IF BONES COULD TALK:

Estimating sex from the glenoid cavity

By:

Chelsea McKenna

A Thesis submitted to

Saint Mary's University, Halifax, Nova Scotia

in Partial Fulfillment of the Requirements for

the Degree of Honours in Biology

March, 2017, Halifax, Nova Scotia

Approved: Dr. Michelle Patriquin
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ABSTRACT

The scapula, including the glenoid cavity has been used for the metric sex estimation of human remains. Studies have shown that using the glenoid cavity for sex estimation requires population specific data. There are currently no studies published using the glenoid cavity of Black American individuals. The objective of this project tests the accuracy of a Cretan discriminant function, created by Papaioannou et al. (2012) when applied to a Black American population. The maximum length (LGC) and maximum breadth (BGC) of the glenoid cavity was measured in 200 Black Americans (100 male, 100 female) from the Robert J. Terry Anatomical Skeletal Collection. The Cretan glenoid cavity discriminant functions were applied to these data to classify the individual as male or female. Upon comparison to the Cretan sample, 100% of female Black Americans were correctly classified, whereas only 69% of male Black Americans were correctly classified. This result indicates that the Papaioannou et al. (2012) discriminant functions could not be used to accurately estimate sex in the Black American sample. To further clarify variation of the glenoid cavity between populations, the Black American descriptive statistics for LGC and BGC were compared to those of contemporary Italians, White Americans, Greeks, Mexicans, Chileans and Guatemalans for each of females and males. Black Americans were statistically different from both sexes in Guatemalans, White Americans and Greeks and female Black Americans and Mexicans exhibited statistical difference. Therefore, for accurate sex estimation using the glenoid cavity in Black Americans, population-specific discriminant functions are necessary.

April 21, 2017

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CHAPTER 1: INTRODUCTION

Creating a biological profile from human skeletal remains helps investigators to identify an individual, which is helpful for forensic and archaeological studies. Biological profiles include information pertaining to the estimation of ancestry, age, sex and stature of an unknown individual. When creating a biological profile, estimating sex is vital as it is required for estimating age and stature from unknown human remains (Stewart 1979, Scheuer & Black 2004). The most accurate way to estimate sex from human remains is through DNA analysis. However, this may not be a viable option if the DNA is degraded or the costs of genotyping are prohibitive (i.e. in developing or under-developed nations) (Lees et al. 2009). Macroscopic (i.e. morphological and metric) methods employed by forensic anthropologists are a valuable alternative as they are less costly and easily accessible. Many bones of the human skeleton exhibit sexual dimorphism (Spradley & Jantz 2011, Tise et al. 2013). This sexual dimorphism in human remains has been invaluable in accurately identifying commingled human remains following mass disasters (Morgan et al. 2006).

1.1 How is sex macroscopically estimated from human remains?

The creation of a biological profile is a vital component of a forensic anthropological analysis. There are two ways of estimating sex from human remains: morphological methods and metric methods. Morphological methods are performed by visually analysing the remains to determine the degree of expression of sex-specific bone characteristics. The accuracy of these visual observations is dependent on the experience of the observer (Stewart 1979). A more objective way of estimating sex from human remains is through metric methods. Metric methods require clearly defined landmarks or

standardized measurements obtained through the use of precise instruments (i.e. sliding calipers and osteometric boards), and are analyzed with statistical software (Stewart 1979). The use of measuring instruments and computational methods decreases human error in calculating variables required to estimate sex. It has traditionally been thought that the pelvis is the best indicator of sex (Phenice 1969, Patriquin et al. 2005), followed by the skull (Spradley & Jantz 2011). Today, almost all bones of the skeleton have been shown to be accurate estimators of sex and recent research shows that post-cranial elements are often more accurate than methods using the skull (Spradley & Jantz 2011, Tise et al. 2013).

1.1.1 Morphological methods of sex estimation

Morphological sex estimation from the skull relies on the visual analysis of observations related to overall shape and size of cranial and mandibular features. Males, overall, have larger, more rugged and robust skulls in comparison to females, who exhibit small, gracile and smooth features (Christensen et al. 2014). These morphological methods can exhibit high degrees of accuracy using certain features, from 71.4% to 100% across various populations from Africa, Asia, Europe and North America (Konigsberg & Hens 1998, Đurić et al. 2005, Norén et al. 2005, Williams & Rogers 2006, Walker 2008, Bigoni et al. 2010, Luo et al. 2013). However, inter-observer error rates are observed to be relatively high as these methods depend heavily on the experience of the observer (Stewart 1979, Konigsberg & Hens 1998, Williams & Rogers 2006).

Morphological evaluation of the post-cranial skeleton show varying degrees of sexual dimorphism. This sexual dimorphism is restricted to the degree of expression of a feature on the bone and sex estimation accuracy rates vary depending on the bone that is

being examined (Christensen et al. 2014). Many populations have been studied using morphological methods to estimate sex from the post-cranial skeleton with overall accuracy rates of 88.9% to 96.6% (Hrdlička 1942, Finnegan 1976, Rogers et al. 2000, Bruzek 2002, Patriquin et al. 2003, Mahfouz et al. 2007, Scholtz et al. 2010, Vance et al. 2011, Klales et al. 2012).

1.1.2 Metric methods of sex estimation

Metric sex estimation from the skull requires measuring maximum and minimum dimensions or measuring based on osteological landmarks to quantify variations in size and shape between male and female skulls (Christensen et al. 2014). Metric methods of sex estimation from the skull show accuracy rates of 53.4% to 100% (Giles & Elliot 1963, Kajanoja 1966, Holland 1986, Song et al. 1992, Steyn & İşcan 1998, Patil & Mody 2005, Kemkes & Gőbel 2006, Dayal et al. 2008, Gapert et al. 2009, Spradley & Jantz 2011, Thapar et al. 2011, Babu et al. 2012, Saini et al. 2012, Ogawa et al. 2013). Metric sex estimation from the teeth exhibits accuracy rates of 61% to 100% (Vodanović et al. 2007, Tharpar et al. 2011, Macaluso Jr. 2011, Peckmann et al. 2015).

Sex has been estimated using metric measurements from almost all bony elements of the human skeleton (Spradley & Jantz 2011, Tise et al. 2013). Studies of many post-cranial bones find that males generally have larger bones than females (Christensen et al. 2014). Many samples from varying populations have been utilized to develop population specific metric sex estimation methods from the postcranial skeleton. The accuracy rates of these studies range from 60% to 95.7% (Marino 1995, Mall et al. 2001, Frutos 2002, Murphy 2002, Bidmos & Dayal 2003, Bidmos & Dayal 2004, Özer et al. 2006, Gualdi-Russo 2007, Steyn & İşcan 2008, Dabbs & Moore-Jansen 2009, Gonzalez et al. 2009,

Dabbs 2010, Macaluso Jr. 2010, Macaluso Jr. 2011, Mastrangelo et al. 2011, Spradley & Jantz 2011, DiMichele & Spradley 2012, Franklin et al. 2012, Papaioannou et al. 2012, Ahmed 2013, Bell 2013, Gama et al. 2014, Garcia-Parra et al. 2014, Králik et al. 2014, Kranioti & Apostol 2014, Mahakkanukrauh et al. 2014, Spradley et al. 2015, Peckmann et al. 2015, Curate et al. 2016, Hudson et al. 2016, Moore et al. 2016, Peckmann et al. 2016, Torimitsu et al. 2016, Zhang et al. 2016). The right talus was found to be the most accurate at 95.7% (Gualdi-Russo 2007) and the first cervical vertebrae resulted in the least accurate measurement at 60% (Marino 1995).

Many studies used the scapula, including the glenoid fossa, to estimate sex (e.g. Di Vella et al. 1995, Frutos 2002, Papaioannou et al. 2012, Spradley & Jantz 2011, Bell 2013, Tise et al. 2013, Spradley et al. 2015, Hudson et al. 2016, Peckmann et al. 2016). The scapula and glenoid fossa, commonly called the shoulder blade, are housed in the upper back, a region of the body with heavy musculature. This heavy musculature prevents fractures to the bone and preserves it for forensic and archaeological contexts (Peckmann et al. 2016). Research has shown that the overall mean measurements of the length of the glenoid cavity (LGC) and breadth of the glenoid cavity (BGC) are larger in males than in females (Di Vella et al. 1995, Frutos 2002, Papaioannou et al. 2012, Bell 2013, Tise et al. 2013, Spradley et al. 2015, Hudson et al. 2016). This is due to differences in the level of androgen hormones between males and females (Notelovitz 2002). The focus of this study is to use the glenoid fossa for estimation of sex in a Black American population.

1.2 How does the scapula develop and function within the human body?

This research focuses on the glenoid fossa, the point of articulation for the scapula and the humerus (glenohumeral joint). This joint is responsible for the 360° rotation of the upper arm (the largest degree of movement of any joint articulation in the human body).

