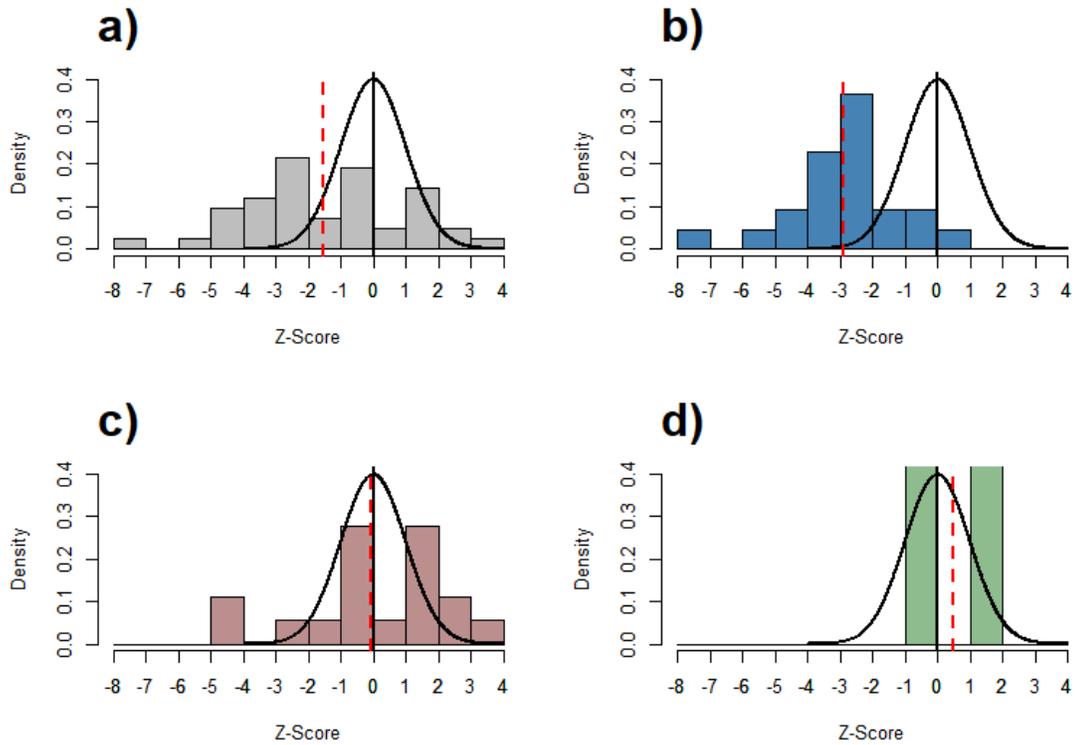
**Figure 5.9.** Plot of diaphyseal length of the femur on the estimated chronological age distribution. Subadults from Chatham County, Georgia are represented by the red growth curve with upper and lower estimates represented by the gray polygon around the curve. The open circles and 10-90% limits represent the Maresh data set. Note, the discrepancy toward the lower end of the polygon is the result of error in age estimation prior to data collection for this thesis.



**Figure 5.10.** Plot of mean estimated stature by mean estimated age against the WHO growth reference curves. Subadults in Chatham County, Georgia are represented by the filled circles. Median growth from the WHO is the gray curve,  $\pm 2$  standard deviations are the red curves, and  $\pm 3$  standard deviations are the blue curves. Inset is the infancy period (0-2), where most of the sample falls. Average modern European American and African American stature is in the open triangle and open square, respectively. The open circle is the average adult stature from the Chatham County skeletal assemblages.

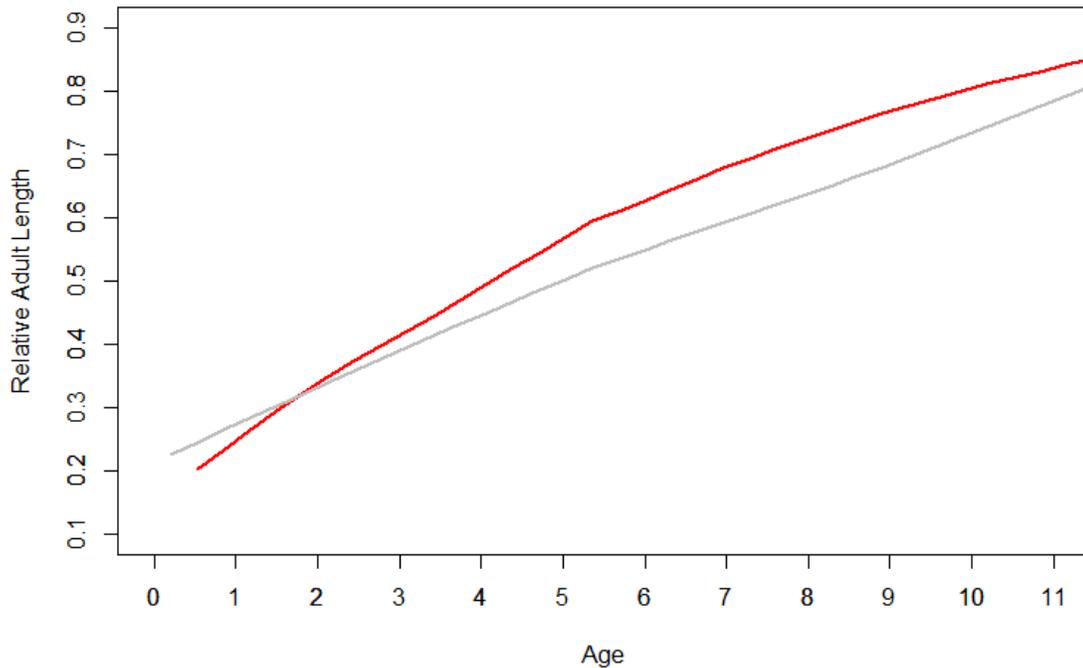
Figure 5.11 presents another analysis of the standardized z-score for stature at Hunter Army Airfield. Growth from the WHO reference data is assumed to follow a standard normal distribution with mean  $\mu = 0$  and standard deviation  $\sigma = 1$ . Described

above, data of an extremely stunted population is assumed to be skewed significantly left where most values fall below 2 standard deviations. In Figure 5.11, Plot A is a histogram of the combined sample population, Plot B is ages 0-3, Plot C is 3-10, and Plot D is ages over 10. The black line is the population mean ( $\mu = 0$ ) and the red dashed line is the sample mean (A = -1.53, B = -2.91, C = -0.067, and D = 0.465). The Hunter sample varies compared to the remainder of the sample populations. Combined, the individuals at Hunter fall behind the WHO reference data, but not to the point of stunting. However, individuals aged 0-3 (sample size = 22) are distributed normally, albeit significantly stunted (mean z-score = -2.91). This analysis corroborates the previous data analyzed in Figure 5.9 and 5.10 – young subadults at Chatham County are significantly stunted during infancy and early childhood. Plots C and D show less evidence of stunting and are influenced by small sample sizes in these age ranges.



**Figure 5.11.** Histogram plot of the density of standardized stature at Freedman’s as compared to the Box-Cox Normal Transformation. The solid black line is at 0, the red dashed line is at the group mean. A) represents the combined results, B) are individuals aged between 0-3, C) are individuals between 3-10, and D) is anyone over the age of 10.

Lastly, Figure 5.12 model’s relative femoral growth through time in Chatham County, Georgia. If growth is normal, it is assumed that the data will follow a logarithmic curve described above. In Figure 5.12, growth faltering occurs beginning at birth and continues up until 2 years of age. At 2 years of age, growth meets and then exceeds the normal growth described by the Maresh growth curve. Put another way, growth rate begins to exceed that of the Denver Growth Study following the stunting event. This may be a result of catch-up growth erasing and exceeding normal growth tempo in order to “catch-up” to terminal adult stature.



