MASCULINIZATION OF FEMALE CRANIA:

THE EFFECTS OF AGE ON NON-METRIC

SEX ESTIMATION ACCURACY

OF THE SKULL

by

Matthew D. Naparstek, B.A.

A thesis submitted to the Graduate Council of
Texas State University in partial fulfillment
of the requirements for the degree of
Master of Arts
with a Major in Anthropology
August 2014

Committee Members:

Michelle D. Hamilton, Chair

M. Kate Spradley

Elizabeth Erhart

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DEDICATION

The dedication of this thesis goes to my parents, Darlene and Scot Naparstek, for their unconditional support. Additional dedication goes to my coworkers and friends at Columbia University, especially Jeffrey Norquist and Michaela Porubanova, for their guidance. Finally, I give dedication to all my colleagues at Texas State University for all their assistance during my tenure at Texas State University.

ACKNOWLEDGEMENTS

I would like to thank my thesis committee members, Dr. Michelle D. Hamilton, Dr. M. Kate Spradley, and Dr. Elizabeth Erhart, for their time and patience during the writing of this thesis. I also thank Dr. Dawnie Wolfe Steadman for assisting me in acquiring access to the William M. Bass Donated Skeletal Collection at the University of Tennessee-Knoxville as well as Dr. Daniel J. Wescott and Sophia Mavroudas for allowing me access to the Texas State University Donated Skeletal Collection. I thank Dr. Grady Early for providing me with a Grady Early Research Grant to help fund my research and travel. Finally, I thank all my colleagues and professors, especially Dr. Scott A. Williams, for originally sparking the idea for the general topic of this thesis during my tenure at New York University

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ABSTRACT

Female skulls are thought to become more masculine in appearance as they increase in age, yet no research has specifically supported this. This study looks at four commonly used morphological traits used for non-metric sex estimation of the skull (nuchal crest, mastoid process, supraorbital margin, and supraorbital ridge) and if their ordinal scores changes with age. A sample of 303 modern American White male and female adult skulls (including the associated mandible if present) between the ages of 30 to 101 years were used. Each skull was placed into one of seven age categories, which were broken down by decade (30-39 years, 40-49 years… 90-101 years). A multiple analysis of variance was run to see if the ordinal scores for each of the four traits changed between the age categories. The results show no statistically significant difference between the age categories for both males and females. Additionally, the sex estimation accuracies for each age category were calculated for both males and females, which revealed changes in the accuracies between age categories. In females, the accuracy rate is lowest (78.26%) in the 40-49 years age category, which may be due sample sizes that are not large enough to capture the complete range of variation. This drop in accuracy could also correspond with changes due to the onset of menopause. In males, the accuracy rate is lowest (85.71%) in the youngest age category used (30-39 years), but then the accuracy rate gradually increases every year. This could be due to the delayed development of more masculinized features in some males until later in life. These findings show that while there may not be a statistically significant change in the ordinal

scores for the four morphological traits between the age categories, non-metric sex estimation of the skull accuracy can still vary greatly. Currently, it is not known why this could be, but the research done for this study begins to show the gaps in the knowledge as well as where future research can take place.

1. INTRODUCTION

The sex estimation of an unknown individual is an essential component of generating the biological profile. Incorrect sex estimation can potentially lead to a sequence of other inaccuracies because the sex estimation of the individual is needed in order to accurately estimate stature, age, and ancestry (France, 1998). There is an observed trend for females to develop more rugose features in their skulls as they increase with age that may compound sex estimation efforts (Goldstein, 1936; Weiss, 1972; Tallgren, 1974; Baughan and Demirjian, 1978; Meindl et al., 1985; Walker, 1995, 2008; Konigsberg and Hens, 1998); however, the implications this has on sex estimation of the skull are not well understood. This study will focus on examining whether female skulls develop more masculinized traits with age, and if so, if this has an effect on sex estimation accuracy rates.

While the pelvis is the best skeletal element to use for sex estimation with levels of accuracy approaching upwards of 98% correct classifications (Stewart, 1954; Phenice, 1969 a; Weiss, 1972; Kelley, 1979; Ferembach et al., 1980; Krogman and Işcan, 1986; Işcan, 1988; Maat et al., 1997; France, 1998; Walrath et al., 2004; Durić et al., 2005; Spradley and Jantz, 2011), it is not always available. The pelvis is not always recovered or found in context with the rest of the skeleton, and it often suffers damage from taphonomic pressures within bioarchaeological or forensic contexts. For example, it was found that 55.3% of females over the age of 44 years from a historical crypt in London, compared to 32.7% of males, had pubic bones so poorly preserved that no sex estimation could be made using them (Walker, 1995).

When the pelvis is not available to use for sex estimation, postcranial elements are the second most accurate skeletal elements. The highest accuracy rates for sex estimation using the postcranium are the humerus in American Black individuals (93.84%) and the radius in American White individuals (94.34%). However, these results only apply to metric techniques for sex estimation of the postcrania and do not look at the accuracy rates of non-metric sex estimation of the skull using sexually dimorphic traits (Spradley and Jantz, 2011). Non-metric analysis of the skull has been argued to be more accurate than metric analysis, but there is little data to support this claim (Konigsberg and Hens, 1998; Spradley and Jantz, 2011).

The skull is also commonly used for sex estimations when the pelvis is absent. Non-metric sex estimation techniques of the skull can have varying rates of accuracy due to the subjective nature of assessing traits for qualitative features. Accurate sex estimation using non-metric techniques requires previous training for consistent estimations; however, it can have high rates of accuracy if performed by an experienced osteologist. Maat and colleagues (1997) achieved an accuracy rate of 96.2% when using the scores of 11 traits of the skull that were used in an equation to calculate the skull's degree of sexualization. Rogers (2005) was able to correctly estimate the sex of 89.1% of skulls with 17 traits. Williams and Rogers (2006) used 14 traits of the skull and had a success rate of 92%. Finally, Walker (2008) found that non-metric sex estimation of the skull using five traits scored subjectively produced an accuracy rate of 90%.

Although sex estimation using the skull is not as accurate as the pelvis or elements of the postcrania (Spradley and Jantz, 2011), sex estimation using the skull is still a valid approach in situations when other more accurate elements are damaged or not recovered. Additionally, it does not require any equipment or equations unlike metric analyses; however, equations can be used for more consistent sex estimations (Maat et al., 1997; Walker, 2008; Stevenson et al., 2009). The skull is usually well persevered compared to other skeletal elements (Novotny et al., 1993). Another application for non-metric sex estimation using the skull is that the skull has been shown to increase sex estimation accuracy when used in conjunction with the pelvis (Ferembach et al., 1980), yet sex estimation using the skull is not without its criticisms.

There are several concerns in the literature about using non-metric sex estimation of the skull ranging from high levels of interobserver error (Walrath et al., 2004) to lower levels of accuracy when estimating the sex of an unknown individual from an unfamiliar population (Durić et al., 2005). Previous publications have suggested that issues may exist when using common non-metric sex estimation techniques of the skull for older individuals (Goldstein, 1936; Weiss, 1972; Tallgren, 1974; Baughan and Demirjian, 1978; Meindl et al., 1985; Walker, 1995, 2008; Konigsberg and Hens, 1998). There is no agreement on whether age impacts sex estimation, with a number of researchers suggesting there is a trend for female skulls to become more masculinized (showing increases in rugosity, size, and more prominent muscle markings) as age increases, causing a decrease in sex estimation accuracies when using non-metric techniques on older female skulls (Goldstein, 1936; Weiss, 1972; Tallgren, 1974; Baughan and Demirjian, 1978; Meindl et al., 1985; Walker, 1995, 2008; Konigsberg and Hens, 1998). Contrarily, other studies have not found there to be any age related change in the sex estimation accuracy of older females (Rogers, 1991, 2005; Williams and Rogers, 2006).

Masculinization of female skulls

While sparse, past research alludes to the masculinization of female skulls impacting sex estimation accuracies. Weiss (1972) was one of the first scholars to publish data on the tendency to estimate older skeletons as male instead of female. He noted that when an adult skull showed intermediate sex characteristics in rugosity and size, there was a bias of about 12% towards estimating the sex as male instead of female. He equates this to possibly being due to using the size and rugosity of traits when estimating male or female. If there is any indication of rugosity for a specific sexually dimorphic trait, the researcher would be more inclined to label that trait as masculine. It is when that trait is absent or slight in rugosity that the researcher will then label that trait feminine. Weiss (1972) concludes that roughly 20% of female skeletons older than 30 years of age are generally misclassified as male, but he does not attempt to answer why that is.

