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The Rhomboid Fossa of the Clavicle as a Sex and Age Estimator

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ABSTRACT: The costoclavicular (rhomboid) ligament connects the first rib to the clavicle, stabilizing the pectoral girdle. It produces skeletal traits that may be tubercles, roughened impressions, shallow groove-like fossae, deep fossae, or leave no trace. A pit or depression at this site is often called a "rhomboid fossa." While these markings may appear pathological, they are normal variants of the clavicle. Using a large contemporary sample (N = 344: 113 females, 231 males), we evaluated the presence of a rhomboid fossa as a sex and age indicator for unidentified skeletal remains.

Logistic regression found significant relationships between the presence of a rhomboid fossa and sex and between presence of a rhomboid fossa and age. Fossae were more common in males (36% left, 31% right) than in females (3% left, 8% right). Posterior probabilities suggest that a fossa on the right clavicle is indicative of a male with 81.7% probability; a fossa on the left is indicative of a male with 92.2% probability. Younger individuals more commonly exhibited rhomboid fossae than older individuals, and the largest fossae were most common in males 20–30 years of age. However, the age effect was not conclusive and must be corroborated by other methods. A test of the sex estimation method on an independent sample (26 males, 23 females) found nine males and only one female with fossae present on the left clavicle.

When the costoclavicular attachment exhibits an impression, a tubercle, or leaves no trace, this method cannot be used for sex estimation. When a clavicle exhibits a rhomboid fossa, it is likely from a male. The greater difference in fossa expression between the sexes on the left clavicle makes use of the left bone preferable. This technique can corroborate other sex estimates or provide an estimate for unknown individuals in the absence of other skeletal indicators.

KEYWORDS: forensic science, sex estimation, age estimation, rhomboid fossa, costoclavicular ligament, rhomboid ligament, clavicle, costal tuberosity, costal impression

The costoclavicular ligament, also known as the rhomboid ligament because of its shape, connects the superior portion of the first rib to the inferior sternal end of the clavicle (Fig. 1). This ligament stabilizes the pectoral girdle and can produce skeletal landmarks on the inferior border of the clavicle including tubercles, impressions, all sizes and depths of grooves or fossae at the site of attachment, or may leave no mark. While White (1) describes landmarks at this site as costal impressions or costal tuberosities, depressed or pitted landmarks at this attachment site have been called "rhomboid fossae" in the anatomical, radiological, and anthropological literature throughout the 20th century (2–10). Inexperienced observers may speculate that these traits are pathological, but they are "normal variants" of the clavicle (11). Previous studies suggest that rhomboid fossae are more common in males than females in populations of European ancestry and are most often clinically insignificant (2–10). In this study, we evaluated the relationship between rhomboid fossae, age, and sex. Specifically, we were interested in using the presence of this trait for age and/or sex estimation of unidentified individuals. Based upon the literature, the anatomy of the costoclavicular syndesmosis, and our personal experience with autopsy cases, we hypothesized that fossae would be more common: 1) in males, and 2) in younger individuals.

Several studies of the rhomboid fossa state that its presence in males is related to muscularity and mechanical usage. In an early study, Pendergrass and Hodes (3) state that fossae are present only in muscular males. However, other studies suggest that muscular mass is not necessarily implicated in rhomboid fossa etiology. For example, Shauffer and Collins (9) describe three male patients with rhomboid fossae: two were of "average musculature" and the third was 11 years of age. While the link between the trait and mechanical stress has not been confirmed, many investigators operate under the assumption that these fossae are correlated with mechanical usage. For example, Stirland (12,13) describes rhomboid fossae as "lesions and bony buildup" at the costoclavicular syndesmosis and cites them as evidence of occupational stress. However, she cautions that effects due to sex, age, and asymmetry may confound use of such indicators to estimate occupational activity patterns from skeletal remains.

Studies of the frequencies of rhomboid fossae have used both radiological and osteological observations. While Parsons (2) reported that 10% of the 286 excised clavicles studied exhibited rhomboid fossae, Shauffer and Collins (9) state that fossae were present in only 59 of 10,000 chest photoflourograms examined (0.59%). This discrepancy in results is likely due to methodology. The more detailed observation possible in studies of excised clavicles gives rise to questions concerning the definition of landmarks at this site.

