Agreement in Sexing and Estimating Stature in Human Skeletal Remains

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ABSTRACT

Forensic anthropology involves the application of anthroposcopic and anthropometric techniques to analyze human skeletal remains. This research outlines the assessment of a set of human skeletal remains for characteristics of sex and stature using forensic anthropological techniques to conclude whether various bones in a human skeleton are in agreement regarding these characteristics. The data for this study was collected using sliding calipers, spreading calipers, a soft measuring tape, and an osteometric board. In addition to the anthropometric data collected for statistical analysis, anthroposcopic data was also used to visually assess the individual. After the data collection concluded, various methods were applied for assessing sex and estimating stature that are used by a multitude of researchers in the field of forensic anthropology. Of the studied individual, the sex was determined to be female and the stature found in the range of five foot five to five foot six inches as determined by a majority of the results. Albeit being affected by some limitations, the study contributed to knowledge in the application of assessment methods for these two characteristics and how well various bones agreed regarding the sex and stature of the individual.

Introduction

This research concerned the assessment of sex and stature of a set of human skeletal remains stored at Monmouth University as of 2021, which were on loan from Rutgers University, Newark. Sex and stature were assessed through the use of anthropometry, anthroposcopy, and statistical calculations used by practitioners in the field of forensic anthropology. This type of analysis can be used to identify unknown persons in the context of criminal investigations, found remains, or incidents regarding mass grave/ disaster victim identification. The examined human remains were found during an archeological excavation of a cemetery and stored at universities in New Jersey for further examination.

Traditionally, the crania, pelvis, and long bones have been found to be integral to these assessments. Due to the consistency of these bones among populations of people, they tended to be the most consistent and accurate to use for conducting analyses of sex and stature. Therefore, these specific bones among others were analyzed from the individual. It was noted while performing the analysis that certain traits can be population specific and variation may be present from the expected results as age and ancestry were not accounted for while performing the statistical calculations.

Methods and Materials

This research was accomplished through a thorough investigation of the remains of a human skeleton stored at Monmouth University. There were a total of 113 bones not with skeleton, leaving 93 bones for this assessment, all of which were in excellent condition. Although this study targeted assessing sex and stature, age at death was established under the larger category of "adult" and various ancestries of White, Black, Asian, and Native American were accounted for.

Data was collected and measurements were made to distinguish if multiple parts of the skeleton were in agreement regarding their identifying characteristics with many methods stemming from journal articles. This data was collected using sliding calipers, spreading calipers, and an osteometric board. In addition, anthroposcopic data was used in conjunction with this morphometric data in order to rate characteristics of the individual. The research methodology and techniques used provided ways to recognize which bones were more consistent for this assessment.

Assessment methods were ascertained from a thorough literature review of methods used in this field. This study primarily focused on discerning sex and stature, though understanding how age and ancestry can be determined are integral processes that can impact these results.

Sex

Sex estimation can be completed through a series of skeletal examinations of the skull and pelvis, which can vary by population (Smithsonian 2021). The skull can be examined using morphoscopic and/ or morphometric techniques (Franklin et al. 2013, 158.e1) as sexual dimorphism is commonly found in cranial size and features based on geography, though the magnitude and expression vary; therefore, population-specific standards are important for sex determination (Franklin et al. 2013, 158.e1). Various measurements of the skull can be accounted for, include bizygomatic breadth (BB), basion-nasion length (BNL), glabello-occipital length (GOL); morphology can include the glabella and superciliary arch, frontal bone, eye orbits, mandibular angle, etc. The pelvic bone is known to be the most sexually dimorphic bone of the human skeleton, so methods have been developed to visually assess and score traits. The pelvis can be examined at the ilia, greater sciatic notch, subpubic angle, subpubic concavity, morphology of the symphysis and ischium, obturator foramen, and diameter of the acetabulum, among other notable features, some of which may be population specific. It has been noted that it may not be necessary to use population-specific formulae concerning sex determination by the pelvis as it is likely constrained by usage for childbearing and possibly weightbearing of the upper body (Franklin et al. 2013; Grabherr et al. 2009; Selliah et al. 2009; Tise et al. 2013; Wilson et al. 2008; Bubalo et al. 2019; Steyn and Patriquin 2009).

If the skull and pelvis are absent, the clavicle, long bones, and fourth lumbar vertebra can be used for determination. In referencing the long bones, measurements can be made on the humerus, radius, femur, and tibia regarding length, diameter of the heads, and epicondylar breadth, with the preauricular sulcus showing a higher accuracy compared to the morphology of the greater sciatic notch, though the highest classification for the rate of sex has been documented using the maximum epiphyseal breadth of the proximal tibia (Selliah et al. 2020). According to Albanese (2013), the ulna is a major sex indicator, and if that is not available for analysis, the maximum diameter of the radial head is a significant predictor; if neither is available, there is an equation that uses the measurements of the clavicle and humerus to estimate sex. The humerus has been found to have a high discriminatory value in sex estimation (92.86%) in population-specific analyses (Kranioti and Michalodimitrakis 2009). Regarding specific Hispanic populations, Tise et al. (2013) found that clavicle maximum length (87.29%), humeral head diameter (85.66%), and humeral epicondylar breadth (85.32%) were the most accurate single measurements compared to the scapula, femur, and tibia, though in cross-validation the radius provided the highest total rate.

The maximum and minimum widths, depths, and heights of the L4 body can be measured excluding any vertebral pathologies, like segmentation error, endplate erosion, severe disc degeneration, spondylosis, and Schmorl's nodes. Multivariate regression analyses that include the mean width, depth, and height of the L4 yielded high sex estimation accuracies in the age groups of 20 (86.4%), 30 (87.7%), and 46 (82.8%) years old (Oura et al. 2018).

Stature

Estimations of stature can typically be performed using long bone lengths (Gocha et al. (2013)), tibial fragments (Spies et al. (2019)), the sacrum (Hayashi et al. (2016)), and a range of other human bones (Maijanen (2009)). However, Marinho et al. (2012) found that sternum length cannot reliably be used to estimate an individual's stature as there was found to be considerable variation.

Craniofacial dimensions of the skull can be used in correlation to body height, including the maximum head breath and length, minimum frontal diameter, bizygomatic breadth, basion-bregma, and more facial lengths in the Frankfurt horizontal plane. In the skull, interpremolar width and intercanine width of teeth can be measured with significant correlation to height, though the combined width of six anterior teeth and arch length may not show a significant correlation to height (Pelin et al. 2010; Gocha et al. 2013; Khangura et al. 2015).