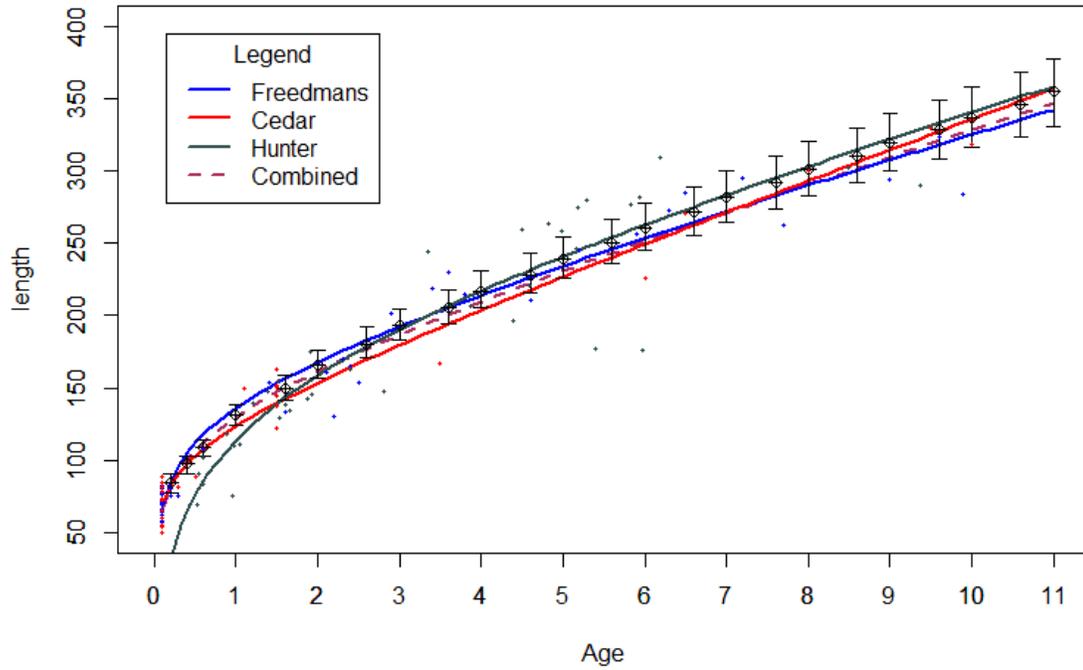
**Figure 5.12.** Plot of relative femoral growth from 0-11 years old (% adult length achieved). Chatham County, Georgia femoral growth is represented by the red line. The Maresh comparative dataset is represented with the gray line. Data were fit using LOESS regression.

#### 5.4 Historic African American Subadult Growth

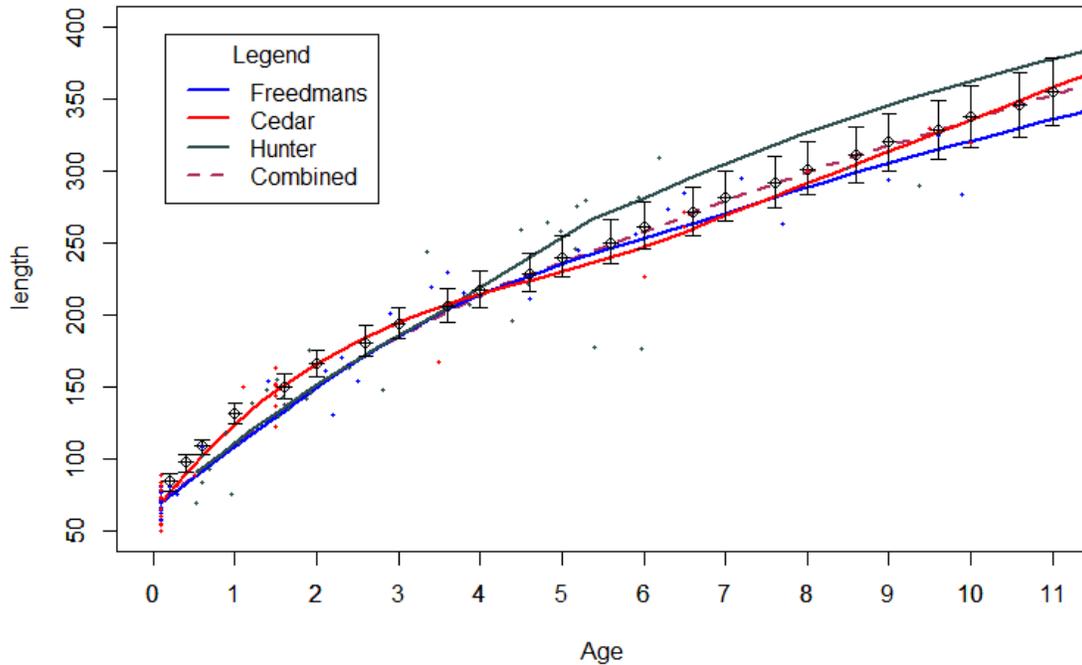
A final addition to the analysis of subadult growth in historic African Americans is to compare growth across all sites. Figure 5.13 is a representation of mean femoral diaphyseal length by site. Here, the subadult remains from Georgia clearly fall below all other sites from birth up to near 3 years of age. Even though some stunting may occur throughout infancy, there appears to be little detrimental effect to growth later in childhood or adolescence. In fact, mean femoral growth at each of these sites falls at or near modern femoral growth. Because most of childhood growth differs little from that of

modern growth, any deviation between individual site may be a result of subtle genetic differences as opposed to significant swings in environmental perturbations.

Figure 5.14 represents another means to display diaphyseal growth using the local regression technique as opposed to the maximum likelihood technique described above. In general, the pattern remains slightly the same in that stunting does occur early, but femoral length normalizes as compared to the Denver growth curve by adolescence. However, upon closer examination there are subtle differences between the two methods that demonstrate the utility of a local approach versus that of the global. For instance, in Cedar Grove Cemetery and Freedman's Cemetery, there is a very clear episode of stunting early in life in both plots, but only the LOESS plot (Figure 5.14) captures a second bout of stunting in early to mid-childhood that could be related to numerous factors such as weaning, disease, nutritional instability, etc. In fact, when you compare the LOESS curves in Figure 5.14 to the relative growth curves described above (Figures 5.4, 5.8, 5.12), the trajectory and subtleties in growth faltering plot out in a similar fashion. While the MLE approach captured the generalities of growth described, the LOESS plot appears to show a more complete picture of growth stunting (sometimes multiple episodes) followed by a normalization and/or increase beyond the length of comparative European American populations.



