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PAPER

ANTHROPOLOGY

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Sex Estimation in Forensic Anthropology: Skull Versus Postcranial Elements

ABSTRACT: When the pelvis is unavailable, the skull is widely considered the second best indicator of sex. The goals of this research are to provide an objective hierarchy of sexing effectiveness of cranial and postcranial elements and to test the widespread notion that the skull is superior to postcranial bones. We constructed both univariate and multivariate discriminant models using data from the Forensic Anthropology Data Bank. Discriminating effectiveness was assessed by cross-validated classification, and in the case of multivariate models, Mahalanobis D^2. The results clearly indicate that most postcranial elements outperform the skull in estimating sex. It is possible to correctly sex 88–90% of individuals with joint size, up to 94% with multivariate models of the postcranial bones. The best models for the cranium do not exceed 90%. We conclude that postcranial elements are to be preferred to the cranium for estimating sex when the pelvis is unavailable.

KEYWORDS: forensic science, forensic anthropology, sex estimation, osteometrics, human osteology, skeletal measurements

When performing a forensic anthropological analysis, sex estimation is one of the first and most important steps. A visual analysis of the pelvis is typically the preferred indicator of sex with a high degree of reliability (1,2). However, not all forensic cases provide the luxury of a complete skeleton. If an individual is left exposed in an outdoor context, taphonomic processes may impede the recovery of all elements. Some cases may consist only of a cranium, others of just a few postcranial bones. Which indicator to use when only the skull and long bones are present is of some debate. Bass (3), Byers (4), and Pickering and Bachman (5) indicate that the skull is the second best indicator of sex assessment, the pelvis being the most reliable. The perception of the skull as the second best estimator of sex persists despite evidence to the contrary (6–9).

As described in introductory textbooks (10–12), a visual observation of the pelvis is performed before, or in conjunction with, a visual observation of the cranium. Further advice for assessing the sex of skeletal elements includes seriation techniques applied to an entire skeletal sample (12). While seriation works well in bioarchaeological analysis, it is not directly applicable to forensic cases, which usually focus on one to a few individuals. However, in the case of mass grave excavation or mass disasters, forensic anthropologists may find seriation an effective technique.

France (7), while noting that the skull is still often presented as the second best indicator of sex, reviews evidence showing that postcranial estimates are generally superior. However, most publications in the forensic anthropological literature of postcranial sex estimation focus on the Terry or Todd collections (6–8,13–15), which are comprised of late 19th and early 20th century birth years. Documentation of cranial and postcranial secular change indicates that the Terry and Todd collections do not accurately represent current forensic anthropological cases (16,17). Further, Jantz and Moore-Jansen (18) found that sex and ancestry estimation techniques based on anatomical collections are not reliable when applied to recent forensic cases. The purpose of this study is two-fold: to test the assertion that the skull is the second best estimator of sex using a recent forensic sample from the U.S. and to establish a hierarchy of sexing reliability, by element, using univariate and multivariate techniques.

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Background

Bass (3), Byers (4), and Pickering and Bachman (5) present the idea that the skull is the second best estimator of sex, without any supporting citations, in texts that could be utilized in introductory forensic anthropology courses. In the latest edition of *Human Osteology*, Bass states that “The skull probably is the second best area of the skeleton to use for determining sex” (3, p. 81). However, the following statement also appears in the same text, “The humerus is the second best bone for sex estimation” (3, p. 151). Byers similarly states “The skull is the second most useful structure for determining sex” (4, p. 184), although when discussing postcranial sex estimation, Byers states that “In addition, most of these studies show that sex determination from multiple postcranial bones yields a higher probability accuracy than sex determination from the skull” (4, p. 194). Pickering and Bachman (5) state that after the pelvis “The skull is the next most reliable skeletal indicator of sex” (p. 84). They further state that “Unfortunately, the pelvis and skull are not present in every forensic case. If these bones are not available the determination of sex is going to be tentative, not definite” (5, p. 86).

It can be confusing that Bass (3), Byers (4), and Pickering and Bachman (5) all state that the skull is the second best estimator of sex and then later state that postcranial elements perform well in sex assessment. Pickering and Bachman's (5) quote indicates that the skull is the second best estimator of sex and that both the skull and the pelvis provide definite sex assessments. If one is using morphological traits with no estimable error rates, classification rates, or any associated statistics, then sex should be considered an assessment. If one is using metric traits of the pelvis, skull, or any single bone or any combination of bones, then it can be considered an estimate, because it provides an estimate in the form of an error rate or expected classification rate. Thus, an assessment differs from estimation and neither should be considered definite. Additionally, metric sex estimation offers error rates rather than subjective visual assessment, in striving for evidentiary standards in forensic anthropology (19,20).

