MORPHOPASSE DATABASE

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Version 1

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Funding Statement
This research was funded by National Institute of Justice Grant 2015- DN-BX-K014. Opinions or points of view expressed in this research represent a consensus of the authors and do not necessarily represent the official position or policies of the U.S. Department of Justice or the National Institute of Justice. Any products and manufacturers discussed are presented for informational purposes only and do not constitute product approval or endorsement by the U.S. Department of Justice or the National Institute of Justice.

Recommended Manual Citation
Klales AR, Cole SJ. 2018. MorphoPASSE: the Morphological Pelvis and Skull Sex Estimation Database Manual. Version 1.0. Topeka, KS: Washburn, University.

Recommended Program Citation
Klales AR. 2018. MorphoPASSE: the Morphological Pelvis and Skull Sex Estimation Database. Version 1.0. Topeka, KS: Washburn, University.

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Contributors

The majority of the data in the database was collected as part of the NIJ grant. Once observer error was assessed, additional data were sourced to increase the overall sample size and number of groups/populations represented in the database. The following individuals graciously contributed skull and/or pelvis data to the MorphoPASSE database:

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Population Samples

The data in the MorphoPASSE Database come from mostly contemporary and historic individuals from various U.S. and international collections; however, the Arikara sample also contains pre- and proto-historic individuals. Most individuals are of known sex, age-at-death, and ancestry with the notable exception being some of the individuals from the Operation Identification Collection housed at Texas State University in San Marcos, Texas, (discussed in more detail below).

The number of individuals listed for each sample represents the number of individuals with at least one trait available for scoring. Some individuals are represented by only the skull or pelvis. Additionally, some traits could not be scored due to missing elements (e.g., mandible), damage, or pathology. Therefore, the number of individuals in each sample will vary depending on the analysis.

Collections Descriptions

Contemporary

1. William M. Bass Donated Skeletal Collection

This contemporary U.S. collection, housed at the University of Tennessee, Knoxville, was started in 1981. It is comprised of mostly donated individuals of known sex, age-at-death, and ancestry. The collection currently consists of individuals with birth years ranging from 1892 to 2016, with the majority of births occurring after 1940. Data collected as part of the grant.

http://fac.utk.edu/wm-bass-donated-skeletal-collection/ (Accessed 03.15.17)

2. Texas State University Donated Skeletal Collection

This collection is housed at Texas State University, San Marcos, Texas, and is comprised of contemporary donated individuals with known sex, age-at-death, and ancestry information. Occupation and health information is also available. Data collected as part of the grant.

http://www.txstate.edu/anthropology/facts/researchers.html (Accessed 07.4.17)

3. Texas State Operation Identification Collection

This contemporary collection is housed at Texas State University, San Marcos, Texas, and is comprised of migrant individuals that perished while attempting to cross the U.S.-Mexico border. Attempts to identify these individuals are being undertaken. As a result, the demographic information of these individuals is inferred based on a number of variables. Ancestry was estimated based on information suggestive of a migrant person, including clothing, cultural and religious artifacts, foreign currency, and geographic location of the remains upon discovery. FORDISC software was also used to estimate ancestry in a number of cases. DNA was used to determine sex in some individuals. In some cases, enough soft tissue was present to determine sex visually. In other cases, FORDISC was used to estimate sex, or artifacts associated with gender were used to infer sex. It should be noted that gender does not always correlate with biological sex; however, in some cases, it was the only way to make a sex prediction. Data collected as part of the grant.

http://www.txstate.edu/anthropology/people/faculty/spradley/Identifying-Migrant-Deaths-in-South-Texas.html (Accessed 07.4.17)

4. Mercyhurst University Forensic Anthropology Laboratory

The individuals from the Mercyhurst University Forensic Anthropology Laboratory (M-FAL) located at Mercyhurst University in Erie, Pennsylvania consist of contemporary, positively identified forensic cases received by M-FAL between the years of 2009 and 2016. Data are courtesy of Dennis Dirkmaat.

5. The Pretoria Bone Collection

This collection is housed at the Department of Anatomy at The University of Pretoria in Hatfield, Pretoria, South Africa. This collection is cadaveric-derived and comprised of contemporary individuals whose remains were either unclaimed or donated to the University beginning in 1943. All individuals in the collection are of known sex, age-at-death, and ancestry. Many of the unclaimed individuals are likely of low socioeconomic status. Data are courtesy of Gabriele Krüger.

L' Abbe, E.N., Loots, M., and Meiring, J.H. The Pretoria Bone Collection: A modern South African skeletal sample. HOMO - Journal of Comparative Human Biology. 2005. 56(2):197-205.

6. Hartnett-Fulginiti Pubic Bone Collection

This collection is housed at the Maricopa County Forensic Science Center (FSC) in Phoenix, Arizona. The collection consists of the pubic bones of contemporary individuals that were autopsied at the FSC. All individuals are of known sex, age-at-death, and ancestry. It should be noted that individuals designated as "white" in this sample may actually be Hispanic, as the FSC designates individuals of white or Hispanic ancestry collectively as "Caucasian." All individuals designated as "Caucasian" have been changed to "white" in the MorphoPASSE database. Data are courtesy of Kyra Stull.

Hartnett KM. Analysis of age-at-death estimation using data from a new, modern Autopsy sample- part I: pubic bone. J Forensic Sci 2010; 55:1145-1151.

7. Osteological Collection of the National Autonomous University of Mexico

This collection is housed within the Physical Anthropology Laboratory in the Department of Anatomy, School of Medicine, at the National Autonomous University of Mexico. This contemporary collection consists of unclaimed Mestizo individuals from shelters, public hospitals, psychiatric institutions, and forensic institutes who died between the years of 1990 and 2010. The demographic information of these individuals is known. Data for the pelvis are courtesy of Jorge Gómez-Valdés and colleagues listed in publication below. Data for the skull was collected as part of the grant.

Gómez-Valdés JA, Garmendia AM, García-Barzola L, Sánchez-Mejorada G, Karam C, Baraybar JP, Klales A. 2017. Recalibration of the Klales et al. (2012) method of sexing the human innominate for Mexican populations. Am J Phys Anthropol 2017;162:600-604.

8. Santa María Xigui Cemetery

These contemporary Otomí indigenous individuals are from the Santa María Xigui Cemetery located in central Mexico with years of death from 1960 to 2010. Sex and age-at-death information are known and were based on cemetery records. Data are courtesy of Jorge Gómez-Valdés and colleagues listed in publication below.

Gómez-Valdés JA, Garmendia AM, García-Barzola L, Sánchez-Mejorada G, Karam C, Baraybar JP, Klales A. Recalibration of the Klales et al. (2012) method of sexing the human innominate for Mexican populations. Am J Phys Anthropol 2017;162:600-604.

9. The Khon Kaen University Human Skeleton Research Centre

This contemporary donated collection is housed at the Kohn Kaen University in Thailand. The individuals in this collection are from North-Eastern Thailand and are of known sex, age-at-death, and ancestry. Many individuals in this collection were farmers; as such, certain skeletal attributes may not be representative of other non-farming populations in Thailand/Southeast Asia. Data are courtesy of Kyle McCormick and Michael Kenyhercz.

Techataweewan N, Tuamsuk P, Toomsan Y, Namking M, Amarttayakong P, Ratanasuwan S, Tayles N. A large modern Southeast Asian skeletal collection from Thailand. Proceedings of the 86th Annual Meeting of the American Association of Physical Anthropologists; 2017 April 19-22; New Orleans, LA.

10. Antioquia Modern Skeletal Reference Collection

This collection is located in Medellin, Colombia. The individuals in this collection are contemporary and are of known sex, age-at-death, and ancestry. Data are courtesy of Julia Garcia de Leon.

Toon C, de Leon JG. A comparison of the Klales et al. (2012) and Pheice (1969) methods of sex estimation on a modern Colombian sample. Proceedings of the 66th Annual Scientific Meeting of the American Academy of Forensic Sciences; 2014 Feb 17-22; Seattle, WA. Colorado Springs, CO: American Academy of Forensic Sciences, 2014.

11. University of the Philippines Skeletal Reference Collection

This collection is housed at the Archaeological Studies Program of the University of Philippines in Diliman. Individuals come from the cemetery population of Manila North Cemetery. Most individuals are of documented age and sex that died during the 21st century. Data are courtesy of Matthew Go and was funded by the U.S. National Institute of Justice (Award Number 2017-IJ-CX-0008) and the Social Sciences and Humanities Research Council of Canada (Award Number 752-2016-0221).

Go MC, Lee AB, Santos JAD, Vesagas NM, Crozier R. A newly assembled human skeletal reference collection of modern and identified Filipinos.

