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The Distal Humerus—A Blind Test of Rogers' Sexing Technique Using a Documented Skeletal Collection

ABSTRACT: Continuous monitoring of existing methods of skeletal diagnosis allows improving the reliability of personal identification in forensic and archaeological contexts. This study reports on a blind test re-evaluating the sexing technique proposed by Rogers (8) involving the distal humerus. A total of 351 humeri (184 male, 167 female specimens) from the documented skeletal assemblage of St. Bride's, London, was analyzed for the following traits: trochlear constriction, trochlear symmetry, olecranon fossa shape, and angle of the medial epicondyle. Individual traits showed substantial sex-discriminatory capacity, with "olecranon fossa shape" being most consistently accurate (84.6%) in predicting sex. The combination of all four traits provided an overall accuracy of 79.1%, including those individuals assessed as "probable" male and female. This renders the technique useful for forensic applications. The distal humerus can be recommended for sex assessment in addition to more established markers, especially since this part of the skeleton is frequently well preserved.

KEYWORDS: forensic science, forensic anthropology, sex assessment, distal humerus, St. Bride's

Correct assessments of the sex of unknown human skeletal remains, whether modern or archaeological, are necessary for palaeodemographic studies and identification of individuals in forensic cases. Sex determination techniques must fulfill two primary criteria in order to be deemed reliable for application: they must provide the ability to accurately predict the biological sex of an individual, and they must offer a low inter-observer error to prove the technique can be accurately used by other researchers. As a result, techniques that facilitate the assessment of basic demographic parameters ought to be constantly re-evaluated to allow these two criteria to be assessed using skeletal populations of known sex and age-at-death. Such populations exhibit variation in morphological appearances, which can be compared and used to evaluate the accuracy of ageing and sexing techniques.

Adult skeletal sex determination is inferred metrically or morphologically by the presence of standardized, regularly occurring, and recordable differences in skeletal morphology between male and female individuals (1–3). It is well accepted that the *os coxae* and the skull provide the highest concentration of sexually dimorphic features in one skeletal region (3–5); however these elements are commonly damaged in the burial environment (6,7). Other events such as fragmentation, disarticulation, and co-mingling of remains readily occur, ultimately inducing uncertainty into the determination of sex. Due to these factors, a need has been identified for reliable sex determination methods to be developed for skeletal elements other than the pelvis and cranium, thus increasing the availability of skeletal elements potentially useful for sex assessment (8).

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The humerus has so far produced variable results when investigated for sexually dimorphic characteristics (9,10 [both cited in 11], 12, 4). Findings have been primarily metric (discriminant analysis), relating to the overall robusticity of the male anatomy compared to that of the female. Observations of morphological characteristics of the humerus related to sex differences have been quite limited. Initially, perforations of the olecranon fossa were indicated to be a female trait (4), while other suggestions were based on the principle that the female skeleton is generally more gracile than the male, with smaller limb bones and lighter muscle markings (4,5,13).

Rogers (1999) developed a visual method of adult sex determination of the posterior distal humerus, working from the hypothesis that the morphology of the distal humerus reflects the formation of the carrying angle of the elbow. This assumption was, in turn, based on the universal sexual dimorphic characteristic of the human body by which males and females express two different overall body shapes. Males are generally more robust than females, with narrower hips and wider shoulders. Female individuals, on the other hand, have narrower shoulders and broader hips, the latter being related to the physiological requirements of childbirth. In each case, the elbow must take on a morphology that allows the extended upper limb to move smoothly past the hips during swinging movements, like those demonstrated during walking (4). Since women have narrower shoulders and wider hips, a greater carrying angle is required at the elbow to allow the arms to swing successfully past the hips. This angle has been reported to measure approximately 10°–15° in males, and 20°–25° in females (8).

Rogers' Study

Rogers (8) initially developed her technique on the Grant Collection (housed at the University of Toronto, see (8) for further details). Three potential sex-specific features (the medial aspect of the trochlea, olecranon fossa shape and depth, and angle of the medial epicondyle) were blind-tested on a sample of 39 individuals.

