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Sex Determination from Hand and Foot Bone Lengths*

ABSTRACT: Numerous studies have addressed sex estimation from the hands and feet with varying results. These studies have utilized multiple measurements to determine sex from the hands and feet, including measures of robusticity (e.g., base width and midshaft diameter). However, robusticity measurements are affected by activity, which can disguise underlying patterns of sexual dimorphism. The purpose of this study is to investigate the utility of length measurements of the hands and feet to estimate sex. The sample consists of white females ($n = 123$) and males ($n = 136$) from the Terry Collection. Discriminant function analysis was used to classify individuals by sex. The left hand outperformed both the right hand and foot producing correct classification rates exceeding 80%. Surprisingly, the phalanges were better sex discriminators than either the metacarpals or metatarsals. This study suggests that length measures are more appropriate than robusticity measures for sex estimation.

KEYWORDS: forensic science, forensic anthropology, metacarpals, metatarsals, phalanges, sex estimation

A number of studies have addressed the issue of sex determination from measurements of the hands or feet (1–8). These studies have varied primarily in terms of the specific bones and populations used to generate either regression equations or discriminant functions. In the hands, most studies have focused on the metacarpals (3,4,8), with the exception of a study by Scheuer and Elkington (2) that included the first proximal phalanx, and one by Smith (5) that included all of the hand phalanges in addition to the metacarpals. In the feet, studies have been published on the metatarsals (6), the metatarsals, proximal phalanges, and distal first phalanx (7), and the talus plus calcaneus (1).

Aside from the work by Steele (1), all of these studies have involved some form of the following measurements on digital bones: length (axial or interarticular), base width, head width, and midshaft diameter. Most have also included base height and head height. Predicted accuracies for the best functions have ranged from 79% to 97.9%, with two studies each from the hands and feet reporting accuracies >90%. These results seem to suggest that the hands and feet are nearly as useful for determining sex as are the skull and pelvis.

However, Burrows et al. (9) have questioned the validity of metacarpal use for assessing sex in human remains. They tested three previously published methods on a sample of recent Euro-American skeletons ($n = 23$), with generally poor results. The methods tested were originally developed by Scheuer and Elkington (2) on recent British skeletons ($n = 60$), by Falsetti (4) on early 20th-century American skeletons ($n = 212$), and by Stojanowski (8) on recent Euro-American skeletons ($n = 80$). The poor results were presumably caused by differences between the populations used to generate the discriminant functions, and the population on which they were tested by Burrows et al. (9). Differences in sexual dimorphism among the different populations could also explain the poor classification results. As would be expected, equations developed from the British skeletons performed least well on modern Americans. For the worst equations, only 10% of females but 100% of males were sexed accurately. Correct classifications were also lower for discriminant functions developed from early 20th century Americans from the Terry collection. These classifications underperformed for the female portion of the test sample by between 4.5% and 15.7%.

As might be expected, best results were obtained using functions developed on recent Euro-American skeletons by Stojanowski (8), but even in this case, 27% of the 33 functions tested produced accuracies that deviated from predicted jackknifed results by more than 10%, and over 60% of the functions deviated by between 5% and 10%. In general, similarity between predicted accuracy and tested accuracy decreased from MC1 to MC5, with the functions for MC2 and MC3 showing the greatest degree of better-than-expected discrimination, and MC4 and MC5 showing worse-than-expected discrimination. On the other hand, all but one of the MC1 functions deviated from expectations by $<3\%$.

The results of these three tests led Burrows et al. (9) to suggest that the different measurements used to generate these functions should be investigated to pinpoint the most "predictive" regions of each bone. In line with this suggestion, the purpose of the present study is to examine the usefulness of the length component of hand and foot bones in sex assessment, and to develop discriminant functions for applying length data to the problem of metric sexing from the hands and feet.