The most common way to estimate stature is through long bones, though foot height can also be used to estimate total stature, specifically by articulating the talus and calcaneus (Gocha et al. 2013). Using single elements of the body for stature estimation, the spine is one of the main components of stature, and thus vertebral dimensions are highly intercorrelated. The mean width, depth, and height of the fourth lumbar vertebra (L4) was calculated from six measurements that were obtained from the L4 body (Oura et al. 2018). Hayashi (2016) rearticulated the pelvic bones to calculate the direct distance between the superior margins of the acetabulae and the sacrum. Three points were used to calculate vertical space height and the distance between the anterior margin of the sacral promontory and the plane between the superior margins of the left and right acetabulae. Reconstructing the pelvis and measuring only the portions of the elements that, when in anatomical position, contribute to standing height, results in estimations of standing height that are typically within 20 millimeters of the adjusted cadaver stature (Hayashi et al. 2016).

Total skeletal height can be taken using the Fully Method, also referred to as the Complete Skeletal Method, which required the measurement of all bones contributing to stature, especially cranial height, second cervical to fifth lumbar vertebra, first sacral body, physiological length of the femur, maximum (condyle-malleolar) length of the tibia, and articulated talus and calcaneus. Other vertebral heights and measurements could also be applied to this method. Distal breadth of the left tibia had the highest correlation with total height for both sexes (Hayashi et al. 2016; Spies et al. 2019; Maijanen 2009). Soft tissue correction factors and age can also be accounted for as proposed modifications to Fully's techniques (1956), as stature is known to decrease with age (Raxter et al. 2006).

Age and Ancestry

There is not one method used by all forensic anthropologists to assess adult age, but by surveying and ranking responses, anthropologists have specified preferred skeletal regions. Of this, the pubic symphysis was voted the most reliable method, then the sternal rib ends, followed by auricular surfaces, and cranial sutures, with dental wear being the least preferred and reliable (Garvin and Passalacqua 2012, 427-432). Using the Hamann-Todd and W. M. Bass collections, adult analyses of the fourth rib and pubic symphysis found that age estimates were impacted by small stature and obesity, as body mass strongly influences skeletal age estimation, in addition to the positive correlation between acetabular changes and osteoarthritis as a possible indicator for older persons (Merritt 2017; Winburn 2019).

Ancestry can be determined using both metric and non-metric approaches. Metric approaches include craniometric analysis with landmarks like the metopion-opisthion, alare-alare, and nasal height as a few examples, along with software like FORDISC, CRANID, AncesTrees, 3Skull program, and geometric morphometric techniques. Chi-square tests can be used to find statistically significant differences in zygomaxillary suture frequencies between ancestral populations. Palate curves and shape can be examined through a computer program as a major indicator of ancestry and are very variable, with correct assessments only found 58% of the time. Dentition morphology can also determine if an individual would have been considered African American, European American, Hispanic from New Mexico, or Hispanic from South Florida (Cunha and Ubelaker 2020; Spradley and Jantz 2016; Maddux et al. 2015; Maier et al. 2015; Edgar 2013).

Theoretical Perspectives

Two main theoretical views framed the research question and methodology. Feminist anthropology focused on increasing women's voices and the female perspective on experience, as well as separating sex and gender in terms of cultural ideas and biological traits. Sex was focused on during the third wave of feminism, addressing that there was no essential idea of "sex" and made calls for changes in defining sex and gender (Lumen 2017).

Feminist anthropology aimed to ask questions about how gendered differences in power and knowledge have been constructed over time, how gender differences are recreated or resisted, and how they are changed (Walter 1995:272-273). This theory has unfolded in three parts, commencing in the 1970s: the anthropology of women, the anthropology of gender, then feminist anthropology. Most applicable to this research was the second wave, during which sex and gender were separated as descriptive categories, rather than used interchangeably. Sex was defined as being determined by biology and in turn, effecting biology, contrasting how gender was culturally defined (Lumen 2017).

The second theory that was utilized was evolutionary anthropology (Duke University 2021). Evolutionary anthropology focuses on the mechanisms and outcomes of evolution as human environments have been drastically altered, particularly over the last 12,000 years (Mattison and Sear 2016:340). Similar populations of people tend to share characteristics that may not be present in other populations, which may change over evolutionary time, but can become characteristic of particular groups. Charles Darwin renowned a theory known as "descent with modification", which emphasized the continuity between populations, subspecies, sibling species, and so on (Penny 2011:e1001096). In essence, similar groups or populations of organisms would pass along traits specific to their group or population, allowing for some change over time, but really allowing for specific traits to be passed down.

Both feminist anthropology and evolutionary anthropology relate to how the body can change over time with the environment and provided a definition for sex, clarifying an assessed characteristic. As a recent development in the early 2000s, feminist anthropology was able to bring their perspectives into the field of biological anthropology, which has helped contribute to how sex is understood (Babb 2007:4); "sex" is understood as the biology of an individual, while "gender" has been concluded to as a social construct. This occurred through the reduction of male bias in research findings, anthropological hiring practices, and the pedagogical production of knowledge, allowing for the implementation of this form of anthropology into a more biological-based field. The focus of evolutionary anthropology on human evolution is useful in understanding why traits are population specific and can explain the development of humans in their environment.

Data and Results

Sex

Sex was attributed using both anthroposcopy and metrics. As the ancestry of the tested individual for this thesis was unknown, testing was extended to a multitude of ancestries, such as White, Black, Native American, and Hispanic.

Using cranial anthroposcopy to attribute sex, out of seven characteristics of male and female skulls, six characterized them as female and one as male: the skull was small and smooth in size, with little to no brow ridge and a high, rounded frontal bone. The nuchal area was smooth, lacking a hook, though there was a large, projecting mastoid (Figure 1). The skull also possessed feminine traits of a sharp supra-orbital margin and pointed chin. In modern populations, variation in cranial features to attribute sex were scaled from (1) as most feminine to (5) as most masculine for the glabella, mastoid, mental eminence, orbital margin, and nuchal area. Equation 1 displays the equations to determine sex; values less than zero were classified as male and values greater than zero were classified as female. Three separate equations following this method were also tested for Native Americans (Eq. 2), two of which deemed the skull to be female.

Table 1. Description of sex measurements.