TABLE 1—*Sexual dimorphism in the distal humerus as proposed by Rogers (8).*

Morphological Feature	Appearance
Trochlear Constriction	♂ = Less constricted ♀ = Spool shaped
Trochlear Symmetry	♂= Asymmetrical ♀ = Symmetrical
Olecranon Fossa Shape	♂ = Shallow triangle ♀ = Deep Oval
Angle of Medial Epicondyle	♂ = Flat or slightly raised ♀ = Distinctly raised

Although the study demonstrated a high inter-observer error (21–32%), the results looked promising, and required further redefinition.

Evaluation of a small sample ($n = 10$) of the documented skeletal collection held at the Department of Anthropology at the University of New Mexico provided two more possible sex-specific traits: the observable constriction of the trochlea and its symmetry. The five proposed traits were blind tested against 40 individuals at the University of New Mexico and 93 individuals from the William M. Bass Donated Skeletal Collection.

Rogers statistically determined that four of the five traits demonstrated sex specific variation (Table 1, Fig. 1). The medial aspect of the trochlea did not exhibit sex specific variation and was subsequently omitted from the developed technique. The combination of the remaining four features of the posterior distal humerus was reported to determine sex with 92% accuracy (8).

The purpose of this study is to re-evaluate Rogers' technique in order to: (a) test its applicability to individuals from an archaeological period, and (b) to test its ability to accurately assess the biological sex of individuals, bearing in mind that methods of sex assessment are considered useful when they produce accuracies of at least 80% (8).

Materials and Methods

The study is based on the adult individuals from the documented skeletal collection held at St. Bride's Church, Fleet Street, London, spanning from the late 17th to the early 19th centuries and comprising individuals of British Caucasian ancestry (Scheuer L, Black S., personal communication. 1995. The St. Bride's Documented Skeletal Collection. Unpublished archive held at the Biological Anthropology Research Centre, Department of Archaeological Sciences, University of Bradford). Rogers' (8) four proposed sexually dimorphic features were blind tested in two independent rounds of observations on a total of 351 left and right humeri, comprising 184 male specimens and 167 female specimens. The utmost of care was taken to independently observe each of the published morphological features (Table 1, Figs. 1*a*, *b*, *c*) in the complete absence of other skeletal elements which could have led to an indication of the individual's sex, i.e., the examination was performed on humeri separated from the remainder of the respective skeletons.

Intra-observer error was assessed using the Chi-square test. Comparison of observations recorded for each trait between the first and second examinations revealed no significant differences ($p < 0.05$). The Chi-square test was also applied to test for differences in trait expression between left and right specimens, i.e., for correspondence in the assignment of either sex.