The claim that the skull is the second best estimator of sex perpetuates a tradition that has been passed from generation to generation without substantiation. This can be traced back to Hrdlicka, Krogman, and Stewart (21–23). Hrdlicka claimed 90% accuracy from a complete skull (22), although he provides no evidence of how he achieved this estimate. Krogman (23) achieved 92% accuracy in visually assessing sex from the skull and only 75% accuracy in visually assessing the postcranial skeleton using the Todd collection. Krogman did acknowledge a male bias in the sample and felt his estimate of sex should be lowered because of the bias (23). When Stewart estimated the sex of American Black skulls, blindly selected from the Terry collection, he only achieved 77% accuracy (23).

Using features commonly evaluated visually as ordinally scored traits via logistic regression and probit models, Konigsberg and Hens (21) could only achieve correct classification rates of 83%. Most recently, Walker (24), using the same ordinal traits as Kongisberg and Hens (21), although using a quadratic discriminant function, achieved 90% accuracy. Thus, statistical models based on visually scored ordinal morphological traits have failed to achieve classification rates as high as Krogman's 92% (21,24,25). Rogers and Saunders achieved classification rates of 89.1% using visual morphological traits (25,26) on a historic skeletal sample and 92% accuracy using a recent documented collection (27) although did not use statistical models to generate classification rates. Further, publications on postcranial sex estimation using metric data provide evidence that postcranial estimates of sex produce estimates equal to or higher than 90% (6,7,13,14,28). Postcranial sex estimation typically relies on metric criteria, which offers less subjectivity than visual assessment of cranial morphological traits.

The goal of the present research is to provide a hierarchy of sexing reliability by element using univariate and multivariate techniques. This will allow for the explicit testing of the assertion that the skull is the second best sex criterion. The objectives of the present research are to utilize data derived from recent human skeletons with birth years after 1929 to account for secular changes and to utilize standard measurements.

Materials

To test the effectiveness of the skull as the second best estimator of sex and to provide up to date classification rates for sex estimation from the postcranial skeleton for forensic anthropologists, primarily in the U.S., data from the Forensic Anthropology Data Bank (FDBl; [18]) are used in all subsequent analyses. The FDB is unique because it contains data from individuals that are derived from the population for which it is used; thus, it can be considered population specific for the U.S.

The FDB contains data on positively identified, circumstantially identified, and unidentified individuals. Only positively identified American Black and White individuals are used in the present analyses. The FDB also contains data on Hispanic, East Asian, and Native American individuals. However, the sample sizes were too small for the East Asian and Native American groups to obtain meaningful results and not enough positively identified male and female individuals considered Hispanic were present in the FDB. Further, only adult individuals (18 years or older) born on or after 1930 are used in the present research. This birth year was chosen based on studies of secular change in the U.S. population (16,17) and to encompass an age range of individuals that represent recent forensic anthropology cases.

TABLE 1—*Sample sizes for American Blacks and Whites.*

Group	Skull (Cranium and Mandible) *n*	Postcranial *n*
American Black Females	71	51
American Black Males	107	92
American White Females	203	185
American White Males	323	311

Because each case submitted to the FDB may or may not have a complete data set owing to trauma or taphonomic changes, such as scavenging, sample sizes are reported separately for the skull and postcranial skeleton (Table 1). While other studies have successfully demonstrated sex estimation from postcranial elements using nontraditional metrics (6,29–35), this study uses standard measurements including 24 cranial, 10 mandibular, and 44 postcranial measurements (36). Postcranial measurements from the left side are used, substituting the right side only when measurements from the left side are missing.

Methods

Both univariate and multivariate methods of sex estimation are utilized for the cranium, mandible, and postcranial elements. An analysis of variance (ANOVA) was run using PROC GLM in SAS 9.1.3 (37) to test the effects of sex, ancestry, and an interaction between sex and ancestry for American Blacks and Whites for all skeletal elements (cranium, mandible, and each postcranial bone). The ANOVA will indicate whether classification functions should be generated separately for American Black and White individuals.

To find the best subset of variables for a discriminant function analysis (DFA), a STEPDISC procedure in SAS 9.1.3 was performed on the cranium, mandible, and each postcranial element. The STEPDISC procedure selects variables using a stepwise discriminant function with the Wilks' lambda criterion using an alpha of 0.05 to select the best measurements for discrimination of sex. These subsets of variables were then run in a DFA using the PROC DISCRIM function in SAS to arrive at D^2 distances, cross-validated classification rates, and Fisher's linear discriminant function scores. For all postcranial measurements, means, standard deviations, and sectioning points along with classification rates were calculated for both American Blacks and Whites.

The sectioning points were obtained by taking the male and female mean and dividing by two. The classification rates for each measurement were obtained by using the sectioning point for estimating sex within the entire sample and dividing the number correct for each sex by the total number of individuals by sex, then averaging the two sex-specific classification rates to generate overall classification rates (38). Values above the sectioning point are considered male, values below are considered female, and values equal to the sectioning point are considered indeterminate.