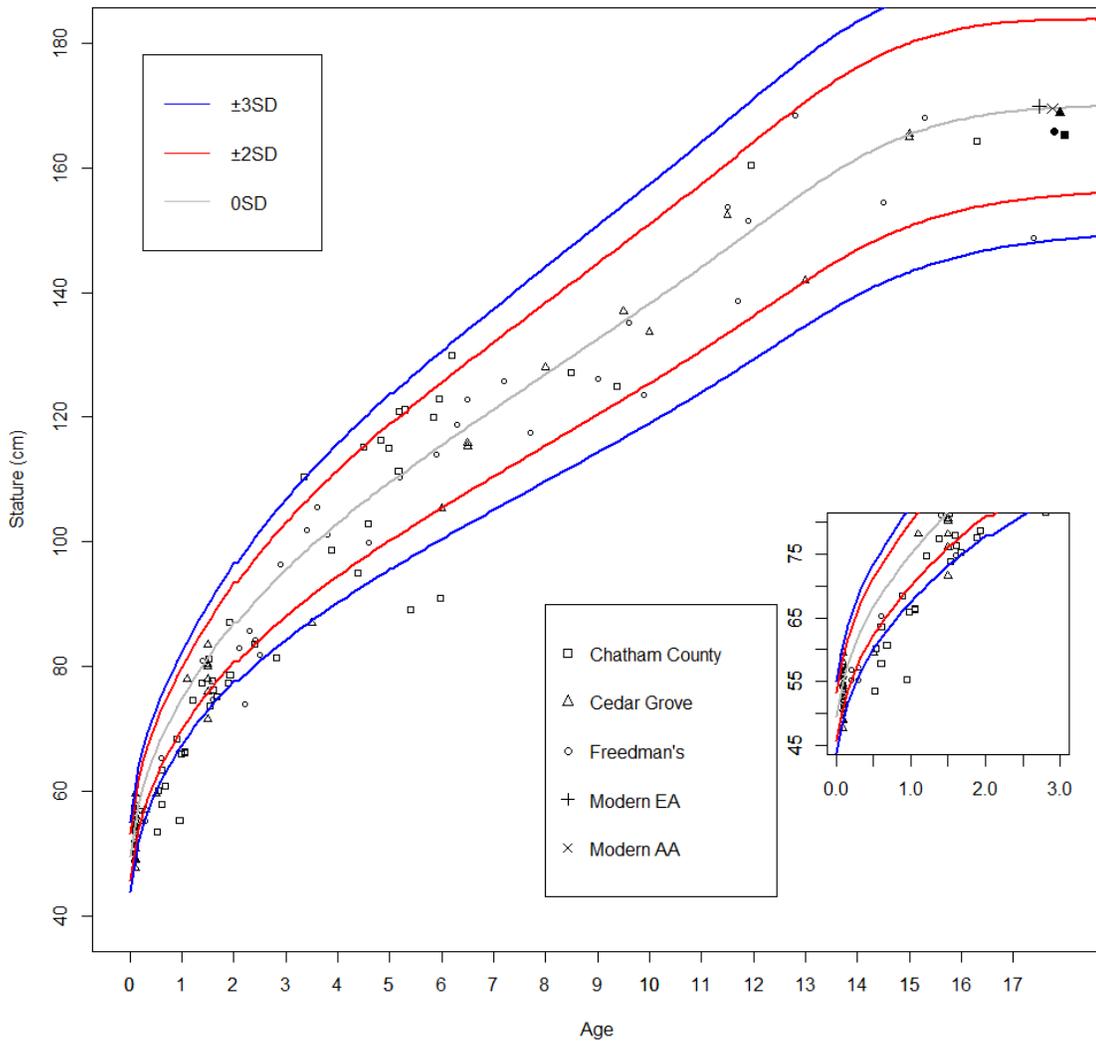
**Figure 5.13.** Maximum likelihood method: Plot of diaphyseal length of the femur on the mean estimated chronological age. Subadults from Chatham County, Georgia are represented by the dark gray growth curve, those at Freedman’s are represented by the blue, and those at Cedar by the red. The open circles and 10-90% limits represent the Maresh data set.



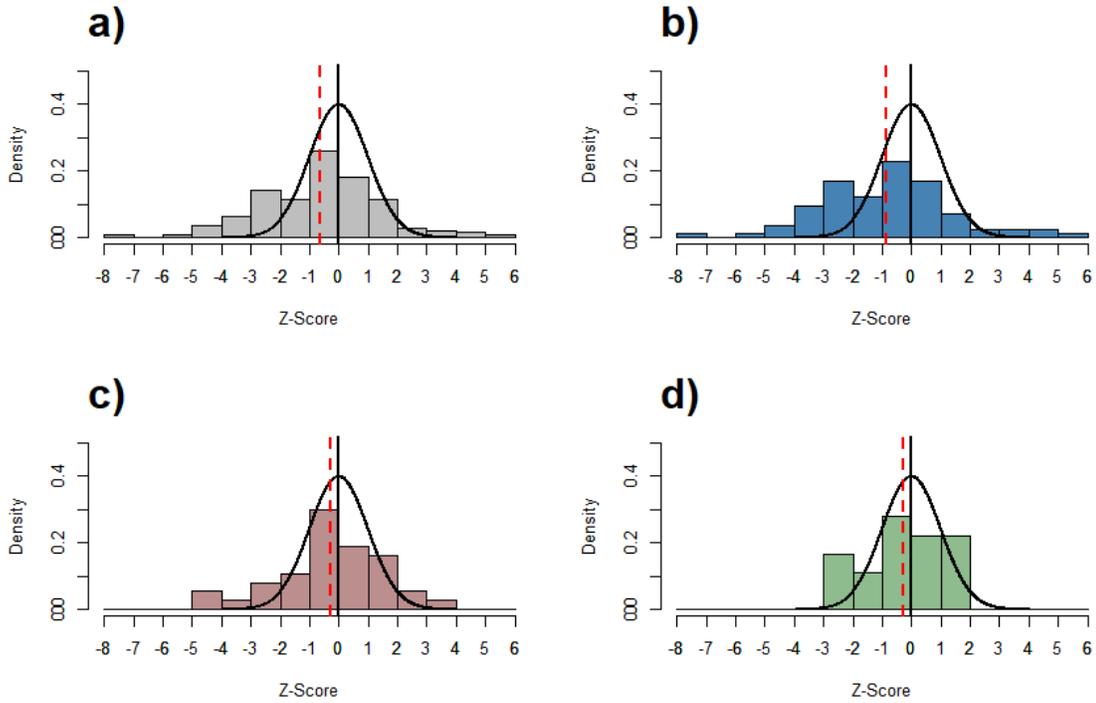
**Figure 5.14.** LOESS method: Plot of diaphyseal length of the femur on the mean estimated chronological. Subadults from Chatham County, Georgia are represented by the dark gray growth curve, those at Freedman’s are represented by the blue, and those at Cedar by the red. The open circles and 10-90% limits represent the Maresh data set.

Next, mean estimated stature is plotted against the WHO reference curve to determine stunting. Any individual that falls below the lower red curve (-2 standard deviations) is considered stunted by the WHO standards. In Figure 5.15, Cedar Grove statures are represented by the triangle, Hunter by the square, and Freedman’s by the open circle. In total, only 36 out of the 139 subadults analyzed in this work fall below 2 standard deviations of the mean. That is, approximately 26% of the sample are considered stunted by the WHO standard. Of the 36 individuals considered stunted, 32 of them (~89%) fall below the age of 6 – again reiterating the few individuals who are stunted tend to be during infancy and early childhood only. Moreover, included in this

plot are the average adult statures of individuals from each site and the modern average of European American and African American populations from the CDC (Fryar et al., 2016). Note, in no instance does adult stature fall below two standard deviations from the mean. Cedar Grove adults are nearly as tall as modern American populations, while those at Freedman's Cemetery and Chatham County cemeteries are slightly shorter. In general, the stunting amplified in the younger age range is not present in the older individuals, and adult stature appears to be similar to even modern American populations.



**Figure 5.15.** Plot of mean estimated stature by mean estimated age against the WHO growth reference curves. Subadults at Hunter Army Airfield are represented by the open squares, Cedar by open triangles, and Freedman’s by open circles. Median growth from the WHO is the gray curve,  $\pm 2$  standard deviations are the red curves, and  $\pm 3$  standard deviations are the blue curves. Inset is the infancy period from 0-3 years of age. Average adult height at Cedar Grove is the closed triangle, Freedman’s is the closed circle, and Chatham County is the closed square. Modern American populations of European Americans and African Americans are in the “+” and “X” respectively.