Historic/Proto- and Pre-historic

1. Hamann-Todd Human Osteological Collection

This historic U.S. collection, housed at the Cleveland Museum of Natural History in Cleveland, Ohio, consists of cadaveric-derived individuals obtained between 1912 and 1938. Most individuals in the collection are unclaimed bodies from the Cuyahoga County Morgue and Cleveland city hospitals. Extensive documentation accompanies each individual in the collection and consists of information including, but not limited to, name, sex, age-at-death, ancestry, cause of death, measurement data, and radiographs. Most data collected as part of the grant with a portion of the data courtesy of Kate Lesciotto.

https://www.cmnh.org/CMNH/media/CMNH_Media/C-R%20Docs/Kirtlandia_Todd-bio_Kern.pdf

2. Robert J. Terry Anatomical Skeletal Collection

This historic U.S. collection, housed at the Smithsonian National Museum of Natural History in Washington, D.C., is comprised of cadaveric-derived individuals obtained between the second decade of the 20th century and 1967. The collection is mostly comprised of unclaimed or donated individuals from local hospitals and institutional morgues in the St. Louis, Missouri area that were originally obtained for use in anatomy courses at the Washington University Medical School in St. Louis. Sex, age-at-death, and ancestry information is known for nearly every individual. Other information, such as cause of death, is also available. Data collected as part of the grant.

http://anthropology.si.edu/cm/terry.htm (Accessed 03.15.17)

3. Nubian Collection at the University of Colorado

These medieval Nubian individuals are housed at the University of Colorado, Boulder. They come from two cemeteries at the Kulubnarti site in Sudanese, Nubia. The individuals in this collection are believed to be from the pre, early, and late Christian periods (550-1450 CE). Data are courtesy of Heather Garvin.

Van Gerven DP, Sheridan SG, Adams WY. The health and nutrition of a medieval Nubian population: the impact of political and economic change. Am Anthropol 1995;97:468-480.

Sandberg PA. 2012. Investigating childhood diet and early life history events in the archaeological record using biogeochemical techniques. PhD Dissertation. Boulder, CO: University of Colorado at Boulder.

4. Arikara Collection at the University of Tennessee, Knoxville

These Arikara individuals are housed at the University of Tennessee, Knoxville. They come from three sites in South Dakota: Mobridge (pre-historic), Larson (proto-historic), and Leavenworth (historic). These individuals are collectively from the period between 1600 and 1830CE. Data are courtesy of Heather Garvin.

Owsley DW, Janyz RL. Intracemetery morphological variation in the Arikara crania from the Sully Site (39SL4), Sully County, South Dakota. Plains Anthropol 1978;23:139-147.

Populations in MorphoPASSE

Contemporary

Asian (177 Males, 86 Females)

U.S. (3 Males, 1 Female) Individuals are from the William M. Bass Donated Skeletal Collection and the Hartnett-Fulginiti Pubic Bone Collection.

Thai (97 Males, 45 Females, Pelvis Only): Individuals are from Khon Kaen University.

Filipino (77 Males, 40 Females, Skull Only): Individuals are from the University of Philippines.

Black (85 Males, 73 Females)

U.S. (35 Males, 23 Females): Individuals are from the William M. Bass Donated Skeletal Collection, the Hartnett-Fulginiti Pubic Bone Collection, the Texas State University Donated Skeletal Collection, and the Mercyhurst University Forensic Anthropology Laboratory.

South Africa (50 Males, 50 Females): Individuals are from the Pretoria Bone Collection.

Hispanic (198 Males, 122 Females)

U.S. (21 Males, 5 Females): Individuals are from the William M. Bass Donated Skeletal Collection, the Hartnett-Fulginiti Pubic Bone Collection, the Texas State University Donated Skeletal Collection, and the Mercyhurst University Forensic Anthropology Laboratory.

Mexico (115 Males, 82 Females): Individuals are from the Osteological Collection of the National Autonomous University of Mexico and Santa María Xigui Cemetery.

Central/South America (62 Males, 35 Females): Individuals are from the Texas State Operation Identification Collection and the Antioquia Modern Skeletal Reference Collection.

Native American (3 Males, 3 Females)

Individuals are from the Hartnett-Fulginiti Pubic Bone Collection and the Mercyhurst University Forensic Anthropology Laboratory.

White (376 Males, 279 Females)

U.S. (326 Males, 229 Females): Individuals are from the William M. Bass Donated Skeletal Collection, the Hartnett-Fulginiti Pubic Bone Collection, the Texas State University Donated Skeletal Collection, and the Mercyhurst University Forensic Anthropology Laboratory.

South Africa (50 Males, 50 Females): Individuals are from the Pretoria Bone Collection.

Historic

Asian (2 Males, 1 Female)

Individuals are from the Hamann-Todd Human Osteological Collection and the Robert J. Terry Anatomical Skeletal Collection.

Black (283 Males, 254 Females)

Individuals are from the Hamann-Todd Human Osteological Collection and the Robert J. Terry Anatomical Skeletal Collection.

Native American (7 Males, 16 Females)

Individuals are from the Hamann-Todd Human Osteological Collection.

Nubian (45 Males, 51 Females, Skull Only)

Individuals are from the Nubian collection housed at the University of Colorado.

White (318 Males, 234 Females)

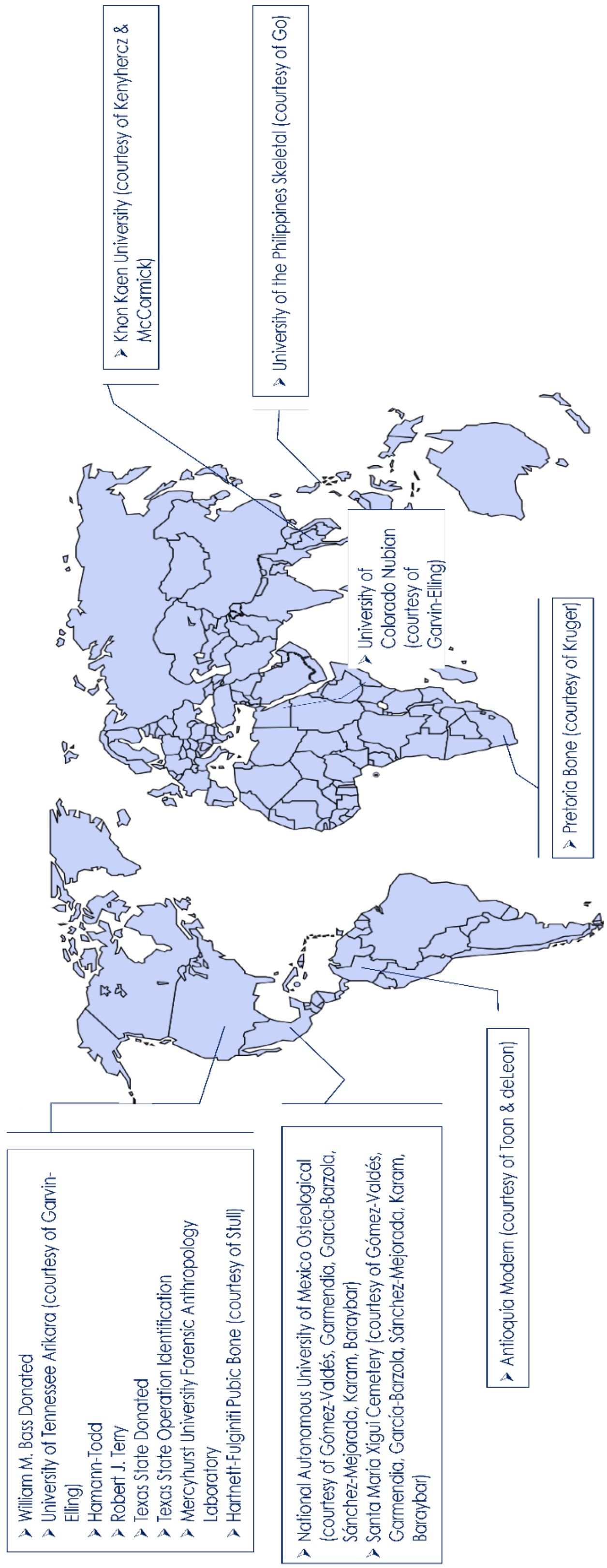
Individuals are from the Hamann-Todd Human Osteological Collection and the Robert J. Terry Anatomical Skeletal Collection.

Proto-historic

Native American (56 Males, 55 Females, Skull Only)

Individuals are from the Arikara collection housed at the University of Tennessee, Knoxville.