Measurement	**Description**
Maximum cranial length (ML)	maximum length of the skull
Maximum cranial breadth (MB)	maximum breadth of the skull, above the supramastoid crest
Basion-bregma (BaBr)	basion to bregma of skull
Basion-nasion (BaNa)	basion to nasion of skull
Bizygomatic breadth (BB)	maximum width across the zygomatic arches of the skull
Basion-prosthion (BaPr)	basion to prosthion of skull
Glabello-occipital length (GOL)	greatest length from the glabella region in the median sagittal plane
Nasion-alveolare (NaAl)	nasion to lowest point on the alveolar border between the central incisors
Palatal breadth (PB)	maximum breadth of the palate
Mastoid length (LM)	length of the mastoid process while orienting the skull in the Frankfort plane; place the upper arm of the caliper in line with the upper border of the external auditory meatus while the lower arm is brought in line with the lowest point on the process while holding the caliper vertically
Pubic length	the base point is inside the acetabulum where the ilium, ischium, and pubic fuse to the end of the pubic bone
Ischium length	the base point is inside the acetabulum where the ilium, ischium, and pubic fuse to the protruding end of the ischium
Scapula body	maximum length of the scapula by measuring the straight distance between the superior and inferior borders
Glenoid fossa of scapula	height of the glenoid cavity
Head of humerus (VHDH)	vertical head diameter measurement of the humerus through diagonal measurement from the most superior point on the margin of the articular surface to the most inferior point on the margin of the articular surface on the head of the humerus
Head of radius	measurement of the radial head through the maximum diameter as the greatest value of the distance when rotating the radius 360°
Head of femur	head diameter of the femur through a diagonal measurement
Clavicle maximum length (MCL)	maximum length from the sternal end of the clavicle to the scapular end of the clavicle
Midshaft of the clavicle for cranial-caudal diameter (CCDC)	the cranial-caudal diameter of the clavicle at midshaft with the flat surface of the scapular end of the clavicle should be held parallel to the arms of the calipers
Epicondylar breadth of humerus (EBH)	the maximum distance between the medial epicondyle and the lateral epicondyle on the distal humerus. Measured using sliding calipers
Anterior-Posterior Diameter of Ulna (APDU)	the anterior-posterior diameter of the ulna perpendicular to the diameter at maximum crest pronouncement. Measured using sliding calipers
Acetabular diameter (AD)	maximum diameter of the acetabulum is measured in a superior to inferior direction (diameter of the acetabulum along the axis of the body of the ischium)
Transverse acetabular diameter (TAD)	maximum acetabular diameter from the pubic eminence on the acetabular rim

Figure 1. Images of the analyzed human cranium from the anterior (1a), lateral (right side-1b, left side-1c), and inferior angles (1d).

Modern Populations*

Values < 0 = male ; values > 0 = female

Variation in the cranial features to attribute sex range from (1) most feminine to (5) most masculine

Glabella = 3 ; Mastoid = 3 ; Mental = 1 ; Orbital Margin = 1 ; Nuchal = 1

$9.128 - 1.375(3) - 1.185(3) - 1.151(1) = 0.297$ FEMALE
Glabella Mastoid Mental
$7.434 - 1.568(3) - 1.459(3) = -1.647$ MALE
Glabella Mastoid
$7.372 - 1.525(3) - 1.485(1) = 1.312$ FEMALE
Glabella Mental
$7.382 - 1.629(1) - 1.415(3) = 1.508$ FEMALE
Mental Mastoid
$6.018 - 1.007(2) - 1.850(1) = 2.154$ FEMALE
Orbital Margin Mental
$5.329 - 0.7(1) - 1.559(3) = -0.048$ MALE
Nuchal Mastoid

Sex: 4 Female, 2 Male

Equation 1. Characteristics of male and female skulls using values from modern populations. Values below zero are considered male and values above zero are considered female. The mental eminence and nuchal area are the most feminine characteristics at (1), the orbital margin is feminine at (2) with both the glabella and mastoid indeterminate at (3).

Cranial metrics, specifically discriminant functions, were also used to determine sex. On the skull, measurements were taken of the maximum length, maximum breadth, basion-bregma, bizygomatic breadth, basion-prosthion, nasion-alveolare, palatal breadth, and the mastoid length. These measurements each had their own equation with a specific coefficient to be multiplied by; the results were added to a total sum of 2285.496. With a sectioning point of 2672.39, the sex was characterized as female as the sum of the cranial metrics was less than this point of determination (Table 2).

Native Americans*

Values < 0 = male ; values > 0 = female

Variation in the cranial features to attribute sex range from (1) most feminine to (5) most masculine

Glabella = 3 ; Mastoid = 3 ; Mental = 1 ; Orbital Margin = 1 ; Nuchal = 1

$3.414 - 0.499(2) - 0.606(1) = 1.81$ FEMALE
Orbital Margin Mental
$4.765 - 0.576(1) - 1.136(3) = 0.781$ FEMALE
Mental Mastoid
$5.025 - 0.797(3) - 1.1085(3) = -0.621$ MALE
Glabella Mastoid

Sex: 2 Female, 1 Male

Equation 2. Characteristics of male and female skulls using values from Native American populations in statistical equations. As in Fig.2, there were more female than male results.

Table 2. Attributing sex using cranial metrics. As the sum of the discriminant functions was less than the sectioning point, the sex was determined as female.

Attributing Sex Using Cranial Metrics (in mm)

Cranial Characteristic	**Discriminant Function**	**Cranial Metric Equation**
Max. Length (ML)	ML x coefficient	$114.29 \times (3.107) = 355.099$
Max. Breadth (MB)	MB x coefficient	$121.69 \times (-4.643) = -565.007$
Basion-Bregma (BaBr)	BaBr x coefficient	$107.23 \times (5.786) = 620.433$
Bizygomatic Breadth (BB)	BB x coefficient	$115.22 \times (14.821) = 1707.676$
Basion-Prosthion (BaPr)	BaPr x coefficient	$90.51 \times (1.000) = 90.51$
Nasion-Alveolare (NaAl)	NaAl x coefficient	$64.8 \times (2.714) = 175.867$
Palatal Breadth (PB)	PB x coefficient	$53.9 \times (-5.179) = -279.148$
Mastoid Length (LM)	LM x coefficient	$29.66 \times (6.071) = 180.066$