TABLE 2—*ANOVA results for the effect of sex, ancestry, and an interaction between sex and ancestry for American Blacks and Whites.*

	Ancestry		Sex		Ancestry * Sex	
Bone	*F*-Value	$p > F$	*F*-Value	$p > F$	*F*-Value	$p > F$
Cranium	17.11	<0.0001	16.24	<0.0001	0.91	0.5881
Mandible	4.60	0.0002	5.51	<0.0001	1.58	0.1469
Clavicle	7.27	<0.0001	163.91	<0.0001	1.01	0.3903
Scapula	6.04	0.0026	279.60	<0.0001	0.21	0.8099
Humerus	16.28	<0.0001	123.60	<0.0001	0.65	0.6619
Radius	23.18	<0.0001	144.55	<0.0001	2.69	0.0456
Ulna	12.12	<0.0001	88.25	<0.0001	0.78	0.5675
Os Coxa	16.69	<0.0001	62.22	<0.0001	2.23	0.0654
Sacrum	10.03	<0.0001	14.73	<0.0001	0.28	0.8431
Femur	8.62	<0.0001	52.52	<0.0001	0.40	0.9363
Tibia	12.39	<0.0001	56.88	<0.0001	0.36	0.9021
Fibula	14.31	<0.0001	79.86	<0.0001	1.32	0.2391
Calcaneus	1.20	0.3023	85.53	<0.0001	0.04	0.9637

Results

Interpretation of the ANOVA results indicates that significant differences exist in both sex and ancestry between American Blacks and Whites in the cranium, mandible, and postcranial skeleton (Table 2). The radius is the only postcranial element to show a significant interaction of sex and ancestry at the $p < 0.05$ level. For the cranium, mandible, and all postcranial elements, significant differences in sex were found at the $p < 0.0001$ level. Further, significant differences in ancestry between American Blacks and Whites were found for the cranium, mandible and all postcranial elements with the exception of the calcaneus. Despite the nonsignificance of the calcaneus for ancestry, all subsequent analyses were run separately for American Blacks and Whites.

The stepwise selected variables for all elements and classification rates for the DFAs are presented in Tables 3 and 4 with the classification functions. The element that provides the highest classification via DFA is the humerus for American Black individuals with an overall classification rate of 93.84% and the radius for American White individuals with an overall classification rate of 94.34%. For both American Blacks and Whites, the cranium provides an overall cross-validated classification rate of 90–91%, while multiple postcranial elements provide higher cross-validated classification rates between 92% and 94% (Tables 5 and 6).

All univariate sex estimation results are presented in Tables 7 and 8 and sorted by classification rate. The top three univariate estimators of sex for American Blacks are femur epicondylar breadth (89% classification rate), tibia proximal epiphyseal breadth (88% classification rate), and scapula height (87% classification rate). The top three univariate estimators of sex for American Whites are tibia proximal epiphyseal breadth (90% classification rate), scapula height (89% classification rate), and femur head diameter (88% classification rate).

Discussion

It might be argued that visual assessment of the skull, evaluating general robusticity or specific features, such as brow ridge size or mastoid size not quantified by traditional measurements, can yield correct classification superior to metric analysis. There is little evidence to support this position. The present research finds that differences in both sex and ancestry exist in the cranium, mandible, and postcranial elements, except for the calcaneus, for both American Blacks and Whites. Further, using metric data, multivariate analyses of long bones provide the best estimates of sex. For American Blacks, the humerus, clavicle, scapula, and femur performed better than a multivariate analysis of the cranium (Table 5). The radius, clavicle, femur, humerus, scapula, ulna, and tibia all performed better than a multivariate analysis of the cranium for American Whites (Table 6).

The FDB provides a robust data set of recent forensic cases. The American Black sample is considerably smaller than the American White sample and raises the question of whether the low error rate for the humerus is a sampling artifact. However, the D^2 value for the humerus in the American Black sample is high, 11.21. The D^2 value is less subject to sampling and suggests significant sexual dimorphism in the American Black humerus. Further, the top three multivariate postcranial elements for sex estimation in American Blacks have higher D^2 values than the top three postcranial elements in American Whites. These D^2 values suggest greater sexual dimorphism in the American Black sample. Interpretation of the univariate results with a classification rate of at least 85% indicates that the joint surfaces of the femur, tibia, and humerus, and maximum length of the radius and the scapula are the most sexually dimorphic areas in both American Black and White individuals.

Konigsberg and Hens (21) and Walker (24) explored sexual dimorphism in the skull through application of statistical models to

TABLE 3—*Stepwise selected variables for American Black and classification functions.*†