Populations Map



Statistical Methods

In keeping consistent with Walker (2008) and Klales et al. (2012), MorphoPASSE allows the analyst to utilize binary logistic regression (LR) analyses for classification and calculation of posterior probabilities of sex membership. Because of the collinearity of these 13 variables, MorphoPASSE also includes random forest modeling (RFM), which is a flexible machine learning algorithm that creates a series of decision trees using bootstrap aggregating of random training subsets and then produces an average prediction based on the "forest." **Option 2 using the RFM is the recommended application in MorphoPASSE.**

OPTION 1: Original Walker (2008) and Klales et al. (2012) Logistic Regression Equations

Regression analysis is a statistical technique used for estimating the relationship between a dependent variable and one or more independent variables. The dependent variable is often referred to as the criterion or outcome variable, and the independent variables are often referred to as predictor variables. Regression analysis is commonly used for predicting an outcome (the criterion variable), which is directly based on the predictor variables. The aim is to obtain the most appropriate model or **regression equation** to explain the relationship between the criterion variable and the predictor variables. The equation can then be used to make predictions about new data. In situations where the criterion variable is categorical in nature – that is, restricted to a limited number of values or categories – the analysis is referred to as **logistic** regression. There are three types of logistic regression: binary, multinomial, and ordinal. In **binary** logistic regression, the criterion variable can belong to one of only two possible. When estimating sex in MorphoPASSE using the original Walker (2008) and Klales et al. (2012) equations, binary logistic regression is used, since the criterion variable is categorical in nature with only two possible outcomes: male or female. The predictor variables used to obtain the outcome are the traits of the skull and the pelvis. More specifically, the predictor variables are the scores assigned to the given traits, which are obtained using written descriptions, illustrations, and photographs to help facilitate the scoring procedure. As with all types of regression equations, the coefficients associated with each trait in the equations are weighted; that is, the more a trait contributes to discriminating between the sexes, the more weight it is given, or the higher the coefficient's value. When selected scores are entered into one of the regression equations, a sex prediction in the form of a posterior probability is obtained. This probability is the likelihood the unknown individual is either male or female based on the scores selected for each trait. Although binary logistic regression is not restricted by many of the assumptions required for linear regression, several assumptions must still be met. These include the following:

1. The sample size is sufficiently large.
2. The outcome must be discrete; that is, the criterion variable belongs to one of only two possible categories (e.g., male or female).
3. There are no outliers in the data.
4. There is no collinearity among the predictor variables → **violated** (the independent variables are highly correlated with one another, see below on RFM)
5. A linear relationship exists between the odds ratio and each independent variable.

Information obtained in part from Field et al. (2012) and Kachigan (1991).

OPTION 2: "On-the-fly" Random Forrest Modeling → Recommended Application

Because of the collinearity of these 13 variables and the inability of LR to easily handle missing data, MorphoPASSE also includes random forest modeling (RFM), which is a flexible machine learning (ML) algorithm that creates a series of decision trees using bootstrap aggregating of random training subsets and then produces an average prediction based on the "forest." Random forest classification uses many random subsets of the variables and repeated sampling of the original data to produce hundreds of decision trees, called an ensemble, and the consensus of the ensemble is used to determine the best classification rules. Random forests can generally tolerate a large number of variables simultaneously, including "noisy" ones (Hefner and Ousley 2014:886). Thousands of random cutoff points in the sample are determined "on-the-fly" to determine the most accurate pooling of the groups (i.e., the sexes in this case) (Williams 2011; Hefner and Ousley 2014). The more trees in the forest the more robust or higher accuracy for sex prediction. This approach prevents overfitting and only selects the most valuable input features, or traits and their scores, for classification. RFM is nonparametric whereby the model is based on the data entered (i.e., not specified *a priori*) and makes no assumptions about that data (e.g., requirement of normal distribution, sample size, etc.). Thus far, ML approaches including decision trees/random forest models have been mostly applied to continuous data for sex estimation; however, these statistical approaches have also shown great promise for morphological traits (binary, discrete, ordinal data) and combined morphological/metric ancestry estimation (Hefner et al. 2014; Hefner and Ousley 2014), but have yet to be widely applied in this capacity to sex estimation.

Scoring Procedures

For each of the eight skull and pubis traits, the manual includes a description of the trait, scoring procedures, and special considerations followed by the individual score descriptions from the original publications, modifications and revisions developed from this research, schematic representations of each trait, and real bone specimen photos of each trait. Prior to applying the two methods or scoring the traits, the analyst should become familiar with the range of variation present by minimally examining the real bone specimens provided in this manual.

For each trait listed below, the analyst should view the specimen and compare it to both the descriptions and figures (drawings and real bone examples) to score the specimen. Take care to note that for some traits multiple features are being scored; therefore, weight or preference should be given to the ones noted below. For example, the mental eminence examines the tubercles, as well as, the portion of the mandible occupied by the eminence. Likewise, the ventral arc examines the ridge of bone, as well as, overall bone shape and morphology.

In the case of bilateral traits, both the left and right sides should be scored as Cole et al. (2017) have demonstrated that using the left side only significantly favors female classification, while using the right side only favors male classification in individuals that are asymmetric.

Lastly, it’s important to note that sometimes, albeit rare in our experience, you may get a specimen that doesn’t exactly fit any one score. In that case, it is recommended that you score the individual to the closest trait representation possible. Additionally, the five-point ordinal scale, as included by Walker (2008) and Klales et al. (2012), adjusts better for slight scoring discrepancies than a three-point scale. For example, if one individual scores a trait as a five and another scores that trait as a four, the classification results are not significantly impacted when all possible traits are used in the analyses.

Walker (2008) Cranial Trait Revisions

Walker's (2008) original publication references the work done previously in Buikstra and Ubelaker (1994). Table 1 of Walker (2008) provides descriptions of the minimal (score 1) and maximal (score 5) expression of each trait; however, intermediate trait descriptions (scores 2-4) are not included. As such, we have included Walker's (2008) original descriptions of scores 1 and 5 and have also provided our own interpretations of these traits based on the data collected for this program. We realize that not everyone may interpret Walker's scores the same; however, high interobserver agreement for all traits with the exception of the mental eminence (Walls et al. 2018) suggest that practioners can apply the modified descriptions below.

Walker (2008:42) suggests holding "the skull at arm's length a few inches from the diagram. Orient the skull so the features can be directly compared with those illustrated. Move the skull from diagram to diagram until the closest match is obtained. Score each trait independently."

Copyright permission for use of images obtained from the Arkansas Archeological Survey.