Traits at this site can take the form of a raised tubercle, a roughened impression, a shallow groove, a deep pit, or no trace at all. Some clavicles exhibit ambiguous traits that reduce the probability of replicable classification. Most studies of excised bones have classified all variants in the category of "rhomboid fossa." Such skeletal observations are not comparable to radiographic studies because the latter can distinguish only deep pits at the site.

Jit and Kaur's (10) study of excised clavicles found that 59% of males and 54% of females in their North Indian sample exhibited some form of skeletal landmark at this site. However, many factors associated with sex and gender (hormone levels, activity patterns, etc.) likely cause different morphological changes. By classifying all skeletal traits exhibited at this site as "rhomboid fossae," their

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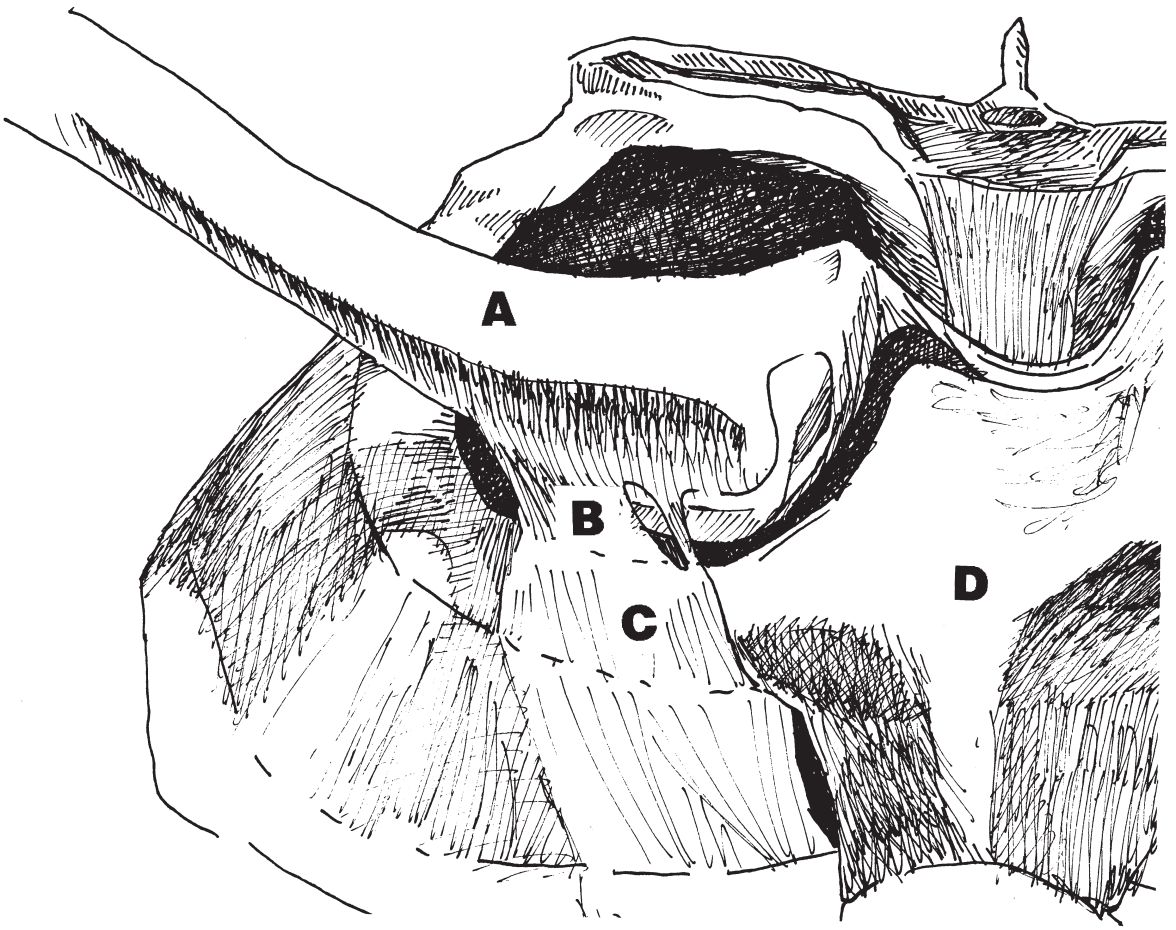

FIG. 1—*The costoclavicular ligament and sites of attachment:* A) *Right clavicle,* B) *Costoclavicular ligament,* C) *First rib, and* D) *Manubrium. Drawing by John Garwood.*

ability to detect dimorphism due to these different factors was reduced. They found no significant differences in "fossa" expression between the sexes using this broad definition.