Other evidence suggesting the masculinization of female skulls occurs with advancing age was found by Meindl and colleagues (1985). They provided statistical evidence that sexually dimorphic traits of the skull are affected with age. A statistically significant negative nonparametric correlation ($r = -0.39$; $p < 0.001$) was found between the cranial score of female skulls and their age. These findings provide support to the notion that female skulls increase in masculinity as they increase in age, but Meindl and colleagues (1985) do not specifically test whether this affects the accuracy of estimating sex in older women.

Some of the best evidence for the masculinization of female skulls as they increase in age comes from research on historical collections by Walker (1995) who noted that older females were improbably underrepresented in nearly all demographic research. He writes that his research shows the development of masculinized traits in females as they increase in age, which would explain the underrepresentation of females. He noted that age changes occur in most cranial traits, but the greatest changes occur in the supraorbital ridge. Males younger than 30 years old were noted as having under-developed supraorbital ridges, with 29% of males less than 30 years of age having an ordinal score of less than three, on a one (very female) to five (very male) scale. On the contrary, only 17% of males 30 years and older scored less than three for their supraorbital ridge resulting in a statistically significant difference ($x^2 = 13.5$, $p = 0.001$). This suggests males become gradually more masculine in their supraorbital ridge as they age (Walker, 1995).

Walker (1995) also saw this change in females as well but at a later age in life. Females 45 years and older had significantly larger supraorbital ridges than younger females. A total of 22.2% of females 45 years and older had supraorbital ridge scores of 3 or more, while only 13.2% of females under 45 years had the same score. Similar to males, female skulls appear to develop more masculinized supraorbital ridges with age (Walker, 1995).

No change in sex estimation accuracy

Several past studies, summarized above, have found evidence for the masculinization of female skulls as they increase in age. Yet, none of the studies that found an increase in masculinization of female skulls studied the effect it had on sex estimation accuracy. Studies by Rogers (1991, 2005) and Williams and Rogers (2006) looked at how age affects the accuracy levels of sex estimation in older individuals, but their study did not have conclusive results.

Research originally done by Rogers (1991), and published over a decade later (Rogers, 2005), looked at an assortment of 17 sex specific morphological traits of the skull from St. Thomas' Cemetery in Belleville, Ontario dating to the 19th century. This cemetery was excavated because the exact location of the graves were unknown and their locations needed to be delineated. All of the 17 traits were chosen for this study from previous publications by Bass (1987), Krogman and Íşcan (1986), Phenice (1969 b), St. Hoyme (1984), and Stewart (1979). Rogers (1991, 2005) attempts to determine which traits commonly used in sex estimation are the most reliable in terms of having high accuracy in estimating the correct sex and low intraobserver error. Rogers (1991, 2005) also attempts to research if there are age related changes to trait morphologies and sex estimation accuracies.

Out of 46 skulls that had their sex determined from historical records, five of the skulls were incorrectly classified as the other sex. All skulls were categorized into one of three age categories: <25 years (n=8), 25-44 years (n=10), and 45+ years (n=28) (Rogers, 2005). A Fisher's exact probability test was run on each individual trait and indicated the zygomatic extension and nuchal crest showed age related patterns of accuracy; however, a chi square test did not show decreased accuracy in sex estimation with an increase in age (Rogers, 1991, 2005). In fact accuracy increased with age. While these results provide a baseline in determining if sex estimation accuracy of the skull changes with age, the sample size used in this study is very small and comes from a historic population. Additionally, the author notes it was impossible to further split the age categories that were used into sex groupings due to the small sample size. Thus, this is not clear evidence that sex estimation accuracy is not affected by age (Rogers, 2005).

Further research that suggests the accuracy of sex estimation using the skull is not affected by age is provided by Williams and Rogers (2006). Using a sample of 50 skulls from the William M. Bass Donated Skeletal Collection, they estimated the sex of all 50 skulls using traits from Rogers (1991, 2005) with minor changes to how the mandible is analyzed. They separated all skulls into the three age categories, but since only two skulls were less than 25 years only two age categories were applicable for their study: 25-44 years (n=10) and 45+ years (n=38). They conducted a Fisher's exact probability test on both males and females to test if age, sex, or a combination of the two affected sex estimation accuracies. In concurrence with the results from Rogers (2005), there were no observable age related changes to the sex estimation accuracies (Williams and Rogers, 2006).

Growth and changes of the skull through life

The growth of the skull is an essential component in understanding sexual dimorphism in male and female skulls. A brief mention of adolescent and early adulthood growth of the skull is appropriate here since this project's focus is on morphological changes to the skull in males and females who are 30 years and older. Rogers (2005) provides a concise yet detailed summary of craniofacial growth during the first few decades of life, which is briefly reviewed below.

Sex estimation of the skull is mainly dependent on the size and rugosity of the skull, and the longer and more intense adolescent period of growth in males allows for observers to estimate skulls as male or female (Rogers, 2005). Research shows that sexual dimorphism in the skull appears as early as six years of age, with males having around a 5% larger cranial capacity than females (Baughan and Demirjian, 1978). This diminishes to only 4% during puberty because the rate of growth in females exceeds that of males during this time. By the age of 18 years the difference expands to over 8% in favor of males (Baughan and Demirjian, 1978).

The shape and size of the skull, including the shape of the face, continues to grow into the third decade of life as well (Baer, 1956). Measurements taken of the total face height, bizygomatic diameter, and nose height all showed continued growth after puberty in males, but females did not show this growth (Baer, 1956). Rogers (2005) equates the extended growth of the skull in males to cause more males to be misclassified as females. Skulls that appear ambiguous or lacking strong masculine features will be assumed to be female since they never developed into the size and shape of typical males (Rogers, 2005). The skull will continue to grow throughout life and males will continue to develop masculine features, but the effects of aging on the skull are not currently well understood.

Work by Israel (1968, 1973, 1979) suggested there are significant changes to the skull late in an individual's life due to bone being continually being deposited beneath the periosteum, which continually enlarges the skull and face throughout adulthood and senescence (Israel, 1978). While Israel (1978) was not able to find specific rates of growth, nor distinguish a difference between males and females, he suggests a mean value increase of 1% in skull thickness every decade of life.

No study has convincingly been conducted to determine if age effects the sex estimation of older females when using the skull. This research will look at the issue of masculinization of female skulls in order to determine whether or not an increase in age affects the score given to sexually dimorphic traits of the skull and lowers sex estimation accuracy when using non-metric traits of the skull. The observed trend of females becoming more masculinized (Goldstein, 1936; Weiss, 1972; Tallgren, 1974; Baughan and Demirjian, 1978; Meindl et al., 1985; Walker, 1995, 2008; Konigsberg and Hens, 1998) could cause older female skulls to be incorrectly classified as males. Even though it is commonly assumed that older female skulls appear to be more masculinized than younger female skulls, no previous studies have specifically focused on if this has any effect on the scoring of morphological traits or the accuracy of sex estimation. A lower accuracy for sex estimation in older females could have serious implications in both archaeological and forensic contexts.

2. MATERIALS AND METHODS

Sample population

In order to study the effect of age on sex estimation accuracies, 303 modern American White male and female adult skulls (including the associated mandible if present) aged between 30 to 101 years were examined for this study. Skulls from two separate modern skeletal collections were used. A total of 262 skulls were examined from the William M. Bass Donated Skeletal Collection at the University of Tennessee and 42 skulls were examined from the Texas State Donated Skeletal Collection at Texas State University. Both collections contain individuals born by the turn of the 20^{th} century to the present, making them representative of a recent White population.

Only White males and females were used so the possible confounding effects of ancestry would not influence the results, and therefore this limits these current results to modern White populations. Additionally, individuals who suffered from bone altering diseases and individuals with antemortem trauma to the skull were excluded from this study as these conditions may have potentially altered the topography of the skull.

In order to provide an adequate sample of different ages, seven separate age categories were created. The seven age categories were organized by decade, beginning with 30-39 years and ending at 90-101 years. The maximum number of available skulls was used in the study (Table 1).