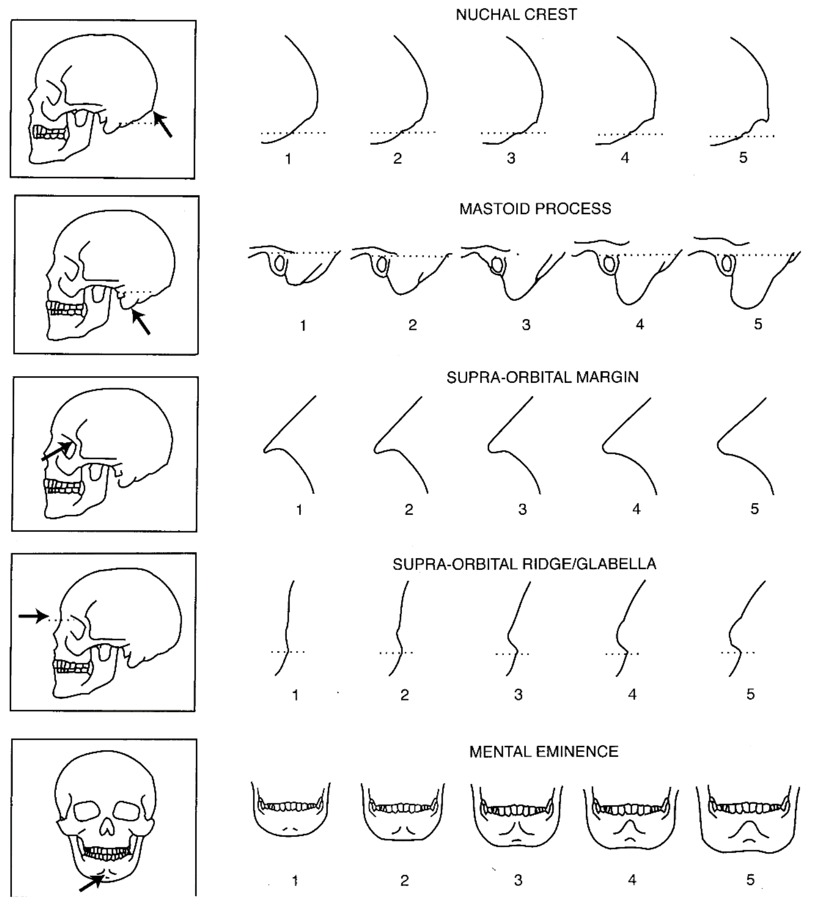
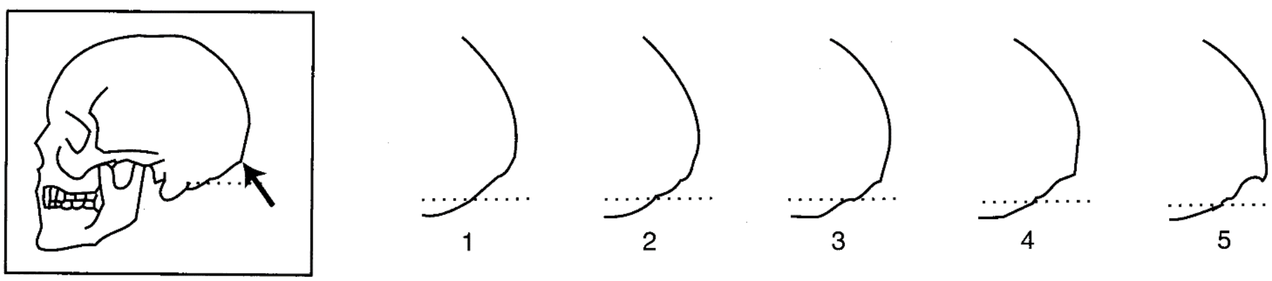
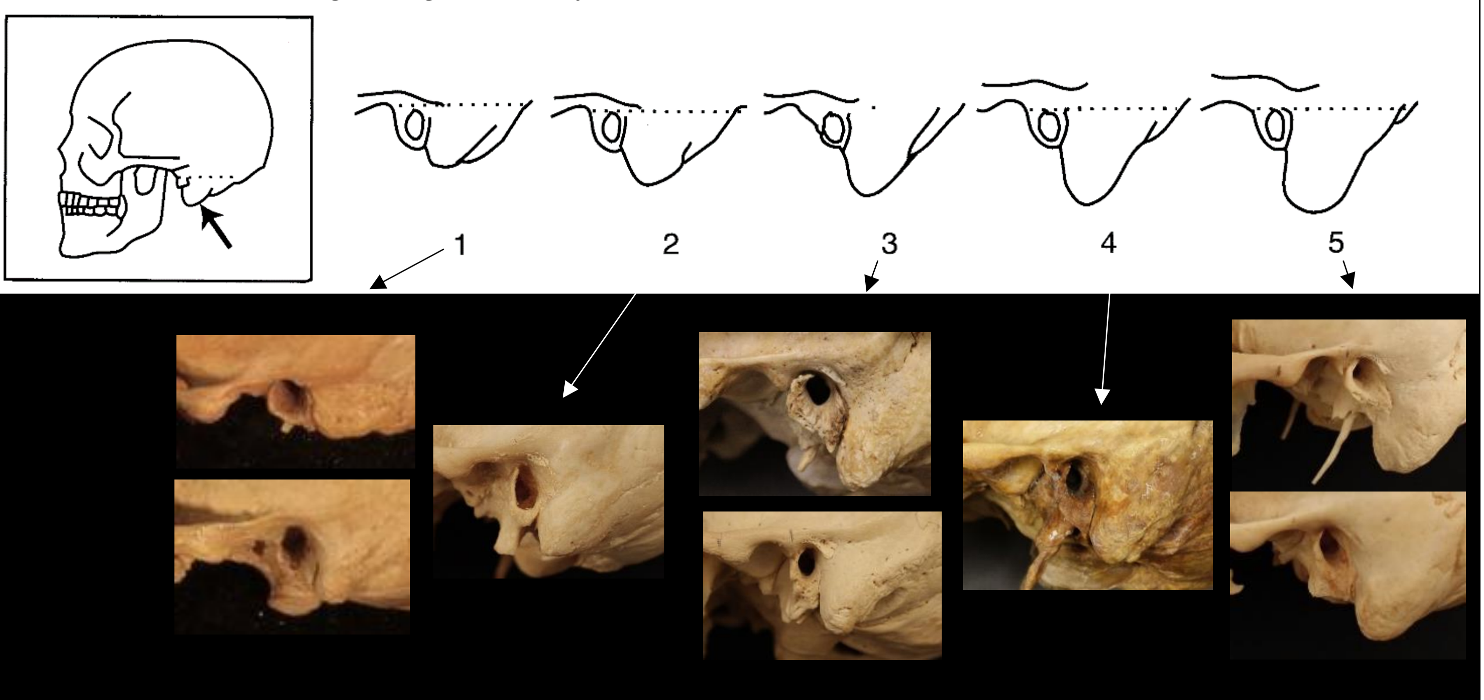


Figure 4. Scoring system for sexually dimorphic cranial features (after Acsadi and Nemeskeri 1970, Figure 16).

1. **Nuchal Crest**
   Abbreviation: NC
   Description: Thick transverse nuchal crest along the squamous portion of the occipital bone, at the external occipital protuberance (EOP), for the attachment of the nuchal and trapezius muscles and the nuchal ligament. Note: inion is the furthest projection of the EOP and is sometimes erroneously used interchangeably with the term nuchal crest and EOP.
   Scoring: View the skull in lateral position (left or right side) and palpate the surface noting any rugosity. When viewing this landmark laterally, the overall robusticity of the superior nuchal line can also be observed and should be considered. Note: Do not score this trait if an occipital bun is present and obscuring the region and also note (see images below) that the location of EOP on the posterior portion of the skull varies considerably based on vault shape.
   Scores:
   1- Smooth. EOP is not evident.
   2- Slight roughening or traces of the nuchal lines. EOP is not evident.
   3- Nuchal lines and EOP evident. EOP is rough and has a lip or edge with slight posterior projection (i.e., you can catch a fingernail on it).
   4- Nuchal lines and marked EOP. EOP is pronounced with clear posterior projection, but has not yet developed a pronounced hook or inferior projection.
   5- Nuchal lines and EOP with rough surface. EOP is very pronounced and can be hooked with marked posterior/inferior projection. A ledge or ridge to either side of the EOP may be present.



2. **Mastoid Process**
Abbreviation: MP (Bilateral Left and Right)
Description: The mastoid process is a conical prominence of bone located on the temporal bones just posterior to the external auditory meatus (EAM). It serves as an attachment site for various muscles including the sternocleidomastoideus, splenius capitis, digastric posterior belly, and longissimus capitis.
Scoring: View the lateral side of cranium (left and right separately). Consider the overall volume of the mastoid process (length and width). More weight should be given to overall volume rather than length or width independently. Consider the size of the mastoid relative to the surrounding structures, such as the EAM and zygomatic process, and overall temporal bone size. Take note of any pathologies impacting the surrounding structures, such as infections of the EAM or within the mastoid air cells. If pathologies are impacting the mastoid process, do not score this trait.
Scores:
    1- Very small with low volume. Short and narrow. Little projection of the mastoid below the inferior EAM border or even with the inferior border in extreme cases. Digastric groove is usually visible.
    2- Small. Short and/or narrow. Low volume. Slight projection of the mastoid below the EAM border. Digastric groove is usually visible.
    3- Medium volume. Projection of the mastoid well below the inferior EAM border or longer than is wide. Digastric groove may or may not be visible.
    4- Large volume. Usually long and wide relative to surrounding structures. Projection of the mastoid below the inferior EAM border. Much wider or longer than the length/width of the EAM. Digastric groove may or may not be visible.
    5- Very large. Very long and wide relative to surrounding structures. Largest volume. Pronounced projection of the mastoid below the inferior EAM border. Digastric groove likely not visible.