Sum: 2285.496

Sectioning Point: 2672.39

Sex: Female

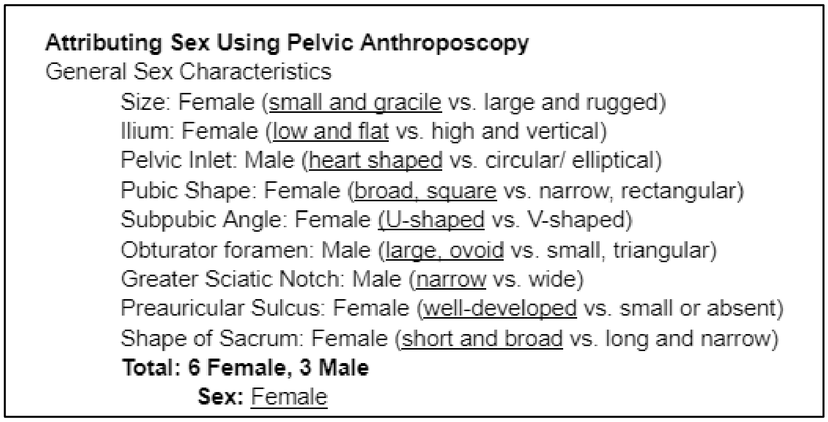
As per the article by Franklin et al. (2013), both direct single variables and direct and stepwise multiple variables were used to identify sex. In the article, for the bizygomatic breadth (BB), the female range was between 111.4-138.0 millimeters, with a mean of 108.9 millimeters, and the male range was 132.7-143.5 millimeters, with a mean of 132.1 millimeters from the article. The BB measurement taken from this skeleton was 115.22 millimeters, categorizing the skeleton as female. BB was considered the most accurate single variable that was tested (85.0%) and also presented the smallest sex bias (-0.5%), so there was a high confidence of the sex based on BB as it falls within the female range. Of the basion-nasion length (BNL), the female range was 85.7-110.4 millimeters with a mean of 99.2 millimeters, and the male range was 92.8-117.2 millimeters with a mean of 106.2 millimeters as presented in the article. The BNL of the measured skeleton was 99.24 millimeters, which overlaps between both the male and female ranges, so the sex cannot be confirmed, but the BNL of this skeleton has the same measurement of the mean of the females from the article by Franklin et al. (2013). The last direct single variable tested in this analysis was glabello-occipital length (GOL), which was found to be 175.40 millimeters. This classified the sex as unknown, but closer to the mean of the females presented in the article at 179.50 millimeters. The male range presented in the article was 167.20-206.99 millimeters, with the mean at 189.60 millimeters. For females, the range was 160.30-194.60 millimeters with the mean at 179.50 millimeters. Franklin et al.'s study (2013), displayed that the measurements expressing the greatest dimorphism amongst a variety of populations including BB, BNL, and GOL, and the GOL was also considered the third most accurate single variable in the article, with an accuracy of 76.8% and a sex bias of 2.1%. For the direct and stepwise multiple variables, the stepwise analysis selected three variables (GOL, BB, LM]), which correctly referred 90.0% of individuals to their respected sex, with a bias of -2.2%. When this was tested through a discriminant equation, the result was -2.3036017 (Table 3). As the result in this study was less than -1.223, the sex of the skeleton was considered female.

Table 3. Direct and stepwise multiple variable equation testing GOL, BB, and LM for sex determination. The female sectioning point was -1.223 or less, and as the equation produced a result of -2.3036017, the skeleton is sexed as female.

Direct and Stepwise Multiple Variable Equation

Equation	Equation with variables plugged in	Grouping centroids and sectioning points
$(GOL\ x\ 0.068697)+$ $(BB\ x\ 0.14250)+$ $(LM\ x\ 0.094575)+(-33.577)$	$(175.4\ \mathrm{x}\ 0.068697)+$ $(115.22\ \mathrm{x}\ 0.14250)+$ $(29.66\ \mathrm{x}\ 0.094575)+(-33.577)$	Male: 1.223 Female: -1.223

Anthroposcopy was also used to attribute sex based on the pelvis. General sex characteristics showed the size of the pelvis as small and gracile, the ilium as low and flat, the pubic shape as more broad and square, with a well-developed preauricular sulcus and short, broad sacrum. These characteristics aligned with a female identification, however there were three masculine general sex characteristics, such as the heart-shaped pelvic inlet, the obturator foramen being large and ovoid, not small and triangular, and the greater sciatic notch being narrow (Figure 2). The total number of general characteristics presented in a six female to three male ratio of traits. Additionally, pelvic anthroposcopy was useful when attributing characteristics of the phenice, which concerns the ventral arc, subpubic concavity, and the medial aspect of the ischiopubic ramus. The ventral arc was categorized as absent or small, rather than present or large as in females. The subpubic concavity was present, which was a female trait; and the medial aspect of the ischiopubic ramus was wide and dull, rather than narrow and sharp. Overall, the phenice possessed more male characteristics.



Attributing Sex Using Pelvic Anthroposcopy
General Sex Characteristics
Size: Female (small and gracile vs. large and rugged)
Ilium: Female (low and flat vs. high and vertical)
Pelvic Inlet: Male (heart shaped vs. circular/ elliptical)
Pubic Shape: Female (broad, square vs. narrow, rectangular)
Subpubic Angle: Female (U-shaped vs. V-shaped)
Obturator foramen: Male (large, ovoid vs. small, triangular)
Greater Sciatic Notch: Male (narrow vs. wide)
Preauricular Sulcus: Female (well-developed vs. small or absent)
Shape of Sacrum: Female (short and broad vs. long and narrow)
Total: 6 Female, 3 Male
Sex: Female

Figure 2. The pelvis was used to assess whether the skeleton was male or female based on visual assessment. As with Fig. 1 and Eq. 1, more female characteristics were present than male.

Using pelvic metrics to find the ischium-pubic index, the pubic length was divided by the ischium length and multiplied by one hundred. The pubic length was measured as 79.90 millimeters and the ischium length was measured as 85.47 millimeters. When these numbers were divided and multiplied by one hundred, the ischium-pubic index was 93.483 millimeters. In Whites, values above 94 are considered female, so under this ancestry, sex would be considered unknown. In Blacks, index values over 91 are considered female, so then the sex would be female.

Bubalo et al. (2019) used acetabular diameter (AD) and transverse acetabular diameter (TAD) (Figure 3) of the pelvis to determine sex. For male sex, AD was to be higher than 54 millimeters and for TAD, it was higher than 52 millimeters. For females, AD was ranged from 47.00-59.00 millimeters and TAD ranged from 46.00-56.00 millimeters. The measurements of the human skeletal remains were 51.55 millimeters for AD and 48.29 millimeters for TAD, indicating that since the measurements were below the male cut-off point and within the range of female for both AD and TAD, the sex of the skeleton was female (Bubalo et al. 2019:222).

Figure 3. The acetabulum of the pelvis was used to assess sex. AD was measured as line 1 and TAD was measured as line 2.

Additional postcranial metrics were collected as well. On the scapula, the body was sexed as unknown, but the glenoid fossa indicated that the sex was female. The head of the humerus was unknown, the radius classified as female, and the femur was considered female in Whites, but unknown in Blacks (Table 4). Considering these metrics, the sex of the individual was unknown, but likely female. Albanese (2013) used a logistic regression in his study regarding postcranial metrics. His logistic regression calculated a *p*-value between 0 and 1 to "allocate an unknown individual and to make a probability statement about the likelihood of a correct allocation for the given case" (Albanese 2013:1413). A *p*-value < 0.5 indicated female and a *p*-value > 0.5 indicated male. This was applied to this skeleton using the maximum length of the clavicle (MCL), cranial-caudal diameter of the clavicle (CCDC), vertical head diameter of the humerus (VHDH), epicondylar breadth of the humerus (EBH), and the anterior-posterior diameter of the ulna (APDU). Solving for the *p*-value (Eq. 3), the results equaled 0.081267412, indicating female; given the combination of measurements used to estimate sex there was a 91.87% probability of a correct classification (1 - 0.08127 = 0.918733), though there was an 8.13% probability that the unknown individual is male based on this statistical estimate.