Methods

All skulls used in this study were selected at random by listing all available White males and females 30 years and older on a Microsoft Excel® sheet and rearranging the order by the institution assigned donation number. This provided an order in which to

TABLE 1. Number of skulls analyzed by age and sex category

Age (Years)	**Males**	**Females**	**Totals**
30-39	15	8	23
40-49	32	23	55
50-59	24	31	55
60-69	27	27	54
70-79	28	20	48
80-89	23	23	46
90+	7	15	22
Sex Totals	156	147	303

study the skulls that was not dependent on the age or sex of the donation and prevented the author from knowing the correct sex or age of the skulls during analysis. The author only analyzed one skull at a time and only had one skull in view at a time so no inadvertent comparisons between two skulls could be made. The correct sex of the skull was unknown to the author during the analysis.

The protocol for each analysis began with the author first locating the corresponding skull from the generated list of donation numbers and bringing it back to his workstation. The skull was removed from the box and placed on a cushion. The author then scored the five traits, described below and in the order assigned (nuchal crest, mastoid process, supra-orbital margin, supra-orbital ridge, and mental eminence), using the descriptions provided in Buikstra and Ubelaker (1994) based on the work of Acsádi and Nemeskéri (1970). The description of the traits and their associated drawing (Buikstra and Ubelaker, 1994) was always visible for comparison during the entire analysis in order to keep intra- and interobserver error to a minimum (Walrath et al., 2004). After each trait was recorded the author crossed off that skull's number from the list and returned the box with the skeleton to its assigned spot. The author then would locate the box of the next donation on the list and start the process over again until all donations on the list were analyzed using the same standardized methodology.

Traits scored

The methodology selected for this study was originally described by Acsádi and Nemeskéri (1970) and was later used by Buikstra and Ubelaker (1994). This methodology was chosen because of its standard use for non-metric sex estimation of the skull. It was developed in 1991 during a seminar held at the Field Museum of Natural History in Chicago to assist in the repatriation of Native American skeletons due to federal law 101-601, the "Native American Graves Protection and Repatriation Act" (Buikstra and Ubelaker, 1994; Walrath et al., 2004). The five cranial traits used in this method are the nuchal crest, mastoid process, supra-orbital margin, supra-orbital ridge, and mental eminence. Each trait was scored from "1" (hyper-feminine with no or very little rugosity and no or light muscle markings) to "5" (hyper-masculine with extreme rugosity and heavy muscle markings). The left side of the skull was used to score the paired traits (mastoid processes and supra-orbital margins) unless postmortem damage obscured assessment from this side. In those cases the right side was used for that individual trait.

Originally, all five traits listed by Buikstra and Ubelaker (1994) were intended to be utilized by the author for this study; however, 112 of the 303 skulls did not have a mental eminence that could be scored because either the mandible was completely absent or antemortem tooth loss had resulted in resorption of the bone of the mandible at the mental eminence. If there was an indication that any amount of bone resorption had occurred the author did not score the mental eminence on that skull. If the mental eminence was not present or unable to be observed the trait was scored as "ABSENT." Because such a large number of skulls did not have an observable mental eminence, this trait was ultimately excluded from the statistical analysis. This left four traits from the cranium (the skull excluding the mandible) available for use in the analysis ("cranium" will be referred to as "skull" for the remainder of the paper unless otherwise noted).

NUCHAL CREST (Appendix1): Buikstra and Ubelaker (1994) describe how each trait should be evaluated. For the first trait, the nuchal crest, they suggest viewing the cranium from its lateral side and comparing the surface with the diagram provided in *Standards for Data Collection from Human Skeletal Remains: Proceedings of a Seminar at the Filed Museum of Natural History* (*Standards*). The observer should focus on the rugosity of the occipital bone while ignoring the shape of the bone below the nuchal crest. A hyper-feminine score (score = 1) would reflect an occipital where there are no bony projections and the surface is flat and smooth. A hyper-masculine score (score = 5) is when the nuchal crest is a well-developed ledge of bone or the bone has grown out to form a hook (Buikstra and Ubelaker, 1994).

MASTOID PROCESS (Appendix 2): The second trait is the mastoid process. To score this trait the size of the mastoid process is compared to the size of surrounding features, such as the external auditory meatus and the zygomatic process. The total size of the mastoid process and not just its length is what needs to be considered when scoring this morphology. It is helpful to compare the size of the mastoid process to the external auditory meatus on the cranium being analyzed to the drawings provided by Buikstra and

Ubelaker (1994). A hyper-feminine mastoid process (score = 1) is only a slight projection. There is very little volume to it. A hyper-masculine mastoid process (score = 5) is one that is several widths and lengths larger than the external auditory meatus. The overall volume of a mastoid process scored as a "5" is described as "massive" (Buikstra and Ubelaker, 1994).

SUPRAORBITAL MARGIN (Appendix 3): The third trait is the supraorbital margin. This trait should be assessed by feeling the "sharpness" of the orbital margin just lateral to the supraorbital foramen. Simultaneously, the diagram provided in *Standards* should be used to compare the thickness of the supraorbital margin in order to properly score the trait. A hyper-feminine supraorbital margin (score = 1) is described as being very sharp, like the edge of a butter knife. A hyper-masculine supraorbital margin (score = 5) is described as being thick and round with the curvature and dullness close to a pencil (Buikstra and Ubelaker, 1994).

SUPRAORBITAL RIDGE (Appendix 4): Finally, the fourth trait is the prominence of the supraorbital ridge. Similar to the nuchal crest, the supraorbital ridge is scored by viewing the cranium from its lateral side. The protrusion of the supraorbital ridge from the frontal and nasal bones is then compared to the diagram from Buikstra and Ubelaker (1994). A hyper-feminine supraorbital ridge (score = 1) is when there is no or very little projection above the orbits. A hyper-masculine (score = 5) supraorbital ridge is when a massive and rounded "loaf-shaped" projection has formed (Buikstra and Ubelaker, 1994). Often, a supraorbital ridge scored as a "5" will be so prominent that it almost appears to have a shelf of bone on its more superior surface.

Statistical methods

First, a discriminant function was produced using the four cranial traits in order to consistently provide a sex estimation for each skull. Next, a multivariate analysis of variance (MANOVA) was used to analyze the data and test the null hypothesis, which is that female skulls do not develop more masculinized features as they increase in age. The MANOVA was run by placing each skull into an age-by-decade category (Table 1) to create seven different cohorts. The trait scores assigned to each morphology were grouped into the age and sex cohorts, and the MANOVA was used to compare trait scores between each age and sex category.

3. RESULTS

Analyses were done using SAS system software for Windows Version 9.2 (Copyright © 2002-2007 SAS Institute) using the total sample of data collected (n = 303) (Appendix 5). A discriminant function was produced using the four traits of the skull and each skull used in the study had its sex estimated using this discriminant function. This gave a consistent sex estimation based solely on the scores given to each morphological trait, ensuring the sex estimations were not affected by additional observations the author made while collecting data on each skull. For each age category an analysis of the frequencies of correct and incorrect estimations was run to provide a cross-validation summary (Table 2).

Descriptive statistics

Overall, 272 out of 303 (89.77%) skulls had their sex correctly estimated using the discriminant function. For females, 131 out of 147 (89.12%) actual female skulls were correctly estimated, while 141 out of 156 (90.39%) actual males were correctly estimated. The cross validation summary also allowed for comparisons to be made between the male and female groups in each age category (Figure 1).

Multiple analysis of variance (MANOVA)

A MANOVA procedure was run to analyze the effect age, sex, and the interaction between age and sex on the four morphological traits (nuchal crest, mastoid process, supraorbital margin, and supraorbital ridge) that were scored in this study. All samples were used in this analysis (n=303). No significant differences were found between each of the four morphological traits and the age categories at a 0.05 level of confidence (Table 3). All four morphological traits had significant differences when compared against sex at a > 0.001 level of confidence (Table 3). Finally, the MANOVA did not find any significant interaction between age and sex for the four morphological traits at a 0.05 level of confidence (Table 3). This means the effect of age on the score of the morphological traits is not dependent on sex, and also the effect of sex on the score of the morphological traits is not dependent on age.