Materials and Methods

Sample

The initial sample consisted of 342 individuals (171 females, 171 males) from the Terry Anatomical Collection housed at the National Museum of Natural History at the Smithsonian Institution. The skeletons were drawn from the "white" portion of the Terry collection and represent Americans of European descent and some European immigrants. Skeletons were selected by age, beginning with the youngest adults, in order to minimize the

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FIG. 1—*Maximum axial length measurements for the metacarpals (left side shown). Bone drawings by Daniel Mehltretter.*

number of unmeasurable bones resulting from osteophytosis, trauma, and poor preservation. For the male portion of the sample, ages ranged from 18 to 60 with a median age of 50 years. For the female portion, ages ranged from 27 to 72 with a median age of 61 years. Skeletons were removed from this initial sample before analysis if measurements had not been taken for all bones of at least the left hand, right hand, or right foot. This criterion reduced the sample to 259 individuals (123 white females, 136 white males). Most individuals with no missing measurements in one of the extremities also had no missing measurements in the other extremities. Bones from the left and right side are distinguished in the Terry Collection by labeling with different colored inks, and curation in separate bags within the box containing each skeleton.

Maximum axial length measurements were taken from the metacarpals and all phalanges of each hand, as well as the metatarsals, proximal phalanges, and first distal phalanx of the right foot, using a miniosteometric board designed by the first author and Jim Kondrat of Paleo-Tech Concepts. Hand bone measurements were devised to simulate maximum axial length measurements taken from radiographs, and should be fairly comparable (10). Interobserver error rates for these measurements range from 0.1% to 1.1% with a median rate of 0.4% (10). Figures 1–3 present the measurement identifications and descriptions.

Statistics

Summary statistics were calculated for all variables. A discriminant function analysis using the cross-validation method, which treats $n-1$ out of n observations, was performed to classify observations into groups defined by sex. Separate discriminant analyses were conducted for each bone row of the left hand, right hand and right foot. In addition, a stepwise discriminant analysis was performed to select the best measurements for discriminating males and females using the complete suite of measurements for each extremity, as well as the measurements for each bone row (metacarpals, proximal phalanges, etc.) separately. Additional discriminant analyses were performed on the variables selected by the stepwise procedure. All statistical procedures were performed using SAS v. 8 for Windows.

Results

Summary statistics for each measurement are presented in Tables 1–3. Numbers of individuals reported in Tables 1–3 reflect all individuals in the study sample with no missing bones for a particular hand or foot.

Discriminant functions using all 19 bones of each hand suggested very little difference in the ability of the left and right hand

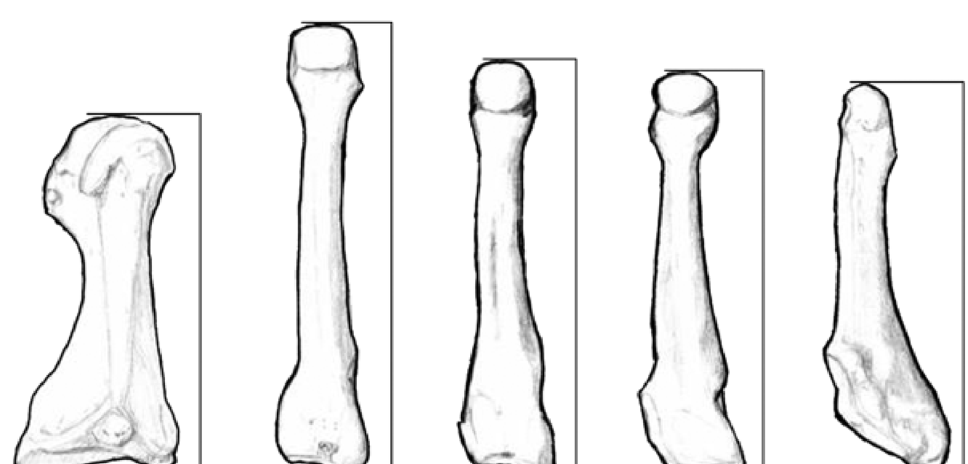

FIG. 2—*Maximum axial length measurements for the metatarsals (right side shown). Bone drawings by Daniel Mehltretter.*