The scapula, including the glenoid fossa, is formed through endochondral ossification. Ossification is the process by which bone is formed from pre-existing mesenchymal tissue (Gilbert 2000). The limb skeleton is generated from lateral plate mesoderm, which is the lateral extension of the paraxial mesoderm in the developing embryo (Gilbert 2000, Scheuer & Black 2004). Cavitation of the glenoid fossa begins in week seven of human development and completes by week ten of pre-natal growth (Scheuer & Black 2004). The scapula varies very little from pre-natal week 12-14 until the time when postnatal growth begins (Table 1). The subcoracoid centre is a secondary ossification centre of the scapula and can be observed by eight to ten years after birth. The subcoracoid centre is located on the upper third of the glenoid surface and is dorsal to the coracoid process (Scheuer & Black 2004). The remaining two thirds of the glenoid surface have an ossification centre that appears between 14 and 15 years after birth (Scheuer & Black 2004). There is no significant sexual dimorphism observed between males and females prior to a normal anticipated adolescent growth spurt in the glenoidal cavity. This growth spurt occurs in females between the ages of 9.5 years and 14.5 years of age, while in males the growth spurt occurs between 10.5 years and 17.5 years of age. The beginning of this growth coincides with the general age range that individuals begin puberty (Rissech & Black 2007). These growth spurts are attributed to the increase in

serum testosterone levels in males and the rise of plasma levels of oestrone and oestradiol in females. These hormones initiate the onset of puberty, triggering an increase in size and shape change in male glenoid fossae in comparison to females (Krabbe et al. 1979).

Table 1.1. Summary of ossification centres of the scapula (Scheuer & Black 2004).

Developmental Timeline	Developmental Event
Prenatal	
Weeks 7-8	Primary ossification centre appears
Weeks 12-14	Main body of scapula close to adult morphology
Birth	
Year1	Majority of main scapula body ossified. Acromion, coracoid, medial border, inferior angle and glenoidal mass still cartilaginous, coracoid begins ossification
Year 3	Coracoid recognizable as separate ossification centre
Years 8-10	Subcoracoid centre appears
Years 13-16	Coracoid and subcoracoid begin fusion to scapular body. Epiphyses appear for glenoid rim. Epiphyses for angle and apex of coracoid appear Acromial epiphysis appears
Years 15-17	Fusion complete between coracoid, subcoracoid and scapular body Epiphyseal islands appear along medial border Epiphysis for inferior angle appear
Years 17-18	Fusion of glenoid epiphyses virtually complete
By 20 years	Fusion of acromial and all coracoid epiphyses complete
By 23 years	All scapular epiphyses fused and adult morphology complete

The glenohumeral joint is stabilized by the muscles of the rotator cuff, the joint capsule and ligaments, thus holding the humerus into the concavity of the glenoid fossa during rotation (Reinold et al. 2004) (Figure 2). This complex stabilization mechanism prevents dislocation of the glenoid fossa and plays a large role in development of the size and shape of an individual's glenoid cavity (Reinold et al. 2004, Notelovitz 2002). The supraspinatus originates on the supraspinous fossa of the scapula, inserting on the greater

tubercle of the humerus and abducting the arm at the shoulder (Muscolino 2005). The infraspinatus originates on the infraspinous fossa of the scapula, inserts on the greater tubercle of the humerus and laterally rotates the arm at the shoulder (Muscolino 2005). The teres minor originates on the superolateral border of the scapula and inserts on the greater tubercle of the humerus. This muscle laterally rotates and adducts the arm at the shoulder (Muscolino 2005). The subscapularis originates on the subscapular fossa of the scapula (ventral face), inserts on the lesser tubercle of the humerus and medially rotates the arm at the shoulder joint (Muscolino 2005). The latissimus dorsi has an extensive origin, including: the thoracolumbar fascia, spinous processes of thoracic vertebrae 7-12, iliac crest (on pelvis), inferior ribs and the inferior angle of the scapula. The latissimus dorsi transverses the glenohumeral joint to insert on the floor of the intertubercular groove on the head of the humerus (Bhatt et al. 2013). The latissimus dorsi is responsible for movements of the arm, such as extension, adduction, horizontal abduction, flexion in an extended position and internal rotation of the shoulder joint. Over-activity of the muscle (or muscle tightness) is responsible for excessive abduction of the scapula, which leads to chronic shoulder and back pain (Mottram 1997, Bhatt et al. 2013).

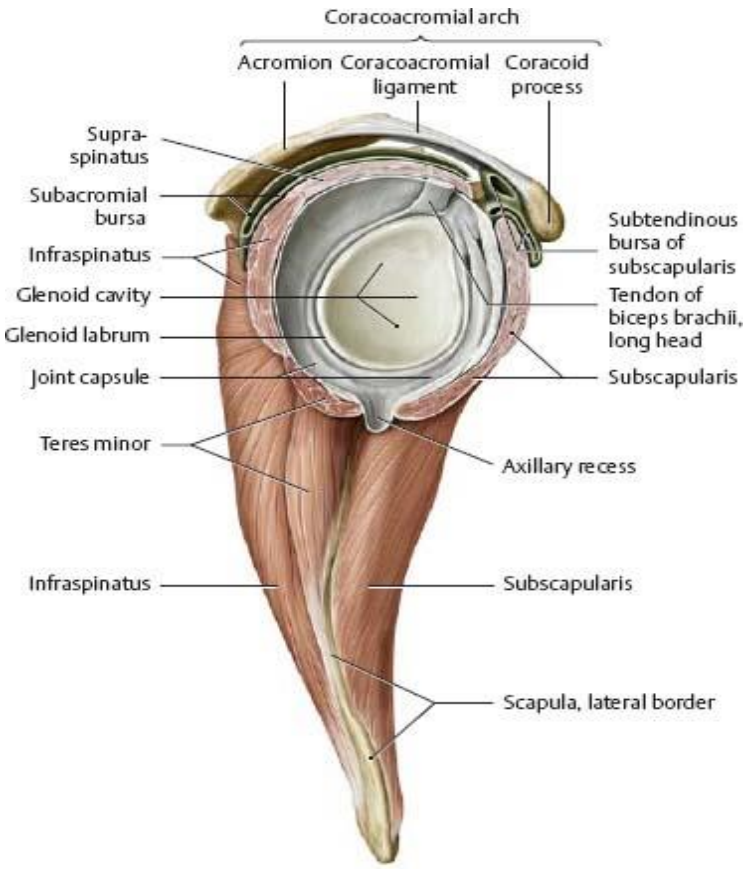

Figure 1.1. Anatomy of the glenohumeral joint, lateral view, humerus removed (Atlas of Anatomy n.d.).

Generally, males have a larger muscle mass than females due to their higher levels of androgenic hormones. These hormones not only influence muscle mass and strength, but also bone formation and bone mineral density (BMD). High androgen levels give males larger and more dense skeletons than those observed in women (Notelovitz 2002). This variation in overall bone size and shape of the glenoid cavity is due to the pull of the glenohumeral muscles on the bone surface as well as the effect of the hormones on bone cell activity such as matrix production, mineralization and organization (Notelovitz 2002). These hormones are also responsible for osteophytic growth and decreased BMD of postmenopausal women. This change is attributed to the decrease in estrogen and

increase in androgen levels that is observed in females after the onset of menopause (Notelovitz 2002). Size variation of the glenoid cavity is also affected by lifestyle factors, which can be observed in the current population of Black Americans from turn of the century St. Louis. Males in the studied materials have much larger glenoid fossae than females, indicating that these males greatly utilized their shoulders and arms in day-to-day life.

1.3 What is the history of the population used in this study?

The first individuals of African descent to arrive in the United States landed in Missouri in 1719 as slaves from Haiti and resided in an area just outside the city of St. Louis (Bourgois 2008). During an economic boom from the late 1830s to the mid-1850s St. Louis became a railway hub and a port for steamships due to its location at the confluence of the Mississippi and Missouri rivers (Meyer 1989). This economic boom caused the city to see a 900% increase in trade arrivals, mostly from New Orleans (Meyer 1989). Between 1860 and 1880, St. Louis became a focal point of the iron and lead industry due to the large deposits of iron ore and lead surrounding the city, which opened up a field employing many black labourers (Meyer 1989).

Between 1860 and 1870, there was a 262% increase in the employment of people in the manufacturing sector of St. Louis. Approximately 5% of the population of Missouri identified as Black American and of these individuals, 37% were employed (Gibson & Crogman 1969). Females were almost exclusively employed by jobs that fit into domestic and personal services (Gibson & Crogman 1969). The role of washerwoman was the most common occupation of a Black female in St. Louis in the mid-to-late 1800s (Corbett 1999). Black males in St. Louis had industrial jobs which included hard manual labour in

agriculture, fisheries and mining (Gibson & Crogman 1969, Corbett 1999). Males were occasionally employed in the domestic services industry as servants if they were unable to find a job as a labourer (Gibson & Crogman 1969).

This difference in occupation and its effects on the body can be observed in the glenoid cavity. Males in the current study generally had osteophytic lipping on all 360° of the margin of the glenoid cavity which is indicative of a large amount of mechanical stress at the joint (Felson & Neogi 2014). Labourers in trades for which Black American men were generally hired will use the full range of movement at that joint to swing an axe in a mine, pull a fishing net into a boat or do fieldwork in the agriculture sector (Corbett 1999). In comparison, females in the current study were generally washerwomen or maids so their osteophytic lipping was focused on the anterior margin of the glenoid cavity. This comes from most of their motions being anteriorly directed, causing significant mechanical stress on this margin of the cavity due to the muscles that insert in that region (Felson & Neogi 2014).