Table 4. Attributing sex using postcranial metrics. The scapula, and humeral, radial, and femoral heads were measured.

Attributing Sex Using Postcranial Metrics (in mm)

Bone		Ancestral Group	Measure	Female Range	Probably Female	Indeterminate Sex	Probably Male	Male Range	Sex
Scapula	Body		158.27	< 140				170+	Indet.
	Glenoid Fossa		35.8	< 36				> 36	Female
Head of Humerus			44.55	< 43	43-44		46-47	> 47	Indet
Head of Radius			15.34	< 22				> 23	Female
Head of Femur*			43.42						
		White		< 42.50	42.5-43.5	43.5-46.5	46.5-47.5	> 47.50	Probably Female
		Black		< 40	40-43	43-44	44-47	> 47	Indet.

* for femoral values, ancestry of the skeleton must be known

MCL: 130.06 mm
CCDC: 8.65 mm
VHDH: 44.55 mm
EBH: 57.26 mm
APDU: 11.28 mm

$$P = \frac{1}{1+e^{-z}}$$

$$z = 0.042 * MCL + 0.595 * CCDC + 0.346 * VHDH + 0.193 * EBH + 0.825 * APDU - 48.806$$

$$z = (0.042 * 130.06) + (0.595 * 8.65) + (0.346 * 44.55) + (0.193 * 57.26) + (0.825 * 11.28) - 48.806$$

$$z = 5.46252 + 5.14675 + 15.4143 + 11.05118 + 9.306 - 48.806$$

$$z = -2.42525$$

$$P = \frac{1}{1+e^{-(-2.42525)}} \rightarrow P = \frac{1}{12.30505533} \rightarrow P = 0.081267412$$

Equation 3. The MCL, CCDC, VHDH, EBH, and APDU were all measured with a logistic regression used to calculate a *p*-value indicative of sex. To solve for the *p*-value, “z” had to be found first, which was then plugged into the equation for “p” to assess skeletal sex.

Another study by Tise et al. (2013), used various bones to conduct univariate sex estimation for individuals considered Hispanic. For characteristics with a classification rate over 80%, sectioning points were established. Bones with a measurement above the sectioning point were considered male, those below the sectioning point were considered female, and those equaling the sectioning point were considered indeterminate. The clavicle maximum length of the tested individual measured 130.06 millimeters with a sectioning point of 147 millimeters. As the measurement is below the sectioning point, the sex is female. In the article, this was the single most accurate characteristic at a total classification rate of 87.29%. The epicondylar breadth of the humerus measured 57.26 millimeters with a sectioning point of 57 millimeters; this was a male characteristic as the breadth measured 0.26 millimeters over the sectioning point.

Stature

Stature was attributed using various estimation methods, some of which stemmed from scholarly journals and each measurement taken was described in Table 5.

Table 5. Description of stature measurements.

Measurement	Description
Maximum head length (MHL)	distance between the glabella and opisthocranion
Maximum head breadth (MHB)	distance between the most lateral points on the parietal bones (euryon) on each side of the head
Minimum frontal diameter (MFD)	least breadth of the forehead between the two frontotemporal points on the temporal ridges
Horizontal circumference of head (HC)	measured from glabella to glabella with the measuring type passing over the opisthocranion
Maximum head height (MHH)	distance between the vertex of the head to the upper border of tragus (tragion)
Bizygomatic breadth (BB)	maximum distance between the most lateral points on the zygomatic area
Bigonial diameter (BGD)	maximum breadth of the lower jaw between the two gonion points on the angles of the mandible
Morphological facial length (FL)	distance between the nasal root (nasion) and the lowest point on the lower border of the mandible in the midsagittal plane (gnathion)
Morphological superior facial length (SFL)	distance between the nasal root (nasion) and the gum between the upper central teeth (prosthion) in the midsagittal plane
Femur	maximum oblique length between the proximal metaphyseal end and the medial surface of the distal metaphysis; diaphyseal length as maximum lengths between the proximal and distal ends
Humerus	diaphyseal length as maximum lengths between the proximal and distal ends
Ulna	diaphyseal length as maximum lengths between the proximal and distal ends
Radius	diaphyseal length as maximum lengths between the proximal and distal ends
Lumbar vertebra (L4)	six measurements: maximum and minimum widths, depths, and heights of the L4 were measured as the maximum and minimum mediolateral, anteroposterior and superoinferior dimensions of the L4 body (respectively)
Fibula	diaphyseal length as maximum lengths between the proximal and distal ends
Tibia	measured as the maximum oblique distance between the lateral metaphyseal surface of the proximal end and the medial metaphysical surface of the distal end
Foot height	height of talus and calcaneus in articulation, from the most superior point on the talus to the most inferior point on the calcaneus
Sacrum	rearticulate pelvic bones to calculate the distance between the superior margins of the acetabulae and the sacrum to calculate the vertical space height (VSH)

Table 6. Attribution of stature based on postcranial metrics. Stature was estimated in both black and white females.