Bone	Classification Function with Stepwise Selected Variables
Clavicle	(0.2877*maximum length) + (0.9636*sagittal diameter at midshaft) + (1.1065*vertical diameter at midshaft) + (−66.6844)
Scapula	(0.25647*height) + (0.2157*breadth) + (−60.55)
Humerus	(0.42616*epicondylar breadth) + (0.92*head diameter) + (0.49507*maximum diameter at midshaft) + (−74.5878)
Radius	(0.12149*maximum length) + (0.65603*sagittal diameter at midshaft) + (0.60906*transverse diameter at midshaft) + (−47.8611)
Ulna	(0.07912*maximum length) + (0.8104*dorso-volar diameter at midshaft) + (0.74434 + transverse diameter at midshaft) + (−44.2026)
Sacrum	(0.09686*transverse diameter of segment 1) + (−4.69561)
Os Coxa	(0.21749*height of os coxa) + (−0.11432*iliac breadth) + (−0.16143*pubis length) + (0.37051*ischium length) + (−45.1877)
Femur	(0.41661*epicondylar breadth) + (0.59516*maximum diameter of head) + (−58.836)
Tibia	(0.42495*maximum proximal epiphyseal breadth) + (0.34828*maximum distal epiphyseal breadth) + (−48.2631)
Fibula	(0.073*maximum length) + (0.09111*maximum diameter at midshaft) + (−29.4408)
Calcaneus	(0.29971*maximum length) + (0.547*middle breadth) + (−46.8862)
Cranium	(0.71406*bizygomatic breadth) + (0.43318*mastoid height) + (−0.59308*biauricular breadth) + (0.34451*upper facial height) + (−0.14842 + minimum frontal breadth) + (0.53049*foramen magnum breadth) + (−0.60805*orbital height) + (0.32505 *nasal height) + (−54.2458)
Mandible	(0.13874*bigonial width) + (0.19311*bicondylar breadth) + (−34.6986)

†Sectioning point is 0, females are negative and males are positive.

TABLE 4—*Stepwise selected variables for American White and classification functions.*†

Bone	Measurements
Clavicle	(0.23645*maximum length) + (0.88675*sagittal diameter at midshaft) + (0.60941*vertical diameter at midshaft) + (−51.7722)
Scapula	(0.19365*height) + (0.25609*breadth) + (−55.6564)
Humerus	(0.04008*maximum length) + (0.4011*epicondylar breadth) + (0.26862 + maximum vertical head diameter) + (0.62205 + maximum diameter at midshaft) + (−59.6723)
Radius	(0.11151*maximum length) + (1.17296*sagittal diameter at midshaft) + (0.7476*transverse diameter at midshaft) + (−51.8801)
Ulna	(0.1189*maximum length) + (0.98611*dorso-volar diameter at midshaft) + (0.89642*transverse diameter at midshaft) + (−0.09097*minimum circumference) + (−54.2634)
Sacrum	(0.23919 + anterior breadth) + (−0.03177 + transverse diameter of segment 1) + (−8.09535)
Os Coxa	(0.15836*height) + (−0.08458*breadth) + (−0.12135*pubis length) + (0.1338*ischium length) + (−21.4996)
Femur	(0.3644*epicondylar breadth) + (0.52629*maximum diameter of head) + (0.02826*bicondylar length) + (−65.70614)
Tibia	(0.02828*length) + (0.6134*maximum proximal epiphyseal breadth) + (0.424*maximum diameter at nutrient foramen) + (−0.13118*circumference at nutrient foramen) + (−58.633)
Fibula	(0.07437*maximum length) + (0.14191*maximum diameter at midshaft) + (−29.5745)
Calcaneus	(0.18618*maximum length) + (0.11285*middle breadth) + (−32.3714)
Cranium	(0.50255*bizygomatic breadth) + (−0.07786*basion nasion length) + (0.24989*mastoid height) + (0.19553*nasal height) + (0.24263*basion-bregma height) + (−0.15875*minimum frontal breadth) + (−0.13224*biauricular breadth) + (0.21776*glabella occipital length) + (−0.09443*frontal chord) + (−0.08327 + parietal chord) + (−0.13411*occipital chord) + (−81.1812)
Mandible	(0.15798*maximum ramus height) + (0.21951*bigonial width) + (0.06335*mandibular length) + (−35.0107)

†Sectioning point is 0, females are negative and males are positive.

TABLE 5—*Cross-validated classification rates for American Black.*

Element	Female *n*	Male *n*	D^2	Female %	Male %	Overall %
Humerus	34	62	11.21	94.12	93.55	93.84
Clavicle	33	56	9.34	93.94	92.86	93.40
Scapula	36	63	8.64	91.67	92.06	91.87
Femur	33	65	8.00	90.91	92.31	91.61
Cranium	43	53	8.14	90.70	90.57	90.64
Ulna	28	51	6.08	92.86	88.24	90.55
Os Coxa	30	44	7.67	90.00	90.91	90.46
Tibia	28	58	6.27	89.29	87.93	88.61
Calcaneous	18	49	5.05	88.89	87.76	88.33
Radius	31	56	5.94	83.87	87.50	85.69
Fibula	26	58	2.71	88.46	82.76	85.61
Mandible	48	58	2.47	75.00	81.03	78.02
Sacrum*	22	51	0.62	77.27	66.67	71.97

*Class means significantly different at the 0.0029 level, all others $p < 0.0001$.

