Length and Robusticity of Metacarpals and Metatarsals to Estimate Physiological Sex from Ancient Maya Skeletal Remains in Northern Belize

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Abstract

For bioarchaeologists, biological sex estimation based on skeletal indicators is a crucial element when creating a biological profile for human remains. While there are several ways for estimating sex, primarily involving examining cranial and pelvic morphology, one useful method that remains underutilized is metric analysis of bones from the hands and feet. Since males and females are sexually dimorphic, the ability to discriminate biological sex from hand and foot bones is possible and is shown to be valid. Skeletal metric data drawn from the hands and feet have successfully discriminated between male and female (bio)archaeological remains in Europe and throughout North America. The results of osteometric data for a Maya population from Nojol Nah in the Blue Creek region of Belize are presented to demonstrate the utility of such metrics in estimating sex. These data are useful to archaeologists or bioarchaeologists working with fragmentary or isolated remains in the field or lab.

Key Words

osteometrics (sexual dimorphism), sexing methods, ancient Maya

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Introduction and Review of Literature

When assessing biological sex on human remains, the primary method(s) of determination often involve analyzing the morphology of the pelvis and the skull due to their sexually dimorphic features. However, in some instances, these components may have undergone damaging taphonomic processes and cannot be analyzed, or they may be completely absent causing a complication in sex estimation. In this case, distinguishing physiological sex must rely on other features such as osteometric data from other elements of the skeleton. Through analyzing this data from metacarpals and metatarsals, biological sex can be estimated on adult and theoretically subadult skeletons. In conjunction with the following assertion, these noted differences are population specific and vary. Not only does this paper prove in favor of the validity of this method, but literature does as well.

Agnihotri, Shukla, and Purwar (2006) sought to examine the osteometric differences in the overall feet between males and females. After assessing overall foot length and breadth. Agnihotri and colleagues found that

> Males had an average foot length about 3cm greater than the females' foot length. The foot breadth was about 1cm greater in males as compared to females. In all age groups, the foot index in females was found to be more than 37, and in males, it was less than 37. Therefore, this value i.e. 37 can be used as deviation point for the determination of sex. Thus the present study indicates a positive correlation between an individual's foot measurements and gender. (Agnihotri et al., 2006, p. 2)

While the application of metacarpal and metatarsal osteometric data collection is an underused methodological approach, these findings demonstrate that the usage of this method yields accurate and applicable results.

Harris and Case (2012) further this study and collected osteometric data from independent tarsal bones to observe if physiological sex can be discriminated (295-305). From their findings, they state, "It is clear from the results of this study that the tarsals show sufficient sexual dimorphism in modern European-Americans for use in metric sex determination"

(Harris & Case, 2012, p. 303). To further this claim, they assert that, "The individual measurements of the tarsals exhibit a range of percent sexual dimorphism as a group (9.8–14.0%) that is higher than the range exhibited by long bone lengths in many other populations" (p. 303). Whereas Agnihotri and colleagues found overall differences in foot size, Harris and Case help illustrate how even osteometric data from the tarsals can too yield viable results.

Not only can data from the overall foot as well as specific measurements of tarsal bones yield viable results, but Case and Ross (2007) found osteometric data from the metatarsal and metacarpals from a European population consisting of 371 adult female and males can be an indicator of physiological sex. In their findings, they elaborate that, "There would appear to be ample justification for favoring length measures over robusticity measures when developing forensic sexing methods. However, the best way to assess the relative value of the length versus robusticity measurements used in past research is to examine studies in which such measurements have been used in combination to study different populations" (Case & Ross, 2007, p. 268). For the research presented in this paper, the sample was derived from the population of ancient Maya from the site of Nojol Nah which dates range from 400 BCE-800 CE (Hammond, 2016, p.3). Therefore, Case and Ross stress the importance of how this methodology is encouraged, valid, and useful.