Table 2: Cross-validation summary for all age categories and sexes

30-39 Years

Correct Sex	Classified Into Sex: Female	Male	Total
Female	8 100.00%	0 0.00%	8 100.00%
Male	2 14.29%	12 85.71%	14 100.00%
Total	10 45.45%	12 54.55%	22 100.00%

40-49 Years

Correct Sex	Classified Into Sex: Female	Male	Total
Female	18 78.26%	5 21.74%	23 100.00%
Male	4 12.50%	28 87.50%	32 100.00%
Total	22 40.00%	33 60.00%	55 100.00%

50-59 Years

Correct Sex	Classified Into Sex: Female	Male	Total
Female	27 87.10%	4 12.90%	31 100.00%
Male	3 12.50%	21 87.50%	24 100.00%
Total	30 54.55%	25 45.45%	55 100.00%

60-69 Years

Correct Sex	Classified Into Sex: Female	Male	Total
Female	27 100.00%	0 0.00%	27 100.00%
Male	2 7.41%	25 92.59%	27 100.00%
Total	29 53.70%	25 46.30%	54 100.00%

70-79 Years

Correct Sex	Classified Into Sex: Female	Male	Total
Female	18 90.00%	2 10.00%	20 100.00%
Male	2 6.90%	27 93.10%	29 100.00%
Total	20 40.82%	29 59.18%	49 100.00%

80-89 Years

Correct Sex	Classified Into Sex: Female	Male	Total
Female	20 86.96%	3 13.04%	23 100.00%
Male	1 4.35%	22 95.65%	23 100.00%
Total	21 45.65%	25 54.35%	46 100.00%

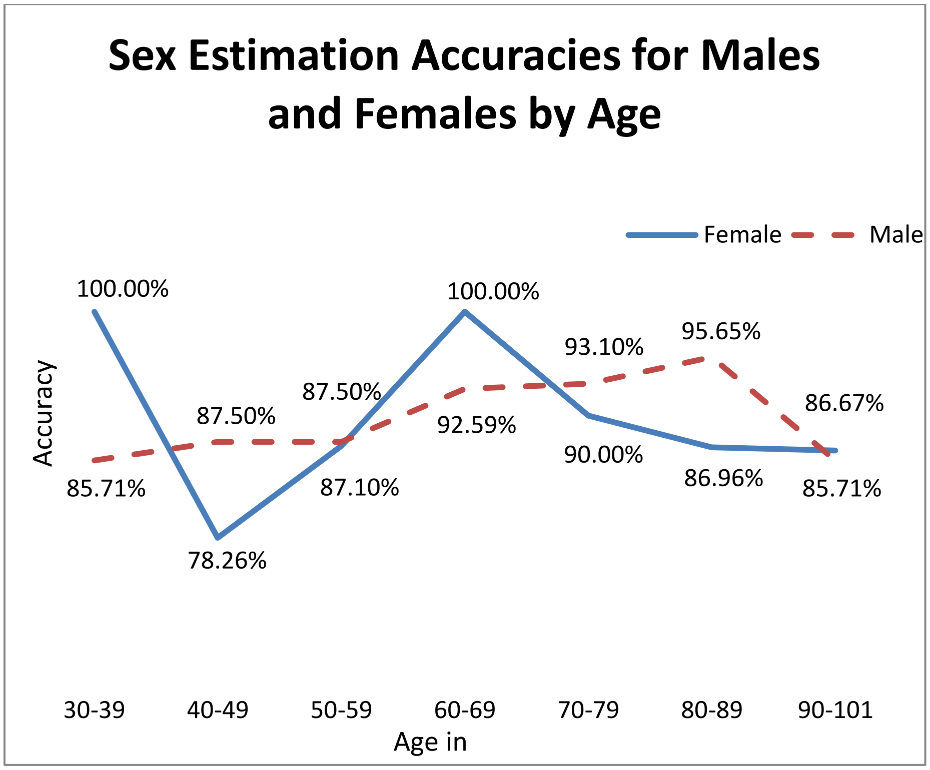


FIGURE 1: Accuracy of non-metric sex estimation using the skull in males and females for each decade of life

Table 3: MANOVA results for the effect of age, sex, and the interaction between age and sex on four morphological traits for males and females

	Age		Sex		Age*Sex	
Trait	F-Value	P-Value	F-Value	P-Value	F-Value	P-Value
Nuchal Crest	1.444	0.197	129.64	< 0.001	1.265	0.274
Mastoid Process	1.243	0.284	111.573	< 0.001	0.979	0.440
Supraorbital Margin	0.753	0.607	64.339	< 0.001	0.278	0.947
Supraorbital Ridge	1.919	0.078	337.751	< 0.001	0.624	0.711

4. DISCUSSION

The main purpose of this study is to determine if female crania become more masculine with an increase in age. The statistical analysis performed did not find any significant differences in the four morphological traits (nuchal crest, mastoid process, supraorbital margin, and supraorbital ridge) in females between the age groups. Additionally, there is no significant difference in the four morphological traits in males between the age groups as well. This means there is no change in the average ordinal score of the four morphological traits between the age categories, which indicates these four morphologies can be used in males and females who are 30 years and older. While no statistically significant difference was found in the four morphological traits, a review of the levels of accuracies in each age group shows clear trends.

This study has shown that there is an overall sex estimation accuracy of 89.77%. This level of accuracy is similar to other studies that have researched non-metric sex estimation of the skull (Krogman and Işcan, 1986; Maat et al., 1997; Rogers, 2005; Williams and Rogers, 2006; Walker, 2008); however, different age groups within this study had widely different levels of accuracy in and between the different sexes (Figure 1).

The accuracies for each separate age category for males and females were also calculated. A look at the changes in accuracies between the decades in males and females shows two findings (Figure 1). First, the sex estimation accuracy for females changes throughout life and has no apparent pattern, with the age of the lowest sex estimation accuracy in females occurring in the 40-49 years age category. This is much earlier than what was initially expected. The second finding is that male cranial sex estimation accuracy increases as age increases. These two findings are discussed below in further detail.

Changing accuracy rates for female sex estimation in each decade of life

Previous research suggests that traits of the female skull used for sex estimation became more masculinized as females increase in age (Goldstein, 1936; Weiss, 1972; Tallgren, 1974; Baughan and Demirjian, 1978; Meindl and Lovejoy, 1985; Walker, 1995, 2008; Konigsberg and Hens, 1998). This implies there should be a continual decrease in the sex estimation accuracy for females when just the skull is used. The statistical analysis done for this study suggests there is no statistically significant change in the scores assigned to the morphological traits between the age categories in females; however, the female sex estimation accuracies vary throughout each decade of life even though there is no significant change in the traits' scores. This could be for a variety of reasons. First, the sample of skulls used for each decade of age in this study may not be large enough to precisely capture the range of variation. Second, the largest drop in accuracy in females occurs in the 40-49 years age category, which coincides with the age of the onset of menopause.

A total of 23 female skulls were used in the 40-49 years age category. Of these 23 skulls, five were misclassified as being male. It is possible that a sample size of 23 is not large enough to accurately represent this group. Constraints on sample size are due to the small number of younger female skulls available in the skeletal collections used, and because of this a larger sample size was not possible. Overall, this study would benefit from a larger number of skulls to analyze in each age category. The small sample size may be one factor that is producing varying levels of accuracy; however there are other factors that may be causing the varied levels of accuracy.

Menopause may be another factor for why the female sex estimation accuracies of the skull are so sporadic. Menopause occurs in females around the ages of 45 to 55 years, and marks the time when menstruation ceases. During menopause there will be a drop in a woman's production of the hormones estrogen and progesterone (Zieve and Storck, 2011). The effects of these hormonal changes can cause a wide range of symptoms including changes to the skeleton. While there are extensive studies on the changes the skeleton and bone undergo during and after menopause (Geusens et al., 1986; Riggs et al., 1986; Krall et al., 1995; Riis et al., 1996; Ahlborg et al., 2003), all research solely focused on the effect menopause has on the loss of bone in the vertebral column as well as the long bones. No studies found looked at changes to the bones in the skull, which leaves a gap in the research.

Since the results of this study show a decrease in the accuracy of non-metric sex estimation using the skull in females around the time of menopause onset, this could indicate menopause may have an effect on the morphology of the skull. This offers an avenue for future research since currently there are no studies focusing on the changes of the skull during menopause.

Increased accuracy in males with an increase in age

Males in the 30-39 years age category scored a sex estimation accuracy of 85.71% (Figure 1). The accuracies increase slightly with each increasing age category, but then drastically drops in the oldest age category, those 90 years and older. The drop in accuracy in the oldest age category may be explained due to the low sample size. Only seven males 90 years and older were available for analysis, and only one out of the seven male skulls in this age category was incorrectly classified as a female. The one incorrect estimation dropped the accuracy for this age group to 85.71%, where otherwise it would have been 100% accurate classification. A larger sample size would likely have resulted in a higher accuracy rate. Additionally, another study noted lower accuracies in younger males (Walker, 1995).