**Figure 5.16.** Histogram plot of the density of standardized stature at combined study sites as compared to the Box-Cox Normal Transformation. The solid black line is at 0, the red dashed line is at the group mean. A) represents the combined results, B) are individuals aged between 0-3, C) are individuals between 3-10, and D) is anyone over the age of 10.

A final comparison is that of Figure 5.16. Here, the standardized stature of historic African American growth is pooled across sites and compared against the standard normal of modern populations. Figure 5.16 is separated into four histograms: the pooled dataset of all subadults, 0-3 years old, 3-10 years old, and over the age of 10. Plots A-C are all near normal distributions with more dispersion as compared to the normal curve and a slight left skew. However, the mean value of each sample (red-dashed line) varies between 0 and -1 – indicative of a sample smaller in stature, but not stunted as compared to the WHO reference sample. Therefore, historic African American stature in

three sites from the American South follows a near normal distribution with a slight left skew – not unlike that seen in modern global subadult populations.

## **6. DISCUSSION**

Given the increased stress on African American populations extending from the antebellum period up through the 20<sup>th</sup> Century, studies of childhood growth and development should indicate groups falling below the contemporaneous length-for-age averages as compared to historic European populations, and far below the modern standard as developed by the WHO. The results of these analyses indicate episodes of growth stunting early in development, followed by a stabilization of growth shortly after the weaning period and continuing up through adolescence. In some cases, growth stunting led to catch-up growth that exceeded the growth trajectory of modern comparative populations. Regardless, a comparison of estimated stature across all sites suggests only a marginally stunted stature profile not significantly dissimilar to that of the World Health Organization's Multicenter Growth Reference Study.

### **6.1 The Demographic Context of Historic African American Health**

The period under study encompasses both the demographic and epidemiological transition in populations from the United States. The demographic transition represents a decline in fertility, mortality, and population growth following the Industrial Revolution (Gage, 2005). The epidemiological transition however, coincides with this shift in population demography, and leads to a decline in infectious disease in favor of degenerative diseases (Saunders and Barrans, 1999; Zuckerman, 2014). However, global populations experienced this transition at separate intervals based on socioeconomic status, ancestry, gender, geography, employment, etc. (de la Cova, 2014).

As it relates to African American populations of the time, there is a documented decrease in African American fertility nationwide (Rose, 1985). Yet, all study sites

suggest estimates of high birthrates supported by census data for Texas, Arkansas, and Georgia (Davidson et al., 2002; Matternes et al., 2010). Couple this with elevated levels of childhood mortality (Preston and Haines, 1991; Gutman and Fliess, 1996), and the death sample is inherently skewed toward the left due to the increased number of subadults. Compared across all three study sites, the age distribution suggests high fertility and high infant mortality prior to the turn of the century, with decreasing numbers through time – most likely the result of the demographic transition because of improving living conditions for African American populations (specifically urban populations) (Davidson et al., 2002). In relation to the results presented here, the demographic numbers suggest that general patterns described above are similar between study sites and the documented census numbers. Thus, growth results presented here are more likely than not representative of the general African American populace.

## **6.2 The Effect of African American Health on Growth and Development**

An exhaustive list of studies is dedicated to the analysis of African American health from the late 18<sup>th</sup> to the mid-19<sup>th</sup> Century (for a review of sites see Steckel and Rose, 2002, Rankin-Hill, 1997; Blakey and Rankin-Hill, 2009). In general, both freed African Americans in the north and enslaved individuals in the south experienced high-levels of stress as compared to their European American counterparts. The Freed individuals fared slightly better than those that were enslaved, albeit increased urbanization led to differences seen in the magnitude and types of diseases present (Davidson et al., 2002). African American health at the onset of the 20<sup>th</sup> Century is grounded in the turbulence of forced segregation, structural inequality, and racial violence at all stages of development.

In general, developmental stress events occurred throughout African American populations. Comparison of linear enamel hypoplasia suggests a greater prevalence of defects amongst African American populations as compared to both European and Native American populations (Rose, 1985; Condon et al., 1998; Davidson et al., 2002; Matternes et al, 2010). Variation in anemia rates reflects climatic differences, parasitic exposure, and nutritional intake. African Americans in Texas, Georgia, and Arkansas did experience bouts of cribra orbitalia and porotic hyperostosis at a decreased rate as compared to prehistoric Native American populations from the Southwest. Yet, the rates were larger as compared to northern European American populations at Monroe County poorhouse and Belleville, Ontario (Saunders et al., 2002; Higgins et al., 2002). Infectious diseases such as congenital syphilis and tuberculosis were present in all sites with increased frequency in urban environments. However, this is not uncommon in global populations, as Ortner (2003) and the numerous studies in Steckel and Rose's (2002) volume suggest that syphilis was endemic in several populations up until the discovery of antibiotics. Lastly, both degenerative joint disease and skeletal trauma are present in all sites, suggesting arduous labor throughout, yet not unlike that measured in European populations from the time.

Health amongst historic African Americans across the southeast is characterized by increased mortality, increased bouts of developmental stress, and higher incidences of infectious disease – contrary to the ongoing epidemiological transition. Certainly, an argument could be made for immense social and health inequality amongst these populations. For example, De La Cova (2008, 2010) documents significant differences between the frequency of syphilis and tuberculosis in African American and European

American skeletal samples from various anatomical collections. Moreover, this inequality is exacerbated by increasingly squalid conditions because of urbanization, little access to healthcare, and poor sanitation. Klaus (2012) suggests children would be the most biologically sensitive to these effects of inequality and structural violence.

The skeletal and historical evidence suggests a childhood filled with stress should lead to increased growth stunting (Y'Ednak, 1976; Jantz and Owsley, 1984; Clark et al., 1986; Saunders and Hoppa, 1993; Ribot and Roberts, 1996; Eveleth and Tanner, 1991; Armelagos et al., 2009; Schillaci et al., 2011). Subadults in Georgia, Texas, and Arkansas do not exhibit the level of stunting throughout the growth period as would be expected given the paleopathological and historical evidence of African American livelihoods. Given the delicate relationship between maternal health and childhood outcomes (Gowland, 2015), the stunting exhibited early in development is most likely the combined result of proximate infectious disease, nutritional deficiency, and inter-generational inertia begun while the mother herself was developing (Barker, 2012).

Moreover, previous studies in growth and development suggest the point of weaning is a delicate period for infants, as the nutrient-load transitions from breastmilk, to complimentary feeding with nonmilk substances (Victoria et al., 1989; Black et al., 2008; Schillaci et al., 2011). In general, the age at weaning declines through time for all populations, although African Americans from the time period tended to breastfeed longer compared to European Americans (Corruccini et al., 1985). At a plantation in Barbados, African American mothers tended to wean their children at approximately 2-3 years of age (Corruccini et al., 1985). Therefore, during the period of weaning infectious disease may combine with increased chronic conditions such as anemia, diarrheal

diseases, and the past life experiences of the mother (e.g. enslavement), to lead to growth stunting that ends shortly after the weaning period, once the child adapts to solid foods and is no longer subject to environmental cues from the mother (Gowland, 2015; Kuzawa and Quinn, 2009). Combined, the stunting exhibited immediately after birth, up through the period of weaning is most likely the result of the entangled epigenetic and environmental landscape.