In conjunction with this source on the concept of population sampling, Wilbur (1998) utilizes osteometrics from the hands of feet from a Native American population sample of 410 adult male and female skeletons. From her research and findings, Wilbur concludes

> The results of the sex determination component of this study indicate that sex determination via the bones of the hands and feet can be accomplished for Native Americans with accuracy comparable to that for metric techniques on other skeletal elements and for other populations. (p. 188)

Based on Wilbur's investigation, there is certain plausibility in the validity of metacarpal and metatarsal osteometric sexing. Beyond this, her findings show

how this methodology is valid in other populations beyond Caucasian and African-Americans.

Another piece of literature which promotes this methodology is Stojanowski (1999). For his data collection, he sampled approximately 200 different skeletons, consisting of adult male and female Europeans as well as African-Americans. For his sample, he employed six different measurements to obtain osteometric data. They "included: midline interarticular length, maximum midshaft diameter, medio-lateral and antero-posterior head breadths, and medio-lateral and anteroposterior base breadths." From his findings, he concludes that, "With the growing literature on sex estimation and stature estimation, [from] using metacarpal dimensions, it is clear that these elements make an important contribution to forensic identification" (p. 251). For this research, similar measurements were employed. In sum, many different pieces of literature help establish the validity of using osteometrics from the hands and feet as way to discriminate biological sex. Along with this, they also convey the importance of gathering data from different populations.

Methods

All data was collected from skeletal remains housed in the bone collection from the Maya Research Project in Blue Creek, Belize. Sample remains ranged from the early to late Classic period (250-800 BCE). For this research, data came from the remains of 92 individuals excavated from the site of Nojol Nah (see Figure 1). Of these, 46 (Male=23, Female=23) were adults and therefore included in this study. For metacarpal data, osteometric data were gathered from nine females and five males (n=14). For metatarsal data, three females and 4 males were measured (n=7). Sample sizes were smaller than originally expected due to both taphonomy and poor preservation.
Figure 1: Map of site Nojol Nah. Marc Wolf, (2015).
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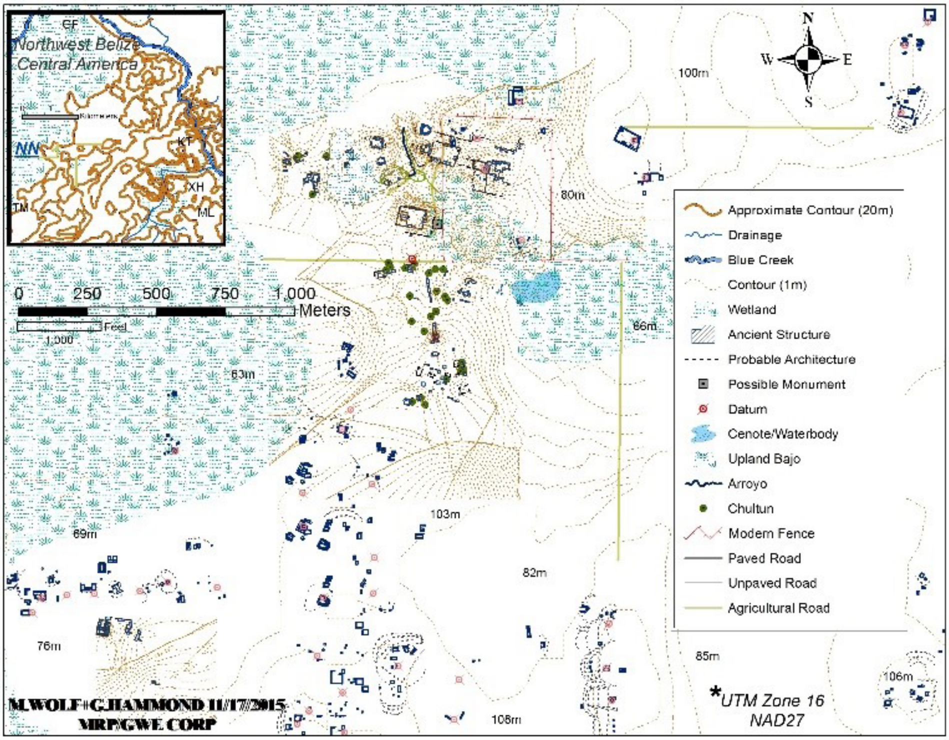