There is a need for these data in bioarchaeology. In the past 30 years, many Black American burial sites have been discovered in states along the northeastern seaboard (i.e. New York and Massachusetts) containing fragmented, dispersed remains (Wall et al. 2008, Blakey 2010, Landon & Bulger 2013). As of July 1, 2015, 13.2% of the total population of the United States of America identified as Black American (US Census Bureau 2015). This large population makes the need for population-specific sex estimation to discriminate between the remains of Black American and White Americans obvious in the United States as a population this large can not go without accurate identification techniques. This bioarchaeological data is used in identification of unknown

individuals involved in mass disasters and accidental deaths that occur in the continental USA and around the world.

1.4 What is the legal significance of accuracy rates for estimating sex?

The development of a biological profile, including methods for estimation of sex, must be tested and accepted by the scientific community before becoming accepted as standards. Osteological methods are deemed reliable in medicolegal proceedings if the resulting accuracy rate of the method is 80.0% or higher (Christensen et al. 2014).

Daubert vs. Merrell Dow Pharmaceuticals, Inc (1993) established the *Daubert* standard, which provides the rule of evidence regarding the admissibility of expert witnesses' testimony during the United States federal legal proceedings. The *Daubert* ruling emphasized the need for objectivity and standards within the scientific method (Holobinko 2012). This case involved mothers taking Benedectin, a prescription drug manufactured by Merrell Dow and known for causing birth defects, to treat their symptoms of morning sickness (Anderson 2014). Merrell Dow presented a physician and an epidemiologist who reviewed the literature related to Benedectin and concluded that there was no statistically significant evidence to link Benedectin and birth defects, as claimed by the plaintiff. The judge stated that the strongest evidence showed a possible rather than significant link between the drug and the alleged birth defects, thus providing general acceptance of the theory or technique by the relevant scientific community (Anderson 2014). *Daubert* criteria are as follows (Anderson 2014):

1) a technique can/has been tested

2) the theory/technique has been peer-reviewed

3) there is a known error rate for the theory/technique, and

4) the theory/technique is generally accepted in the relevant scientific community

A Canadian Supreme Court case, *Regina v. Mohan*, which was finalized in 1994, had much the same effect in Canada that *Daubert* had in the United States. The *Regina v. Mohan* case is a leading Supreme Court of Canada decision on the use of experts in trial testimony (Holobinko 2012). Dr. Mohan was a practising pediatrician who was charged with sexually assaulting four of his female patients. A psychiatrist, Dr. Hill, was called by the defense. He testified that the defendant did not display traits normally observed in an individual who exhibits sexually deviant behaviour (Anderson 2014). Dr. Hill had only treated three sexually deviant doctors and the trial judge in the case deemed his testimony inadmissible due to its lack of scientific backing (Anderson 2014). The *Mohan* criteria for admissibility of expert evidence is decided by the trial judge and includes (Anderson 2014):

1) Is the testimony relevant to the case?
2) Is the testimony necessary?
3) Is there absence of exclusionary rule?
4) Is the witness properly qualified?

Probative value versus prejudicial effect must be addressed for all evidence presented at trial. This means that the value of the evidence must not be overborne by its impact on the trial process (Anderson 2014).

As demonstrated above by the *Daubert* and *Mohan* rulings, objective, accurate, and peer-reviewed scientific methodologies are critical in the admissibility of evidence in legal proceedings. Therefore, forensic anthropology has begun to focus on creating objective rather than subjective methods (Lesciotto 2015).

1.5 What are the objectives of this study?

The objectives of this research are to: (1) examine sexual dimorphism of the glenoid fossa in a Black American population. It is expected based on previous studies that males will be significantly larger in both variables in comparison to females, (2) test the accuracy of sex estimation discriminant function equations for the glenoid fossa developed from a White European population by Papaioannou et al. (2012) when applied to a Black American population. It is hypothesized that the White European discriminant function will not accurately discriminate between male and females in the Black American population and a population-specific discriminant function will have to be generated, and (3) compare the results of the Black American population to populations other than White Europeans.

CHAPTER 2: METHODS

2.1 Skeletal Materials used for this study

The *Robert J. Terry Anatomical Skeletal Collection* was started in 1898 by Robert Terry under the permission of his supervisor, A.V.L. Brokaw, at the Missouri Medical College. Cadavers from the medical college were used to create the collection. After students were finished examining the bodies, the bones were macerated to remove any remaining tissue and the skeletons were stored as part of this collection. Cadavers were obtained primarily from local St. Louis hospitals and morgues, while a few came from other institutions throughout Missouri (Hunt & Albanese 2005). Currently, the bones are stored in metal drawers in a secure, climate-controlled room at the National Museum of Natural History, Smithsonian Institution in Washington, D.C. This collection contains 1728 individuals: 461 White American males, 546 Black American males, 5 Asian males, 323 White American females and 392 Black American females. Years of birth range from 1828 to 1943 and years of death range from 1924 to 1962 for the Black American individuals. Demographic information, including sex, year of birth, age at death, ancestry and cause of death (where possible), were known for each of the 1728 individuals.

This project examined 200 arbitrarily chosen human scapulae (100 males and 100 females) of Black American ancestry. The age at death of our samples ranged from 22-72 years of age. Only adult scapulae were examined (Table 2.1), because the scapular epiphyses of juveniles and young adults are not fully ossified until the age of 22 years making the estimation of sex from the glenoid fossa difficult and less accurate (Scheuer & Black 2004). Scapulae exhibiting pathologies, post-mortem damage, and those exhibiting

antemortem and perimortem remodelling were excluded from the study prior to choosing the 200 included in the study sample.

2.2 General Measurements

Following Papiaoannou et al. (2012), the length of the glenoid cavity (LGC) and the breadth of the glenoid cavity (BGC) of the scapula were measured (Figures 2.1 and 2.2, Table 2.2). Measurements of 200 individuals were taken directly from the scapula to the nearest 0.01 mm using digital sliding calipers. A subsample of 30 randomly selected individuals (15 males and 15 females) were used to test for bilateral asymmetry between left and right scapulae, and inter-and intra-observer error (Buikstra & Ubelaker 1994). The significance threshold for all tests was $\alpha=0.05$.

Table 2.1. Age distribution of male and females whose scapulae were measured in this study.

AGE RANGE (YEARS)	MALE SAMPLES (N)	FEMALE SAMPLES (N)
22-29	25	22
30-39	36	28
40-49	23	24
50-59	12	15
60-69	4	10
70-79	0	1
TOTAL	100	100

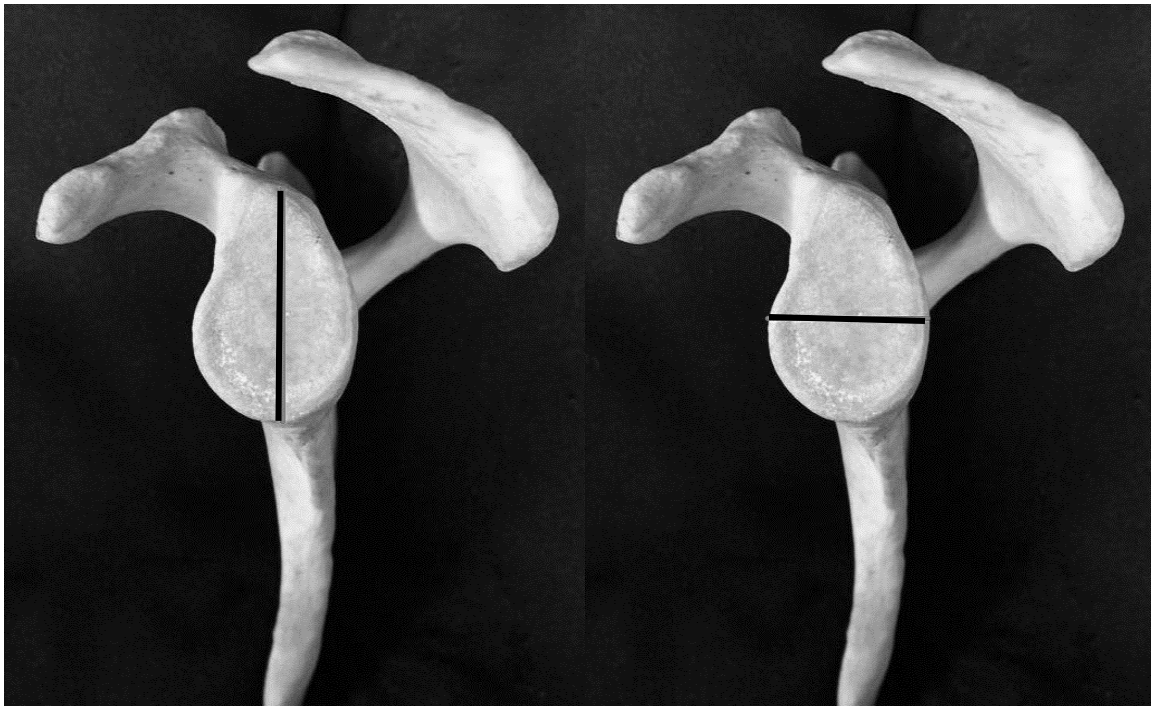

Figure 2.1: Length and Breadth of Glenoid Cavity, lateral view (Photo by C. McKenna).