3. **Supra-Orbital Margin**

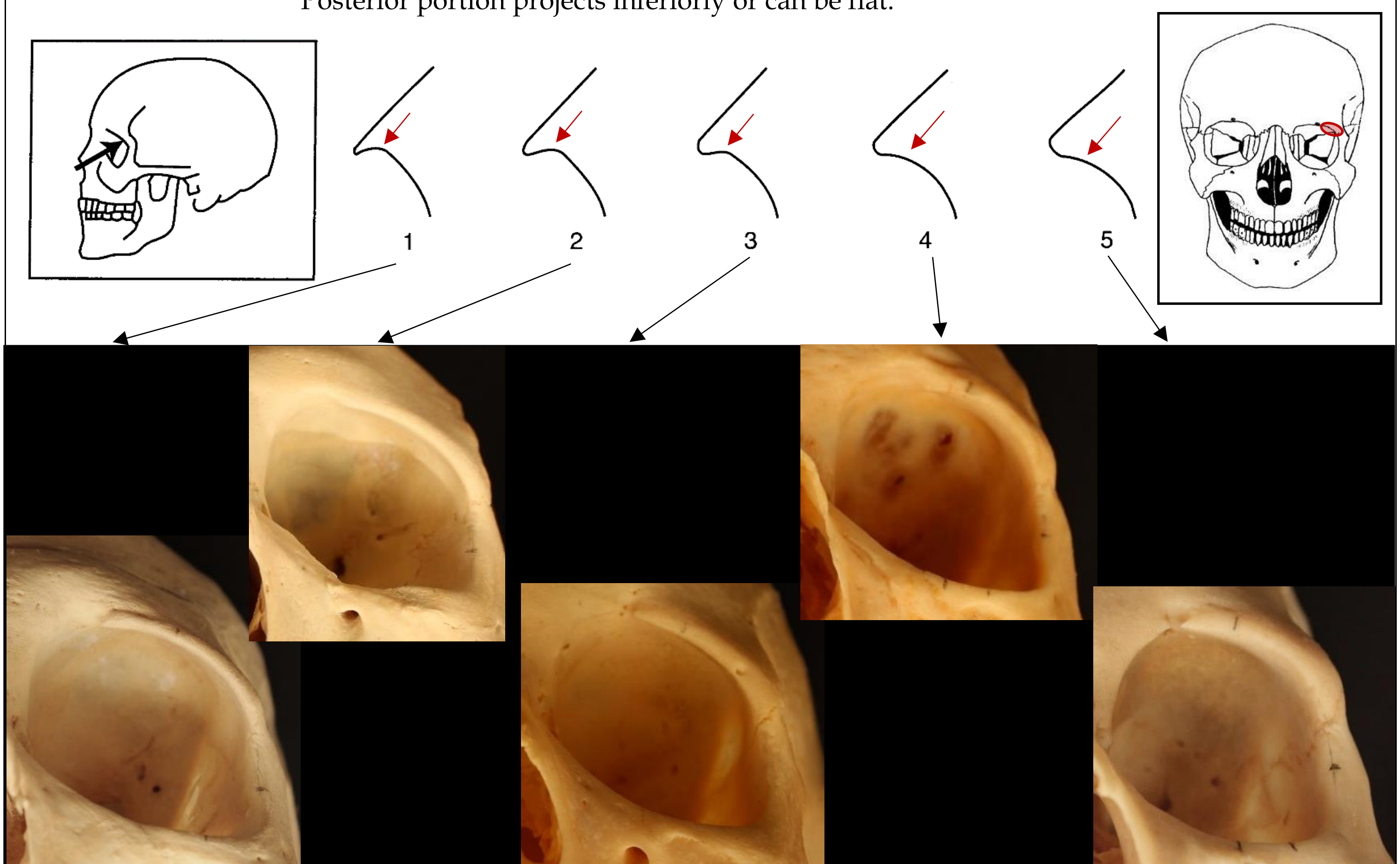
Abbreviation: SO (Bilateral Left and Right)

Description: The superior border of the orbit, comprising the inferior-lateral portion of the frontal bone.

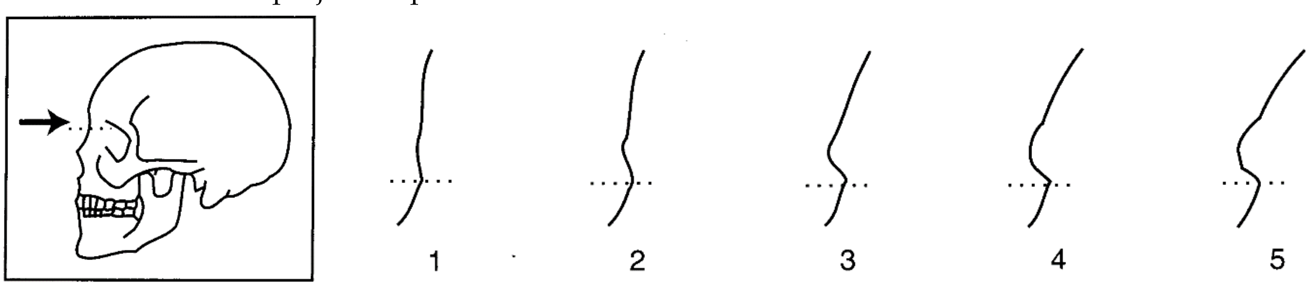
Scoring: The portion just lateral to the supra-orbital foramen or notch should be palpated (red circle) by pinching the margin of the bone between forefinger and thumb. The degree which the margin posteriorly recurves (red arrows) into the orbit should also be considered secondary to the thinness/thickness. Walker's original figures were developed using a cross-sectional scan of the supraorbital margin, so the scorer must translate the width and degree of sharpness into a cross-sectional representation of that feature.

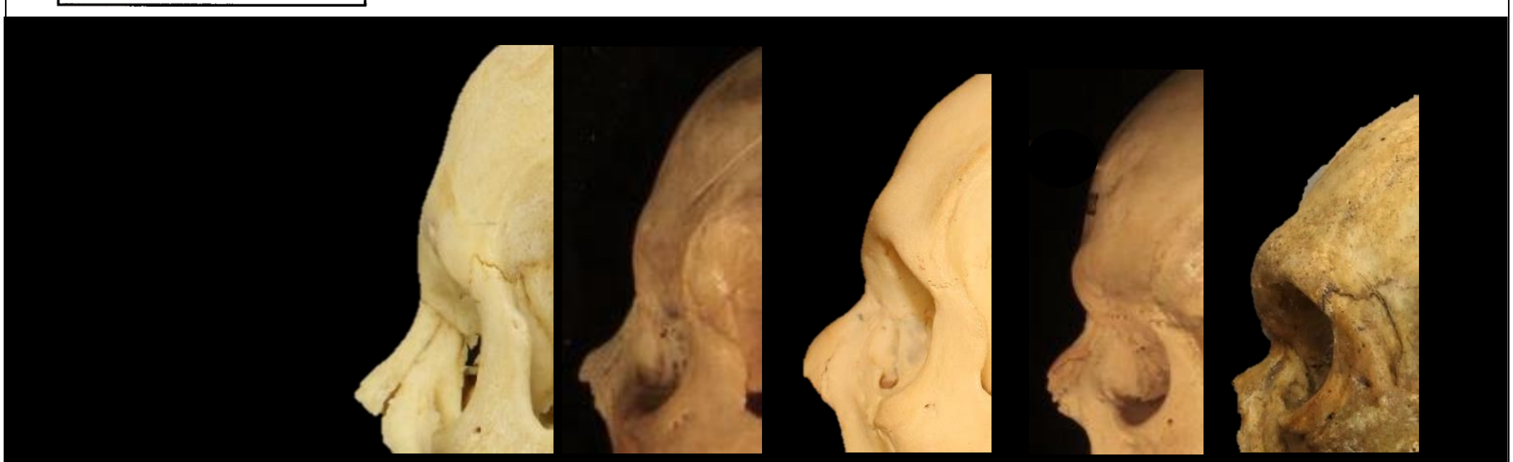
Scores:

1- Very sharp and thin. Texture approximates that of a dull knife blade. Posterior portion very concave.
2- Sharp and thin. Posterior portion concave.
3- Blunted but thin. Posterior portion either concave or flat.
4- Blunted/rounded edge and thick. Posterior portion projects inferiorly or can be flat.
5- Blunted/rounded edge that is very thick. Approximate width of a pencil or pen. Posterior portion projects inferiorly or can be flat.



4. **Glabella or Supra-Orbital Ridge**
Abbreviation: G
Description: Glabella refers to the anatomical landmark located along the "most anterior midline point on the frontal bone, usually above the frontonasal suture" or nasion landmark (Buikstra & Ubelaker 1994:72). When viewing this landmark laterally, the overall browridge morphology can also be observed and should be considered. In some cases the left and right browridges may project more anteriorly than the actual glabella landmark. The projection of the entire browridge, when viewed laterally, should be considered and included in scoring. In some cases the landmark glabella may be depressed while the entirety of the supraorbital region is projecting in lateral view. In these cases, score the overall projection of the region when viewed laterally.
Scoring: View the lateral side of cranium and locate the most anterior projection of the frontal bone in the region near glabella. It may help to touch the region to find the most anterior projection of the frontal bone.
Scores:
1- Little to no anterior projection at midline or in the supraorbital region. Bone is smooth and nearly vertical.
2- Slight anterior projection at midline or along the supraorbital region. Bone may be slightly ridged or projecting beyond the landmark nasion.
3- Glabella and/or the browridges project anteriorly past the nasion landmark.
4- Glabella and the browridges project anteriorly past the nasion landmark and are rounded.
5- The region is massive and rounded (loaf-shaped) projection. Marked anterior projection past the nasion landmark.