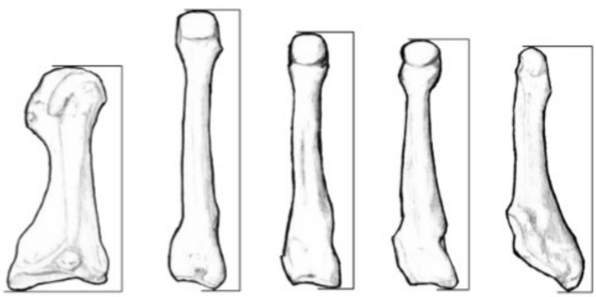
Figure 1: Map of site Nojol Nah. Marc Wolf, (2015). (Reused with permission of Marc Wolfe, 10/2018)

Measurements were collected using Mitutoyo Digital Calipers from both the left and right extremities to maximize sample size and consisted of all five metacarpals and metatarsals.

Four measurements were employed for data collection. Samples were measured in overall length, width at both the proximal and distal ends, as well as width of the metacarpal/tarsal diaphysis.

Figure 2: Overall length as well as width at the proximal, distal and midline were collected on metatarsals. Illustration (Case & Ross, 2007: 265 Figure 1).

Figure 3: Measurements for the metacarpals consisted of the same in figure



1. Illustration (Case & Ross, 2007: 265 Figure 2).

Article Figure 2 and 3 above: (Figure 1 and 2) used with permission from John Wiley and Sons, Publisher of (Case & Ross) Case, D.T. & Ross, A.H. (2007, Jan. 31) Sex Determination from Hand and Foot Bone Lengths* (license number: 4444950111784)

Data was recorded and analyzed. Averages and standard deviations were calculated for each sample as well as a T-test was conducted to determine statistical significance.

Results

Despite a small sample size, T-test results on both metatarsal and metacarpal osteometric data show that the original hypothesis for this project was indeed correct; physiological sex could be discriminated based on this data. Statistical significance was determined by a T-test between male and female metrics, $p<0.05$. In both metatarsal and metacarpal data, female and male ranges were quite distinguishable. In conjunction with this, it appears data from the length was best at displaying this range difference. Tables 1 and 2 illustrate usable data gathered.

Measurement	Sex	N	Mean, sd (mm)	Range (mm)	T-test, M to F, p=
RMC1-Length	M	4	47.685±2.36	45.32-50.04	0.021
	F	6	43.18±2.12	41.05-45.30	
RMC1-Prox. Width	M	4	15.56±0.89	14.67-16.46	0.031
	F	6	13.90±0.19	13.70-14.10	
RMC1-Distal Width	M	4	16.01±0.51	15.49-16.53	0.012
	F	6	14.69±0.78	13.91-15.48	
RMC2-Length	M	3	71.91±0.79	71.17-72.70	0.001
	F	5	61.88±3.07	58.80-64.95	
RMC2-Prox. Width	M	3	19.06±0.61	18.44-19.67	0.002
	F	5	15.85±0.53	15.32-16.38	
LMC2-Length	M	2	72.35±0.62	71.72-72.97	0.0008
	F	4	62.89±1.86	61.02-64.75	
LMC2-Distal Width	M	2	15.52±0.05	15.46-15.57	0.028
	F	4	13.48±1.02	12.45-14.51	
RMC3-Length	M	3	70.10±1.73	68.37-71.83	0.005
	F	6	60.60±5.12	55.47-65.73	
RMC3-Distal Width	M	3	14.68±0.75	13.92-15.44	0.023
	F	6	12.62±0.52	12.09-13.15	
RMC4-Length	M	3	60.92±1.51	59.41-62.44	0.002
	F	6	54.20±2.88	51.32-57.08	
RMC4-Distal Width	M	3	12.95±0.45	12.50-13.41	0.001
	F	6	10.88±0.55	10.33-11.43	