Table 2.2. Description of measurements (modified from Hudson et al. 2016).

Measurement	Description
Length of glenoid cavity (LGC)	Vertical (superior-inferior orientation) length of the glenoid cavity
Breadth of glenoid cavity (BGC)	Horizontal (anterior-posterior orientation) breadth of the glenoid cavity

2.3 Statistical Analyses using R

2.3.1 Testing for Normality

The data sets were separated into groups by sex (i.e. males and females). Shapiro-Wilk normality tests were conducted on each sex for glenoid cavity length and breadth. Probability plots were generated to analyze the distribution of the data. Normally distributed data were analyzed using t-tests, and non-normally distributed data were analyzed using non-parametric tests, including Wilcoxon or Mann-Whitney. Mean values

represent the balance point of normally distributed data but medians are used in non-normally distributed plots.

2.3.2 Bilateral Asymmetry

To determine whether bilateral asymmetry existed between the left and right glenoid fossae, a Mann-Whitney test was used to compare measurements from each of the 30 arbitrarily selected individuals (15 males and 15 females). The robustness of this test makes Mann-Whitney a good choice for establishing the presence of bilateral asymmetry, and can be used regardless of the data's normality. The protocol developed by Buikstra and Ubelaker (1994) states that only bones from the left side are measured in anthropological analysis. The right scapula was used as a replacement in four of the 200 examined individuals due to an observable pathology or no left bone being present. Due to the high correlation between right and left scapulae (r=0.95), this exchange of right for left glenoid fossae measurements should not impact the accuracy of the analysis (Cross Validated 2010).

2.3.3 Analyzing the Black American data with the Cretan discriminant function using R.

The White European collection is a cemetery sample collected from St. Konstantinos and Pateles in Heraklion, Crete. The individuals were born in Crete, an island off the coast of Greece in the Mediterranean Sea, between 1867 and 1956. This population was chosen due to its temporal similarity to the Black American sample. Also, the genetic dissimilarity between the populations would support the need for population-specific discriminant functions should the differences in LGC and BGC between the Cretans and Black Americans be significant. The study by Papaioannou et al (2012) also

measured the same aspects of the glenoid cavity of the scapula using the same methodology as the current study.

Discriminant function analysis determines which variables discriminate between two naturally occurring groups (i.e. males and females). Discriminant scores are obtained by multiplying an independent variable by an unstandardized coefficient and adding or subtracting from a constant (Hudson et al. 2016). Papaioannou et al. (2012) developed a discriminant function separating the data by sex using a sectioning point, or cutoff point, for the linear discriminant. The Black American data were analyzed using Papaioannou et al.'s Cretan discriminant function ($S_{gl}=0.221(LGC) + 0.382(BGC) – 18.14$). S_{gl} is a term that pertains specifically to the glenoid cavity.

The scores obtained from the Black American data were compared to the Cretan sectioning point to determine if there was a need for a population-specific discriminant function. Scores above the sectioning point (i.e. $S_{gl}>0$) for each measurement were assigned as males and scores below the sectioning point (i.e. $S_{gl}<0$) were assigned as females, as was done for the White Europeans. This population was chosen as there has not yet been any studies of this kind performed on either Black African or Black American populations. Although Macaluso Jr. (2010) has done work on estimating sex from the glenoid cavity, he used photographs so his values can not be used in this study. Using photographs to estimate sizes of physical bone is done using a different methodology than the current study used and therefore his values could not be compared to the current population.

2.3.4 Comparison of descriptive statistics between populations

The Black American means and standard deviations were compared separately to published values for Cretans (Papaioannou et al. 2012), Italians (Di Vella et al. 1995), Guatemalans (Frutos 2002), contemporary Greeks (Bell 2013), White Americans (Bell 2013), Mexicans (Hudson et al. 2016), and Chileans (Peckmann et al. 2016). These analyses were performed using two sample t-tests and a Bonferroni correction of $p=0.008$.

2.3.5 Intra- and Inter-observer error

Intra-observer error was examined to determine if the measurements collected by an individual observer were repeatable. C. McKenna remeasured the LGC and BGC variables from the same random subset of 30 individuals (15 males and 15 females) that was used in the bilateral asymmetry test. BGC was analyzed using a paired t-test and LGC was analyzed using a Wilcoxon signed ranks test.

Inter-observer error arises if the repeatability of measurements made by different observers is low. An undergraduate research student at the National Museum of Natural History re-measured the LGC and BGC of the same subsample of 30 individuals (15 males and 15 females) that was used for the intra-observer analysis. Both BGC and LGC were analyzed using paired t-tests. The significance threshold for both intra- and inter-observer error was set at $\alpha=0.05$.

CHAPTER 3: RESULTS

3.1 Descriptive statistics of the measurements for the glenoid cavity length and breadth

Normality tests suggest that male LGC and BGC data were normally distributed (p=0.99, p=0.73 respectively), as were female LGC measurements (p=0.72). Female BGC data were non-normally distributed (p=0.01). The descriptive statistics of the Black American population are outlined in Table 3.1.

Table 3.1. Descriptive statistics of a Black American historic population (100 males and 100 females). All measurements are in millimeters (mm).

Measurement	Sex	Mean (SD)	Median	Minimum	Maximum
LGC	Male	37.65 (1.99)	37.77	32.37	43.23
	Female	32.77 (1.72)	32.77	28.71	36.55
BGC	Male	27.56 (1.75)	27.56	23.39	31.25
	Female	23.44 (1.72)	23.47	19.05	30.69

3.2 Validation of sexual dimorphism in the Black American sample

Sex influenced both LGC (Wilcoxon W=305.5, n= 100, p<0.001) and BGC (Wilcoxon W=443.5, n=100, p<0.001) variables, indicating statistically significant sexual dimorphism in the Black American sample (Figures 3.1 and 3.2). Validating sexual dimorphism was done using Wilcoxon rank sum test (Mann-Whitney-Wilcoxon).

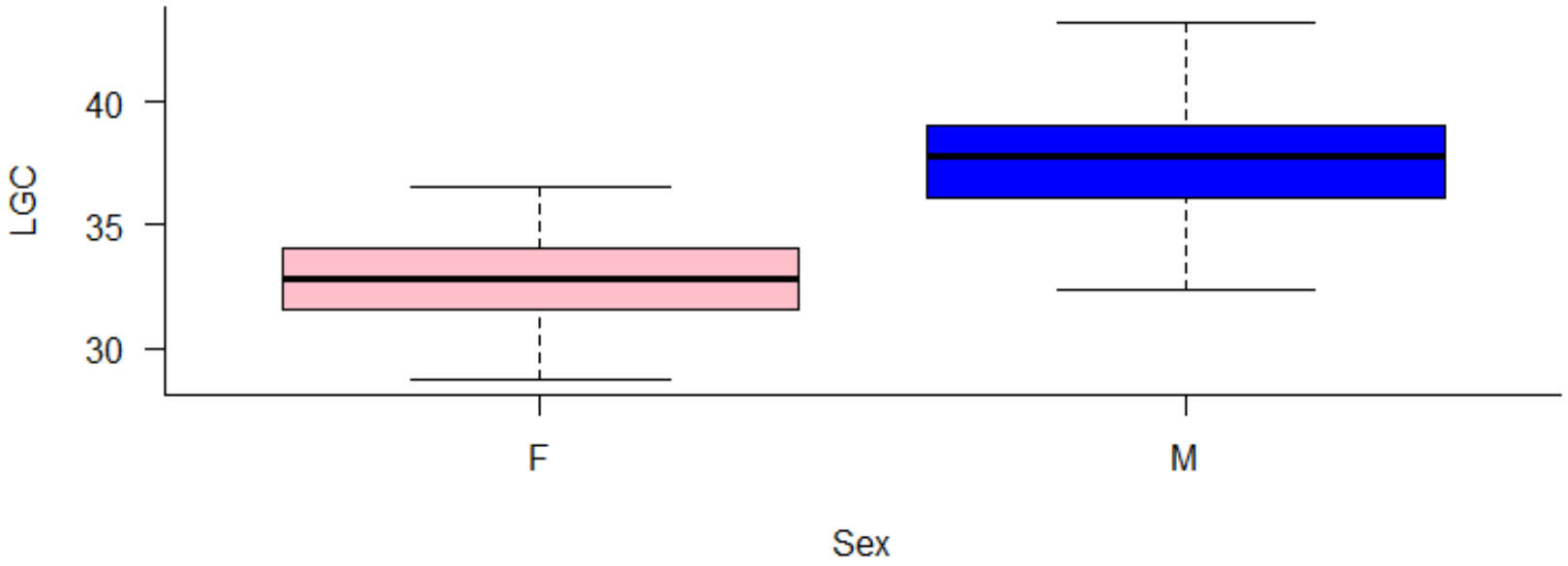

Figure 3.1. Sexual dimorphism (mean and SD) in length of glenoid cavity measurement (mms) of Black Americans at 95% confidence.