In all cases, length and stature by the end of the developmental period are similar (slightly taller in the case of Cedar Grove) to growth in the modern comparative datasets. Yet, given the paleopathological and historical data, stress most likely consumes the entire developmental lifespan of these groups. This begs the question, given the immense environmental constraint suggested by previous studies, what explains the growth seen at Freedman's, Cedar Grove, and Chatham County, Georgia following the initial bout of stunting after birth?

### **6.3 Diachronic Trends in African American Growth**

Historical trends in growth reveal geographic and temporal variability in the magnitude and prevalence of stunting in African American populations. Little variability in male terminal adult stature exists between enslaved African Americans from the 18<sup>th</sup> to the 20<sup>th</sup> Century. Whereas, African American females from the 18<sup>th</sup> and 20<sup>th</sup> Centuries are slightly taller as compared to those enslaved individuals in the 19<sup>th</sup> century (Kelley and Angel, 1987). Higman (1979) and Margo and Steckel (1982) both generalize that stature is improving in the United States as compared to West Africans and enslaved individuals on sugar plantations in the Caribbean. Rathbun (1987) equally posits that enslaved adult individuals on South Carolina plantations are within the *normal* range of

stature. General overall trends in adult African American stature are as follows: 1) the height of adult slaves in any context is consistent through time and space, 2) By the standards of the time, African Americans were quite tall, 3) the nutritional status of African Americans declines throughout the antebellum period, and 4) rural populations tended to be taller than urban populations (Steckel, 1979; Margo and Steckel, 1982; Komlos, 2014; Komlos and Coclanis, 1997; Komlos, 1998; Bodenhorn, 1999; Sunder, 2004).

A far more interesting picture emerges when subadult growth and/or height is contrasted with terminal adult stature. By and large, enslaved African American children and those born free during Reconstruction are severely undernourished and significantly shorter compared to their contemporaneous European counterparts and modern populations (Kelley and Angel, 1987; Steckel, 1986; Goode-Null et al., 2009). Komlos (2014) furthers this notion and suggests childhood stature generally fell between the first and tenth centile [negative one and two standard deviations] of modern standards. Yet, following initial bouts of malnutrition, there is a documented period of catch-up growth that often led to adult stature measured at or near the mean of contemporaneous growth standards (Komlos, 2014; Carson, 2008; Margo and Steckel, 1982; Komlos and Coclanis, 1997; Komlos, 1998; Bodenhorn, 1999). Researchers attribute this increase to children entering the labor force (enslaved or otherwise) and upon the increase of overall nutrition at the turn of the 20<sup>th</sup> Century (Carson, 2008).

Measurements of growth and health amongst African American populations are not abnormal when compared to the larger American populace. There is a marked decline in both height and nutritional status in Europeans and African Americans during the

antebellum years (Komlos, 2014). Much of this is attributed to urbanization, industrialization, a rise in food prices, and the inability for all American populations to find sustainable nutrition – particularly in urban areas. This may explain the height differences seen between rural and urban populations, as rural populations have the ability to buffer these effects with self-sustainable agriculture. This documented trough in femoral length and stature is followed by a recovery and increase in stature beginning during reconstruction and extending up through the present day (Meadows Jantz and Jantz, 1999). There are subtle differences in the velocity and timing of this change between African Americans and European American populations, but these were found to not be statistically significant by Meadows Jantz and Jantz (1999). Thus, while previous portions of this study have shown the immense developmental health issues experienced by African American populations, they are not markedly different in adolescent growth and adult height when compared with European-American populations.

Figure 6.1 illustrates the similarities in adult height between each study site and several additional historic skeletal assemblages. These sites encompass a period extending antebellum through the early 20<sup>th</sup> Century. Remley Plantation (1840-1870) is an enslaved African American assemblage from South Carolina (Rathbun and Steckel, 2002). Monroe County poorhouse (1826-1863) is an almshouse assemblage of impoverished European Americans from Rochester, New York (Higgins et al., 2002). Golden Gate Cemetery (1868-1906) is an urban poor assemblage of European Americans from San Francisco, California (Buzon et al., 2005). Lastly, Belleville Cemetery (1821-1874) is a middle-class Canadian European skeletal assemblage from southern Ontario (Saunders et al., 1993; Saunders et al., 2002). Combined, the boxplots in Figure 6.1 show

that individuals from Dallas, Cedar Grove, and Chatham County all grow as tall or taller than contemporaneous (or slightly earlier) European American populations. Moreover, the secular trend described previously in American populations is visible in both ancestral groups. There is an approximately six centimeters increase in African American stature from antebellum (Remley Plantation) to post-1900 (Cedar Grove). Lastly, there is an approximately five centimeters increase in European American stature over the same period (Monroe County to Golden Gate).

Contextually, Reconstruction-era and early 20<sup>th</sup> Century subadult African American populations in Texas, Georgia, and Arkansas are neither dissimilar to historic African Americans nor to contemporaneous European American populations. All show significant stunting at younger ages, exacerbated by infectious disease, infant mortality, and maternal health. However, if an individual survives this tumultuous period, catch-up growth leads to a stabilization of growth and stature that in some cases expands beyond average European American growth. Without a doubt, the conditions in which these populations developed were far worse than their European counterparts – infant mortality is higher, structural inequality led to an inability to access basic resources, and racial violence pervaded American society. Yet, after an initial period of growth disruption, growth does not show considerable evidence of stunting throughout the remainder of the developmental period.

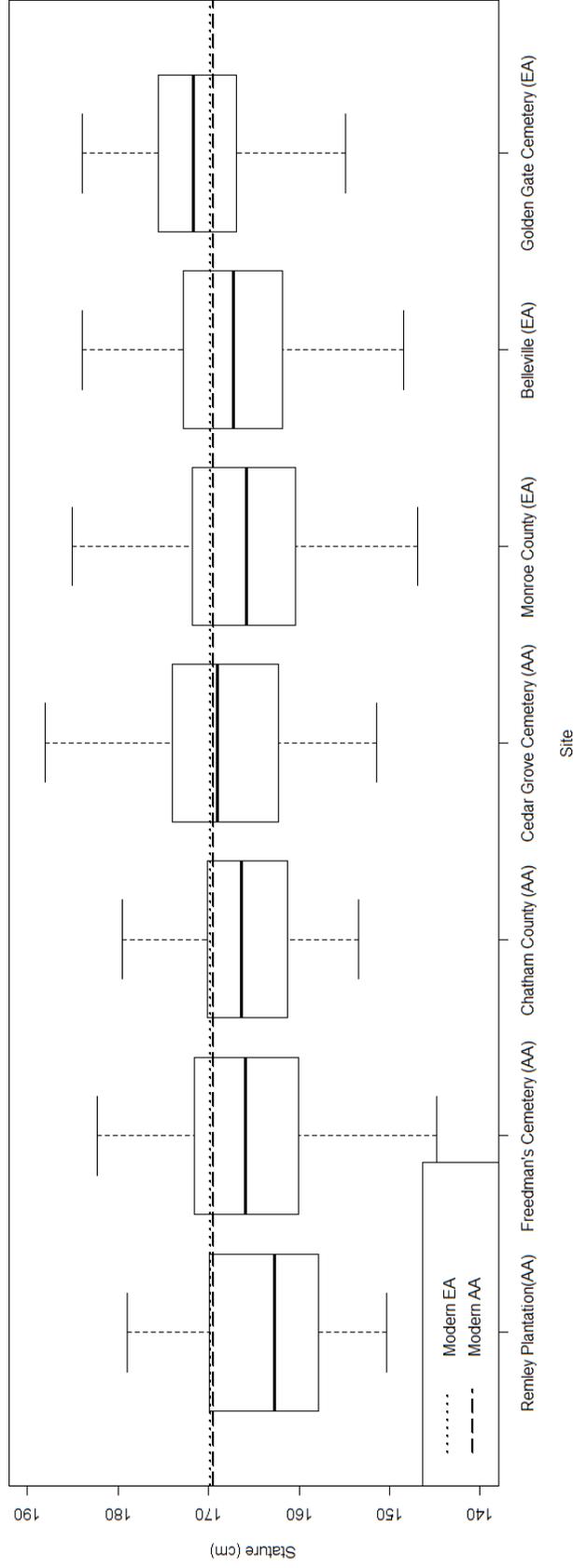


Figure 6.1. Histograms showing median stature at various historic skeletal assemblages throughout the United States and Canada., Remley Plantation: 1840-1870, Freedman's: 1869-1907, Chatham County: 1870-1916, Cedar Grove: 1881-1927, Monroe County: 1826-1863, Belleville: 1821-1874, Golden Gate: 1868-1906. The dashed lines represent the average modern African American and European American stature. The left side of the plot are the four described African American communities, while the right are the three described European American communities.