TABLE 6—*Cross-validated classification rates for American White.**

Element	Female *n*	Male *n*	D^2	Female %	Male %	Overall %
Radius	112	232	7.72	96.43	92.24	94.34
Clavicle	107	200	7.82	97.20	90.00	93.60
Femur	121	239	8.39	95.87	91.21	93.54
Humerus	125	242	8.87	95.20	90.91	93.06
Scapula	125	230	7.41	95.20	90.87	93.04
Ulna	97	196	8.55	91.75	93.88	92.82
Tibia	93	185	7.58	91.40	91.89	91.65
Cranium	139	236	7.24	88.49	91.53	90.01
Os Coxa	86	149	4.57	90.70	87.92	89.31
Calcaneous	83	182	3.69	81.93	83.52	82.73
Fibula	95	200	2.93	81.05	81.50	81.28
Mandible	71	74	2.86	85.92	75.68	80.80
Sacrum	84	163	1.26	73.81	69.94	71.88

*All class means significantly different, $p < 0.0001$.

standard ordinally scored traits. Their results are heuristic and provide statistical validity for sex estimation using the skull. However, their classification rates do not achieve accuracy as high as multivariate metric analysis of the postcrania. Highlighting the importance of familiarity with sexual dimorphism within a particular population group, Walker (24) also discusses the subjectivity in recording cranial nonmetric traits and notes, "Usually, knowledge of the range of variation in a population is slowly accumulated through years of personal experience" (p. 40). Metric studies also offer less subjectivity to those with little experience. Adams and Byrd (39) tested the inter-observer error of 13 standard and nine nonstandard measurements and found that pubis length and the subtrochanteric measurements of the femur to be the most problematic. They suggest that these problematic measurements are because of an ambiguous landmark, in the case of pubis length, and an ambiguous definition, in the case of the subtrochanteric dimensions. However, Adams and Byrd's (39) study indicates that metric data are reliable even when collected by researchers with varying levels of experience.

Sex estimation from the postcranial skeleton has been recognized in publications since the early 20th century (40). Pearson's 1915 article "On the Problem of Sexing Osteometric Material" (40) has been regarded by Steel as being "*one of the most important contributions made to the sexing of long bones by measurement*" (41, p. 213). It was in Pearson's 1915 article that he suggested that the postcranial skeleton can be used for sex estimation (40). Postcranial metrics continue to provide better estimates of sex than nonmetric or metric traits of the skull. In fact, a single measurement of maximum proximal epiphyseal breadth of the tibia, in the case of American Whites, provides the same classification rate as a multivariate analysis of the cranium. Further, multivariate analyses of the clavicle, scapula, humerus, radius, ulna, femur, and tibia (Tables 5 and 6) provide better classification rates than a multivariate analysis of the skull.

Conclusions

The results presented in this paper highlight that sex estimation using the postcranial skeleton, via multivariate analyses, provides estimates superior to a multivariate analysis of the cranium by means of continuous metric data or ordinal, nonmetric data (21,24). Further, in the case of the American White population group, a single measurement from the proximal tibia provides the same classification rate as a multivariate analysis of the cranium. It is important to remember that population-specific estimates of sex

