Richard A. Lazenby,[1] *Ph.D.*

Identification of Sex from Metacarpals: Effect of Side Asymmetry

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ABSTRACT: This study tests the effect of bilateral asymmetry on the success rate of correct prediction of sex based on osteometric dimensions of the second metacarpal, using a method proposed by Scheuer and Elkington. A total of 351 bones from 179 individuals (47 documented as to age and sex), including 172 pairs, obtained from a 19th century cemetery were used to test the null hypothesis of no effect. A high success rate (>90%) for correct identification was found for males irrespective of side, although the larger right second metacarpal was a significantly better predictor. Conversely, there was a much lower success rate for females irrespective of side (<65%), although the smaller left metacarpal tended to give better results. The high success rate for males and low rate for females likely reflects the greater skeletal robustness of this historic sample relative to modern individuals. It is concluded that side asymmetry can have a significant effect on predictive efficiency for the Scheuer and Elkington model. As well, it is questionable whether the technique should be applied to non-industrial, that is, more skeletally robust, populations.

KEYWORDS: physical anthropology, skeletal sex determination, human identification, second metacarpal, bilateral asymmetry

Scheuer and Elkington [*1*] recently published a method for the determination of sex using osteometric data from metacarpals I through V, and from the first proximal phalanx. Their rationale for introducing a new method to the battery of existing techniques is two-fold. First, partial skeletons may be found lacking those regions (pelvis and skull) most diagnostic of sex in humans. Second, larger long bones for which sex determination methods exist are often recovered damaged from both forensic and archaeological contexts, while small tubular bones such as metacarpals are found comparatively intact. Scheuer and Elkington show that the second metacarpal has the highest probability of correct sex determination (79%); however, in a small holdout sample the first metacarpal correctly identified 94%, while the second metacarpal managed a more modest 78% success rate.

Scheuer and Elkington's osteological sample was obtained from dissecting room cadavers; however, they did not specify whether the bones were taken from left or right hands, or a combination of the two. Bilateral asymmetry in the appendicular skeleton is well recognized [*2*], and in the case of hand bones tends to be directional [*3–6*]. Plato and co-workers [*4,5*], using radiogrammetric data from the Baltimore Longitudinal Study on Aging, found that external dimensions of the second metacarpal in males are larger on the right side, and

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[1] School of Human Biology, University of Guelph, Guelph, Ontario, Canada.

significantly so for individuals assessed as right-hand dominant. While left-hand dominance diminishes the magnitude of side asymmetry (that is, the differences become insignificant), the right side continues to be larger on average. Similar findings are reported for female participants of the BLSA [*6*]. The relationship of side asymmetry to lateral hand dominance is consistent with both experimental and observational data noting positive correlation between mechanical loading and bone size [*7–9*]. Unilateral sports activity, for example, has been shown to result in larger bones on the playing side [*10*].

The existence of side asymmetry in metacarpal dimensions as a function of lateral hand dominance may be problematic for Scheuer and Elkington's method of sex determination. Smaller bones of the male left hand may score as 'female'; while the opposite may hold for women: the larger right hand may score as 'male.' This study tests the following null hypothesis: side asymmetry has no effect on the success rate of correct sex determination. It should be noted that, while Scheuer and Elkington examined all five metacarpals, this hypothesis is tested using data from the second metacarpal alone.

Material and Methods

Left and right second metacarpals, unilaterally[2] or as pairs, were obtained from a large 19th century skeletal collection excavated from the St. Thomas Anglican Church cemetery, Belleville, Ontario. The cemetery operated from 1821 to 1874; the interments were predominantly individuals of United Kingdom and Western European extraction [*11*]. A proportion of this sample consists of individuals of documented sex and age (referred to here as 'known'); the remainder ('unknown') were identified using multifactorial methods of sex and age determination [*12*]. Sample demographics are given in Table 1, including the number of paired elements in each category.

The following osteometric data were collected using Helios dial calipers accurate to 0.05 mm: interarticular length (IAL); mediolateral base width (MLBW); anteroposterior base width (APBW); mediolateral head width (MLHW); anteroposterior head width (APHW); and maximum midshaft diameter (MSD). All variables are as defined by Scheuer and Elkington [*1*]; to conserve space they will not be reiterated here. Repeat measurements on a randomized subset ($n = 29$) found average per cent error to range from 0.17 (LMC IAL) to 4.02 (LMC APBW); none differed significantly.