## 6.4 Potential and Limiting Factors of African American Growth

Quantitative genetic traits such as those modelled after the growth of osseous tissue are shown to be highly heritable. In some cases, this heritability ( $h^2$ ) could reach as high as 80% (Silventoinen, 2003; Duren et al., 2013; Bernstein and Dufour, 2017). In general, African Americans tend to have longer bones as compared to European American populations (Meadows Jantz and Jantz, 1999). Moreover, Garn and colleagues (1973) show African American children often are taller than their European American counterparts, while Steckel (1986) suggests slight differences existed in the 19<sup>th</sup> Century between enslaved and freed African Americans and European Americans. Given the circumstances in which these groups developed, it is quite extraordinary that variables like femoral growth do not lag significantly behind. These results, combined with others, show increased genetic control exhibited over these quantitative traits, even with adverse environments suspected to exert a negative influence.

An even greater issue to decouple is the role of genetic and/or environmental factors that lead to the catch-up growth exhibited in this study and beyond. Described as the “African Enigma” in Komlos and Kelly’s (2016) volume, is there a means to explain tall African American stature given the poor growth environments? Certainly, the genetic data described above would suggest that African Americans should show a preponderance toward a taller adult stature given optimal growth conditions (Moradi and Hirvonen, 2016). To achieve adult stature, historic African American populations underwent catch-up growth that in some cases led to rapid growth acceleration beyond the average of modern comparative populations. This process is documented in populations throughout the United States (see Chapter 6.3).

The mechanisms behind such catch-up growth are equally subject to intense scrutiny. There is little evidence to pinpoint an exact genetic cause of catch-up growth. While there is a case to be made about increased hormonal interaction (e.g. insulin-like growth factor; Mielke et al., 2011; Marino et al, 2008), environmental variables tend to show the greatest correlation with catch-up growth. Steckel (1986, 2000) shows that catch-up growth occurred when enslaved individuals came of working age and diet increased to account for labor productivity. During Reconstruction and after the 20<sup>th</sup> Century, sanitation in African American communities began to slowly increase, health care became more accessible, and access to a greater caloric intake led to an increasingly better growth environment as individuals aged (Davidson et al., 2002). Perhaps then, African American growth and development is less about the initial stunting event, and more about the resiliency of the body to adapt and/or develop given less than optimal conditions (Martin et al., 2013).

### **6.5 Life Before Death: Social Buffering in a Historic African American Context**

Freedom, both pre- and post-Emancipation translated into an ability to explore and develop a unique social identity for African American communities. Freed communities in Dallas, Savannah, and beyond began to develop independent of the greater urban area (Davidson, 2004; Matternes et al., 2010; Davidson et al., 2002). African American communities began to advance and perpetuate their own institutions such as economic ventures, the African American church community, political involvement, etc. (Perdue, 1971). African American health professionals became more prominent beginning in the 1890s (Davidson et al., 2002), while the first private African American medical facility opened in Savannah in 1893 (Perdue, 1971). Moreover,

universities across the country began to appear in the Tuskegee-Hampton model allowing for better access to higher education (Glasrud and Smallwood, 2007). African American politicians began to speak out, reform was slow, but even still, African American communities sought a means to cope with the structural inequalities that pervaded American society at the turn of the century.

However, these opportunities were not afforded to all African American communities. There is a stark difference between those in urban compared to rural areas. Oftentimes, rural communities were at the mercy of the landowner and/or environmental perturbations that lead to an unpredictable agricultural market (Davidson et al., 2002). Perhaps the best coping mechanism for many of these communities was the Church, which permeated the very fabric of life in some of these rural communities (Rose, 1985; Wilson, 2005). Regardless of the means, the institutional structure of communities in Dallas, Savannah, and Cedar Grove allowed for a certain degree of cultural buffering to the outside stressors that acted upon African American health. While conditions associated with crowding, malnutrition, and arduous labor may occur in high frequencies in each of these populations, the cultural institutions in place certainly aided in the abatement of consequences in all but the most frail. The robustness of early African American social institutions and the resilience to which human growth seems to respond to initial disruption may help to explain the pattern of growth seen amongst these sites and beyond.

## **6.6 Historic African American Growth in Context**

A final portion of this analysis is a broad glimpse into what (if any) role the study of historic growth may play in the study of modern human growth variation, especially as

it relates to the broad theoretical framework described in the introduction. It is generally accepted that populations of disparate ethnic backgrounds have the same genetic potential throughout the period of growth and development. That is, populations under the same nutrition and health conditions attain similar mean heights (Bhandari et al., 2002; Habicht et al., 1974; WHO MGRS and de Onis, 2006). As discussed above, positive secular trends in adult stature exist in both African American and European American populations (Meadows Jantz and Jantz, 1999). Thus, even while growth is stunted during early childhood as described here in the early 20<sup>th</sup> Century, there is still an overall net increase in terminal adult stature. A similar paradox is seen in modern populations from Africa. In general, children grow up during a severe period of developmental stress, but are oftentimes quite tall in adulthood (Deaton, 2007; Moradi and Hirvonen, 2016). Perhaps these trends can equally be attributed to catch-up growth following the weaning period. Regardless, the resiliency shown in the human growth described in historic African American communities may provide an additional explanation to contextualize other developmental stress markers and their impact on both proximate and long-term skeletal development and physiological health.

Current trends in biological anthropology have led to a push for a broader theory of bioarcheology (Knudson and Stojanowski, 2008). Much of this work is placed within a broad description of skeletal health and biological stress (Goodman and Martin, 2002), while also including a description of skeletal morbidity and its relationship to social class (Larsen, 1999). In turn, recent advances in the field have led to a contextualization of poor skeletal health (stunted growth being an example) in relationship to broader health and/or social disparity as a result of structural inequality acting to marginalize certain

populations (Klaus, 2012; Goodman and Leatherman, 1998). Moreover, this same theorization has led to an extension of the Developmental Origins of Health and Disease hypothesis (DOHaD) (Armstrong et al., 2009) into the lexicon of bioarchaeology, while not completely addressing the heterogeneity of certain skeletal disease markers or the agency to which marginalized populations such as historic African American communities take to alleviate the pressures of inequality, particularly as it relates to proximate skeletal response as opposed to hypothesized adult health issues.