5. **Mental Eminence**

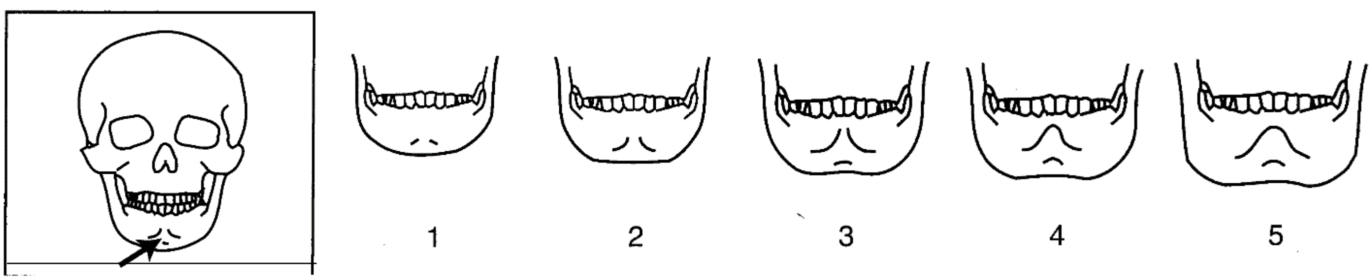
Abbreviation: ME

Description: The mental eminence is also known as the mental protuberance. It is a bony protuberance located along the midline of the mandible at the center of the chin and is the attachment site for the mentalis muscle. Lateral to the protuberance, on either side, are the mental tubercles. Together, the protuberance and tubercles make up the mental trigon. Note that the tubercles can be absent or can project anteriorly or inferiorly. In some cases there may be two tubercles present on one or both sides of the protuberance. When this occurs, score the most lateral tubercles. There is considerable variation in the expression of the shape (i.e., squareness), total area, and the tubercles, and these traits are not necessarily all correlated.

Scoring: Begin by holding the mandible with your thumbs on the mental protuberance at midline, then move your thumbs laterally. If no tubercles are encountered, see scores 1-2. If tubercles are encountered, see scores 3-5. More weight should be given to the presence or absence of tubercles.

Scores:

1- Pointed or rounded and smooth with no evidence of a projecting protuberance or tubercles.
2- Slightly delimited or roughened area at the protuberance with no tubercles.
3- Slightly or fully delimited projecting protuberance with anteriorly or inferiorly protruding tubercles that are close to the midline or mandibular symphyses.
4- Inverted T-shape with widely spaced anteriorly or inferiorly protruding tubercles. Mental trigon occupies a good portion of the anterior mandible.
5- Inverted T-shape with very widely spaced anteriorly or inferiorly protruding tubercles. Mental trigon takes up most of the anterior mandible.



Klales et al. (2012) Pelvic Trait Revisions

Phenice (1969) originally defined three sexually dimorphic traits of the pubis: the ventral arc, subpubic concavity, since renamed subpubic contour in the Klales et al. (2012) modification, and the medial aspect of the ischio-pubic ramus. Phenice's (1969) work was based on earlier work by Grant et al. (1965). The descriptions below are nearly verbatim from the Klales et al. (2012) method modification of Phenice's (1969) original method; however, trait weighting has been added to clarify. Observer agreement studies examining all three traits were high and Walls et al. (2018) suggest that practioners can apply the modified descriptions below.

Copyright permission for use of images obtained from the American Journal of Physical Anthropology. The original schematics and real bone images from the 2012 publication are included along with new images of the ventral surface for the SPC.

Orientation for the SPC and VA:

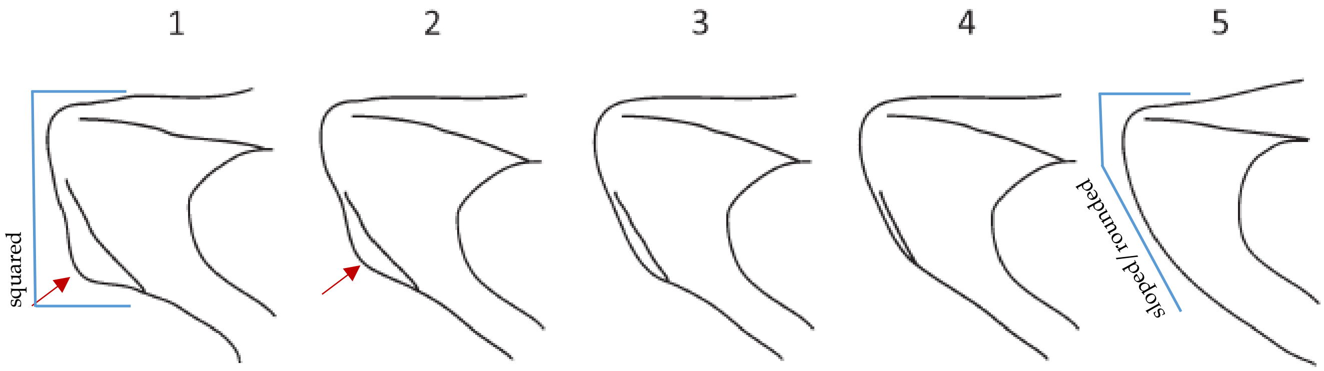
Orientation for the MA:

*should feel area just below symphyseal face

1. **Subpubic Contour**
Abbreviation: SPC
Description: Phenice (1969:300) described the subpubic concavity as ''a lateral recurve which occurs in the ischio-pubic ramus of the female a short distance below the lower margin of the pubic symphysis. . . [which] is absent in the male pelvis.'' The concavity of the inferior female ischio-pubic ramus results in a greater subpubic angle where the two innominates articulate, and a generally more gracile form when compared with males. Klales et al. (2012) modified Phenice's trait name to the subpubic contour and modified the description to include the entire length of the ramus rather than just the area below the symphyseal face.
Scoring: The Phenice (1969) and Klales et al. (2012) article originally suggest scoring this trait in dorsal view; however, ongoing research suggests the trait is easier to score in ventral view, especially for less experienced observers. This trait should be scored with the bone in the same orientation as when the VA is being scored. If the ramus exhibits a marked concavity, it should be scored a 1 or 2, while if a convexity is noted the specimen should be scored a four or five (even if a small concavity is noted just below the symphyseal face- see images).
Scores:
1- Well-developed concavity present inferior to symphyseal face and along most of the length of the inferior ramus.
2- Slight concavity present inferior to symphyseal face that extends partially down inferior ramus.
3- Bone is nearly straight along the entire length of ischio-pubic ramus with no obvious concavity or convexity observable. A very slight indentation may exist just inferior to the symphyseal face.
4- Slight convexity, especially pronounced along the middle portion of the inferior ramus. A very slight indentation may exist just below the symphyseal face and/or along the lower third; however, middle portion of ramus is convex.
5- Well-developed convexity, pronounced along the entirety of the inferior ramus.

1 2 3 4 5

2. **Ventral Arc**
Abbreviation: VA
Description: The ventral arc is "a slightly elevated ridge of bone which extends from the pubic crest and arcs inferiorly across the ventral surface of the lateral most extension of the subpubic concavity where it blends with the medial border of the ischio-pubic ramus'' (Phenice, 1969: 298). The ventral arc serves as an attachment site for various muscles including the gracilis, adductor brevis, and adductor magnus. While a true ventral arc is only present in females, a ridge of bone along the ventral aspect of the pubis can also be found in males: however, the angle and orientation of this bony ridge is different in males and females, allowing distinctions between the sexes to be made. Klales et al.'s (2012) modified Phenice description includes the angle and orientation of the bony ridge in relation to the symphyseal face, and also takes into consideration the overall morphology of the region inferior and medial to the arc (red arrows indicates extra triangle of bone). The overall shape of this region should be considered (e.g., squared in scores 1-2 vs. sloping on inferior edge in scores 3-5) secondary to the presence and angle of the arc (blue lines).
Scoring: The ventral surface of the pubis bone should be perpendicular to the viewer and the superior pubic ramus should be aligned horizontal or straight. In proper orientation, the symphyseal face should not be visible, only the ventral edge or rim.
Scores:
1- Arc present and oriented at an approximate angle of 40° or more relative to the symphyseal face. A large triangular portion of bone is located inferior to the arc, giving the pubis a squared-off appearance.
2- Arc present and oriented at an approximate angle of 25–40° relative to the symphyseal face. A small triangular portion of bone is located inferior to the arc, giving the pubis a somewhat squared-off appearance.
3- Arc (or bony ridge) present and oriented at a slight angle (less than 25°) relative to the symphyseal face. A slight, non-triangular portion of bone is located inferior to the arc.
4- Bony ridge present and oriented approximately parallel to the symphyseal face. Hardly any additional bone is present inferior to the arc. Bone has a sloping appearance on the inferior symphyseal face.
5- No arc present (therefore, no additional bone present inferior to the arc). Bone has a sloping appearance on the inferior symphyseal face.