Measurement	Sex	N	Mean, sd (mm)	Range (mm)	T-test, M to F, p=
RMC5-Length	M	2	55.24±1.31	53.92-56.55	0.016
	F	4	48.85±1.88	46.97-50.73	
RMC5-Distal Width	M	3	14.36±0.93	13.42-15.30	0.049
	F	5	12.19±1.55	10.64-13.75	

Table 1: Usable data from metacarpal (MC).

Measurement	Sex	N	Mean, sd (mm)	Range (mm)	T-test, M to F, p=
RMT1-Length	M	3	64.61±0.86	63.75-65.47	0.025
	F	3	56.24±0.86	53.49-58.98	
RMT1-Prox. Width	M	2	21.21±0.67	20.54-21.89	0.027
	F	3	18.24±0.65	17.58-18.89	
RMT1-Distal Width	M	3	23.70±0.42	23.27-24.12	0.008
	F	3	21.03±0.06	20.34-21.72	
RMT1-Width at midpoint	M	3	15.45±0.66	14.78-16.11	0.019
	F	3	12.33±1.08	11.24-13.41	
LMT1-Distal Width	M	2	23.72±1.11	22.60-24.83	0.043
	F	2	18.79±0.91	17.87-19.70	
RMT2-Length	M	3	80.17±0.28	79.89-80.45	0.032
	F	2	68.86±1.56	67.29-70.42	
RMT4-Distal Width	M	3	15.52±0.05	13.11-13.42	0.026
	F	2	11.44±0.33	11.11-11.77	
RMT3-Length	M	2	77.85±2.91	74.93-80.76	0.046
	F	2	64.99±1.95	63.03-66.95	
RMT3-Distal Width	M	2	23.81±0.71	23.10-24.52	0.037
	F	2	15.59±0.06	15.53-15.65	

Table 2: Usable data from metatarsal osteometrics (MT).

Discussion and Conclusions

Results from the data analysis clearly show that osteometric data of MC and MT data is valid in discriminating physiological sex. As previously mentioned, the best measurement observed in helping to distinguish sex appeared to be the overall length. Case and Ross also made a similar observation upon their research. They found that the length of the hands and feet bones are less affected than other aspects of the bone over lifetime activity, therefore, length is a more reliable osteometric data point (Case & Ross, 2007). In many instances, the data show a clear difference in the measurements between male and females. For example, among females, the range of the right third metacarpal was 55.47-65.73mm. For males, this range was 68.37-71.83mm. This can also be observed in measurements from the metatarsals. For example, the length for the right first metatarsals show the male range extended from 63.75 to 65.47mm and the female range was 53.49 to 58.98mm. Both of these instances help illustrate how the length of both metacarpals and metatarsals can show a clear discrimination between male and females.

While length was a primary indicator of skeletal sex estimation, robusticity also appeared to show promising results in regards to discriminating between male and female remains. For instance, the averages for proximal and distal width of the right first metacarpal varied between the sexes. The average proximal width for males was 15.56mm versus the female average of 13.90mm. This pattern is also present in the distal width measurement of first right metatarsal. Female ranges extended from 20.32mm to 21.72mm, versus the male range of 23.27mm to 24.14mm.

Although sample sizes were small, the results of this study clearly demonstrate how sexual dimorphism manifests in the human skeleton, and yield positive results with population specific data. The data gathered from these samples support that metatarsal and metacarpal osteometric measurements in adults can assist in estimating the biological sex of skeletal remains. Not only do the results support this hypothesis, but previous literature has tested this methodology as well and help confirm its validity. For future work, collecting more data from a larger sample size would be of interest. Along with this, applying this data to help produce a continuum of metatarsal and metacarpal osteometrics would further assist in the estimation of sex.

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