Mann and Murphy (8) acknowledged the "catch-all" nature of earlier definitions and limited their definition of rhomboid fossae to only those traits that were "depressed" and "crater-like." Their examination of 350 excised clavicles found that depressions in the region of the ligament attachment were present in both sexes, but only males exhibited depressions longer than 15 mm. They did not describe the distribution of fossae, the demographics of their sample, or the actual frequency of the various landmarks they describe.

Materials and Methods

A sample of 344 clavicle pairs was compiled from the William F. McCormick collection housed at the University of Tennessee in Knoxville. The presence and type of skeletal trait at the attachment site of the costoclavicular ligament were recorded for 231 males and 113 females. Both juvenile and adult individuals were sampled to assess the relationship between age and the type of skeletal trait. The age range for the sample spanned from 10 to 92 years (overall $\bar{\chi} = 44.4 \pm 16.7$ years).

Due to the regional demographics of the collection, the sample is predominately white, with only 38 blacks and 5 "other" non-whites included (Table 1). Individuals with antemortem fractures or pathological features were not included in the original sample.

TABLE 1—*Sample demographics*.

Sample	Male	Female
White	195	106
Black	33	5
Other	3	2
Total = 344	231	113

Our analysis of former scoring methods required us to devise a repeatable, simple definition of each trait. To maximize the power of discrimination the various skeletal traits at the ligament attachment site were originally scored on a four point ordinal scale (see Fig. 2 captions). Raised tubercles were assigned the score of "zero," slight impressions with no depression were scored "one," small depressed fossae were scored "two," and large depressed fossae were scored "three." Due to a lack of foresight, no scores were assigned if the ligament left no mark on the bone and they were treated as missing data.

Interobserver variation in measurements caused by the irregularity of the fossae, the qualitative definitions of "small" and "large" fossae, and the continuous range of variation in the non-fossae landmarks led us to collapse the four category scale. While different factors may cause tubercles and impressions, these traits were

often ambiguous. Additionally, only a few individuals (formerly classified as missing data) lacked a discernable landmark at the site, making the category inappropriate for statistical analysis. These three categories were combined into one category called "fossa absent" (Fig. 2A, 2B). De-emphasizing the variation within the non-depressed traits (and emphasizing their similarity) greatly increased our power of discrimination. The increased sample size for this category also provided a more robust statistical analysis.

Previous experience suggested that depressed rhomboid fossae were more common in males, so we focused on this more easily defined trait as a possible sex and age estimator. Following Mann and Murphy (8), we defined a rhomboid fossa as a pitted or depressed marking. However, our classification includes all landmarks that indicate the ligament excavated the bone at this site. This includes traits with areas of pitting and "perforated" bone, as well as shallow linear grooves (Fig. 2C–2G). All cases with such traits were reclassified as "fossa present." This resulted in a binary scale that made the method more reproducible and greatly decreased interobserver error.

Age and sex biases present in forensic samples can lead to results that are artifacts of sampling rather than true effects. We deliberately selected as many female clavicle pairs as possible (without regard to age) to avoid underrepresentation of females. In addition, we constructed an approximate 2:1 ratio of males to females. This resulted in a sample that was large enough to insure statistical reliability and scaled to insure adequate representation of both sexes as available from the McCormick collection.

Statistical Analysis and Results

To assess the equality of our age distributions, we subjected our largest homogenous subsamples (white males and white females) to the Kolmogorov-Smirnov (K-S) test for ordinal categorical data (14). This test measures the difference between two samples by comparing their cumulative distributions across specified categories. Unlike the usual chi-square test of association, it retains the information coded by the ordinal arrangement of the data.

The greatest difference between the white male and female age distributions was present between the ages of 49–59 years, but was not significant at the 5% level (Fig. 3). This allowed us to drop age as a covariate in further analysis and suggested that any significant differences would be due to true effects rather than sampling bias.

A K-S test was also run to test for differences between the white and black subsamples, with males and females combined. The greatest difference was present between the ages of 19–29 years, but was not significant at the 5% level, again suggesting that age-related effects would not be artifacts of sampling (Fig. 4). However, because the black sub-sample consisted of more males than females, the interpretation of any race effect must consider a possible race-sex interaction. Only a larger black sample would elucidate the true relationship.