This thesis argues that these broad theories within bioarchaeology may not provide the best means to contextualize the types of patterns exhibited by the current results. To be clear, structural inequality is pervasive throughout the 18<sup>th</sup> to 20<sup>th</sup> centuries and extends well into the present. By Klaus' (2012) definition of structural inequality in bioarchaeological populations, communities in Cedar Grove, Dallas, and Savannah all experience marginalization in the form of differential access to resources, racism, violence, urban planning, etc. Moreover, levels of infant mortality, infectious disease prevalence, and increased levels of skeletal stress, clearly show a divide between historic European American and African American populations (Steckel and Rose, 2002). While an examination of growth during the early developmental years may suggest significant stunting and therefore, reinforce notions of bioarchaeological evidence for structural violence, achieved adult stature would seem to contradict these results.

Again, it must be reiterated that this discussion is not to dismiss the tangible implications of structural violence in the past and present. These have been documented repeatedly in places such as historic Peru (Klaus, 2012), modern Haiti (Farmer, 2006), and in modern Latin American countries (Beatrice and Soler, 2016). Instead, the results

here are meant to show that a skeletal analysis of childhood growth of a marginalized population must be contextualized beyond the proximate skeletal morbidity markers, frequency statistics, and their relationship to predicted adult health and mortality. For example, Eveleth and Tanner's (1991) moniker, a child's growth rate is perhaps the best means to gauge a population's health and nutritional status. Which part of the growth curve? Is infancy more important, or is adolescence? If one were to look at ages 0-5 in this sample, they may deduce that African American populations are severely stressed. However, if one were to analyze later childhood and adolescence, growth may even supersede the reference population. Even if these growth results were combined with the paleopathological results of these studies (Condon et al., 1998; Rose, 1985; Matternes et al., 2010), a similar picture emerges. Stress markers abound in childhood and adult examples, yet growth – a variable oftentimes used alone to classify a population as unhealthy – eventually normalizes at or near the modern average in most individuals.

This thesis advocates for a broader research strategy in the analysis of subadult human skeletal growth – one that encompasses genetic variation, historical context, human agency, resiliency, and skeletal morbidity considering environmental pressures. As discussed in Moradi and Hirvonen (2016), the damage during early childhood as evidenced by stunting is partly reversed during later childhood and adolescence. Perhaps such growth masks the true health differences experienced by disparate populations, or perhaps even the crucial period of growth studies should be the window that encompasses the catch-up growth as opposed to that before, in which initial stunting occurred (Moradi and Hirvonen, 2016). Either way, this study must only be read in terms of interpreting adult and population-level health using skeletal remains. Eveleth and Tanner's (1991)

seminal work, Well's (2017), among others, all demonstrate the worldwide variability of growth in relationship to health and genetics of modern, living populations. Thus, while this thesis proposes caution when using only stature and/or growth to analyze the skeletal remains of past populations, it does not wish to delve into the utility of skeletal remains in answering questions of disease-risk as it relates to childhood health. Suffice it say, childhood growth and development of historic African American populations exhibits growth stunting to a degree that suggests significant childhood disease risk is independent of terminal adult stature.

### **6.7 Resilience Theory in Bioarchaeology**

The study of populations in transition, such as Historic African Americans at the turn of the 20<sup>th</sup> Century, affords bioarchaeologists the opportunity to investigate the adaptive capability of the physical human body to both environmental and genetic constraints during times of increased hardship. Often, bioarchaeological research questions seek to address the nexus of stress and disease and their relationship to proximate health, adult outcomes, and the resulting consequences to the greater community (e.g. Klaus, 2014; Gowland, 2015; Goodman and Leatherman, 1998). In effect, many of these studies treat any correlative relationship between stress, mortality, and morbidity as evidence supporting the developmental origins of health. Moreover, many of these studies operate under the presumption that a linear relationship exists between stressor and outcome – that is, a certain stressor must equate to a certain outcome (see Armelagos et al, 2009). While research within human biology does show a connection between early life insult and adult health (see Barker and Osmond, 1986; Barker et al., 1989), perhaps a different approach could be taken to address physiological

change and/or transformation at smaller time scales such as that seen throughout the developmental window of human subadults. Reitsema and colleagues (2017) suggests large-scale and/or long term causal relationships such as that demonstrated between childhood health and adult outcomes may mask events represented by small-scale change in human physiology and behavior. In other words, while previous studies have sought to interpret growth regarding the detriment to later adult health, this thesis argues that an interpretative framework that encompasses how and why the human body responds to initial episodes of stunting is an equally valuable avenue of research.

At the core, this presupposition could be passed off as developmental plasticity. That is, the human body's ability to mold or transform its phenotype in response to environmental pressure (Agarwal, 2016). Catch-up growth is often categorized as a form of developmental plasticity (Said-Mohamed et al., 2017), which may in fact reflect the significant canalization of human growth, particularly later in the developmental period (Cameron, 2006). Recent theoretical works ground catch-up growth and notions of plasticity firmly within a life history theory model (Tanner, 1962; Cameron, 2006; Said-Mohamed, 2017). While important, life history theory as it currently stands is firmly grounded within a neo-Darwinian model that revolves around the optimization of fitness, reproduction, and survival (Bogin et al., 2007). Further, other studies subsumed under the broad umbrella of life course theory include “developmental programming” and the “predictive adaptive response.” Developmental programming suggests growth stunting is the result of maladaptive effects that increase later disease risk (Barker et al., 1989), while the predictive adaptive response suggests that small size at or near birth is the result of poor fetal development and if ameliorated, then “over growth” can occur (Gluckman

and Hanson, 2005). Regardless, each of the above theoretical positions are difficult to directly apply to skeletal data due to its cross-sectional nature, and again a short-sighted neo-Darwinian vision that may not account for individual human agency, the ecological niche within which it develops, and the ability of the human skeleton to transform based on proximate stressors independent of long-term adaptation or evolutionary pressure (Fuentes, 2016).

This work argues that a more compelling analysis should be undertaken in light of ecological resilience theory. Resilience is defined as “the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks” (Walker et al., 2004). In the case of human growth, the human body functions like an ecological system – it is acted upon by physiological and environmental barriers and through such, molds and transforms based on the means in which these barriers act within the system. In this system, adaptability is pushed beyond a neo-Darwinian definition and instead represents the capacity of these barriers described above to influence the outcome – “normal” growth. When the existing system is no longer able to maintain equilibrium (homeostasis in the human body), then it transforms, while essentially maintaining the same function (Walker et al., 2004). The compatibility of such a model within human growth is as follows: the environment introduces some stressor that disrupts homeostasis and the human growth trajectory. Resilience is the body’s ability to combat such stressor without change, or total cessation of growth and/or death in human populations. The human body’s reaction to such a stressor, such as stunting, represents the adaptive mechanism ensuring resilience occurs – like the predictive adaptive response model described above. Lastly, once the stressor is

removed, growth can return to normal, and due to the documented canalization of growth later in the developmental period (Cameron, 2006), is able to begin to catch-up to the initial predicted stature imprinted within the phenotype of individuals.

Two things underlie the above description. First, regardless of the critique of strict neo-Darwinian interpretations, growth is inherently a biological process and therefore, is part of a long-term suite of evolutionary pressures that define why, when, and how the developmental period occurs (see Stinson, 2000). Second, in an ecological niche, the human body is not a “system” that exists independent of outside influence. On the contrary, a multitude of separate socioecological systems act on the human body in the form of cultural institutions, climatic variation, labor practices, familial relationships, dietary habits, etc. (Reitsema et al., 2017). The reason this thesis proposes the use of socioecological resilience theory as opposed to developmental plasticity within a life history theory is as follows: 1) It does not apply linear causality to the system such as that introduced through current adaptive models, 2) The feedback loop includes a component of human agency and ecological variables built into the overall framework, and 3) resilience does not have to occur through deep time, it could simply be represented by bouts of stunting and catch-up over roughly an 18-year (developmental) period.