Walker (1995) wrote how males younger than 30 years of age have significantly less developed supraorbital ridges than older males. Younger males who are delayed in developing these more masculinized traits until later in life would appear more feminine and thus would be more likely to be misclassified as female early in life. Consequently, as males get older they may appear more masculine from the continued growth of the skull (Baer, 1956), which would explain the increase in sex estimation accuracy using the skull as males increase in age. While there may not be a statistically significant change in the scores of their morphological traits, older males were demonstrated as consistently having higher accuracy levels. In this study, there is a tendency for males to increase in accuracy as they become older (Figure 1).

Comparison to previous findings

Rogers' (1991, 2005) and Williams and Rogers' (2006) results from their studies came to a different conclusion than this study about the changes of female sex estimation accuracies using the skull. This study found a trend in the data for females to vary in their accuracies between different age categories, while Rogers (1991, 2005) and Williams and Rogers (2006) found that age did not affect accuracy. This could possibly be from differences in methods used. While this study broke down the age categories into decades for a total of seven groups, Rogers (1991, 2005) only used three age categories: <25 years, 25-44 years, and 45+ years, while Williams and Rogers (2006) used the age categories of 25-44 years and 45+ years. Breaking down the age categories into wider ranges of time may not have allowed for more finite changes in the accuracies to be captured.

Additionally, the sample sizes used in this study compared to Rogers (1991, 2005) and Williams and Rogers (2006) vary greatly. This study used a sample size of 303 individuals, while Rogers' (1991, 2005) study used a much smaller sample size (due to skeletal collection constraints) of 46 skulls and Williams and Rogers (2006) used a sample size of 50 skulls.

While Rogers (1991, 2005) and Williams and Rogers (2006) were one of the first to look at if accuracies change with age when using non-metric sex estimation techniques of the skull, their studies may not show the true changes in accuracies that occur with changes in age. This is because the small sample sizes they used may not have captured the finite changes in accuracies that occur. Additionally, the small sample sizes used also did not allow for more age categories to be compared since there were not enough individuals to make up groups large enough for comparison.

Implications in a forensic and bioarchaeology context

Researchers have developed different techniques for estimating the sex of an unknown individual using visual morphologies of the skull (Acsádi and Nemeskéri, 1970; Rogers, 1991, 2005; Williams and Rogers, 2006; Walker, 2008; Stevenson et al., 2009). Knowing that sex estimation accuracies vary throughout every decade of life in adults can help add a cautionary approach when constructing a biological profile, which may lead to fewer inaccurate sex estimations. The effects of age on the skull are not well researched calling into question the degree of validity of non-metric sex estimation when used within a medicolegal setting. Sex estimation biases are seen in other contexts as well.

Within a bioarchaeology context, sex estimation can be plagued with difficulties ranging from differences in the robustness of populations (Maat et al., 1997; Durić et al., 2005) to poor preservation of skeletons (Walker, 1995). Weiss (1972) noticed archaeological sites almost always have more males than females, yet it is hard to imagine that sex ratios in prehistoric human populations were skewed in such a way. Males appear to be overrepresented in the archaeological record for two reasons. Walker (1995) describes what he calls 'sexism in sexing" as one of the reasons. "Sexism in sexing" refers to observations Walker (1995)made about osteologists subconsciously discriminating against females in sex estimations due to the modern stereotype that males are big and robust and females are small and gracile. As females age and their skulls continue to grow this makes it difficult to undo the expectation that female skulls are only small in size.

The second reason for the underrepresentation of females in the archaeological record is due to the poor preservation of female skeletons compared to males. Walker (1995) calculated that from the excavated Saint Bride's skeletal collection in London there was a statistically significant greater number of female pubic bones compared to males that were so poorly preserved that they could not be used for sex estimation (x^2=4.7, p=0.030). Since other skeletal elements are not as accurate as the pelvis for sex estimation (Stewart, 1954; Phenice, 1969 a; Weiss, 1972; Kelley, 1979; Ferembach et al., 1980; Krogman and Işcan, 1986; Işcan, 1988; Maat et al., 1997; France, 1998; Walrath et al., 2004; Durić et al., 2005; Spradley and Jantz, 2011), this would reduce the accuracies for female skeletons and under represent them in the record.

5. CONCLUSION

Numerous researchers have noticed a more masculinized overall appearance in older female skulls compared to younger females (Goldstein, 1936; Weiss, 1972; Tallgren, 1974; Baughan and Demirjian, 1978; Meindl et al., 1985; Walker, 1995, 2008; Konigsberg and Hens, 1998). However, this study shows that when the nuchal crest, mastoid process, supraorbital margin, and supraorbital ridge are used there is no significant difference in the scores given to these traits for non-metric sex estimation between age groups. This raises the question of why female skulls appear to look more masculine as they get older, but when their traits are scored no statistically significant difference is detected.

Additionally, trends in the sex estimation accuracies of males and females occur even though there are no statistically significant results. While sex estimation accuracies in males rise as age increases, the accuracies in females varies and then appears to gradually decrease with age starting at about 70 years old.

This study is a step towards understanding the changes the skull undergoes in adulthood as it increases in age as well as showing where future research can focus on in order to better understand how the skull is affected by age. Some of the questions this study was not able to answer include: 1) why are there trends in male and female sex estimation accuracies using the skull if the traits do not statistically significantly differ by age, and 2) is the large drop in accuracy rates in females between the ages of 40-49 years a factor of menopause, and if so what influences are acting on the skull to reflect that? Future research should be undertaken to answer these questions. Finally, this study specifically focuses on White males and females. Because non-metric sex estimation using the skull is highly affected by ancestry (Maat et al., 1997; Durić et al., 2005), changes in non-metric sex estimation using the skull in other ancestry groups should be studied.

This study highlights several gaps in the research on the changes the skull undergoes as age progresses in adulthood, but it also shows how caution should be used when performing non-metric sex estimations using the skull. Younger adult skulls (30-49 years) that appear feminine may be underdeveloped males who have not developed the stereotypical heavy muscle marking and rugosity associated with males. Additionally, female skulls around the age of 40-49 years are more likely to be misclassified as male than at any other age. Finally, older skulls (70+ years) with rugose characteristics may be females that have developed a more masculinized appearance as the skull continues to grow. It is important to realize the directions of these biases for each age group when performing non-metric sex estimations because the sex biases are different for each age group. By doing so, more accurate sex estimations using the skull can be achieved for individuals in the targeted age ranges.

APPENDIX SECTION

APPENDIX 1: Examples of scores for the nuchal crest where 1= definite female, 3=ambiguous, and 5=definite male.

Trait Score

Nuchal Crest

1

3

5

APPENDIX 2: Examples of scores for the mastoid process where 1= definite female, 3=ambiguous, and 5=definite male.

Trait Score

Mastoid Process

1

3

5

APPENDIX 3: Example of scores for the supraorbital margin where 1= definite female, 3=ambiguous, and 5=definite male.