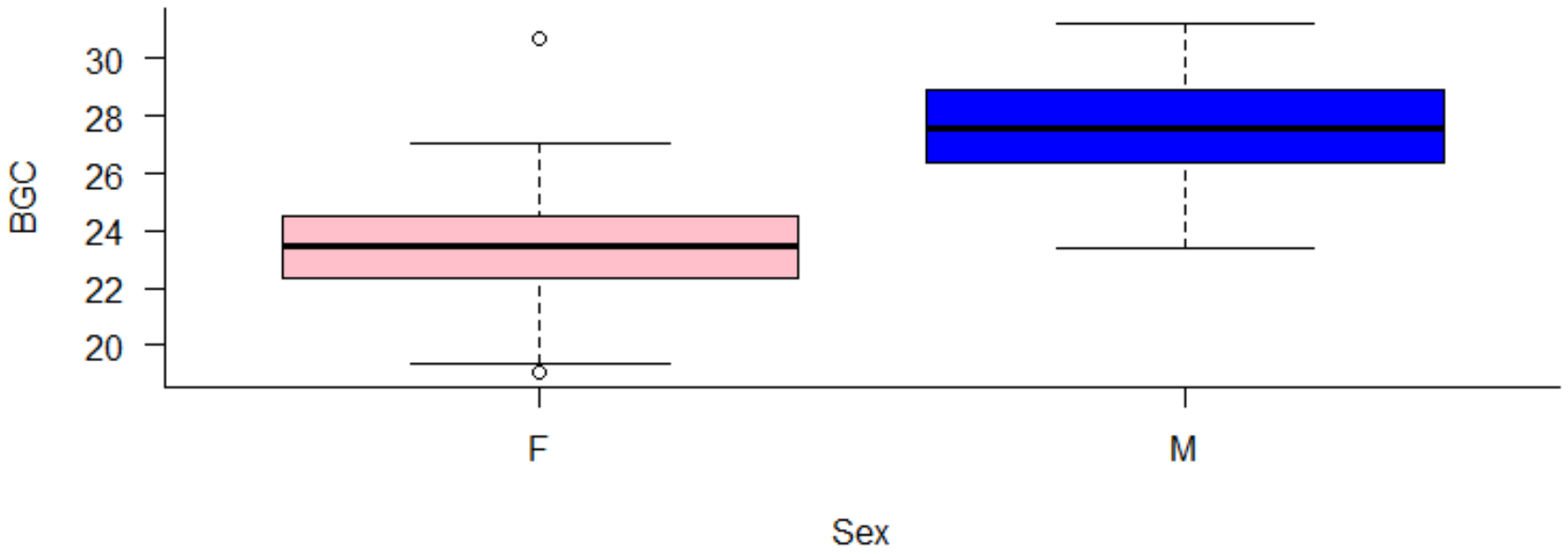

Figure 3.2. Sexual dimorphism (mean and SD) in breadth of glenoid cavity measurement (mms) of Black Americans at 95% confidence.

3.3 Does the Papaioannou et al. (2012) discriminant function fit our population?

The accuracy of the glenoid fossa discriminant function generated by Papaioannou et al. (2012) when applied to the Black American sample is shown in Table 3.2. Males were estimated correctly with an accuracy rate of 69%, and females were estimated correctly with an accuracy of 100%. This gives an overall accuracy rate of 84.3% when using the White European discriminant function applied to a Black American population. A consideration of the sex bias ratio (% females correctly classified-% males correctly classified) highlights the bias in this equation towards females.

3.4 Comparison of the descriptive statistics of the Black American and Cretan populations

Results showed that mean LGC and mean BGC for male Cretans are significantly larger than those for Black American males (Figures 3.3 and 3.4). This difference is statistically significant in the BGC ($t=-5.41$, $p<0.001$) but not in the LGC ($t=-1.49$, $p=0.14$). In comparison, female Cretan LGC ($t=-2.60$, $p=0.01$) and BGC ($t=-4.46$, $p<0.001$) means are significantly larger than Black American female means (Figures 3.3 and 3.4).

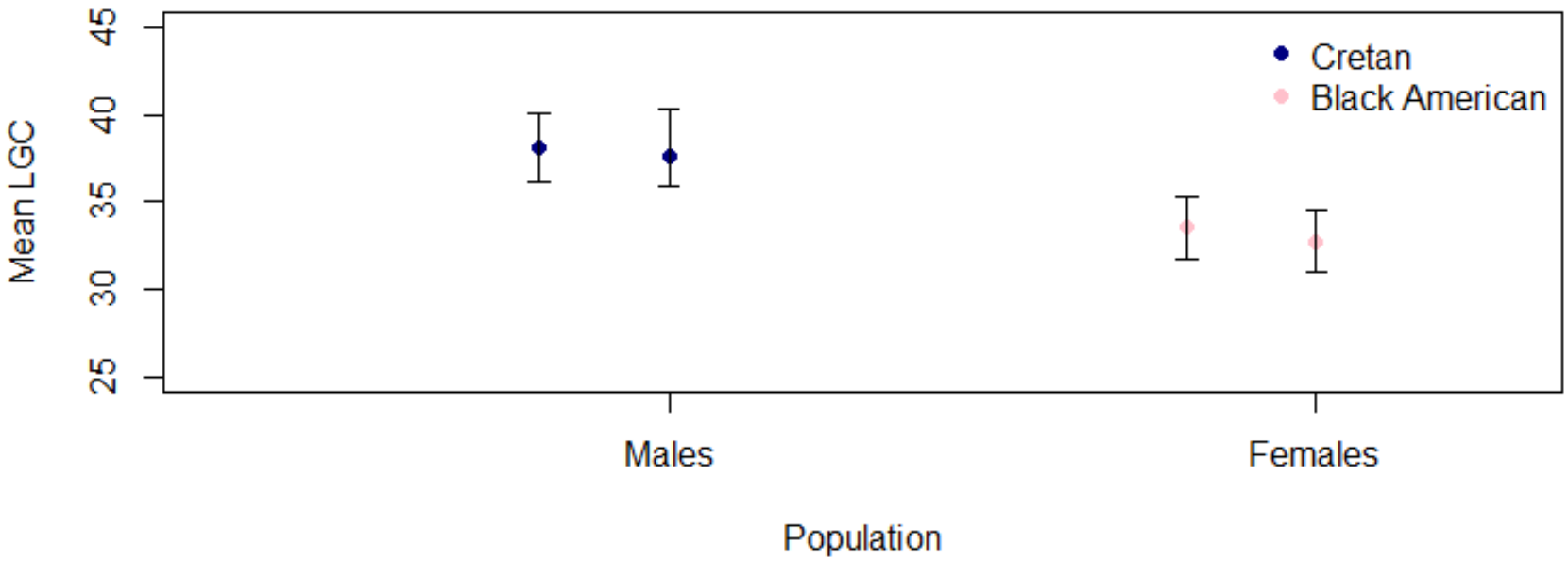

Figure 3.3. Comparison of Cretan and Black American mean LGC at 95% confidence. *= significant at Bonferroni correction p=0.008.

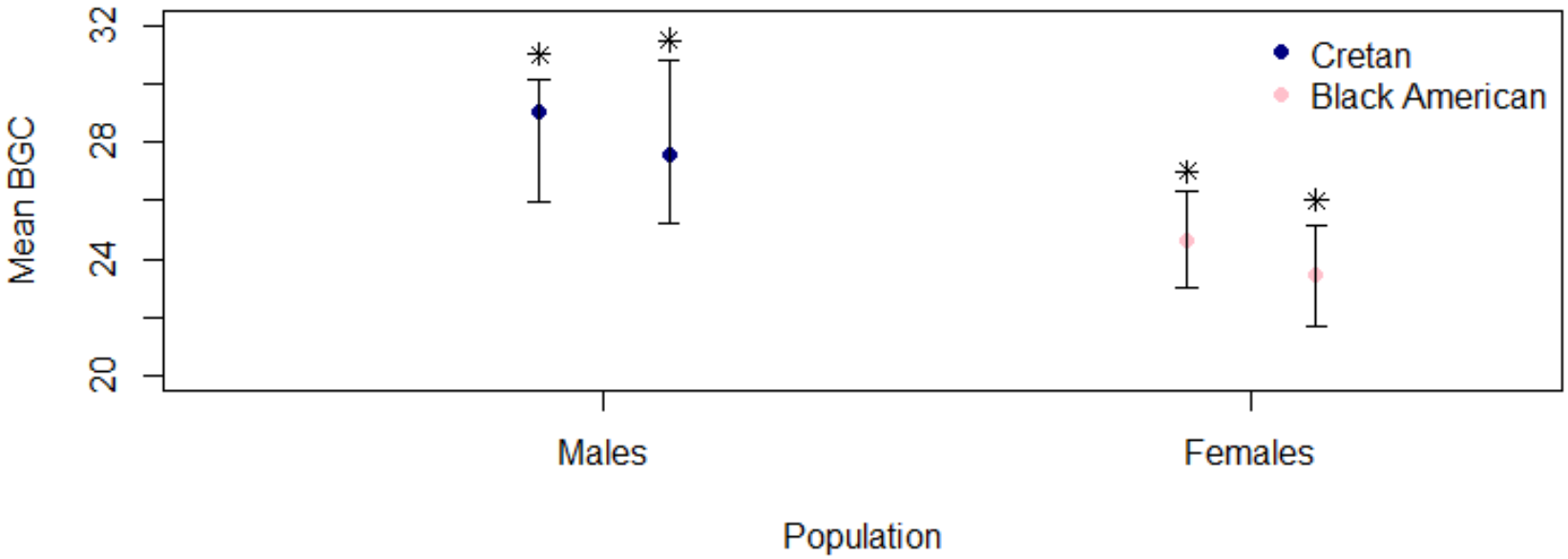

Figure 3.4. Comparison of Cretan and Black American mean BGC at 95% confidence. *= significant at Bonferroni correction p=0.008.