Impressions were the most common skeletal trait found at the ligament attachment site for both males and females, with roughly half of each sex exhibiting this trait. The data coded by the original

FIG. 2—*Scoring criteria and definitions. Fossa Absent:* 2A: *Tubercle—raised ridge or mound of bone at attachment area for costoclavicular ligament. (Costal tuberosity).* 2B: *Impression—no depression present, but roughened outline of costoclavicular ligament present on bone. Not shown: no discernible mark on bone. Fossa Present:* 2C: *Small fossa—small depression with depth enough to cast a shadow: may or may not show exposed trabecular bone.* 2D: *Large Fossa—large depression with depth enough to cast a shadow: may or may not show exposed trabecular bone.* 2E, 2F: *Groove-like fossa—shallow or deep linear groove, may be surrounded by raised areas of bony growth—no exposed trabecular bone, and* 2G: *Series of small shadowed pits—no exposed trabecular bone.*

FIG. 2—*(Continued).*

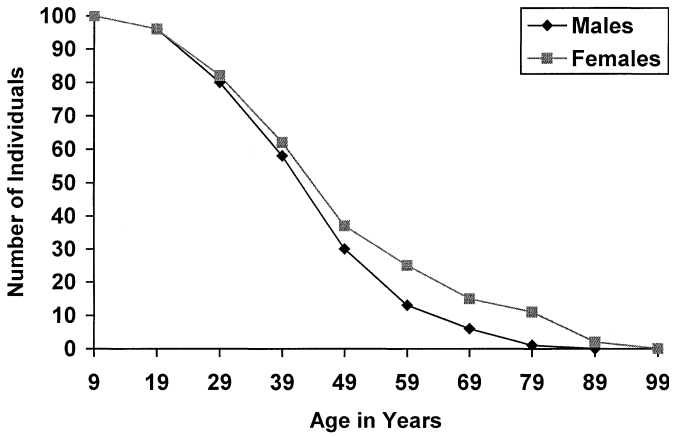

FIG. 3—*Results of K-S test: white males versus white females.* D = *0.126512, Critical value (α = .05) = 0.16. Percentage survivorship plotted against age illustrates the differences between the cumulative distributions for white males and females. The greatest difference occurs between the ages of 49 and 59 years, but is not significant at the 5% level.*

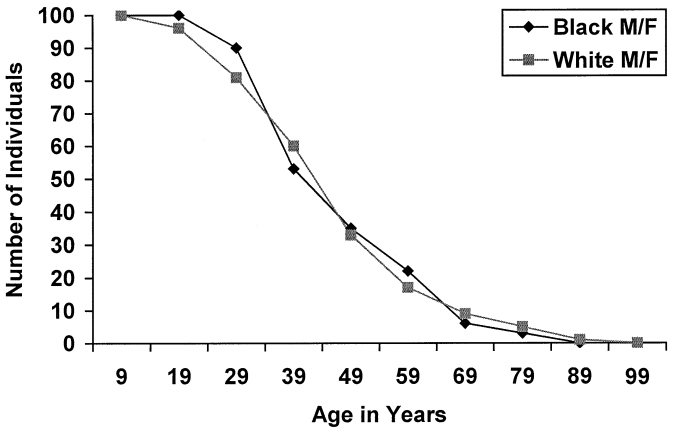

FIG. 4—*Results of K-S test: white males/females versus black males/females.* D = *0.08743, Critical value (α = .05) = 0.23. Again, the percentage survivorship for each sex plotted against age shows the differences between the cumulative distributions for the black and white samples. The greatest difference is found between the ages of 19 and 29 years, but is not significant at the 5% level. However, these results are based upon a small black sample and should be viewed with caution.*

four class ordinal scale illustrated an age distribution of the largest, deepest fossae most common in young males (Fig. 5). There is a notable trend for the largest fossae to be exhibited in younger males, with the greatest number of large fossae found in males between the ages of 20 and 30 years. This suggests that the largest fossae may be considered suggestive of "young" males, although this must be corroborated by other methods because these large fossae are not limited to this age group. Only three females exhibited this largest class of fossae. The youngest (16 years) and oldest (62 years) females exhibited bilateral fossae, and the third "middle-aged" female (33 years) exhibited the trait on the left clavicle. Due to the small number and discontinuous distribution of females with fossae, no age-related trend is suggested.