TABLE 7—*American Black univariate sectioning points and classification rates.*

	Female			Male				
Measurement*	*N*	Mean	SD	*N*	Mean	SD	Sectioning Point	Classification Rate
Fem. Epicondylar Br. (62)	33	72.88	3.86	65	83.35	3.97	78	0.89
Tib. Prox. Epiphyseal. Br. (70)	29	69.14	3.68	60	78.73	5.07	74	0.88
Scapula Height (38)	36	138.61	8.46	64	160.7	8.6	150	0.87
Fem. Max. Head Diam. (63)	39	41.33	2.18	69	47.22	2.47	44	0.86
Humerus Epicondylar Br. (41)	34	55.38	2.66	65	64.14	3.87	60	0.86
Humerus Head Diameter (42)	37	41.03	2.46	68	46.99	2.3	44	0.86
Scapula Breadth (39)	36	95.92	6.52	64	109.55	6.71	103	0.86
Radius Max. Length (45)	37	239.19	12.45	69	267.58	13.68	253	0.85
Clavicle Max. Length (35)	38	142.21	7.77	62	156.81	7.41	150	0.84
Calcaneus Max. Length (77)	20	76.45	4.62	50	85.38	4.74	81	0.83
Fem. AP Subtroch Diam. (64)	37	25.86	2.56	66	28.73	2.28	27	0.83
Ischium Length (59)	30	77.33	4.91	47	89.15	6.23	83	0.83
Ulna Max. Length (48)	33	256.42	15.01	63	285.56	13.89	271	0.83
Ulna Phys. Length (51)	25	226.48	13.38	53	254.51	13.94	240	0.83
Fibula Maximum Length (75)	32	367.09	22.11	65	400.55	22.05	384	0.82
Fem. Bicondylar Length (61)	36	444.94	25.63	65	484.32	25.9	465	0.81
Humerus Max. Length (40)	39	309.46	15.95	76	340.91	17.1	325	0.81
Os Coxa Height (56)	36	191.69	11.78	61	211.59	10.1	202	0.81
Tib. Diameter Nut. For. (72)	30	32.23	2.81	59	37.31	2.85	35	0.8
Calcaneus Mid. Breadth (78)	18	38.89	2.4	50	44.06	2.84	41	0.79
Fem. Circum. Midshaft (68)	30	82.7	5.23	59	91.78	10.43	87	0.79
Femur Max. Length (60)	42	448.45	27.6	78	488.9	25.98	469	0.79
Tibia Circum. Nut. For. (74)	22	88.05	5.92	53	101.38	8.1	95	0.79
Tibia Length (69)	31	375	23.91	66	410.18	23.39	393	0.79
Bizygomatic Breadth (3)	68	122.43	5.13	93	130.76	4.80	127	0.78
Bicondylar Breadth (29)	49	110.08	5.91	59	117.22	4.94	32	0.77
Cranial Maximum Length (1)	69	177.49	5.99	104	187.17	7.21	182	0.76
Hum. Min. Diam. MS (44)	37	16.03	1.92	66	19.48	1.72	18	0.76
Tib. Dist. Epiphyseal Br. (71)	29	45.14	3.09	58	51.47	4.59	48	0.75
Hum. Max. Diam. MS (43)	37	20.54	1.82	66	23.94	1.73	22	0.74
Clavicle Sag. Diameter (36)	33	11.33	1.16	62	14.08	2.23	13	0.73
Fem. Trans. Diam. (67)	35	24.06	2.1	64	27.64	2	26	0.73
Radius Sag. Diam. MS (46)	32	11.38	1.72	56	13.16	1.14	12	0.72
Radius Trans. Diam. MS (47)	32	13.56	1.74	56	16.02	1.7	15	0.72
Bigonial Diameter (28)	50	88.14	6.19	63	95.70	6.47	42	0.72
Height at Mental Foramen (26)	42	29.50	2.63	54	32.35	3.77	21	0.71
Basion-Bregma Height (4)	68	131.75	5.97	103	137.13	5.80	134	0.71
Upper Facial Height (10)	64	66.45	4.22	94	72.55	3.93	70	0.71
Maximum Ramus Height (32)	29	55.86	6.44	40	61.43	6.78	25	0.71
Cranial Base Length (5)	69	98.86	4.85	101	104.02	4.20	101	0.69
Fem. Trans. Subtroch (65)	36	28.92	2.51	66	32.24	2.57	31	0.69
Chin Height (25)	50	32.54	3.67	61	37.21	3.47	37	0.68
Biorbital Breadth (17)	60	95.20	3.87	91	99.99	4.57	98	0.68
Nasal Height (13)	63	48.21	2.60	95	52.29	3.23	50	0.67
Fem. AP Diam. Midshaft (66)	36	28.33	2.31	64	31.81	2.49	30	0.67
Sacrum Trans Diam. S1 (55)	22	45.27	4.94	51	51.69	9.15	48	0.67
Frontal Chord (19)	62	107.94	5.63	92	112.90	5.73	110	0.67
Tib. Transverse Nut. For. (73)	31	23.35	2.4	59	26.81	2.73	25	0.66
Maximum Alveolar Breadth (7)	61	62.56	4.51	88	66.57	4.57	65	0.65
Biauricular Breadth (9)	58	115.84	4.83	90	121.23	4.32	119	0.65
Iliac Breadth (57)	35	144.6	9.69	59	152.98	9.07	149	0.64
Ulna Dorso-Volar Diam. (49)	32	13.16	2.49	56	15.68	2.37	14	0.64
Ulna Min. Circum. (52)	26	32.85	3.91	50	36.76	5.1	35	0.64
Parietal Chord (20)	59	112.19	5.41	93	116.55	7.14	114	0.64
Ulna Trans. Diam. (50)	32	13.28	2.26	56	16.82	2.66	15	0.63
Mastoid Length (24)	60	28.45	3.29	93	32.11	3.38	30	0.62
Mandible Length (33)	30	78.43	5.65	39	82.77	5.00	35	0.62
Upper Facial Breadth (12)	48	101.77	5.06	84	107.06	4.55	104	0.62
Max. Cranial Breadth (2)	70	132.70	5.17	101	136.27	5.17	134	0.61
Fibula Max. Diam. MS (76)	26	13.88	1.63	61	16.85	6.86	15	0.61
Basion-Prosthion Length (6)	65	98.63	6.38	90	103.94	5.48	101	0.61
Clavicle Vert. Diameter (37)	33	9.39	1.37	62	11.31	2.21	10	0.59
Foramen Magnum Breadth (23)	61	34.49	2.35	91	36.24	2.57	35	0.56
Minimum Frontal Breadth (11)	63	93.06	4.99	92	95.96	4.67	95	0.55
Maximum Alveolar Length (8)	56	56.02	3.77	83	57.93	3.96	57	0.55
Orbital Breadth (15)	64	38.41	2.11	95	40.26	2.48	39	0.53
Sacrum Ant. Breadth (54)	28	102.36	10.13	53	100.58	11.45	101	0.52
Foramen Magnum Length (22)	51	28.53	1.80	73	29.93	2.34	29	0.52
Minimum Ramus Breadth (30)	52	32.44	3.25	63	34.14	3.93	41	0.51
Occipital Chord (21)	60	96.65	6.25	88	98.80	7.35	98	0.50