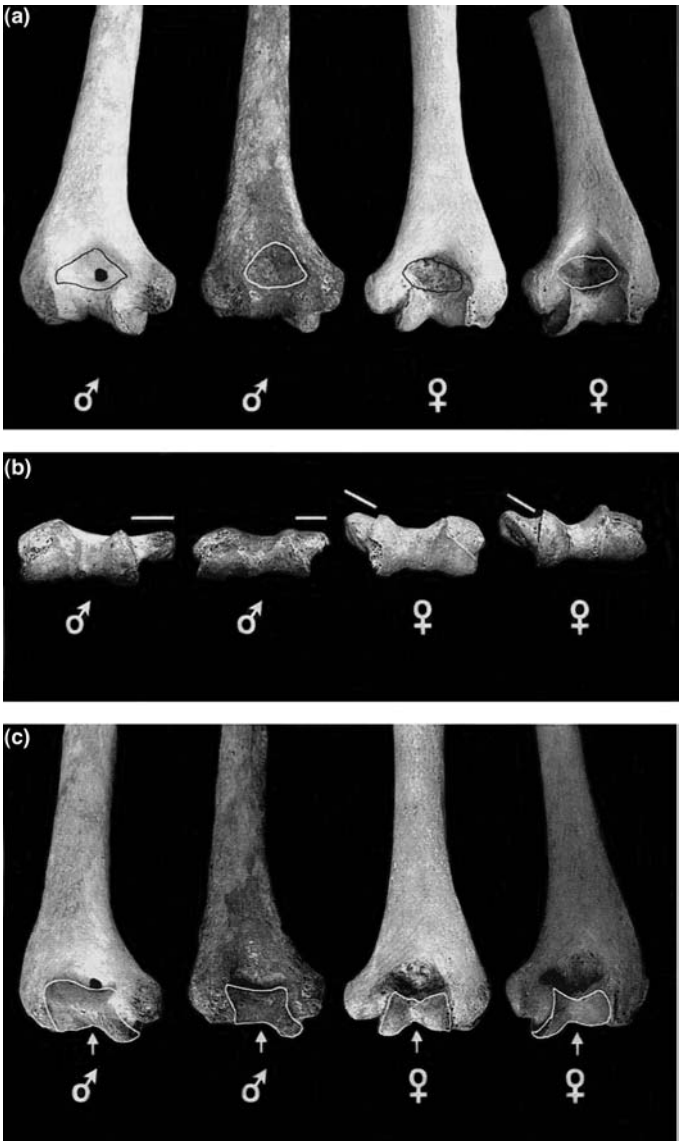

FIG. 1—*Sexually dimorphic features proposed by Rogers (8:58–59). FIG. 1a: Olecranon fossa shape; FIG. 1b: Angle of the medial epicondyle; FIG. 1c: The sexually dimorphic appearances of trochlear symmetry and trochlear constriction. All images modified from Rogers (8).*

Results

Lateral Expression of Traits

With the exception of two traits, all morphological characteristics were found to display bilateral expression without notable differences (Table 2). The two traits that did not follow this pattern were "trochlear constriction" and "angle of medial epicondyle" and were both recorded in male individuals.

Accuracy

The assessment of accuracy included two different approaches: sex assessment of individuals using all traits recommended by Rogers (8) for sex determination and a test of the reliability of single traits. Individuals were categorized into one of three appearances: male, female or indeterminate, as inferred by Rogers (8), based on 351 observations (male = 184, female = 167). The accuracy with which each individual trait corresponded to the documented

TABLE 2—*Chi-squared results indicating trait expression (unilateral or bilateral) observed for male and female individuals.*

Feature	*N*	χ^2	*p*
Trochlear Constriction			
Males	184	11.8	<0.05
Females	167	2.54	>0.05
Trochlear Symmetry			
Males	184	4.47	>0.05
Females	167	1.93	>0.05
Olecranon Fossa Shape			
Males	184	2.16	>0.05
Females	167	3.09	>0.05
Angle of the Medial Epicondyle			
Males	184	8.12	<0.05
Females	167	5.46	>0.05
All Four Traits Together			
Males	184	2.21	>0.05
Females	167	1.36	>0.05

TABLE 3—*Number and relative amount of males and females exhibiting each trait form.*

	Males ($n = 184$)		Females ($n = 167$)	
Trait Form	*N*	%	*N*	%
Trochlear Constriction				
Less Constricted	96	52.2	18	10.8
More Constricted	64	34.8	147	88.0
Indeterminate	24	13.0	2	1.2
Trochlear Symmetry				
Asymmetrical	145	78.8	19	11.4
Symmetrical	27	14.7	132	79.0
Indeterminate	12	6.5	16	9.6
Olecranon Fossa Shape				
Triangular	159	86.4	22	13.2
Oval Shaped	16	8.7	128	76.6
Indeterminate	9	4.9	17	10.2
Medial Epicondyle				
Flat/Slightly Raised	133	72.3	23	13.8
Distinctly Raised	45	24.5	130	77.8
Indeterminate	6	3.3	14	8.4