3.5 Comparison of Black American population means with means from other populations

The Black American data were also statistically compared to data from Mexicans (Hudson et al. 2016), Italians (DiVella et al. 1995), Guatemalans (Frutos 2002), Greeks (Bell 2013), White Americans (Bell 2013) and Chileans (Peckmann et al. 2016).

There is a significant difference in the mean LGC (Figure 3.5) of female Black Americans when compared to female Mexicans ($t=-4.02$, $p<0.001$), female Guatemalans ($t=4.70$, $p<0.001$) and female White Americans ($t=-3.46$, $p<0.001$). Black American males are significantly different from male Guatemalans ($t=4.86$, $p<0.001$) and male White Americans ($t=-4.45$, $p<0.001$) when comparing mean LGC values (Figure 3.5).

There is a significant difference in the mean BGC (Figure 3.6) of female Black Americans when compared to female Guatemalans ($t=3.81$, $p<0.001$), female Greeks ($t=-7.60$, $p<0.001$) and female White Americans ($t=-7.60$, $p<0.001$). Black American males are significantly different from male Guatemalans ($t=4.80$, $p<0.001$), male Greeks ($t=-4.07$, $p<0.001$), male White Americans ($t=-9.91$, $p<0.001$) and male Chileans ($t=3.91$, $p<0.001$) when comparing mean BGC values (Figure 3.6).

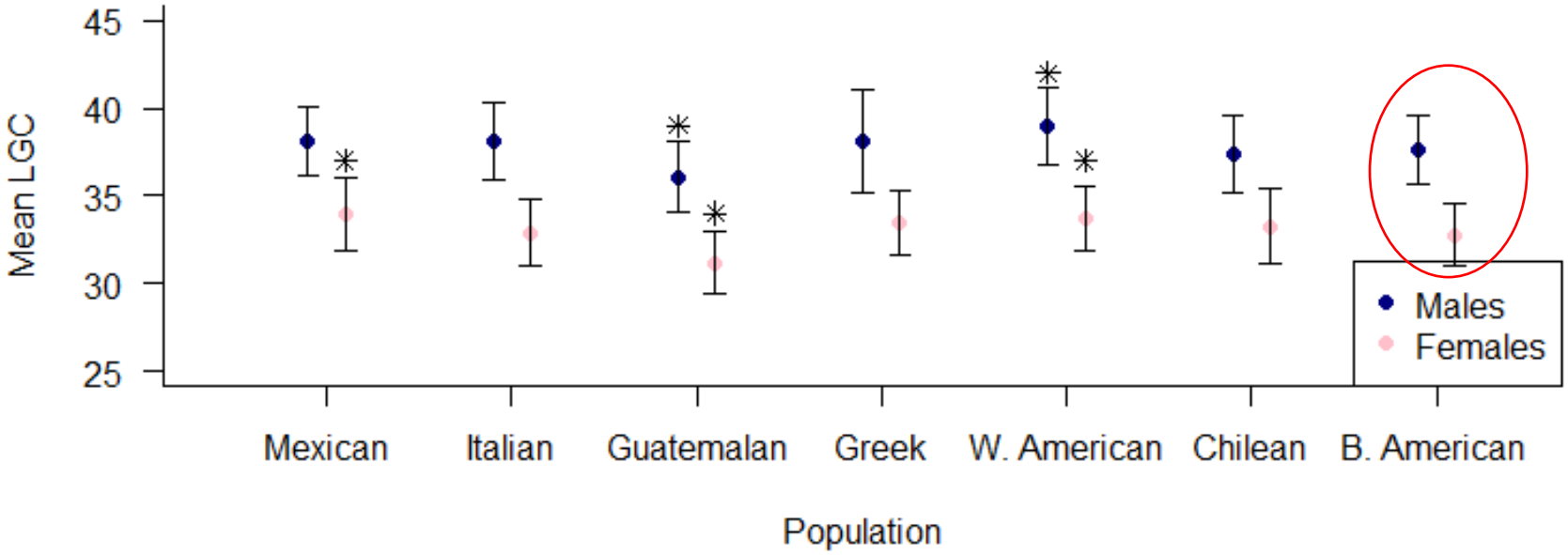

Figure 3.5. Mean LGC of Black Americans compared to other populations at 95% confidence. *= significant at Bonferroni correction p=0.008, current study in red circle.

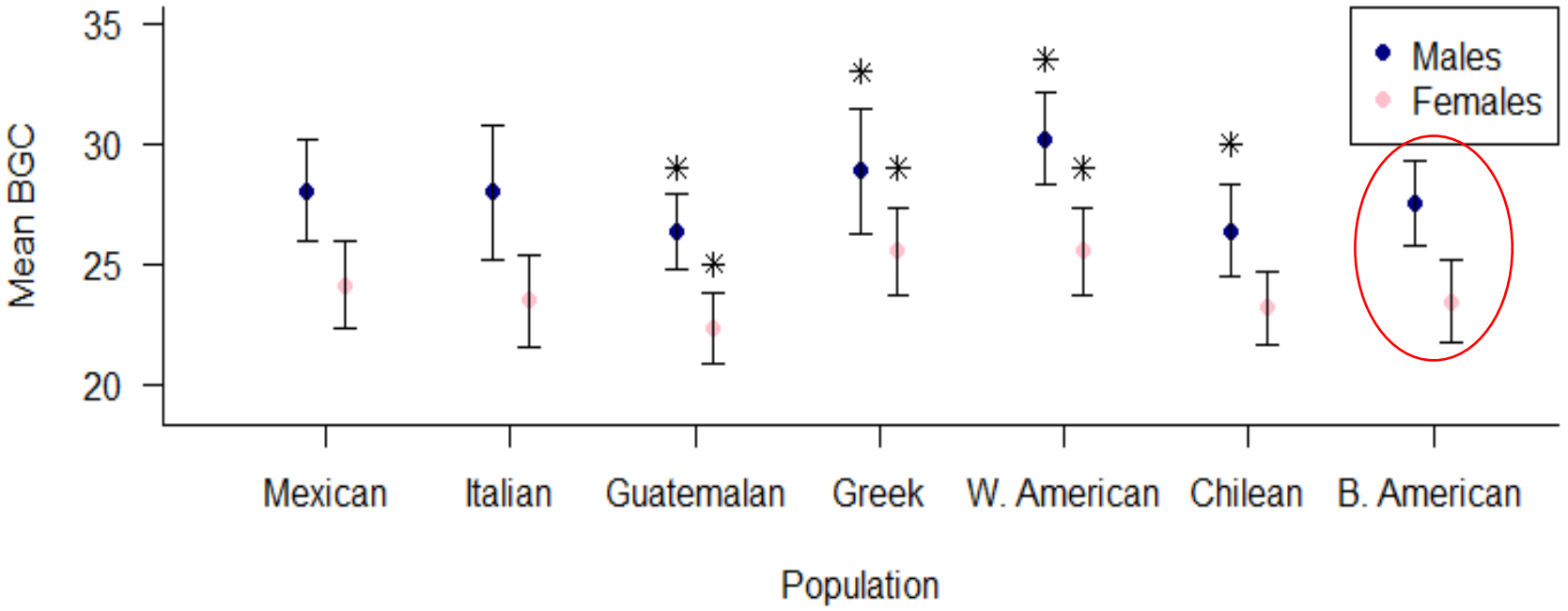

Figure 3.6. Mean BGC of Black Americans compared to other populations at 95% confidence. *= significant at Bonferroni correction p=0.008, current study in red circle.

3.6 Intra- and Inter-observer error

The LGC (Wilcoxon V=465, n=30, $p<0.001$) and BGC ($t=3.11$, n=30, $p=0.004$) variables were found to be significantly different between the original sample and the re-measured sample when measured by the same person ($p<0.01$), resulting in high intra-observer error. Similarly, high inter-observer error was also present for one of the two variables.

There was a significant difference between the measurements of two people for LGC ($t=9.03$, n=30, $p<0.01$), but not for BGC ($t=0.44$, n=30, $p=0.66$). This result indicates that the BGC variable is repeatable by other researchers but the LGC variable is not.

CHAPTER 4: DISCUSSION

Differences in LGC and BGC measurements have been found to be accurate estimators of sex in White Europeans (Papiaoannou et al. 2012, Bell 2013), White Americans (Bell 2013), South African Blacks (Macaluso Jr. 2010), Mexicans (Hudson et al. 2016), Chileans (Peckmann et al. 2016), Guatemalans (Frutos 2002) and Italians (Di Vella et al. 1995). These variables have also been found to be diagnostic in archaeological populations in New Zealand (Murphy 2002), East Anatolia (Özer et al. 2006) and Tell El-Amarna (Dabbs 2010). These studies all found that male LGC and BGC are larger than those of females. This finding indicates sexual dimorphism, and can be linked to temporal period, lifestyle factors, genetics and socio-economic status.