Continued

TABLE 7—*Continued.*

Measurement*	Female *N*	Female Mean	Female SD	Male *N*	Male Mean	Male SD	Sectioning Point	Classification Rate
Interorbital Breadth (18)	59	22.49	3.10	91	23.67	3.13	23	0.49
Nasal Breadth (14)	69	25.12	1.69	103	26.15	2.31	26	0.49
Sacrum Ant. Height (53)	28	101.64	10.36	52	104.15	11.76	103	0.49
Orbital Height (16)	65	34.38	2.00	95	35.13	2.40	35	0.47
Maximum Ramus Breadth (31)	28	42.11	3.75	27	42.63	3.73	26	0.47
Pubis Length (58)	30	76.93	7.73	46	76	8.72	76	0.47
Mandible Angle (34)	29	123.59	7.59	37	124.57	7.65	35	0.46
Body Thickness at M. For. (27)	44	11.64	2.02	56	12.23	2.11	22	0.42

*Numbers correspond to measurement definitions found in Moore-Jansen et al. (36).

TABLE 8—*American White univariate sectioning points and classification rates.*

Measurement*	Female *N*	Female Mean	Female SD	Male *N*	Male Mean	Male SD	Sectioning Point	Classification Rate
Tib. Prox. Epiphyseal. Br. (70)	113	69.19	3.37	226	79.31	4.1	74	0.90
Scapula Height (38)	127	141.87	9.48	231	163.33	8.95	153	0.89
Fem. Epicondylar Br. (62)	129	74.53	3.8	248	85.27	4.38	80	0.88
Fem. Max. Head Diam. (63)	142	42.05	2.09	261	48.4	2.6	45	0.88
Humerus Epicondylar Br. (41)	136	54.9	3.8	258	64.38	3.64	60	0.87
Radius Max. Length (45)	130	228.22	11.21	251	253.41	12.95	241	0.86
Os Coxa Height (56)	124	201.06	13.71	235	222.94	10.8	212	0.85
Scapula Breadth (39)	127	95.48	5.07	237	108.15	6.33	102	0.84
Ulna Max. Length (48)	127	244.94	11.66	250	271.07	13.49	258	0.84
Humerus Head Diameter (42)	139	42.47	2.44	256	48.81	3.22	46	0.83
Clavicle Max. Length (35)	123	139.79	7.04	224	156.96	9.33	148	0.82
Humerus Max. Length (40)	144	305.75	14.43	263	333.99	17.03	320	0.82
Hum. Min. Diam. MS (44)	139	15.32	1.35	256	18.9	1.79	17	0.82
Ulna Phys. Length (51)	105	217.69	11.71	217	240.17	12.68	229	0.82
Fem. Bicondylar Length (61)	134	431.96	20.87	250	470.75	23.63	451	0.82
Tibia Circum. Nut. For. (74)	106	85.36	6.31	199	97.65	7.16	92	0.81
Fibula Maximum Length (75)	117	351.29	19.65	235	386.49	22.11	369	0.81
Femur Max. Length (60)	151	436.15	20.63	268	474.21	23.23	455	0.80
Tibia Length (69)	131	358.02	19.27	246	392.89	22.67	375	0.79
Fem. Circum. Midshaft (68)	112	81.36	6.07	217	91.88	8.24	87	0.78
Tib. Dist. Epiphyseal Br. (71)	116	46.01	3.69	227	51.8	3.57	49	0.78
Tib. Diameter Nut. For. (72)	130	31.52	2.68	242	36.32	2.8	34	0.76
Calcaneus Max. Length (77)	90	77.94	6.13	195	86.46	5.23	82	0.76
Calcaneus Mid. Breadth (78)	84	39.1	3.13	184	44.16	2.94	42	0.76
Fem. Trans. Diam. (67)	142	23.96	2.02	254	27.8	2.39	26	0.75
Bizygomatic Breadth (3)	180	121.01	4.11	292	129.80	5.25	125	0.75
Ischium Length (59)	102	81.02	5.64	162	89.74	8.08	85	0.74
Bigonial Diameter (28)	125	89.74	4.75	162	98.27	6.46	94	0.74
Cranial Base Length (5)	184	99.51	4.71	302	106.12	4.60	103	0.73
Radius Sag. Diam. MS (46)	117	10.47	1.19	236	12.93	1.22	12	0.73
Ulna Trans. Diam. (50)	116	13.78	2.15	230	16.83	2.22	15	0.73
Cranial Maximum Length (1)	192	178.52	7.37	308	188.04	7.49	183	0.73
Basion-Bregma Height (4)	188	134.57	4.94	300	141.39	5.49	138	0.72
Hum. Max. Diam. MS (43)	141	19.82	1.75	256	23.34	2.08	22	0.72
Radius Trans. Diam. MS (47)	117	13.77	1.65	236	16.49	1.74	15	0.72
Fem. AP Diam. Midshaft (66)	139	27.28	2.30	254	30.69	2.54	29	0.72
Upper Facial Breadth (12)	135	100.04	3.47	245	105.04	4.45	103	0.71
Fem. Trans. Subtroch (65)	140	28.46	2.42	265	32.09	2.73	30	0.71
Bicondylar Breadth (29)	111	110.06	5.39	154	117.27	6.13	114	0.71
Biauricular Breadth (9)	172	117.19	4.55	286.00	123.07	5.22	120	0.70
Ulna Min. Circum. (52)	100	33.59	4.73	202.00	37.39	3.86	35	0.7
Fem. AP Subtroch Diam. (64)	139	25.22	2.37	264.00	28.72	2.73	27	0.69
Tib. Transverse Nut. For. (73)	128	21.84	2.07	239.00	25.23	2.58	24	0.69
Maximum Alveolar Breadth (7)	151	57.85	4.14	247.00	61.44	4.33	60	0.69
Nasal Height (13)	170	49.52	3.03	285.00	53.00	2.98	51	0.68
Mastoid Length (24)	176	27.45	3.51	287.00	31.65	3.58	30	0.68
Biorbital Breadth (17)	163	92.89	3.83	287.00	97.38	4.03	95	0.68
Clavicle Sag. Diameter (36)	117	10.66	1.49	211.00	13.06	1.78	12	0.67
Upper Facial Height (10)	164	66.59	4.33	261.00	71.36	4.30	69	0.67
Sacrum Trans Diam. S1 (55)	86	45.49	4.29	170.00	51.02	6.88	48	0.66
Maximum Ramus Height (32)	82	57.44	4.92	86.00	63.27	6.58	60	0.65