TABLE 4—*Accuracy of sex determination using features of the distal humerus.*

Feature	Male ($n = 184$)	Female ($n = 167$)	Total ($n = 351$)
Trochlear Constriction	52.2%	88.0%	69.2%
Trochlear Symmetry	78.8%	79.0%	78.9%
Olecranon Fossa Shape	86.4%	76.6%	81.8%
Angle of Medial Epicondyle	72.3%	77.8%	74.9%
Combined	72.4%	80.4%	76.2%

sex ranged between 52.2% and 88.0%. Between 1.2 and 13.0 % of traits showed no correspondence with either male or female features and were recorded as "indeterminate" (Table 3). All traits scored approximately equal for males and females, with the exception of trochlear constriction. Total accuracies ranged from 69.2% (Trochlear constriction) to 81.8% (Olecranon fossa shape), with an overall correspondence of trait expression with sex of 76.2%.

Due to considerable morphological variation in trait expression, not all individuals yielded consistent assignments of sex from all traits examined. Depending on the nature of this outcome, two types of indeterminate individuals were identified. The first type has already been discussed by Rogers (8) and was defined as individuals whose trait expressions resulted in an equal number of male and female traits observed. For such cases Rogers (8:59) suggested the allocation of a higher diagnostic weight to the shape of the olecranon fossa, i.e., making this trait the decisive diagnostic criterion. When this recommendation was followed and applied to a total of 32 individuals so affected, 21 individuals were found to correctly indicate the documented sex. Two individuals remained ambiguous, as the shape of the olecranon fossa was indeterminate, with no inclination towards one sex or the other. This procedure proved to be much more accurate for males, with 18 out of 21 individuals matching the documented sex, while this was only possible for three out of eleven females. By following this suggestion, a combined accuracy for these individuals, males and females, was found to be 65.6% (Table 5).

TABLE 5—*Type I indeterminate individuals. Correct allocation of sex after allowing for a higher diagnostic weight of "Olecranon fossa shape" (see text).*

	Males	Females	Total
Initially indeterminate	21	11	32
Weighted sex	18	3	21

The second type of indeterminate individual was defined as those in this study for which a definite sex could not be assigned for one or more (usually two) traits, and which would result in one or more of the four categories being assigned a score of "probable M" and "probable F" upon initial assessment; for example: Trochlear constriction: probable female, Symmetry: female, Olecranon fossa shape: female, Medial epicondyle: male. These individuals were assigned an overall score of indeterminate sex ("I"). Due to the considerable occurrence of trait expressions found to demonstrate morphologies other than described by Rogers, these tentatively assigned sexes were assessed further and seriated to investigate morphological variation, i.e., it was attempted to place the indeterminate specimens within a morphological series ranging from specimens with unambiguous male to intermediary morphologies and unambiguous female trait expressions, and in order to ascertain the closest resemblance of the trait expression graded "probable."

Out of 28 male individuals deemed to be indeterminate due to more tentative sex determinations, 21 could be assigned to the correct sex, while all but one out of 38 females corresponded to the correct sex (Table 6). The combined accuracy of this re-assessment was 87.9%. Given this result, these estimates have demonstrated to be as useful as those with less ambiguous initial determinations, and are recommended for future application.

When all traits were included and their trait expression tested for correspondence with the sex proposed by Rogers, the overall accuracy was found to be 79.1%. With all traits females can be more consistently sexed; and their correspondence figures are beyond 80% accuracy throughout. In male individuals trochlear constriction appears to be an unreliable trait, a finding probably confounded by different trait expressions on left and right humeri.

TABLE 6—*Type II indeterminate individuals. Correct allocation of sex after seriating individuals initially classified as 'probable' male or female (see text).*

	Males	Females	Total
Initially indeterminate	28	38	66
Re-assessed sex	21	37	58

One particular morphological feature deserves further attention. Rogers (8:58) mentioned that "the female olecranon fossa is primarily a deep oval, but in some cases it may exhibit a shallow proximal extension in addition to the deep oval." Eight individuals from the St. Bride's collection were found to possess this proximal ledge. In order to test the validity of Rogers' claim, these eight individuals were subjected to a separate analysis, which indicated that six out of the eight individuals with this ledge were indeed documented as females. It appears that this characteristic can be used as an additional, supplementary trait to support the diagnosis of female sex.