4.1 Sexual dimorphism in the Black American sample

The first objective of this project was to determine the presence of sexual dimorphism in the glenoid cavity of a historic Black American population. This study has demonstrated that the dimensions of the glenoid cavity are sexually dimorphic and therefore have good predictive value when estimating sex. Sexual dimorphism can be explained by an interaction between both genetic and environmental effects. This study found the LGC and BGC in males in the Black American sample were significantly larger than those of the Black American females (Figure 3.1 and 3.2).

The human scapula and glenoid fossa do not exhibit sexual dimorphism prior to puberty. Puberty occurs between 9.5 and 14.5 years in females and between 10.5 and 17.5 years in males (Rissech & Black 2007) and is initiated by an increase in serum testosterone levels in males and in plasma oestrone and oestradiol in females. These hormonal increases cause sex-specific changes to occur in the whole body, including the

bones (Krabbe et al. 1979). Males have more muscle mass, a higher bone mineral density, and more rapid bone formation than females due to higher levels of androgenic hormones (Notelovitz 2002). High levels of testosterone in a pubertal male reduce bone resorption and increase the periosteal apposition of bone. In females, oestrogen conserves bone mass, suppresses bone turnover and maintains the balance between bone formation and resorption. This absence of bone maintenance in males leads to a larger skeleton, and a larger glenoid fossa, in males than females (Wells 2007), further supporting the findings of this study.

Sexual dimorphism of the scapula and glenoid fossa is also dependent on physical activity patterns. Physical activity applies mechanical stress to the bone in the area where the muscle attaches. Mature bone size is dependent on muscle mass (Felson & Neogi 2014). This can be explained by Wolff's law of bone remodelling which states that mechanical loads applied to living bone will influence the structure of bone tissue (Ruff et al. 2006). Since males are genetically pre-dispositioned to have larger muscles, their bones are impacted by Wolff's law and therefore, are larger and heavier than females (Notelovitz 2002). Therefore, this would support the findings in this research for larger LGC and BGC measurements in males than in females.

Labour divisions will also have a large impact on an individual's bone size. In this Black American population, males were labourers (e.g. agriculture, fishing, mining) and therefore used sufficient amounts of upper body muscles to necessitate bone remodelling of the glenoid fossa. In comparison, women who worked as domestic servants used ample musculature of their upper bodies but in a more uni-directional motion when compared to the rotational motion utilized by male labourers (Corbett 1999, Felson & Neogi 2014). Kelley and Angel (1987) examined the occupational stresses in Black American slaves,

and their findings are supported by what has been observed in the current study. Kelley and Angel (1987) also found that younger females in the slave population exhibited patterns reflective of heavy lifting on their bones that would not be found in other populations of young females (i.e. white females) during this time. They also support housework as the main occupation of female slaves as reflected in the arthritis patterns present on their bones (Kelley & Angel 1987).

Research shows that glenoid cavity dimensions (LGC and BGC) are sexually dimorphic, and can therefore be used to estimate sex from skeletal remains (Di Vella et al. 1995, Frutos 2002, Murphy 2002, Özer et al. 2006, Dabbs 2010, Macaluso Jr. 2010, Papiaoannou et al. 2012, Bell 2013, Hudson et al. 2016, Peckmann et al. 2016). In the current project, the Black American population follows this trend, with males having significantly larger glenoid cavity dimensions than females.

4.2 Comparison of populations

The second objective of the project was to determine the accuracy of a discriminant function developed for a White European population by Papaioannou et al. (2012) when applied to the Black American population. Papaioannou et al. (2012) developed sex-specific discriminant functions for White Europeans using a historic Greek cemetery sample from Crete. This function resulted in high accuracy rates when applied to the Cretan population (males: 90.1%; females: 93.9%; overall: 91.8%). (Note: The Papaioannou et al. (2012) White European population will be referred to as Cretans.)

When applied to the Black American population, the White European discriminant functions diagnostic ability decreased for male individuals (Table 3.2). The sex bias of 31% is indicative that smaller Black American males will be classified as

female using this discriminant function. The sex bias also indicates that Black American males are smaller in glenoid cavity dimensions than Cretan males and that Black American females are similar to Cretan females in these variables. When applying the White European discriminant function to the Black American population, the accuracy rates for sex estimation are low (below the legally significant 80%). This finding supports the existing literature that suggests discriminant functions are not transferable between populations and population-specific discriminant functions are necessary to accurately diagnose sex when using postcranial elements (DiVella et al. 1995, Frutos 2002, Spradley & Jantz 2011, Papaioannou et al. 2012, Bell 2013, Tise et al. 2013, Hudson et al. 2016, Peckmann et al. 2016).

4.2.1 Comparison of the Black American population with the Cretan population

Both males and females from Crete were significantly larger in the BGC variable than the Black Americans but there was no statistically significant size difference in LGC between Black Americans and Cretans for either sex (Figures 3.3 and 3.4). This research suggests that only the BGC variable shows a statistically significant difference between Black American and Cretan males and females (Figure 3.4).

Research has shown that several elements of the skeleton can be used as estimators of stature to determine the living height of an individual and variation in living stature contributes to bone size (Spradley & Jantz 2011, Tise et al. 2013). The significant differences in the BGC and lack of significance in the LGC can be accounted for by the similarity in living stature between the two populations. Previous research shows that glenoid cavity dimensions are correlated with stature and overall, taller populations have larger LGC and BGC values (Peckmann et al. 2016). The opposite is also true, with

shorter individuals having smaller LGC and BGC values than their taller counterparts. In living individuals, the average height of Black American males and females from the Terry collection were recorded as 172.73 cm and 160.89 cm respectively (Trotter & Gleser 1952). Cretan males and females have an average height of 168.49 cm and 157.5 cm respectively (Roberts 1954, Becker 1975).

Physical size differences between populations can be attributed to both lifestyle and genetic factors. Therefore, an individual who shares more genetics with taller populations will have larger LGC and BGC values as glenoid cavity size is correlated to stature differences. In general, white populations are taller than those of African or Hispanic ancestry (Komlos & Baur 2004). The genetic ancestry of Black Americans is highly understudied. Parra et al. (1998) examined a New Orleans population and found that a genetic contribution of 22.5% (+/- 1.6%) from White Europeans was present in the Black American genome from this region. Many of the Black American individuals who resided in St. Louis were brought to the area from New Orleans as slaves therefore, this New Orleans population is genetically representative of the current sample (Bourgois 2008). Another study from Harvard University agrees with this genetic contribution. Bryc et al. (2015) found that 24% of a Black American's genetic ancestry is comprised of White European genes. As for the Cretan population, there is no genetic admixture with Black Americans. Arniaz-Villena et al. (1999) suggests that Cretans are more closely related genetically to French and Italians rather than other Greeks. The difference may be due in some part to genetic and geographical differences among populations, but this can not be determined without some future research into the genetics of these two specific populations.

Black American individuals living in Missouri when this collection was curated were slave labourers or domestic servants, who either escaped or purchased their freedom. In comparison, the Cretans were employed largely in agriculture (Perakis 2010). Olive oil was the primary export in Crete and many individuals were farmers (Perakis 2010). Indicators of labour divisions are present on the bones of the upper body of these individuals. Male Black Americans were labourers in industries such as mining, fishing and agriculture and Cretan males worked primarily in agriculture. Black American and Cretan male jobs would impact the bone in similar ways. Activity patterns, such as labour divisions, are attributed to differences in glenoid cavity size based on mechanical stresses applied to the bone (Felson and Neogi 2014), therefore individuals who participate in more labour-intensive jobs will have larger glenoid cavity dimensions than individuals who are not subjected to these mechanical stresses. Black American males had more variety in their labour patterns, which could account for the significant difference in the BGC measures between Black American and Cretan males (Figure 3.3 and 3.4). Manual labour jobs other than farming could cause anteriorly directed stress on the glenoid cavity, which could further contribute to the differences in these two male populations. Black American females sampled were domestic servants and these types of jobs require more anteriorly directed motions. This can cause more stress to the anterior margin of the glenoid cavity. Cretan females were mainly farmers, making the wear patterns comparable to those observed in Cretan males. This difference in labour patterns between Cretan and Black American females may explain the significant differences found in their glenoid cavity breadth but it would not account for the lack of statistically significant difference in the LGC values (Figure 3.3 and 3.4).

Socio-cultural differences can affect the growth patterns of individuals within a population. Socio-economic factors include access to healthcare, proper nutrition, exposure to toxins and disease risk (Hudson et al. 2016). Socio-economic factors have a significant impact on an individual's height and body size therefore, individuals with a higher socio-economic status will be larger than those from a lower status (Stinson 1985). Acheson and Fowler (1964) found that White European individuals with a higher socio-economic status are larger and taller than those at a lower socio-economic level, and this finding was reinforced by Stinson (1985). Regardless of the stature differences explained above, the Cretan population should be larger in height and glenoid cavity dimensions than the Black Americans due to their elevated socio-economic status. However, this difference is only true in the BGC variable (Figure 3.3 and 3.4). The Black American population were slave labourers, generally living in impoverished neighbourhoods with little to no access to healthcare due to the segregation of hospitals. Hospital segregation lowered the quality of care as Black doctors did not have the education that a White doctor at the time would possess (Burgess 1928, Bourgeois 2008). It is with poverty and segregation in mind that this study demonstrates Black Americans belonging to a lower socio-economic level than the Cretans. The Cretans were farmers, which was a highly prosperous industry during the late 19th and early 20th century in the Mediterranean region (Perakis 2010). The Cretans would have had better access to healthcare, due to their proximity to an urban centre at Heraklion (Papaioannou et al. 2012). The Cretan population also had the ability to support themselves working on their own farms, while the Black American population worked farms not belonging to them and therefore, did not have the advantage of using it as a food source. The impoverished neighbourhoods and lack of healthcare access Black Americans faced made them vulnerable to disease,

poor nutrition and toxins which have shown to impact proper growth patterns and bone response (Stinson 1985).