Attribution of Stature Based on Postcranial Metrics in Females (in cm)			
Bone	**Length**	**Whites**	**Blacks**
Humerus	31.9	ST = 2.534 * Hum + 86.62 ST = 2.534 * 31.9 + 86.62 ST = 167.4546 cm 65.926876 in / 12 → 5 ft 0.49390634 * 12 → 5 in **ST = 5 ft 5 inches**	ST = 3.785 * Hum + 47.35 ST = 3.785 * 31.9 + 47.35 ST = 168.0915 cm 66.1776236 in / 12 → 5 ft 0.51480197 * 12 → 6 in **ST = 5 ft 6 inches**
Ulna	25.6	ST = 3.346 * Uln + 82.82 ST = 3.346 * 25.6 + 82.82 ST = 168.4776 cm 66.39296311 in / 12 → 5 ft 0.52746926 * 12 → 6 in **ST = 5 ft 6 inches**	ST = 3.285 * Uln + 80.70 ST = 3.285 * 25.6 + 80.70 ST = 164.796 cm 64.8801852 in / 12 → 5 ft 0.4066821 * 12 → 4 in **ST = 5 ft 4 inches**
Radius	23.8	ST = 3.530 * Rad + 83.29 ST = 3.530 * 23.8 + 83.29 ST = 167.304 cm 65.8675848 in / 12 → 5 ft 0.4889654 * 12 → 5 in **ST = 5 ft 5 inches**	ST = 3.781 * Rad + 75.20 ST = 3.781 * 23.8 + 75.20 ST = 165.1878 cm 65.0344369 in / 12 → 5 ft 0.4195364 * 12 → 5 in **ST = 5 ft 5 inches**
Femur	46.7	ST = 2.624 * Fem + 49.26 ST = 2.624 * 46.7 + 49.26 ST = 171.8008 67.637975 in / 12 → 5 ft 0.63649791 * 12 → 7 in **ST = 5 ft 7 inches**	ST = 2.449 * Fem + 54.86 ST = 2.449 * 46.7 + 54.86 ST = 169.2283 66.6251817 in / 12 → 5 ft 0.55209848 * 12 → 6 in **ST = 5 ft 6 inches**
Tibia	37.5	ST = 2.351 * Tib + 80.11 ST = 2.351 * 37.5 + 80.11 ST = 168.2725 cm 65.2488832 in / 12 → 5 ft 0.52074027 * 12 → 6 in **ST = 5 ft 6 inches**	ST = 2.855 * Tib + 58.20 ST = 2.855 * 37.5 + 58.20 ST = 165.2625 cm 65.0638462 in / 12 → 5 ft 0.42198719 * 12 → 5 in **ST = 5 ft 5 inches**
Fibula	36.8	ST = 2.487 * Fib + 76.51 ST = 2.487 * 36.8 + 76.51 ST = 168.0316 cm 66.1540409 in / 12 → 5 ft 0.51283674 * 12 → 6 in **ST = 5 ft 6 inches**	ST = 2.993 * Fib + 55.83 ST = 2.993 * 36.8 + 55.83 ST = 165.9724 cm 65.3433339 in / 12 → 5 ft 0.44527782 * 12 → 5 in **ST = 5 ft 5 inches**

Not all anthropometric measurements taken based off of journal articles could be applied to the skeleton in this study. Pelin et al. (2010) only used indexes for male subjects, so as there are no female-specific indexes that could be used, this article could not be applied for practical purposes as it would not adequately assess the skeleton based on the previously identified sex. Khangura et al. (2015) used dentals to establish stature, specifically intercanine width (IC) and interpremolar width (IP). However, these measurements were unable to be completed in this study as the required teeth were not present in the maxilla and/ or mandible. A third article by Hayashi et al. (2016) used vertical space height to determine skeletal height. Unfortunately, this article required vertebral height (C3-L5) and the assessed skeletal was missing one cervical and four thoracic vertebrae, so the estimation could not be completed.

Additional analyses were conducted. The humerus, ulna, radius, femur, tibia, and fibula were all measured (Table 6) and plugged into statistical equations for both White and Black female stature formulas. The individual was estimated to be around five foot five inches or five foot six inches consistently, regardless of ancestry. The lowest the range descended was five foot four inches based on the measurement of the ulna in Black females and the highest the range extended was five foot seven inches based on the femur length of White females. Most of the bones used in this assessment were consistent when estimating the stature of this individual (± 1 inch).

Additional testing was conducted on the femur, tibia, fibula, humerus, radius, and ulna based on the article by Gocha et al. (2013). Four populations, White, Thai, Chinese, and Burmese, were used in stature estimation (Table 7). The tibia was not analyzed in Trotter and Gleser’s (1952) estimation nor were the humerus, radius, and ulna in Sangvichien et al.’s (1985) estimation. In each of the tests, the stature was variable, though the “Thai” estimation produced the most consistent results between 5 foot two and five foot three inches.

Table 7. Comparative analysis of functions used for stature estimations. The femur, tibia, fibula, humerus, radius, and ulna were tested using equations for four separate populations.

Comparative Analysis For Stature Estimation Methods						
Method	**Femur**	**Tibia**	**Fibula**	**Humerus**	**Radius**	**Ulna**
Trotter and Gleser (1952) - “White”	2.47 x Fem + 54.1 *169.449 cm (5’6”)*	-	2.93 x Fib + 73.4 *181.224 cm (5’11”)*	3.63 x Hum + 60.47 *176.267 cm (5’9”)*	4.74 x Rad + 57.43 *170.242 cm (5’7”)*	4.27 x Uln + 60.26 *169.572 cm (5’6”)*
Sangvichien et al. (1985) - “Thai and Chinese”	2.5815 x Fem + 49.24 *169.79605 cm (5’6”)*	2.9716 x Tib + 54.60 *166.035 cm (5’5”)*	2.4256 x Fib + 71.49 *160.75208 cm (5’3”)*	-	-	-
Taik and San (1972) - “Burmese”	2.34 x Fem + 58.46 *167.738 cm (5’6”)*	3.436 x Tib + 36.92 *165.77 cm (5’5”)*	2.922 x Fib + 58.46 *165.9896 cm (5’5”)*	3.00 x Hum + 67.22 *162.92 cm (5’4”)*	2.864 x Rad + 88.70 *156.8632 cm (5’1”)*	3.043 x Uln + 79.67 *157.5708 cm (5’2”)*
Mahakkanukrauh et al. (2011) - “Thai”	2.778 x Fem + 40.602 *170.3346 cm (5’7”)*	2.620 x Tib + 63.089 *161.339 cm (5’3”)*	2.629 x Fib + 64.562 *161.3092 cm (5’3”)*	2.911 x Hum + 69.424 *162.2849 cm (5’3”)*	3.459 x Rad + 75.275 *157.5992 cm (5’2”)*	3.323 x Uln + 72.792 *157.8608 cm (5’2”)*

Aside from long bones, the L4 was tested using simple models presented in linear regression equations for stature. The mean width, depth, and height of the L4 was calculated corresponding to the maximum and minimum dimensions of the vertebra. These calculations in addition to the sum of the measurements, cross-sectional area, and volume were calculated for stature in female-based equations, though they mostly produced an estimated height of four foot two inches with a maximum height of five foot one inch (Table 8).

Table 8. Assessment of the L4 vertebra for stature estimations. The mean width, depth, and heights were measured, along with the sum of the measurements, CSA, and volume applied in formulas for stature estimation.