Discussion and Conclusions

It was found that a visual assessment of the distal humerus could accurately determine the sex of skeletal remains. However, it is felt that Rogers' (8) sex determination technique does not sufficiently allow for the amount of natural variation that occurs between individuals of the same sex found in this study. The results of this blind test reveal that when all four traits were used to determine or confirm the sex of a documented individual, slightly lower accuracies were obtained than for the test of individual traits. This suggests that the four traits should be applied individually, as is the case with any other sex-indicative trait, rather than attempt to base sex assessment solely on the morphological appearance of the distal humerus.

A decreased overall accuracy (see Tables 4 and 8) was obtained in this study than was recorded in Rogers' (8) publication, and is believed to be the direct result of natural variation in morphology found between members of the same sex. Suggestions are made here to describe this observed variation, resulting in the introduction of the categories "probable male" and "probable female," as a wide variety of variation of trait expression was identified upon examination of the St. Bride's population. These differing appearances made unequivocal sex determination problematic, as Rogers did not discuss how to resolve such observations.

In this study, a total of 86 elements displayed features whose trait expressions could not have been unequivocally assigned following Rogers' instructions; with the consequence of approximately 25% of the elements having no definitively assigned sex. It is felt that the majority of these elements do possess sexually dimorphic characteristics and these are in fact as accurate as those more definite observations, as they reflect the presence of morphological variation within the sexes, just with a different variation than was suggested by Rogers. As a result, further investigation is needed to improve the overall applicability of this technique.

It is proposed that indicative morphologies suggested by Rogers' (8) were the extremes that could be observed for each trait. These extremes were found to be insufficient to capture the existing morphological variation, as not all demonstrated morphologies could be placed into one of three categories (definite male, definite female, indeterminate). Instead, the more tentative "probable" sex designations can be used, as they are widely employed when assessing other morphological traits such as greater sciatic notch, mental eminence, etc. (2).

An additional discrepancy with the Rogers technique was the finding that male individuals of St. Bride's demonstrated unilateral expression of both trochlear constriction and angle of the medial epicondyle, which may or may not be related to the handedness of such individuals (15). It is believed that the effects of handedness and occupational stresses on the morphology of the distal humerus and thus the expression of sexually dimorphic features is worthy of further investigation.

Visual representations have long been provided to act as guidelines to aid in the discrimination between morphological variants relating to biological sex. As indicated above, much variation exists within the traits proposed by Rogers, and thus an investigation into a more convenient and effective way of identifying sex was undertaken. Line drawings of the distal surface of the trochlea are presented here as a *possible* means of comparing the different morphologies of trochlear constriction and trochlear symmetry. These diagrams are supposed to incorporate the observed general variation within these two traits, as identified in the St. Bride's population, and allow for the inclusion of the 'probable male' and 'probable female' categories. The diagrams were produced through the analysis of tracings of the distal edge of the trochlea and capitulum with the dorsal side facing up. This allows the extent of trochlear constriction and distal portion of trochlear symmetry to be captured and reproduced in simple line drawings (Figs. 2 and 3).

An additional observation was made upon assessment of trochlear constriction that may prove to be helpful in the determination of sex. It is suggested that females demonstrate a sharp V-shaped type of constriction, while males exhibit a broader and rounded U-shaped morphology. It is proposed that these diagrams be subjected to further testing as to their effectiveness in aiding the identification of trochlear constriction and symmetry variation found within and between the sexes. This observation may also prove to be useful if examined in future re-examinations of this sex determination technique.