1
2
3
4
5
squared
sloped/rounded

3. Medial Aspect of the Ischio-Pubic Ramus

Abbreviation: MA

Description: The male expression is described as ''a broad surface which is found on the ischio-pubic ramus immediately below the symphyseal surface,'' while the female condition consists of a sharp ''ridge which is found here... in contrast to the broad surface in the male'' (Phenice, 1969: 300). In addition to the ridge, the female form is narrower than the male form. Consider the thickness of the ramus relative to the surrounding structures and overall innominate size. The presence of a ridge or plateau should be given more weight than the overall relative width of the ramus.

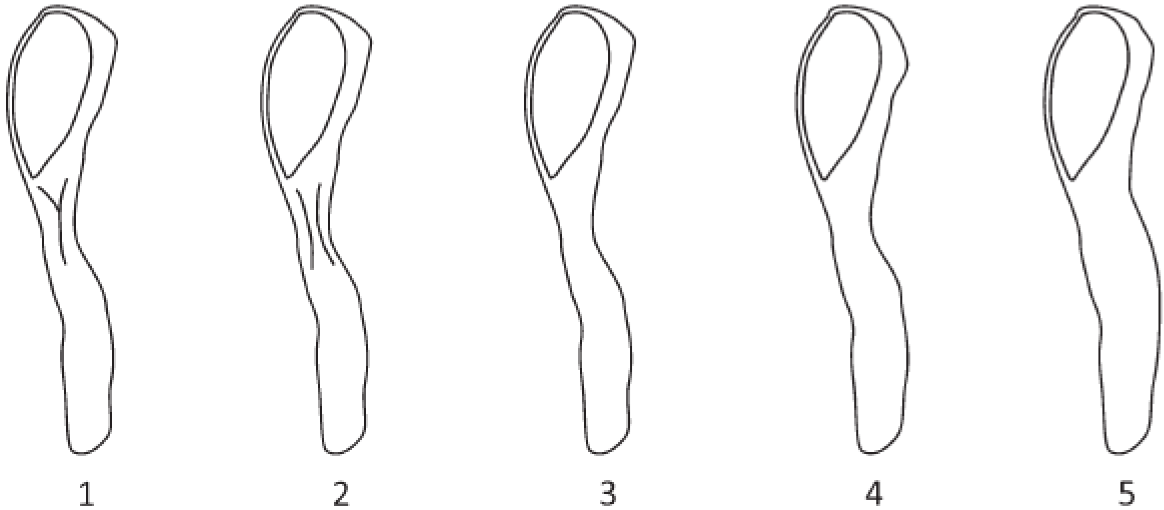
Scoring: The symphyseal face should be held perpendicular to the viewer and the scorer should palpate the area below the symphyseal face to approximately 1/3rd of the way down the ischio-pubic ramus. If a ridge or plateau is present, see scores 1-2. If no ridge is present, see scores 3-5 and evaluate based on width.

Scores:

1- Ascending ramus is narrow dorso-ventrally, especially just below the symphyseal face where a sharp ridge of bone is present.
2- Ascending ramus is narrow dorso-ventrally, especially just below the symphyseal face where a plateau/rounded ridge of bone is present.
3- Ascending ramus is narrow or of medium width dorso-ventrally with no ridge or plateau present.
4- Ascending ramus is broad dorso-ventrally with no ridge or plateau present. Occasionally there will be slight pinching below the symphyseal face.
5- Ascending ramus is very broad dorso-ventrally with no ridge or plateau present. Lacks pinching below the symphyseal face and is broad along the entire length.

Left: close-up example of the ridge (red arrows) below the symphyseal face. Note that although the width of the ramus is relatively wide, the presence of the ridge is given more weight and dictates that it should be scored as a 1.

Right: close-up example of the plateau (orange arrows) below the symphyseal


1
2
3
4
5

MorphoPASSE Scoring Sheet

Scoring Form
© Klales and Cole (2018)

Case #:___________________ Analyst: ___________________
Date:______/______/______ Time:_________

Traits should be scored based on the MorphoPASSE manual descriptions and figures

SKULL

Nuchal Crest	Mastoid Process	Glabella	Supraorbital Margin	Mental Eminence
	Left:		Left:	
	Right:		Right:	

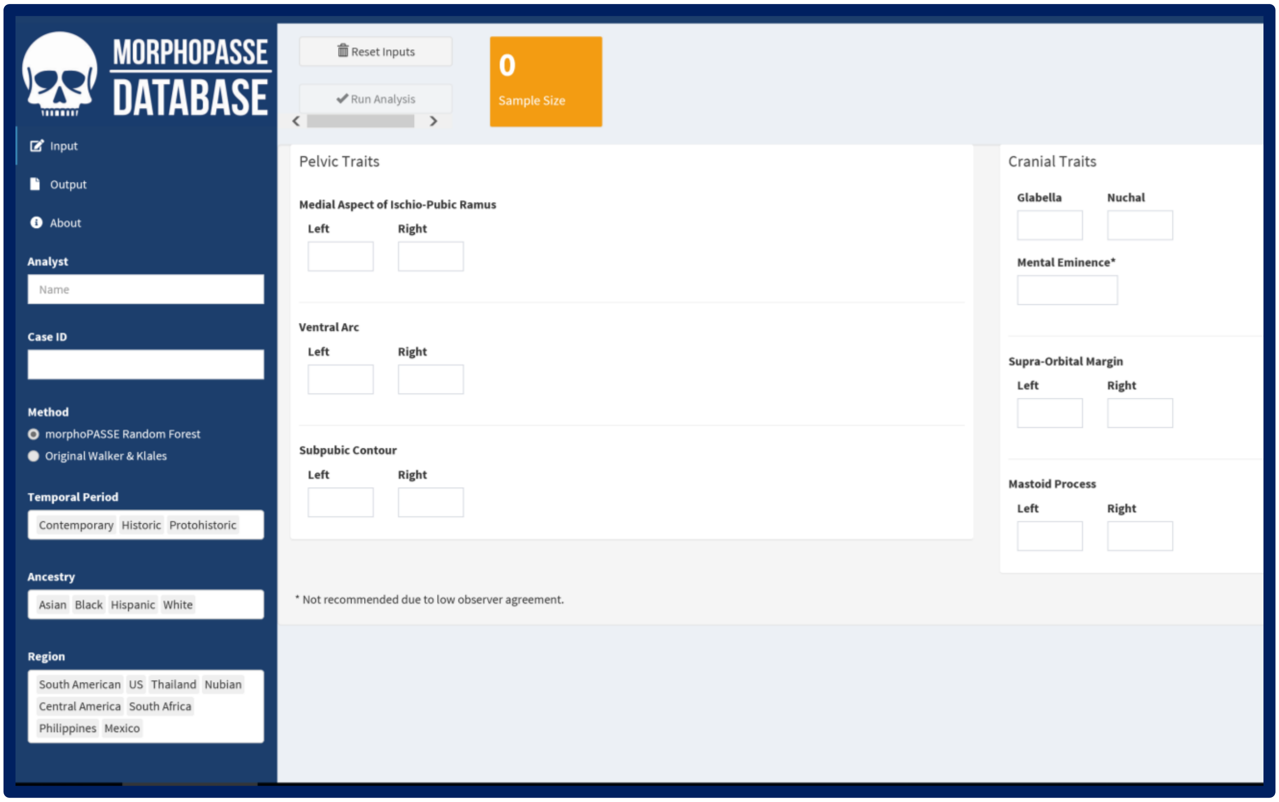
Notes:____
____
____

PELVIS

Ventral Arc	Subpubic Contour	Medial Aspect of Ischio-Pubic Ramus
Left:	Left:	Left:
Right:	Right:	Right:

Notes:____
____
____

MorphoPASSE Interface



Above is the MorphoPASSE input interface.

Analyst: Recommended that the analyst includes their full name or initials. Appears on the output.

Case ID: Recommended that analyst includes case number, burial ID, etc. being analyzed. Appears on output.