Assessment of the L4 Vertebra for Stature Estimations

Recorded Dimensions (mm)	Averages of the Corresponding Dimensions (cm)	Stature Formula (cm)	Stature Estimations (cm)
max. width: 41.62	mean width: 3.621	ST = 0.953 * W + 125.198	ST = 128.648813
min. width: 30.80	mean depth: 2.552	ST = 1.207 * D + 125.805	ST = 128.885264
max. depth: 30.69	mean height: 2.693	ST = 1.558 * H + 123.216	ST = 127.411694
min. depth: 20.35	sum of the measurements: 17.732	ST = 0.337 * SM + 96.975	ST = 102.950684
max. height: 28.02	cross-sectional area: 7.25770107 CSA = * (mean width/ 2) * (mean depth/ 2)	ST = 2.314 * CSA + 140.331	ST = 157.12532
min. height: 25.84	volume: 19.544989 V = * (mean width/ 2) * (mean depth/ 2) * (mean height)	ST = 0.852 * V + 140.765	ST = 157.417331

Discussion

Sex

Regarding the cranium, using solely visual evidence, the skull presented mainly female characteristics, outnumbering male characteristics. Data from assessing cranial metrics classified the individual as either female or unknown using individual and multiple variables. For the direct single variables, BB, BNL, and GOL were individually tested, resulting in a definite female and two unknown metrics that were closer to the female ranges. Using the stepwise multiple variable equation, three variables were selected (GOL, BB, and LM). To be categorized as female, the result needed to be -1.223 or less and as the product was -2.3036017, this was a female classification.

With pelvic anthroposcopy, both female and male characteristics were present, such as the general sex characteristics being determined as female, while the phenice presented as more masculine. Using pelvic metrics, sex was also classified as female under a Black ancestry and as most likely female under a White ancestry using the ischium-pubic index. Referencing the study conducted by Bubalo et al. (2019), the AD and TAD of the pelvis both classified the sex of the individual as female as well. Other postcranial metrics using the clavicle, humerus, and ulna were successful in assessing the sex as female, with the exception of the epicondylar breadth of the humerus based on the sectioning point defined by Tise et al. (2013).

Part of proposed question sought to answer was whether the various bones in the human skeleton agree on the sex of the individual, which the data attests that most of the bones tested were in agreement. This corresponded with the expected outcome as it was expected that many of one’s physical characteristics should be in agreement, but it was also expected that there would be outliers, which was represented by the data in this study. As there was a lesser amount of characteristics considered “undetermined” or “male”, this individual was determined to be female, though this shows how not every bone in the human body used to sex individuals will completely agree on the sex of that person.

Stature

Working with the data for stature, three articles were not able to be applied for this analysis, which reduced the data intake. However, relevant data was collected based on several other article-based analyses.

Testing the long bones against Black and White female stature formulas provided a consistent height between five foot five inches and five foot six inches; as the ancestry of the skeleton was not explored due to the constraints of this research - one academic year, more than one ancestry was tested for analysis of stature. Using the ulna in black females resulted in the smallest stature estimation at five foot four inches, which could possibly be explained by the individual having longer lower-limb proportions. In this same proportional idea, the femur length in White females was the tallest estimation.

Testing postcranial metrics following the 2013 article by Gocha et al. provided variable results. Their target population focused on South-East Asians, so when foot height (talus-calcaneus articulation) was taken, the height (7.31 cm) fell into the male range (5.05-7.75 cm). As the skeleton was sexed as female, this test could not be completed following a male formula. Long bone measurements of four ancestries was completed using comparative analysis regression formulae; seven of the twenty formulae produced results consistent with other tests (5’5” to 5’6”). Nine of the results were below this range and four were above it. The lowest stature estimate was five foot one inch and the highest was five foot eleven inches. Applying multiple ancestries to an individual whose ancestry was unknown produced a variety of results. The femur appeared to be the most consistent throughout the populations, with the radius and ulna leading to shorter stature in Burmese and Thai populations compared to white populations.

Utilizing an article by Oura et al. (2018), six dimensions were taken of the L4. The population sample was of middle-aged Finns, which did not appear to correlate with these results as they were quite variable, which could be due to population-specific differences, errors in measurement, or that Oura et al. worked with MRI scans, while this study utilized physical remains. This research found the height to be around 4 foot 2 inches, which was lower than all other estimates, so this data was not reliable in stature estimation for this study.

In examining skeletal remains for agreement in stature, the results differed. Some variation was expected, but whether it was because not all of the studies were applicable in this situation or whether the methods were outdated and not geared towards this individual, it was evident that ancestry can play a major role in how stature can be estimated.

Conclusions and Recommendations

This study contributes to knowledge in the application of known methods of assessment for sex and stature when applied to a skeleton of unknown and unconfirmed sex and stature, revealing the effectiveness of assessment methods in the agreement of these characteristics. The study was adapted based on the methods that were possible to test on the skeleton as limitations affected this study. Limitations included time constraints, a lack of the necessary features to conduct the assessment, and/ or a lack of the formulae needed to accurately complete the assessments.

In the future, more time to assess the remains and possibly look into ancestry would be preferred, as it was evident that it affected stature estimations. Testing more than one skeleton would be ideal as well as it may show differences present among multiple individuals and whether the methods were in agreement throughout multiple skeletons as they were in this study.

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References

Albanese, John. “A Method for Estimating Sex Using the Clavicle, Humerus, Radius, and Ulna.” *Journal of Forensic Sciences* 58, no. 6 (2013): 1413-1419.

Babb, Florence E. “The Future of Feminist Anthropology/ The Feminist Future of Anthropology.” *Anthropology News (Arlington, VA)* 48, no. 8 (2007): 4-5.

Bubalo, Pero, Marija Baković, Martina Tkalčić, Vedrana Petrovečki, and Davor Mayer. “Acetabular osteometric standards for sex estimation in contemporary Croatian population.” *Croatia Medical Journal* 60, no. 3 (2019): 221-226.

Cunha, Eugénia and Douglas H. Ubelaker. “Evaluation of Ancestry from Human Skeletal Remains: A Concise Review.” *Forensic Sciences Research* 5, no. 2 (2020): 89-97.

Duke University. “About Evolutionary Anthropology.” Department of Evolutionary Anthropology. Duke Trinity College of Arts and Sciences, 2021. Accessed 10 November 2021. https://evolutionaryanthropology.duke.edu/about

Edgar, Heather J. H. “Estimation of Ancestry Using Dental Morphological Characteristics.” *Journal of Forensic Sciences* 58, no. S1 (2013): S3-S8.

Franklin, Daniel, Andrea Cardini, Ambika Flavel, and Algis Kulikas. “Estimation of Sex from Cranial Measurements in a Western Australian Population.” *Forensic Science International* 229, no. 1 (2013): 158.e1-158.e8.

Garvin, Heather M. and Nicholas V. Passalacqua. “Current Practices by Forensic Anthropologists in Adult Skeletal Age Estimation.” *Journal of Forensic Sciences* 57, no. 2 (2012): 427-433.

Gocha, Timothy P., Giuseppe Vercellotti, Lara E. McCormick, and Traci L. Van Deest. “Formulae for Estimating Skeletal Height in Modern South-East Asians.” *Journal of Forensic Sciences* 58, no. 5 (2013): 1279-1283.