The following analyses were performed, with $\alpha = 0.05$:

1. A paired t-test for differences between sides in the St. Thomas sample; by sex and category (known and unknown). This test establishes the existence and direction of any side asymmetry; and

TABLE 1—*Age/sex distribution of the St. Thomas Anglican Church sample.*

	Males		Females	
	Known (26)	Unknown (76)	Known (21)	Unknown (56)
Total *n* bones	50	152	37	112
Age ($\bar{x} \pm$ SD)	52.5 ± 18.3	42.9 ± 11.1	46.4 ± 21.1	42.4 ± 11.9
n Pairs	24	76	16	56

NOTE: Total number of individuals in each category is shown in parentheses.

[2]Some of the hand bones were, in fact, damaged postmortem or (more rarely) during excavation; others bore evidence of pathological alteration of joint surfaces. Bones which could not be reliably measured were excluded from the analysis.

2. Success rate for prediction of sex in the St. Thomas sample, by side and category, using Scheuer and Elkington's regression equation for the second metacarpal, employing all six osteometric variables. Values greater than 1.5 are considered female, and less than 1.5 are deemed male. Testing the known and unknown sample separately was carried out as an ad hoc comparison of the effectiveness of the second metacarpal method relative to standard multifactorial techniques of sex determination.

3. Agreement between sides for paired metacarpals was examined using McNemar's Test for paired comparisons [*13*]. A one-tailed test was used under the prior expectation that in males, the right side will be more effective than the left; and in females, the opposite will hold true.

Results

Table 2 provides summary data for the St. Thomas sample, by sex, side and category. A comparison of knowns versus unknowns (not reported here) found no significant differences. The analysis for side asymmetry is reported in Table 3. With the exception of interarticular length (IAL), the right side has larger values than the left. In contrast to earlier radiogrammetric studies [*4–6*], IAL does not differ between sides in this sample (unknown females excepted), while the large differences in MSD are consistent with earlier studies. Among articular dimensions, only MLBW and APHW tend not to exhibit side asymmetry. These results support the general observation that right hand dominance is the norm for human populations, and lends credence to the mechanical model [*7–9*], which specifies that greater functional loading produces larger bones.

TABLE 2A—*Means ± standard errors for the left and right metacarpals, knowns.*

	Males				Females			
	Left (25)		Right (25)		Left (20)		Right (17)	
	Mean	s.e.	Mean	s.e	Mean	s.e.	Mean	s.e.
IAL	65.29	0.80	65.49	0.78	62.19	0.87	62.44	1.10
MLBW	19.00	0.20	19.33	0.24	16.52	0.22	16.75	0.27
APBW	16.92	0.32	17.52	0.35	15.39	0.35	16.25	0.26
MLHW	15.89	0.19	16.13	0.18	14.39	0.25	14.86	0.28
APHW	14.85	0.18	15.10	0.19	13.51	0.20	13.52	0.21
MSD	9.70	0.14	9.99	0.14	8.66	0.15	9.01	0.18

NOTE: Number of individuals given in parentheses.

TABLE 2B—*Means ± standard errors for the left and right metacarpals, unknowns.*

	Males				Females			
	Left (76)		Right (76)		Left (56)		Right (56)	
	Mean	s.e.	Mean	s.e	Mean	s.e.	Mean	s.e.
IAL	66.27	0.39	66.13	0.39	62.10	0.42	62.42	0.43
MLBW	18.88	0.17	18.94	0.16	16.51	0.14	16.73	0.13
APBW	17.31	0.18	17.60	0.17	15.66	0.17	16.19	0.15
MLHW	15.86	0.13	16.12	0.16	14.04	0.13	14.25	0.12
APHW	15.00	0.13	15.22	0.13	13.64	0.15	13.66	0.14
MSD	9.69	0.10	10.05	0.11	8.28	0.07	8.62	0.08

NOTE: Number of individuals given in parentheses.