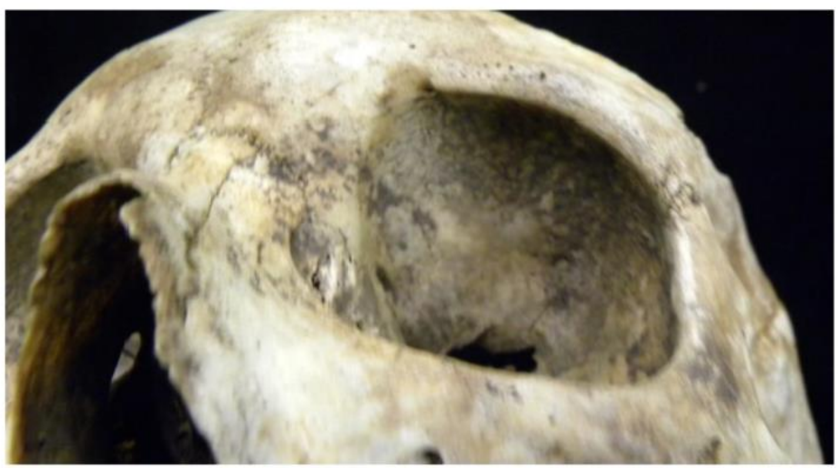
Trait Score

Supraorbital Margin

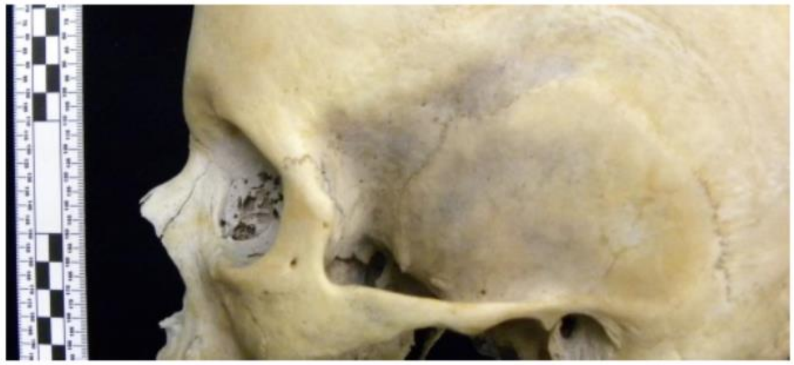
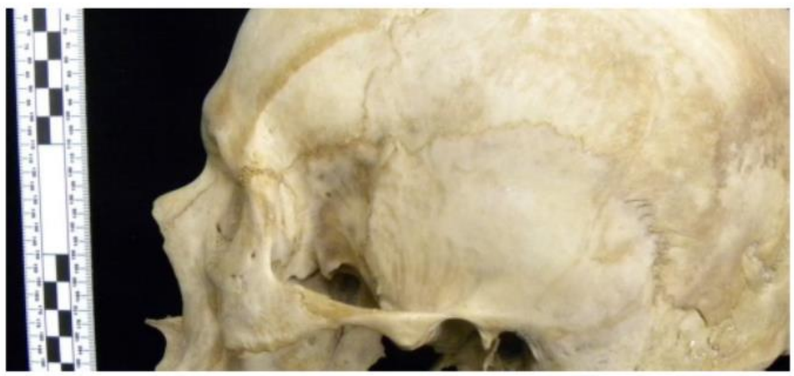
1

3

5



APPENDIX 4: Example of scores for supraorbital ridge where 1= definite female, 3=ambiguous, and 5=definite male.

Trait Score	Supraorbital Ridge
1	
3	
5	

APPENDIX 5: Age, sex, and trait scores assigned for each skull used in this study. Skeleton ID #'s shaded in grey are from the Texas State Donated Skeletal Collection at Texas State University, and those left white are from the William M. Bass Donated Skeletal Collection at the University of Tennessee.

Skeleton ID #	Age	Sex	Nuchal Crest	Mastoid Process	Supraorbital Margin	Supraorbital Ridge	Mental Eminence
13-88	31	Male	4	4	3	3	4
30-09	31	Female	2	3	2	2	3
03-2009	31	Male	4	4	2	3	3
10-2010	32	Male	5	5	3	5	5
13-91	33	Male	5	5	4	4	4
24-09	33	Male	5	4	3	4	3
40-08	33	Female	2	3	2	3	ABSENT
57-09	34	Female	3	3	4	1	3
04-10	35	Male	5	4	3	3	3
38-10	35	Male	4	2	2	3	4
02-89	36	Male	3	5	2	4	4
39-01	36	Female	4	2	3	3	ABSENT
77-07	36	Female	2	3	1	1	2
31-09	37	Male	4	4	3	5	5
27-91	38	Female	3	1	2	2	1
74-05	38	Male	4	5	5	4	5
27-93	39	Male	4	4	3	5	4
29-00	39	Male	3	4	4	3	3
32-06	39	Female	3	2	2	2	1
33-02	39	Male	5	4	5	5	4
44-04	39	Male	4	5	4	4	4
88-10	39	Female	3	3	2	2	3
01-00	40	Male	4	3	3	3	3
01-2011	40	Male	4	4	4	3	3
07-94	41	Male	3	4	4	3	4
22-95	41	Male	4	3	3	4	3
36-05	41	Male	4	4	5	4	5
43-10	41	Female	3	1	1	1	2
66-05	41	Male	4	4	4	4	2
66-10	41	Female	3	1	2	3	2
74-06	42	Female	4	2	1	1	2
03-00	43	Male	4	3	2	3	3
63-06	43	Male	3	3	1	3	4
72-10	43	Male	4	3	3	4	5
01-05	44	Male	4	4	3	4	3

09-01	44	Male	5	5	4	4	3
51-07	44	Female	3	3	2	2	2
53-07	44	Male	3	3	3	4	3
77-09	44	Female	2	1	1	2	ABSENT
82-09	44	Male	4	4	2	3	4
113-10	45	Female	4	1	2	3	ABSENT
28-90	45	Female	3	4	3	3	3
69-06	45	Female	4	1	1	1	2
73-04	45	Male	5	3	2	4	4
81-05	45	Male	3	4	3	5	4
11-03	46	Female	1	1	2	2	2
16-91	46	Male	4	3	2	5	4
19-88	46	Male	4	4	3	3	4
21-06	46	Male	5	3	2	5	5
30-93	46	Male	5	4	2	5	ABSENT
35-07	46	Female	4	3	2	1	2
84-08	46	Female	3	3	4	2	1
85-05	46	Female	3	2	2	1	1
87-10	46	Female	3	2	3	3	4
93-08	46	Female	4	4	4	4	4
07-10	46	Male	3	3	3	4	4
61-08	47	Female	2	2	2	2	2
66-04	47	Male	4	5	2	5	4
74-08	47	Male	4	5	5	3	4
87-09	47	Female	3	2	1	2	1
92-05	47	Female	5	5	3	2	3
16-2012	47	Male	4	5	4	3	3
32-2012	47	Female	1	1	2	2	2
116-10	48	Female	4	1	2	2	2
128-09	48	Female	4	1	3	3	ABSENT
13-03	48	Male	4	3	2	3	3
13-2012	48	Male	4	5	4	5	3
05-05	49	Male	4	4	3	3	ABSENT
08-09	49	Female	3	2	3	2	4
10-03	49	Male	4	3	3	3	4
10-88	49	Male	5	3	3	3	5
12-02	49	Female	4	4	4	4	4
109-07	49	Female	5	5	2	3	3
111-10	49	Male	4	2	5	3	3
16-07	49	Male	4	3	3	4	ABSENT
01-2009	49	Male	4	3	4	4	4

15-2011	49	Male	3	5	4	5	4
07-01	50	Female	4	2	2	2	2
52-04	50	Male	4	5	3	4	5
61-04	50	Male	4	4	2	2	ABSENT
64-10	50	Female	1	1	1	1	1
83-07	50	Male	4	4	4	4	ABSENT
85-06	50	Male	3	3	4	4	4
89-06	50	Female	3	2	2	1	2
95-08	50	Male	5	3	3	4	ABSENT
31-05	51	Female	3	2	2	3	2
33-03	51	Female	1	2	2	1	2
34-93	51	Male	3	3	3	5	ABSENT
40-06	51	Female	3	2	1	2	ABSENT
42-02	51	Male	4	3	2	3	ABSENT
44-05	51	Male	4	4	4	4	3
50-04	51	Male	3	4	3	3	3
03-06	52	Female	2	3	2	1	ABSENT
01-93	53	Female	3	3	3	3	2
02-98	53	Female	3	1	2	2	ABSENT
04-2010	53	Female	3	3	2	1	2
06-2011	53	Female	3	2	2	1	ABSENT
08-2011	53	Male	3	4	2	4	ABSENT
07-2012	53	Female	2	4	2	2	ABSENT
04-93	54	Male	3	3	3	4	3
09-99	54	Female	4	1	4	3	4
11-04	54	Female	2	1	3	1	ABSENT
117-08	54	Male	4	4	4	4	4
123-09	54	Female	5	4	5	4	5
12-2010	54	Male	4	3	3	3	2
09-2011	54	Female	3	4	2	2	3
12-2011	54	Female	2	2	3	3	4
11-00	55	Male	4	2	4	5	ABSENT
103-10	55	Female	3	3	2	2	1
106-10	55	Female	3	2	2	3	ABSENT
14-88	55	Male	4	3	2	4	ABSENT
18-99	55	Male	4	4	3	4	4
19-03	55	Male	4	4	3	4	5
20-99	55	Male	5	4	2	2	3
43-08	55	Female	2	2	3	2	3
09-97	56	Male	4	2	2	2	ABSENT
101-09	56	Female	4	1	3	1	2