Once the categories were collapsed to the binary scoring system, the raw data again showed fossae were more common in males and on the right clavicle in both sexes (Table 2). The collapse to the binary scoring system did not alter the age distribution for either clavicle: fossae were most common in males between the ages of 20 and 30 years. This result remains suggestive of age rather than definitive, since individuals outside this age range also exhibited fossae.

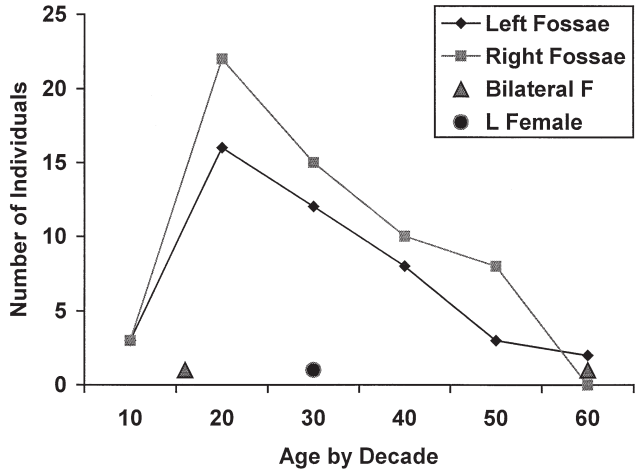

FIG. 5—*Age distribution of largest rhomboid fossae.*

TABLE 2—*Distribution of rhomboid fossae.*

	Left	Right
Males	72/231 = 31%	83/231 = 36%
Females	3/113 = 3%	9/113 = 8%

TABLE 3—*Results of logistic regression.*

	Likelihood Ratio X^2		*p*	
	Left	Right	Left	Right
Age	14.66	21.89	0.0001	0.0001
Sex	20.88	21.66	0.0001	0.0001
Race	0.40	3.11	0.5273	0.0777*

* Near-significance should be interpreted with caution due to small sample sizes and grouping of observations from non-white individuals.

Logistic regression for ordinal categorical data was performed to test the significance of multiple variables simultaneously (15). This method fits a linear regression to the data using a logit link model that accommodates binary and ordinal response data. Regression parameters are estimated using a maximum likelihood estimate method, and predictive equations can be generated (16). Our goal to produce a sexing method based upon discrete traits could have been attained simply by using posterior probabilities, but we anticipated an effect due to age. Logistic regression allows assessment of possible effects due to covariates that are not possible using simple probabilities.

The presence of a rhomboid fossa at the costoclavicular ligament attachment site was modeled as dependent upon age, race and sex. Because logistic regression allows for continuous variables, age was not coded as a categorical variable. The results confirm that age and sex have a significant relationship presence of a rhomboid fossa for both right and left clavicles. Race was not significant for either the right or the left clavicle when the other variables were in the model (Table 3).

The posterior probabilities for sex based upon the type of skeletal trait reflect what was seen in the raw data: males were more likely to exhibit a fossa at the site of attachment (Table 4). For this sample, if a right clavicle exhibits a fossa at the site of attachment, the posterior probability of the individual being male is 81.7%; the probability that the individual is female is 18.3%. If a rhomboid fossa is present on a left clavicle, the posterior probability of the individual being male is 92.2%, while the probability that the individual is female is only 7.8%. This level of discrimination is not possible when the rhomboid syndesmosis takes a form other than a fossa. For the left or right clavicle, the posterior probabilities for males and females, if no fossa is present, are roughly 40% and 60%, respectively. This reflects our methodology that grouped all non-fossa skeletal traits into a single category.

When these probabilities are used to calculate odds ratios, the left clavicle's value for sex estimation is more apparent. The odds that a male exhibits a fossa on the right clavicle are roughly six times greater than the odds that a female clavicle exhibits a fossa. For the left, the odds that a male exhibits a fossa are almost 17 times greater than the odds that a female exhibits a fossa.

Due to the continuous scale for age, posterior probabilities cannot be easily calculated or applied for age estimation. However, the calculated odds ratios of 1.05 (left clavicles) and 1.04 (right clavicles) show that with each year of age increase, the odds of exhibiting a fossa at the attachment site decrease. Therefore, younger individuals are more likely to have fossae. While this effect is also highly significant, the application of predictive formulae for age estimation would be neither efficient nor user-friendly. Coding age as a continuous variable increased our ability to detect this age-related trend. However, it prevented estimation of age from the raw data as was possible from the discrete distribution of the sex variable.