Continued

TABLE 8—*Continued.*

Measurement*	Female			Male			Sectioning Point	Classification Rate
	N	Mean	SD	*N*	Mean	SD		
Frontal Chord (19)	178	109.92	4.84	292.00	114.73	5.58	112	0.65
Chin Height (25)	117	29.14	3.05	167.00	32.26	3.74	31	0.65
Max. Cranial Breadth (2)	192	136.05	5.00	307.00	140.01	6.48	138	0.64
Maximum Ramus Breadth (31)	49	38.71	3.85	74.00	43.51	5.90	41	0.63
Clavicle Vert. Diameter (37)	117	9.09	1.76	211.00	11.19	1.80	10	0.63
Basion-Prosthion Length (6)	166	92.17	5.81	258.00	97.31	6.22	95	0.63
Mandible Length (33)	84	73.44	5.99	91.00	77.21	6.44	75	0.62
Height at Mental Foramen (26)	98	27.48	3.03	145.00	29.97	3.83	29	0.62
Orbital Breadth (15)	173	38.98	2.24	288.00	41.11	2.44	40	0.62
Minimum Frontal Breadth (11)	178	93.69	4.88	299.00	96.65	4.97	95	0.60
Occipital Chord (21)	175	98.01	5.53	294.00	100.47	5.39	99	0.60
Minimum Ramus Breadth (30)	121	28.61	2.88	167.00	30.99	3.24	30	0.59
Maximum Alveolar Length (8)	147	50.76	3.26	237.00	53.97	4.22	52	0.59
Foramen Magnum Breadth (23)	151	30.06	2.38	270.00	31.98	2.29	31	0.59
Parietal Chord (20)	178	113.60	6.30	294.00	118.04	7.14	116	0.59
Sacrum Ant. Height (53)	100	110.11	12.08	179.00	112.75	13.92	111	0.57
Iliac Breadth (57)	124	155.63	8.47	237.00	160.41	9.84	158	0.56
Fibula Max. Diam. MS (76)	101	14.41	1.82	205.00	15.95	2.59	15	0.54
Nasal Breadth (14)	177	22.59	1.90	296.00	23.77	2.02	23	0.53
Foramen Magnum Length (22)	177	35.50	2.44	295.00	37.09	2.36	36	0.53
Interorbital Breadth (18)	173	20.00	2.63	279.00	21.04	2.76	21	0.52
Body Thickness at M. For. (27)	100	10.48	2.04	143.00	11.51	2.24	11	0.51
Ulna Dorso-Volar Diam. (49)	116	11.64	2.16	230.00	14.79	2.11	13	0.44
Orbital Height (16)	175	33.31	2.17	289.00	33.77	2.15	34	0.44
Sacrum Ant. Breadth (54)	105	108.57	14.01	187.00	107.06	9.20	108	0.41
Mandible Angle (34)	76	126.93	7.20	84.00	126.61	7.35	127	0.40
Pubis Length (58)	96	84.39	8.71	160	81.14	9.1	83	0.37

*Numbers correspond to measurement definitions found in Moore-Jansen et al. (36).

from the cranium and postcranial skeleton must be used. The data presented in this paper utilize a recent forensic sample and provide population-specific sex estimates from the postcranial skeleton for American Blacks and Whites in the U.S. Because sectioning points and associated classification rates are provided for all standard postcranial measurements, these estimators can be used on fragmentary remains.

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