Table 4 presents results for the efficacy of the Scheuer and Elkington predictive formula as a function of side. The method appears highly successful so far as males in general are concerned, and in fact correctly identifies all of the known males in the sample. The success rate for females presents a strikingly different case, with a high proportion of mis-identifications. Among paired metacarpals, females again exhibit poor results; in over 60% of the known women, both sides score as males. Although there were few mis-identifications in the combined male sample, the right side is a better predictor than the left ($z = 2.45$; $P < 0.01$); in females, neither side is more effective ($z = 1.15$; $P > .10$), i.e., both left and right metacarpals are equally poor. Relative to standard multifactorial methods, the second metacarpal performs reasonably well in identifying the unknown males (89% to 97% agreement); much less so in unknown females (ca. 60%).

The expectation that one side would out-perform the other can be seen in Fig. 1. The slope indicates unity, that is, the case in which both sides give equal results. Female data are plotted in Fig. 1*A*; values below 1.5 are misidentified. The fact that the majority of points are shifted above the line indicates that the left metacarpal tends to be a more successful predictor than the right. In males (Fig. 1*B*), the scatter is again shifted above the line, closer to the left metacarpal demarcation value of 1.5. This reflects the greater likelihood of the right metacarpal to correctly identify sex (that is, give values below 1.5).

Discussion

This study tests the effect of side asymmetry in the second metacarpal on the successful prediction of sex, using a regression model developed by Scheuer and Elkington [*1*]. Although both the left and right second metacarpals are quite successful in predicting sex in the male sample, the null hypothesis of no effect must be rejected for males, since the right side has a significantly greater success rate than the left. While no such side effect could be demonstrated in females, it is noteworthy that a greater number of incorrect determinations were made from the more robust and 'male-like' right hand.

TABLE 3—*Side asymmetry in the St. Thomas Church sample.*

	Known				Unknown			
	Male (24)		Female (16)		Male (76)		Female (56)	
	$\bar{x}$ diff	$P \leq$	$\bar{x}$ diff	$P \leq$	$\bar{x}$ diff	$P \leq$	$\bar{x}$ diff	$P \leq$
IAL	−0.098	0.54	−0.009	0.97	−0.136	0.23	0.325	0.01
MLBW	0.300	0.10	0.200	0.23	0.067	0.37	0.223	0.03
APBW	0.548	0.00	0.534	0.01	0.288	0.01	0.526	0.00
MLHW	0.296	0.00	0.331	0.00	0.263	0.00	0.213	0.01
APHW	0.181	0.09	0.091	0.41	0.214	0.00	0.037	0.74
MSD	0.235	0.01	0.266	0.05	0.361	0.00	0.336	0.00

NOTE: Number of metacarpal pairs given in parentheses.

TABLE 4—*Percent correct sex identification from the second metacarpal as a function of side and sex.*

	LMC	RMC	Pairs
Males, unknown	89.5	97.4	97.4
Males, known	100.0	100.0	100.0
Females, unknown	64.3	58.9	76.8
Females, known	50.0	29.4	37.5