The logistic regression calculates a score that measures how well the model fits the data with the current variables. The -2log L scores of 48.65 and 62.97 (left and right clavicles, respectively) are each highly significant (both $p = 0.0001$), which indicates that the existing variables do not fully explain the variation. This suggests at least one important factor (and possibly *several* important factors) affecting the presence or absence of a rhomboid fossa has not been included. Given the popular conception, the most obvious factor to consider is mechanical usage. However, the association between rhomboid fossae and increased muscle mass has been questioned due to its presence in pre-pubescent and physically "average" individuals (9). Additionally, the highly symmetric expression of the trait within each sex in our sample further challenges this relationship. Since upwards of 80–85% of Americans are right-hand dominant, one would expect significantly greater expression of fossae on the right clavicle if the trait was strongly correlated with habitual activity patterns. However, the slightly more common expression of the trait on the right clavicle and in male individuals does suggest some relationship with mechanical loading or activity. The etiology may be more complex than simple biomechanics, involving biochemical and genetic factors in a complex relationship with patterns of mechanical force. This relationship remains unresolved.

TABLE 4—*Posterior probabilities.*

Element	Event	Probability
Left clavicle	*P* (male/fossa)	92.2%
Left clavicle	*P* (female/fossa)	7.8%
Left clavicle	*P* (male/no fossa)	41.4%
Left clavicle	*P* (female/no fossa)	58.6%
Right clavicle	*P* (male/fossa)	81.7%
Right clavicle	*P* (female/fossa)	18.3%
Right clavicle	*P* (male/no fossa)	41.0%
Right clavicle	*P* (female/no fossa)	59.0%

Blind Testing of the Sexing Method

Two of the authors (LEF and NLR) tested the method on a sample of 49 individuals (26 males, 23 females) from the William M. Bass Skeletal Collection housed at the University of Tennessee. The collection is composed of recently deceased individuals from the East Tennessee region. Therefore, the demographics and regional characteristics are comparable to the McCormick sample. All descriptive information was masked during observation and each investigator scored the sample independently. Differences in processing between the original McCormick collection and the test sample from the Bass collection led to a few discrepancies in scoring between the two observers based upon our written definition. These problems prompted us to clarify our original description. An objective third observer was then able to successfully estimate sex for these difficult cases based upon the revised description.

As with the McCormick collection, rhomboid fossae in the Bass test sample were more common in males than in females, and more common on the right clavicle. Of the 10 fossae observed on left clavicles from the test sample, nine were from males, one from a female. (This fossa was of the largest class.) These results closely match those predicted by the calculated posterior probabilities and confirm that the rhomboid fossa trait is found more often on the left clavicle of male individuals.

Conclusions

Our results indicate that age is a significant factor in the presence of rhomboid fossae on the inferior border of the clavicle. However, exact age assignment based upon the presence of these fossae is problematic. The presence of a rhomboid fossa is not an adequate criterion for accurate age estimation because the trait is found in individuals as young as 12 years and as old as 90 years. However, presence of an extremely large, deep fossa (on either side) is suggestive of a "young" male (<30 years), but this supposition must be corroborated by other methods.

Presence of a rhomboid fossa can be used as an indicator of sex because males exhibit fossae more frequently than females. It must be reiterated that our definition of rhomboid fossae includes landmarks characterized by shadowed pits, shallow grooves, a series of small perforations, or other evidence that the ligament has excavated the bone and created actual depressions (see Fig. 2C–2G). Because tubercles are difficult to define and impressions are commonly found in both males and in females, these traits are not used for estimation in this method. Similarly, the absence of a skeletal trait is not appropriate for estimation due to small sample size.

While 93% of the fossae in the original sample were present on male clavicles, the occurrence of this trait will vary from sample to sample. Sex ratios (and perhaps population activity patterns) are expected to influence the frequency of rhomboid fossae. Therefore, an estimate of sex based upon this method for individuals from other populations cannot be accompanied by a posterior probability of the estimate. However, given the preponderance of fossa on male clavicles it can be said that if a fossa is present, the specimen is likely from a male. This is especially true for the left clavicle,

given the greater discrepancy of fossa expression between males and females on the left bone. Our test of the sexing method confirms it can be used to corroborate other estimates of sex or provide a sex estimate for unknown individuals in the absence of other skeletal indicators.

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