4.2.2 Comparison of the Black American population with other populations

The third objective of this study was to compare measurements from the Black American population with other populations using the same method of sex estimation. Using published estimates of population mean and standard deviation, this study compared our population to those of White Europeans (Greeks) (Bell 2013), White Americans (Bell 2013), Italians (Di Vella et al. 1995), Mexicans (Hudson et al. 2016), Chileans (Peckmann et al. 2016) and Guatemalans (Frutos 2002). Low accuracy rates for sex estimation were found, which further supported the need for population-specific discriminant functions for the estimation of sex in unknown human remains.

Research has shown that modern Greeks, Italians and White Americans have larger average heights than those observed in historic Black Americans (Ogden et al. 2004, Nation Master 2014, Average Height 2017). The theory that taller populations will have larger glenoid cavity dimensions is supported in the findings of this study when the Black Americans were compared to the Greek, Italian and White American populations. White Americans had significantly larger glenoid fossae than Black Americans in both LGC and BGC variables for both sexes (Figures 3.5 and 3.6). Greeks were significantly larger in both male and female BGC but male and female LGC showed no significant difference when compared to the Black Americans (Figures 3.5 and 3.6). Italians showed no significant size differences in either LGC or BGC values, but the Italian sample size was low, which could contribute to this lack of significant size difference.

White American genomes are comprised of about 98.6% White European genetics (Bryc et al. 2015) and the Greek and Italian populations are White Europeans therefore, these three white populations would share many of the same genetics with one another. In comparison, historic Black Americans possess a genetic contribution from White Europeans of about 22-24% (Parra et al. 1998, Bryc et al. 2015). This could account for the lack of similarity between the Black Americans and the Greeks, Italians and White Americans. The Greek, Italian and White American populations used for our comparison are more modern when compared to this sample of historic Black Americans. This temporal difference could attribute to these individuals living in a more thriving economy and potentially not having as labour intensive jobs as historic populations would have held. Modern populations would have come from a higher socio-economic status than the historic Black American population, allowing easier access to healthcare and proper nutrition for healthier bone development (Stinson 1985). This lack of labour intensive jobs and increased access to healthcare and nutrition could be a factor contributing to the larger size of the White populations when compared to the Black Americans (Figures 3.5 and 3.6).

Research has shown that skeletal remains of Mexican, Chilean and Guatemalan ancestry are shorter than Black Americans (Frutos 2002, Hudson et al. 2016, Nation Master 2017). This agrees with past research stating that individuals who are shorter will have smaller glenoid cavity dimensions (Spradley & Jantz 2011, Tise et al. 2013). We did not find evidence of size differences among Black American and Mexican males however, significant size differences can be observed in LGC among Black American and Mexican females (Figures 3.5 and 3.6). Difference in stature does not explain the

significantly larger LGC present in the Mexican females or the significantly larger BGC in Chilean males when compared to their Black American counterparts.

Individuals with a high rate of activity will have larger glenoid cavities than those with a more sedentary lifestyle. The Mexican population came from a time where a low percentage of its workforce was employed in labour intensive fields. Per Brown et al. (1999), only 20% of Mexican males and 22% of Mexican females were employed in labour-intensive fields. This low number of individuals in labour intensive jobs could explain why the two populations were similar and no significant differences were found (Figure 3.5 and 3.6). However, Mexico experienced a severe economic decline in the early 1980's and they did not recover as rapidly as expected (Bergoeing et al. 2002). Although they were a modern population, they shared a similar socio-economic status as the historic Black Americans. This could account for the similarity between the Black American and Mexican populations. Genetic background impacts the variation between populations however, only 1.3% of the Mexican genome was inherited from African ancestry (Parra et al. 2004) and can be disregarded in this comparison.

This study found that all four variables of the indigenous Guatemalan population were significantly smaller than the Black American sample (Figures 3.5 and 3.6). The Guatemalan population that was studied by Frutos (2002) is a modern indigenous population, meaning they had low socio-economic status contrary to being a modern population. Their low status is due to lack of access to proper nutrition and healthcare. As well, due to their rural lifestyle, they worked in labour related fields comparable to those employing the historic Black Americans. This similarity in lifestyle and socio-economic status should result in similarities between Guatemalans and Black Americans, however this study shows that the two populations are significantly different in both LGC and

BGC variables (Figure 3.5 and 3.6). Genetic differences between the Black Americans and Guatemalans may be responsible for the significant size differences in glenoid fossa as only 3.6% of the Guatemalan genome is inherited from individuals of African ancestry (Sőchtig et al. 2015), indicating they are not closely related.

There was no significant size difference between the Chilean and Black American glenoid fossae aside from the male BGC variable (Figures 3.5 and 3.6). There is a low genetic relatedness between the Black Americans and Chileans as only 2.4% of the Chilean genome is composed of African genetics (Eyheramendy et al. 2015). These genetic differences could account for some of the variation between these populations, but it is a low percentage and would not have a large impact on the variation in glenoid fossa size. The Chilean population was also a modern population when compared to the historic Black Americans. From the year 1960 to the present, Chile has experienced an increase in the GDP of their country, causing it to be listed by the World Bank as a high-income country and one of the most stable countries in South America (World Bank 2016). This raises the socio-economic status of Chile to an equal or higher level than the historic Black Americans would have experienced, leading to only the BGC value being significantly different among the two populations (Figure 3.5 and 3.6).

4.3 Intra- and Inter-Observer Error

Intra- and inter-observer error are important components of forensic anthropology as they indicate the replicability of the performed measurements. Intra-observer error is assessed by the same researcher who took the sample measurements re-measuring a random sub-sample (in this case, 30 individuals) from the study and calculating the mean error between the two sets of measurements. When examining the LGC and BGC values

obtained by the current researcher in both instances, they were seen to be inconsistent ($p<0.001$). This suggests that the accuracy of the current researcher was not maintained.

The variation observed in the measurements performed by a single investigator are not ideal, and are thought to be due to the lack of experience of the researcher when placing the caliper on the bone. As the error rate for the study was only 0.01mm, it is easy for an inexperienced observer to place the caliper on a slight angle, or for the caliper itself to slip in either direction. The individual may have also struggled to place the instrument on the exact same location on each bone, leading to some individuals being measured at not the exact widest or longest point of the glenoid cavity. Early measurements that should have been discarded as practice were used in the study and exchange of these values for those that were taken at a time where the researcher had ample time to practice would have resulted in more reproducible results.

Inter-observer error assesses the replicability of the measurements between researchers. It is assessed by a separate investigator re-measuring a random sub-sample of the sample population and comparing the mean error to the original values. To test this, another undergraduate student studying the Terry collection at the NMNH, Smithsonian Institution, re-measured 30 individuals from the sample population of 200 Black Americans. There was no significant difference between the current author and the undergraduate student for the BGC variable. However, the LGC variable showed a significant difference with a $p<0.001$ (significance threshold was established at $p=0.05$), indicating inconsistency between the two investigators.

The variation observed in the LGC variable is also not ideal and can be attributed to many of the same causes as the single researcher faced. Incomplete or confusing

instruction of the measurements between the individuals, as well as inexperience of the second investigator could lead to the high rate of error seen in this measurement.

Due to the inexperience of both observers, this data should not be disregarded as this project is important in many bioarchaeological and forensic contexts. There is a large number of individuals who identify as Black Americans who currently reside in the United States of America as well as burial grounds being unearthed containing individuals who identified with this group in the past. Data from this project could help to identify any number of these individuals and aid in returning those who are missing to their families. It is for these reasons that the value of these measurements should not be overshadowed by the high prevalence of intra- and inter-observer error rates.

4.4 Future Research

This study has contributed to the wide field of forensic anthropology and bioarchaeology. It adds support to the theory that the dimensions of the glenoid cavity are sexually dimorphic and population-specific discriminant functions are required to sex an individual from skeletal remains. Creation of a population specific discriminant function for this Black American population should be carried out. This discriminant function would have to be tested on a Black African population to establish if data from other black populations can be used to identify Black Americans. Future research into the everyday life of this population could shed more light on the effects of socio-economics on these individuals as a population.

Very little research has been carried out on Black Americans around the turn of the 20th century. Today, Black Americans make up a high percentage of the American population (13.2% as of 2015, US Census Bureau 2015). This high percentage of

individuals identifying as Black Americans, as well as the large numbers of unidentified Black American remains being discovered in bioarchaeology, supports more research into sex, stature and age estimation of these individuals. This advancement in identification of Black Americans could change what the world knows about American history, for better or worse.

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