42-06	56	Female	4	4	2	2	3
43-09	56	Male	2	3	3	2	3
47-01	56	Female	3	1	2	3	ABSENT
59-09	56	Male	5	5	5	5	5
23-2012	56	Male	5	5	4	4	2
56-07	57	Female	3	3	2	3	2
56-08	57	Female	3	2	2	1	2
61-09	57	Male	4	3	2	3	3
01-2012	57	Female	4	3	3	2	ABSENT
41-01	58	Female	3	3	1	1	2
57-08	58	Female	3	3	2	2	3
63-03	58	Female	3	2	3	1	ABSENT
79-05	59	Female	3	3	2	2	3
80-05	59	Female	3	1	3	2	2
91-05	59	Male	5	5	5	5	4
04-02	60	Female	3	2	2	2	ABSENT
101-06	60	Female	2	2	2	3	3
101-08	60	Female	2	3	2	1	ABSENT
05-2009	60	Male	4	5	4	5	4
03-08	61	Female	2	4	2	2	ABSENT
03-07	61	Female	1	1	1	1	2
05-03	61	Male	4	3	4	2	4
100-10	61	Male	3	4	3	4	5
10-02	61	Male	4	3	2	4	3
22-05	61	Male	4	4	5	5	5
02-92	62	Female	1	2	2	2	2
02-99	62	Male	3	3	3	4	3
06-08	62	Female	1	3	2	1	ABSENT
06-09	62	Male	3	4	2	4	4
06-92	62	Female	3	3	3	2	ABSENT
102-10	62	Female	3	2	1	2	1
15-2012	62	Male	5	3	4	5	3
01-10	63	Female	2	1	1	2	ABSENT
03-83	63	Male	4	3	2	4	ABSENT
08-94	63	Male	4	2	3	4	ABSENT
09-02	63	Male	3	5	3	3	4
10-10	63	Female	4	2	1	2	3
102-08	63	Female	2	2	2	2	3
21-99	63	Male	4	3	2	4	ABSENT
09-2010	63	Male	5	3	3	4	4
35-2012	63	Female	4	4	2	2	2

08-01	64	Male	4	5	5	5	ABSENT
09-95	64	Female	3	2	2	3	3
03-10	65	Male	4	3	2	4	3
06-91	65	Male	4	2	2	4	ABSENT
09-98	65	Male	5	3	3	3	2
14-10	65	Female	3	2	2	2	ABSENT
18-09	65	Male	4	3	3	4	3
20-02	65	Male	3	3	2	4	ABSENT
02-2008	65	Female	3	3	4	2	3
13-2011	65	Male	4	2	3	3	ABSENT
103-07	66	Male	4	3	3	3	ABSENT
121-09	66	Female	3	3	2	1	2
23-2011	66	Female	2	2	2	1	3
11-90	67	Female	1	2	2	1	ABSENT
05-2010	67	Male	4	4	5	4	ABSENT
10-08	68	Male	3	4	4	4	3
105-07	68	Female	4	2	1	1	2
105-07	68	Female	3	3	2	2	ABSENT
117-10	68	Female	4	4	3	2	ABSENT
21-90	68	Male	3	4	2	3	3
03-2011	68	Male	4	3	2	4	3
04-2011	68	Female	3	2	3	1	2
06-95	69	Female	1	3	2	2	ABSENT
10-98	69	Female	4	2	2	2	2
104-09	69	Male	4	1	3	5	ABSENT
108-07	69	Male	3	3	4	2	2
13-02	69	Female	3	1	2	2	ABSENT
15-07	69	Female	2	2	2	2	ABSENT
04-03	70	Male	5	2	3	3	ABSENT
09-08	70	Male	4	2	3	3	ABSENT
103-06	70	Male	5	4	4	3	ABSENT
114-10	70	Female	3	1	1	1	ABSENT
13-2010	70	Male	4	3	3	4	4
07-06	71	Male	4	5	3	3	ABSENT
07-95	71	Female	1	2	1	2	ABSENT
105-09	71	Male	4	5	5	4	ABSENT
13-97	71	Female	4	2	1	1	ABSENT
19-05	71	Male	4	3	2	5	ABSENT
20-06	71	Female	3	1	2	1	ABSENT
20-92	71	Male	4	3	3	4	4
02-2010	71	Male	4	4	3	4	ABSENT

44-01	72	Male	3	4	2	4	ABSENT
64-03	72	Male	4	4	2	4	ABSENT
91-10	72	Male	3	3	3	4	2
01-04	73	Female	1	1	3	2	ABSENT
20-07	74	Male	5	2	3	4	ABSENT
26-99	74	Female	3	2	2	1	3
31-08	74	Male	5	4	3	4	ABSENT
35-09	74	Female	2	2	2	1	1
20-2011	74	Female	3	2	3	2	2
13-04	75	Male	3	3	3	4	ABSENT
13-08	75	Female	2	1	2	1	ABSENT
17-07	75	Male	4	4	3	5	4
27-10	75	Male	4	2	2	3	ABSENT
55-08	75	Female	2	2	2	2	ABSENT
69-10	75	Female	3	2	2	1	2
03-2008	75	Male	5	4	5	4	4
11-2011	75	Male	4	5	3	4	4
17-2011	75	Female	3	2	3	4	2
11-05	76	Female	2	4	2	3	2
23-93	76	Male	4	4	2	3	ABSENT
34-03	76	Male	3	3	2	3	ABSENT
15-09	77	Female	3	4	2	1	2
26-90	77	Male	5	5	3	5	3
31-01	77	Male	5	4	2	3	5
90-07	77	Female	3	3	2	2	ABSENT
91-06	77	Female	3	3	2	1	ABSENT
92-07	77	Male	5	3	4	3	ABSENT
06-2009	77	Female	2	2	2	2	3
07-10	78	Male	2	5	4	4	ABSENT
22-90	78	Male	3	2	2	3	ABSENT
67-10	78	Male	4	4	4	3	4
01-83	79	Female	2	2	1	1	ABSENT
01-97	79	Male	4	4	4	2	4
08-02	79	Female	3	3	2	1	2
11-08	79	Female	4	3	1	3	3
121-08	79	Male	5	4	2	3	ABSENT
02-95	80	Female	2	3	3	2	2
06-07	80	Male	4	2	4	4	ABSENT
06-93	80	Female	1	1	1	3	ABSENT
110-10	80	Female	3	1	2	2	ABSENT
15-98	80	Female	3	2	3	3	ABSENT

05-2011	80	Male	4	3	3	4	ABSENT
02-07	81	Male	3	5	3	4	4
108-08	81	Female	1	2	2	1	ABSENT
120-08	81	Female	3	1	2	2	ABSENT
18-06	81	Male	4	5	4	4	4
20-93	81	Female	2	1	2	1	ABSENT
09-07	82	Male	4	5	4	4	ABSENT
12-87	82	Male	4	2	3	3	ABSENT
103-08	82	Male	3	5	5	3	3
114-08	82	Male	4	1	4	5	4
124-09	82	Female	3	1	2	2	ABSENT
16-99	82	Female	3	2	2	3	ABSENT
21-93	82	Female	3	2	1	1	2
18-94	83	Female	3	2	2	3	ABSENT
20-01	83	Female	4	1	1	3	2
24-2012	83	Female	5	1	3	2	3
01-01	84	Male	4	3	3	4	3
12-08	85	Male	4	2	1	4	ABSENT
102-09	85	Male	5	2	3	4	3
126-09	85	Female	3	4	4	3	4
19-02	85	Female	3	1	1	2	ABSENT
19-98	85	Male	3	4	3	4	ABSENT
21-02	85	Female	3	3	3	3	ABSENT
26-06	85	Male	4	3	2	3	4
32-03	85	Female	3	2	2	1	2
54-08	85	Female	3	2	3	2	1
13-01	86	Male	4	4	2	3	ABSENT
15-10	86	Female	2	2	3	2	3
16-04	86	Male	4	4	3	4	ABSENT
16-92	86	Male	4	4	4	5	ABSENT
02-96	87	Male	3	4	3	5	2
07-03	87	Male	5	5	4	3	ABSENT
20-09	87	Female	2	2	2	2	2
04-2009	87	Female	4	3	4	3	3
07-2011	87	Male	5	5	3	4	4
03-98	88	Male	4	2	2	4	ABSENT
05-00	88	Male	3	4	4	4	ABSENT
11-01	88	Female	4	2	2	2	1
27-99	88	Male	5	4	5	5	ABSENT
101-07	89	Female	2	2	3	2	ABSENT
21-94	89	Male	4	3	1	3	ABSENT

04-01	90	Male	4	3	2	4	4
13-06	90	Male	4	4	3	4	3
68-09	90	Female	2	1	2	2	ABSENT
108-09	91	Female	2	1	2	3	ABSENT
17-04	91	Female	3	3	3	2	2
02-2009	91	Male	4	4	5	5	ABSENT
11-2010	91	Male	4	5	3	3	3
37-09	92	Female	3	2	2	2	2
78-08	92	Female	2	2	2	3	1
89-11	92	Female	3	2	2	1	1
?01-09	93	Female	2	3	2	3	3
33-01	93	Female	4	3	3	3	ABSENT
94-06	93	Female	2	2	2	2	2
10-97	94	Male	4	1	2	4	ABSENT
122-09	94	Female	3	1	2	2	2
23-09	94	Female	2	3	2	2	ABSENT
33-99	94	Female	4	4	2	2	2
46-09	95	Female	3	4	3	3	2
01-02	96	Male	3	3	3	4	3
112-08	97	Female	3	3	3	2	3
32-99	97	Male	4	3	3	5	ABSENT
26-2012	102	Female	3	2	3	1	4

WORKS CITED

Acsádi GY, Nemeskéri J. 1970. History of human life span and mortality. Budapest: Akadémiai Kiadó.