On the other hand, resilience is not incompatible with current models in bioarchaeology regarding stress, health, and skeletal response (Temple, 2014; Goodman et al., 1988; Thomas et al., 1977). In fact, it is more likely than not that notions of resilience fit into a greater model describing the overall trajectory of the human experience. In a way, it is a more osteobiographical approach with an ability to account for individual variability in height not as some long-term adaptive (or maladaptive) trend,

but instead the result of nested ecologies both within and outside the human body (Stodder and Palkovich, 2012). This does not diminish the possibility that adult health is inextricably linked to childhood development, but instead personifies the need for a more holistic biological anthropology that accounts for human agency, genetic variation, historical context, resilience, and the socioecological systems within which human populations develop.

Therefore, this work proposes the utility of an ecological-oriented resiliency theory in the study of historic African American growth and development. Furthering the model described in Walker et al., (2004) and Reitsema et al., (2017), such a framework takes individual stunting and limits the resulting skeletal response through genetic variation, physiological maintenance, historical context, human agency, and cultural buffering. Instead of expending discussion attempting to explain spurious correlations in morbidity and mortality in the past via adaptation or lack thereof, resilience theory broadens the discourse to one that encompasses genetic and cultural mechanisms that act on smaller time scales, while less concerned about causal maladaptive relationships. This is not to say research designs associated with the longer-term implications of DOHaD, stress, disease, and frailty are deficient, but instead, they are limited in scope. As stated previously, bioarchaeological analyses should include a broad research design that not only addresses health and stress in the past, but also discusses individual human agency (whatever or however that agency is influenced) and the role in individual outcomes. The ability for young African American individuals to achieve near-modern growth given the tumultuous environment should be discussed in light of this achievement, and not in light of what may happen thirty years later. With both a combination of socioecological

resilience and the adaptive paradigm of life course theory, African American growth is the result of small-scale skeletal responses due to internal and external structures that serve to buffer the human body until genetic growth potential is achieved. The explicit use of resilience in this thesis should serve to illuminate the potential in studying not only the linkage between life course events, but also, individual skeletal bodies in light of genetic and/or cultural mechanisms that mediate skeletal response to adversity and the patterning of adversity across populations. This is especially important when analyzing childhood in the past: a bounded life course period with both immense dependence on outside cultural influence and undeniable lifetime consequences.

## **6.8 Limitations**

As with any study of skeletal remains, numerous limitations may prevent clear interpretation of the results. The most glaring limitation present in any study of skeletal growth is an inability to provide a known age. Such issues associated with error in age estimation have been discussed at length in this thesis and beyond (see Konigsberg and Holman, 1999). There is little research done on the ability to correct for such error. This thesis dealt with these issues through growth curve modelling that led to a “cone” of estimated growth as opposed to a discrete curve/line. Estimation and analysis is exacerbated by sample sizes that are less than optimal when examining long-term trends. The samples here are small and skewed toward the younger end. While this is not unexpected given the high rates of infant mortality described in the samples, it would mean that perhaps the growth curves are equally skewed left (stunted) because of the lack of older children who may exhibit close to normal femoral lengths and stature. Equally, sex estimation of subadult remains is a contentious topic and little agreement exists

between the best means to even attempt such a task. For this reason, sex was not estimated here. As a result, all groups of study, including reference populations, present pooled averages of combined subadult growth. Therefore, it is likely these results fail to accurately present the minutiae of sex-specific growth variation, especially as it relates to differential effects of stress and stunting on long-term trends in growth (Meadows Jantz and Jantz, 1999).

Continuing from the discussion in Chapter 6.6, the use of skeletal remains lends to a whole suite of problems when examining population-level health based on the death assemblage. Given the influence of heterogeneity of frailty and selective mortality (Wood et al., 1992), it is difficult to pinpoint the relationship between the sample under study and those that lived well into adulthood. Put simply, the groups have died, making them by definition, the frailest individuals from each population. Perhaps growth is independent of any factor that leads to death, or alternatively, stunted growth and death are related to the same condition. While some studies have sought to relate growth to mortality (Clark et al., 1986; Armelagos et al., 2009), growth variables should only be used in conjunction with several others to analyze morbidity and not mortality alone (Klaus, 2014; Temple, 2014). Either way, Saunders and Hoppa (1993) conclude that while mortality bias is present in subadult populations, the effects are likely smaller than the bias introduced by the age and/or sex estimation.

The cross-sectional structure of skeletal growth studies in the past is subjective to intensive study. Konigsberg and Holman (1999), Tanner (1978), and Bogin (1988), all demonstrate that important periods of growth may go unobservable because of a single measurement as opposed to serial data of an individual throughout all the developmental

period. Regrettably, there is very little any researcher of skeletal biology can do to account for the lack of data. Perhaps more-robust statistical techniques including the use of Bayesian modelling based on known serial growth data is a fruitful place to begin (Konigsberg and Holman, 1999).

Lastly, the regrettable truth is that none of the femoral measurements and dental development scores were collected by the author. This lends to an inability in accounting for any measurement error accurately, and is especially present in the estimation of age using dental development scores. The author has sought to minimize this error through careful examination of the published age intervals and where necessary, correction and/or exclusion of data that may include significant error and hence, introduce more bias into the results.

## 7. CONCLUSIONS AND FUTURE DIRECTIONS

African American populations endured and combated enormous hardships in the period leading up to and immediately following the beginning of the 20<sup>th</sup> Century. Large-scale migration following Emancipation led to a redistribution of the African American populace in cities and counties nationwide. Regardless of geography or circumstance, these populations universally developed in areas with violent racism, unhealthy conditions, and oftentimes, a life filled with death and uncertainty. Yet, communities of African Americans from urban city blocks to rural farmsteads found a way to cope with increased levels of stress throughout childhood and beyond.

Stunting certainly existed in these populations – the results here speak to such. Yet, the more important message is that of resiliency. Given all that is stacked against these groups, growth and development seems to find a means to rebound following early insult. The cause of such rebound most likely being some combination of genetic, environmental, and social factors that act to mediate and buffer older children from increased stunting. This effect is not novel and is pervasive throughout the literature studying the history of African American anthropometry. Maybe then, broader research questions addressing skeletal growth should equally include a discussion about the ability of osseous tissue to reach genetic potential even in the face of increased stress. Instead of focusing on the adult health outcomes of skeletal insults (contentious and arguably difficult to prove beyond simple correlation), why not push for studies that equally address the agency of children and the cultural buffering that aids them in achieving their genetic growth potential.

Eveleth and Tanner (1990) are of course correct in their assessment of childhood growth. In fact, their results coupled with continued medical intervention by the WHO and CDC in developing countries serve to expand upon and push forward this notion of resilience in childhood growth and development. If the assumption is that increased nutrition to the mother and child will aid in achieving that target goal, regardless of the developmental environment, then perhaps historical African American populations are an early example of this protocol in action.

As for the future, childhood growth and development will and should continue to be a strategic focus for biological anthropologists and public health officials alike. The means in which global human populations cope, adapt, and thrive in even the harshest of conditions is indeed something to marvel at. While traditional analyses in bioarchaeology seek to include stunted growth as just another example of childhood stress, the nuance and tempo of the entire growth cycle may elucidate even greater patterns of resilience in the evolution of human growth. Life was not ideal for African Americans at the turn of the 20<sup>th</sup> Century – with stress, disease, and too often, the heavy burden of racism – yet, communities thrived, children grew, and the history of African American growth and development would come to represent the very resiliency that defines human biological variation and adaptation in an ever-changing world.

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