Method Options:

MorphoPASSE "on-the-fly" random forest model **RECOMMENDED**

Original Walker (2008) and/or Klales et al. (2012) binary logistic regression equations

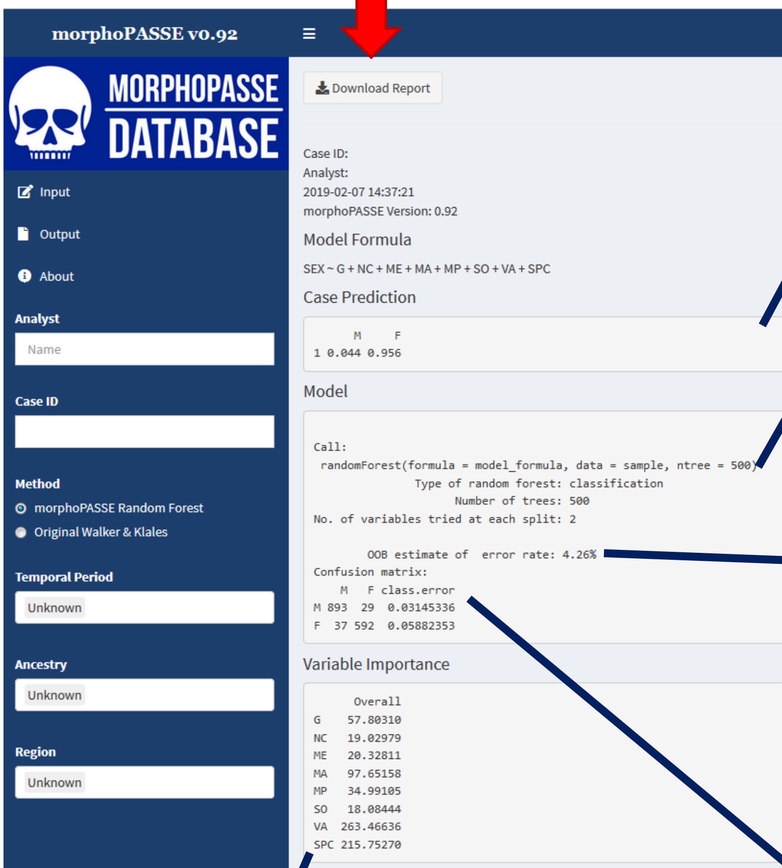
Temporal Period: Analyst can select contemporary, historic, or protohistoric. If no temporal period is selected, the model will include all periods when classifying the case.

Ancestry: Analyst can select ancestry of their case if known. If no ancestry is selected, the model will include all groups/populations when classifying the case.

Region: Analyst can select geographic region of their case if known. If no region is selected, the model will include all regions when classifying the case.

MorphoPASSE RFM Output

Note: we recommend downloading the report for easier interpretation of the results.



Case Prediction provides the probability of sex membership. In this example, the probability of being Female is 95.6%.

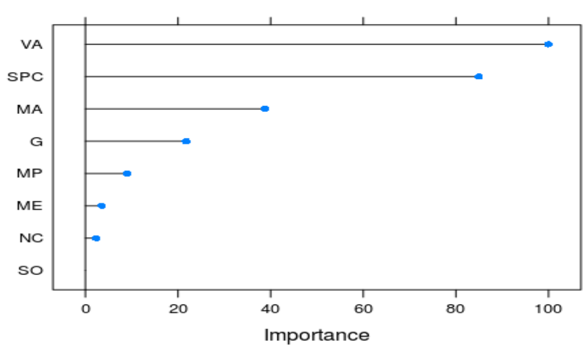
Model is the model summary. The type of RF will be classification because sex is a binary variable. The number of trees is included along with the number of predictor variables considered at each node of the decision tree.

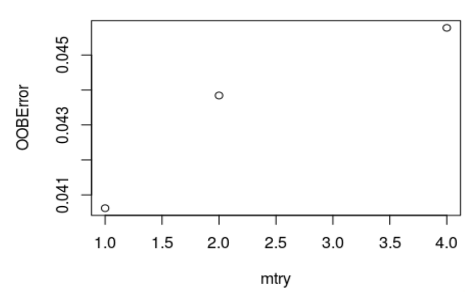
The *"out of the bag" (OOB)* estimate of the error is based on bootstrap aggregation. At each iteration created with a subset of data, the unused data is tested in the tree to produce an average of errors for the entire set of decision tree.

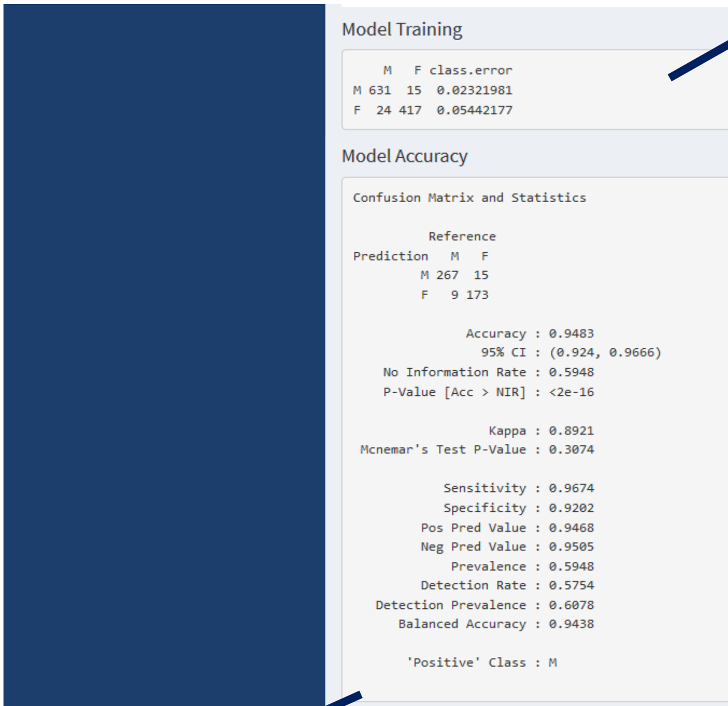
Model tuning *mtry* is the number of variables randomly sampled as candidates for each node and is also presented visually (see image below right).

The confusion matrix presents the accuracy of the model based on true negatives, true positives, false positives, and false negatives. In this example, the model incorrectly predicts male 3.1% of the time and incorrectly predicts female 5.9% of the time.

Variable Importance (mean decrease in Gini coefficient) describes how important each of the variables are when classifying sex. The most important variable will be the one with the highest mean decrease in the OOB error. Typically, the pelvic traits will always be of more importance than the skull traits due to the higher degree of sexual dimorphism in the pelvis. This information is also presented visually (see image below left). In this example below, the ventral arc (VA) is the best variable.







Model Training

```
    M   F class.error
M 631  15  0.02321981
F  24 417  0.05442177
```

Model Accuracy

```
Confusion Matrix and Statistics

          Reference
Prediction   M   F
         M 267  15
         F   9 173

               Accuracy : 0.9483
                 95% CI : (0.924, 0.9666)
    No Information Rate : 0.5948
    P-Value [Acc > NIR] : <2e-16

                  Kappa : 0.8921
 Mcnemar's Test P-Value : 0.3074

            Sensitivity : 0.9674
            Specificity : 0.9202
         Pos Pred Value : 0.9468
         Neg Pred Value : 0.9505
             Prevalence : 0.5948
         Detection Rate : 0.5754
   Detection Prevalence : 0.6078
      Balanced Accuracy : 0.9438

       'Positive' Class : M
```

Model Training provides cross-validated classification accuracy of the entire sample. In this example, the cross-validation is set to 10 folds, repeated 10 times (see output from downloaded report below) and is 96.3% in this example. The *Kappa* statistic provides the accuracy of the model taking into account random chance and will typically be lower than the accuracy. The details of the model training, the percent accuracy, and Kappa statistic are only provided in the downloaded report (see example below).

Model Training

Random Forest

1087 samples 8 predictor 2 classes: 'M', 'F'

Pre-processing: scaled (8), centered (8) Resampling: Cross-Validated (10 fold, repeated 10 times) Summary of sample sizes: 979, 979, 979, 978, 978, 977, … Resampling results:

Accuracy	Kappa
0.9625616	0.9220327

Tuning parameter 'mtry' was held constant at a value of 2

	M	F	class.error
M	631	15	0.02322
F	24	417	0.05442

Model Accuracy tests the model on a hold-out sample from the database. In this example, the classification accuracy is 94.8% with a Kappa value of 89.2%.

The following are also provided:

Sensitivity: true positive (TP) / (TP + FN)

Specificity: true negative (TN) / (FP + TN)

Positive predictive value = (TP) / (TP + FP)

Negative predictive value = (TN) / (FN + TN)

Contributing and/or Accessing MorphoPASSE Data

Contributing:

If you have collected or will be collecting the Walker (2008) or Klales et al. (2012) traits and are willing to contribute data to this project, please email alexandra.klales@washburn.edu for more information. Options include:

1) Providing data to be used "behind the scenes" for the database formulae. Contributor's data will NOT be made publicly available and will NOT be used for research and/or publications. Contributors will be listed in the database, on the website, and in manual revisions.

2) Providing data to be used in the database and that will be made publicly available (i.e., can be used by others for research and/or publications) along with the grant data. Contributor will be listed in the database, on the website, and in manual revisions.

An Excel scoring sheet can be found at www.MorphoPASSE.com.

Accessing:

Most of the raw data contained within the MorphoPASSE database are available to outside researchers wishing to utilize the trait scores. To access the data, please submit a research request form via email to alexandra.klales@washburn.edu.

The research request form can be downloaded here:
https://www.morphopasse.com/research-request.html

Citations

Field A, Miles K, Field Z. Discovering statistics using R. London: SAGE Publications Ltd, 2012.

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