In conclusion, the results of this blind test indicate that despite considerable variation in trait expression and overlap between males

TABLE 7—*Frequency and relative occurrence of trait forms in males and females, including those individuals with re-assessed sex diagnoses.*

Trait Form	Males ($n = 184$)		Females ($n = 167$)	
	N	%	*N*	%
Trochlear Constriction				
Less Constricted	104	56.5	18	10.8
More Constricted	80	43.5	148	88.6
Indeterminate	0	0	1	0.6
Trochlear Symmetry				
Asymmetrical	147	79.8	27	16.2
Symmetrical	37	20.1	139	83.2
Indeterminate	0	0	1	0.6
Olecranon Fossa Shape				
Triangular	163	88.6	31	18.6
Oval Shaped	21	11.4	134	80.2
Indeterminate	0	0	2	1.2
Medial Epicondyle				
Flat/Slightly Raised	137	74.5	30	18.0
Distinctly Raised	47	25.5	137	82.0
Indeterminate	0	0	0	0

TABLE 8—*Overall accuracy of sex determination using features of the distal humerus, including re-assessed individuals of initially indeterminate sex.*

Feature	Male ($n = 184$)	Female ($n = 167$)	Total ($n = 351$)
Trochlear Constriction	56.5%	88.6%	71.8%
Trochlear Symmetry	79.9%	83.2%	81.5%
Olecranon Fossa Shape	88.6%	80.2%	84.6%
Angle of Medial Epicondyle	74.5%	82.0%	78.6%
Combined	74.9%	83.5%	79.1%

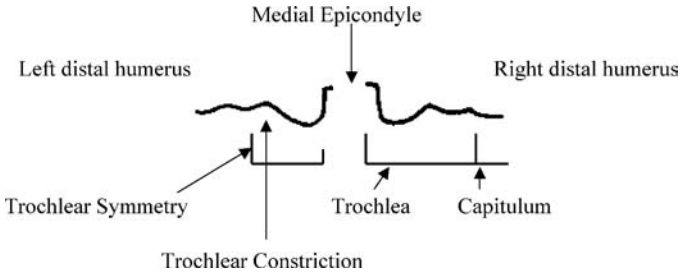

FIG. 2—*Explanation of line drawings provided in Fig. 3.*

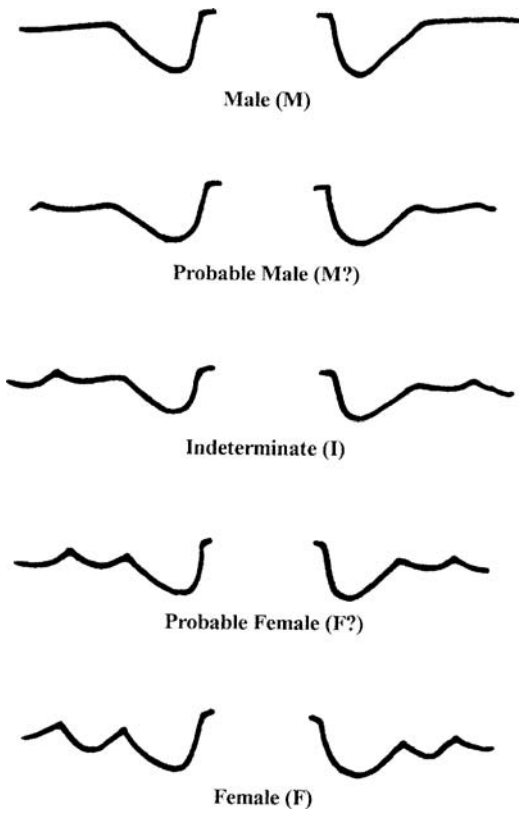

FIG. 3—*Sexual dimorphism in trochlear constriction and trochlear symmetry, based on observations in the documented collection of St. Bride's.*

and females, the method of sex assessment from morphological markers of the distal humerus proposed by Rogers (8) possesses a significant capacity to distinguish between the sexes. Individual traits, in particular olecranon fossa shape, can be recommended as powerful additional sex discriminatory features of the human skeleton. Overall, sexing of skeletons based on sexual dimorphism of the distal humerus alone can be obtained, even though with larger margins of error. A revised template for the assessment of trochlear constriction provides additional diagnostic support.

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