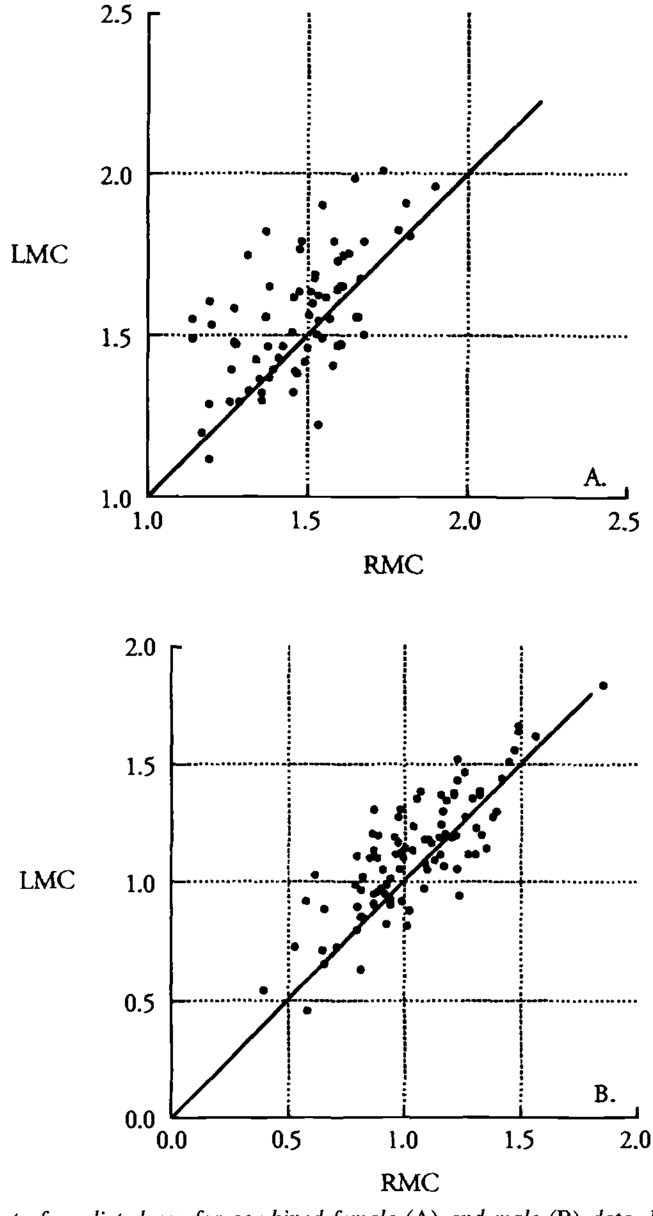

FIG. 1—*Plot of predicted sex for combined female* (A) *and male* (B) *data. Line indicates unity (complete agreement between sides).*

Two results from this study deserve particular mention. The first is the relatively high success rate (ca. 90% to 100%) seen for males. This is considerably greater than the 79% probability of success predicted by Scheuer and Elkington [*1*] for this bone, and matches or exceeds their highest level of success (94%, sexes combined) using the first metacarpal. The second important finding is the dismal success rate seen in the female sample, with 50% or more of the known individuals being incorrectly identified as males. It is likely that both findings are products of the same phenomenon. The St. Thomas sample originates from a 19th century settler cemetery, and it is reasonable to expect that both males and females in the contributing population would have led active lifestyles, possibly with a large component of physical labor. This would produce larger skeletal dimensions in both sexes through epigenetic mechanisms in which higher functional loading promotes skeletal growth and maintenance [7]. This hypothesis predicts that the St. Thomas cemetery sample is significantly larger osteometrically than the modern dissecting room sample used by Scheuer and Elkington. A one-sample t-test was undertaken to compare the two data sets (data drawn from their Table 2), by side and sex. This analysis found that in 17 of 24 comparisons, larger dimensions characterize the older, 19th century cemetery sample, 12 of which—mostly males—are significant at $\alpha = 0.05$. Interestingly, in 4 of the female comparisons (left and right MSD and APHW), the St. Thomas mean values were smaller ($P < 0.05$). These results are generally consistent with a temporal trend for declining skeletal robustness observed by Ruff [8] in the femur and tibia, comparing several skeletal samples from Upper Paleolithic to modern industrial periods. This trend was especially evident in males. In the present context, the generally larger bones of the St. Thomas sample would elevate the success rate for correct identification of male second metacarpals, as well as the rate for misidentification of female metacarpals.

Two general conclusions can be reached based on the results of this study. First, bilateral asymmetry as a product of lateral hand dominance has an effect on the success rate for correct prediction of sex from the second metacarpal. In males, the right side is more likely to provide a correct identification, while in females the left side tends to have a higher success rate. Second, a trend for declining bone robustness through time suggests that it would be inappropriate to apply this method to remains from archaeological contexts. It must be kept in mind, however, that this study tests only one of the five metacarpals for which Scheuer and Elkington [1] derived predictive formulae. It would be of interest to know whether other metacarpals mimic the results observed for the second metacarpal.

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Address requests for reprints or additional information to
Richard Lazenby, Ph.D.
School of Human Biology
University of Guelph
Guelph, Ontario
Canada N1G 2W1