Ahlborg HG, Johnell O, Turner CH, Rannevik G, Karlsson MK. 2003. Bone loss and bone size after menopause. N Engl J Med 349:327–334.

Baer MJ. 1956. Dimensional changes in the human head and face in the third decade of life. Am J Phys Anthropol 14:557–575.

Bass WM. 1987. Human osteology. Columbia: Missouri Archaeological Society, Inc.

Baughan B, Demirjian A. 1978. Sexual dimorphism in the growth of the cranium. Am J Phys Anthropol 49:383–390.

Buikstra JE, Ubelaker DH. 1994. Standards for data collection from human skeletal remains. (Haas J, editor.). Fayetteville, AK: Arkansas Archeological Survey.

Durić M, Rakocević Z, Donić D. 2005. The reliability of sex determination of skeletons from forensic context in the Balkans. Forensic Sci Int [Internet] 147:159–64. Available from: http://www.ncbi.nlm.nih.gov/pubmed/15567621

Ferembach D, Schwidetzky I, Stloukal M. 1980. Recommendations for age and sex diagnoses of skeletons. J Hum Evol 9:517–549.

France D. 1998. Observational and metric analysis of sex in the skeleton. In: Reichs KJ, editor. Advances in the Identification of Human Remains. Springfield, IL: Charles C. Thomas.

Geusens P, Dequeker J, Verstraeten A, Nijs J. 1986. Age-, sex-, and menopause-related changes of vertebral and peripheral bone: population study using dual and single photon absorpitometry and radiogrammetry. J Nucl Med 27:1540–1549.

Goldstein MS. 1936. Changes in dimension and form of the face and head with age. Am J Phys Anthropol 22:37–89.

St. Hoyme LE. 1984. Sex differentiation in the posterior pelvis. Coll Antropol 69:139–153.

Işcan MY. 1988. Rise of forensic anthropology. Yearb Phys Anthropol 31:203–230.

Israel H. 1968. Continuing growth in the human cranial skeleton. Arch Oral Biol 13:133–137.

Israel H. 1973. Age factor and the pattern of change in craniofacial structures. Am J Phys Anthropol 39:111–128.

Israel H. 1978. The fundamentals of cranial and facial growth. In: Falkner F, Tanner JM, editors. Human Growth: Postnatal Growth. New York: Plenum Press. p 357–380.

Israel H. 1979. Evidence for continued apposition of adult mandibular bone from skeletalized materials. J Prosthet Dent 41:101–104.

Kelley M. 1979. Sex determination with fragmented skeletal remains. J Forensic Sci [Internet] 24:154–158. Available from: http://www.ncbi.nlm.nih.gov/pubmed/512598

Konigsberg LW, Hens SM. 1998. Use of ordinal categorical variables in skeletal assessment of sex. Am J Phys Anthropol 107:97–112.

Krall EA, Parry P, Lichter JB, Dawson-Hughes B. 1995. Vitamin D Receptor Alleles and Rates of Bone Loss; Influences of Years since Menopause and Calcium Intake. J Bone Miner Res 10:978–984.

Krogman WM, Işcan MY. 1986. The human skeleton in forensic medicine. Springfield, IL: Charles C. Thomas.

Maat GJR, Mastwijk RW, Van Der Velde E a. 1997. On the reliability of non-metrical morphological sex determination of the skull compared with that of the pelvis in The Low Countries. Int J Osteoarchaeol [Internet] 7:575–580. Available from: http://doi.wiley.com/10.1002/(SICI)1099-1212(199711/12)7:6<575::AID-OA308>3.0.CO;2-4

Meindl RS, Lovejoy CO, Mensforth RP, Don Carlos L. 1985. Accuracy and direction of error in the sexing of the skeleton. 68:79–85.

Meindl RS, Lovejoy CO. 1985. Ectocranial suture closure: a revised method for the determination of skeletal age at death based on the lateral-anterior sutures. Am J Phys Anthropol [Internet] 68:57–66. Available from: http://www.ncbi.nlm.nih.gov/pubmed/4061602

Novotny V, Işcan MY, Loth S. 1993. Morphologic and osteometric assessment of age, sex and race from the skull. In: Işcan MY, Helmer RP, editors. Forensic analysis of the skull. New York: Wiley-Liss. p 71–88.

Phenice TW. 1969a. A newly developed visual method of sexing the os pubis. Am J Phys Anthropol 30:297–301.

Phenice TW. 1969b. Intra- and interobserver concordance in classifying dental morphology. Am J Phys Anthropol 69:299–315.

Riggs BL, Wahner HW, Melton LJ 3rd, Richelson LS, Judd HL, Offord KP. 1986. Rates of bone loss in the appendicular and axial skeletons of women. Evidence of substantial vertebral bone loss before menopause. J Clin Invest 77:1487–1491.

Riis BJ, Hansen MA, Jensen AM, Overgaard K, Christiansen C. 1996. Low bone mass and fast rate of bone loss at menopause: equal risk factors for future fracture: a 15-year follow-up study. Bone 19:9–12.

Rogers TL. 1991. Sex determination and age estimation: skeletal evidence from St. Thomas' Cemetery Belleville, Ontario.

Rogers TL. 2005. Determining the sex of human remains through cranial morphology. J Forensic Sci [Internet] 50:1–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/15932077

Spradley MK, Jantz RL. 2011. Sex estimation in forensic anthropology: skull versus postcranial elements. J Forensic Sci [Internet] 56:289–296. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21210801

Stevenson JC, Mahoney ER, Walker PL, Everson PM. 2009. Technical note: prediction of sex based on five skull traits using decision analysis (CHAID). Am J Phys Anthropol [Internet] 139:434–41. Available from: http://www.ncbi.nlm.nih.gov/pubmed/19350636

Stewart TD. 1954. Sex Determination in the skeleton by guess and by measurement. Am J Phys Anthropol 12:385–392.

Stewart TD. 1979. Essentials of Forensic Anthropology. (Thomas CC, editor.). Springfield.

Tallgren A. 1974. Neurocranial morphology and ageing- a longitudinal roentgen cephalometric sutdy of adult Finnish women. Am J Phys Anthropol 41:285–294.

Walker PL. 1995. Problems of preservation and sexism in sexing: some lessons from historical collections for paleodemographers. In: Saunders S, Herring A, editors. Grave Reflections: Portraying the Past Through Skeletal Studies. Toronto: Canadian Scholars' Press. p 31–47.

Walker PL. 2008. Sexing skulls using discriminant function analysis of visually assessed traits. Am J Phys Anthropol [Internet] 136:39–50. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18324631

Walrath DE, Turner P, Bruzek J. 2004. Reliability test of the visual assessment of cranial traits for sex determination. Am J Phys Anthropol [Internet] 125:132–137. Available from: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15365979

Weiss KM. 1972. On the systematic bias in skeletal sexing. Am J Phys Anthropol 37:239–249.

Williams BA, Rogers TL. 2006. Evaluating the accuracy and precision of cranial morphological traits for sex determination. J Forensic Sci [Internet] 51:729–735. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16882212

Zieve D, Storck S. 2011. Menopause. U S Natl Libr Med [Internet]. Available from: http://www.ncbi.nlm.nih.gov/pubmedhealth/PMH0001896/