Grabherr, Silke, Christine Cooper, Susi Ulrich-bochsler, Tanya Uldin, Steffen Ross, Lars Oesterhelweg, Stephan Bolliger, Andreas Christe, Pierre Schnyder, Patrice Mangin, and Michael J. Thali. "Estimation of Sex and Age of ‘Virtual Skeletons’ - a Feasibility Study." *European Radiology* 19, no. 2 (2009): 419-29.

Hayashi, Atsuko, Paul D. Emanovsky, Michael Pietrusewky, and Thomas D. Holland. “A Procedure for Calculating the Vertical Space Height of the Sacrum When Determining Skeletal Height for Use in the Anatomical Method of Adult Stature Estimation.” *Journal of Forensic Sciences* 61, no. 2 (2016): 415-423.

Khangura, Rajbir Kaur, Keya Sircar, and Dilpreet Singh Grewal. “Four Odontometric Parameters as a Forensic Tool in Stature Estimation.” *Journal of Forensic Dental Sciences* 7, no. 2 (2015):132-136.

Kranioti, Elena F. and Manolis Michalodimitrakis. “Sexual Dimorphism of the Humerus in Contemporary Cretans – A Population-Specific Study and a Review of the Literature.” *Journal of Forensic Sciences* 54, no. 5 (2009): 996-1000.

Lumen. “Chapter 3: Anthropological Theory. Feminist Anthropology” in *Cultural Anthropology*, edited by Lumen Learning (2017). https://courses.lumenlearning.com/culturalanthropolog y/chapter/feminist-anthropology/

Maddux, Scott D., Alexandria N. Sporleder, and Casey E. Burns. “Geographic Variation in Zygomaxillary Suture Morphology and its Use in Ancestry Estimation.” *Journal of Forensic Sciences* 60, no. 4 (2015): 966-973.

Maier, Christopher A., Kang Zhang, Mary H. Manhein, and Xin Li. “Palate Shape and Depth: A Shape-Matching and Machine Learning Method for Estimating Ancestry from Human Skeletal Remains.” *Journal of Forensic Sciences* 60, no. 5 (2015): 1129-1134.

Maijanen, Heli. “Testing Anatomical Methods for Stature Estimation on Individuals from the W. M. Bass Donated Skeletal Collection.” *Journal of Forensic Sciences* 54, no. 4 (2009): 746-752.

Marinho, Luísa, Dina Almeida, Agostinho Santos, and Hugo F.V. Cardoso. “Is the Length of the Sternum Reliable for Estimating Adult Stature? A Pilot Study Using Fresh Sterna and a Test of Two Methods Using Dry Sterna.” *Forensic Science International* 220, no. 1 (2012): 292.e1-292.e4.

Mattison, Siobhán M. and Rebecca Sear. “Modernizing Evolutionary Anthropology: Introduction to the Special Issue.” *Human Nature (Hawthorne, N.Y.)* 27, no. 4 (2016): 335-350.

Merritt, Catherine E. “Inaccuracy and bias in adult skeletal age estimation: Assessing the reliability of eight methods on individuals of varying body sizes.” *Forensic Science International* 275, (2017): 315.e1-315.e11.

Oura, Petteri, Jaro Karppinen, Jaakko Niinimaki, and Juho-Antti Junno. “Sex Estimation from Dimensions of the Fourth Lumbar Vertebra in Northern Finns of 20, 30, and 46 Years of Age.” *Forensic Science International* 290, (2018): 350.e1-350.e6.

Oura, Petteri, Niina Korpinen, Jaakko Niinimäki, Jaro Karppinen, Markku Niskanen, and Juho-Antti Junno. “Estimation of Stature from Dimensions of the Fourth Lumbar Vertebra in Contemporary Middle-Aged Finns.” *Forensic Science International* 292, (2018): 71-77.

Pelin, Can, Ragiba Zağyapan, Canan Yazici, and Ayla Kürkçüoğlu. “Body Height Estimation from Head and Face Dimensions: A Different Method.” *Journal of Forensic Sciences* 55, no. 5 (2010): 1326-1330.

Penny, David. “Darwin's Theory of Descent with Modification, versus the Biblical Tree of Life.” *PLoS biology* 9, no. 7 (2011): e1001096.

Raxter, Michelle H., Benjamin M. Auerbach, and Christopher B. Ruff. “Revision of the Fully Technique for Estimating Statures.” *American Journal of Physical Anthropology* 130, no. 3 (2006): 374-384.

Selliah, Pranavan, Federica Martino, Marco Cummaudo, Lara Indra, Lucie Biehler-Gomez, Carlo Pietro Campobasso, and Cristina Cattaneo. “Sex Estimation of Skeletons in Middle and Late Adulthood: Reliability of Pelvic Morphological Traits and Long Bone Metrics on an Italian Skeletal Collection.” *International Journal of Legal Medicine* 134, no. 5 (2020): 1683-1690.

Smithsonian. “Male or Female?” *Smithsonian National Museum of Natural History* (2021). Accessed 14 November 2021. https://naturalhistory.si.edu/education/teaching-resources/written-bone/skeleton-keys/male-or-female

Spies, Amy Joy, Mubarak Ariyo Bidmos, and Desiré Brits. “Using Tibial Fragments to Reconstruct the Total Skeletal Height of Black South Africans.” *Forensic Science International* 298, (2019): 424.e1-424.e9.

Spradley, M. Katherine and Richard L. Jantz. “Ancestry Estimation in Forensic Anthropology: Geometric Morphometric Versus Standard and Nonstandard Interlandmark Distances.” *Journal of Forensic Sciences* 61, no. 4 (2016): 892-897.

Steyn, M. and M. L. Patriquin. “Osteometric Sex Determination from the Pelvis – Does Population Specificity Matter?” *Forensic Science International* 191, no. 1 (2009): 113.e1-113.e5.

Tise, Meredith L., M. Katherine Spradley, and Bruce E. Anderson. “Postcranial Sex Estimation of Individual Considered Hispanic.” *Journal of Forensic Sciences* 58, no. S1 (2013): S9-S14.

Walter, Lynn. "Feminist anthropology?" *Gender & Society* 9, no. 3 (1995): 272-288.

Wilson, Laura A., Norman MacLeod, and Louise T. Humphrey. “Morphometric Criteria for Sexing Juvenile Human Skeletons Using the Ilium.” *Journal of Forensic Sciences* 53, no. 2 (2008): 269-278.

Winburn, Allysha Powanda. “Validation of the Acetabulum as a Skeletal Indicator of Age at Death in Modern European-Americans.” *Journal of Forensic Sciences* 64, no. 4 (2019): 989-1003.