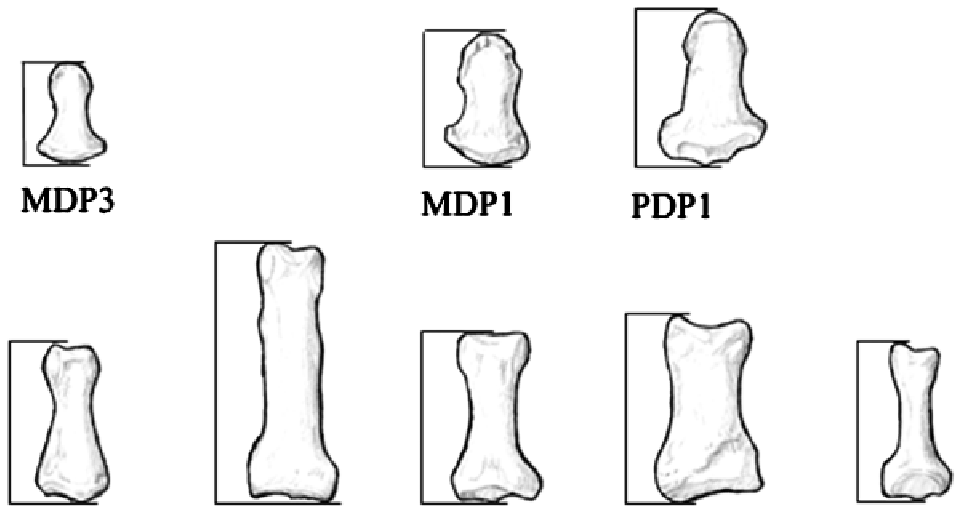

FIG. 3—*Selected maximum axial length measurements for the manual and pedal phalanges. Manual phalanges (preceded by an "M") are from the left side, and pedal phalanges (preceded by a "P") are from the right side. Bone drawings by Daniel Mehltretter.*

to correctly classify skeletons by sex. When analyzed by bone row, however, the left hand correctly classified skeletons better than either the right hand or the right foot, with more rows exceeding the 80% correct classification rate (Tables 4–6). For the left hand, all bone rows except for the metacarpals correctly classified the sexes in more than 80% of cases. For the right hand, only the proximal and distal phalanges exceeded 80% correct classification. None of the bone rows in the foot exceeded the 80% classification threshold, although the distal first phalanx alone came very close (79.6%). The only bones from the right hand that outperformed the left were the proximal phalanges, and none of the bone rows in the foot outperformed their analogs in the hands.

The left hand also produced the best discriminant functions based on stepwise selected variables. Five functions exceeded the 80% classification rate, while two functions exceeded 85% correct classification. In the right hand, three functions correctly classified individuals >80% of the time, and in the foot, two functions did so. Furthermore, the best functions in the right hand and foot required measurement of three to five bones, while the best functions in the left hand required only one to three bones. Those discriminant functions with better than 80% correct classification are provided in Tables 7 and 8.

Discussion

Results of the discriminant analysis clearly indicate that the left hand should be preferred over the right, and that the hands should be preferred over the feet, for sexing based upon length measures. It is also clear in both the hands and feet, that the phalanges are better at discriminating sex than the metacarpals or metatarsals. This result is interesting, given the fact that most previous sexing studies using hand and foot bones have focused on the metacarpals and metatarsals. Furthermore, the ability of the phalanges to correctly classify skeletons by sex seems to improve in a distal direction. In both the left hand and the right foot, the best functions based on bone rows are produced by the distal phalanges. In the

TABLE 1A—*Left hand summary statistics for females.**

Variable	*N*	Mean	Standard Deviation	Minimum	Maximum
LMC1	121	42.68	2.699	36.33	50.65
LMC2	121	64.70	3.959	55.67	76.12
LMC3	121	63.38	4.382	50.40	76.40
LMC4	121	54.12	3.649	45.12	63.07
LMC5	121	50.08	3.205	43.44	59.20
LPP1	121	29.76	1.905	24.86	35.37
LPP2	121	38.75	2.373	33.23	46.29
LPP3	121	42.69	2.798	36.72	52.13
LPP4	121	39.41	2.674	30.04	47.87
LPP5	121	31.13	2.308	20.32	36.85
LIP2	121	22.72	1.744	19.04	27.36
LIP3	121	27.58	2.025	23.72	33.59
LIP4	121	26.14	1.982	21.55	31.42
LIP5	121	18.28	1.866	10.25	22.05
LDP1	121	21.36	1.593	17.89	27.13
LDP2	121	16.28	1.307	13.32	19.73
LDP3	121	17.13	1.433	10.27	21.53
LDP4	121	17.15	1.299	14.08	21.77
LDP5	121	15.63	1.291	9.94	18.82

*All measurements in millimeters.

TABLE 1B—*Left hand summary statistics for males.**

Variable	*N*	Mean	Standard Deviation	Minimum	Maximum
LMC1	124	46.83	3.634	23.15	54.86
LMC2	124	70.02	4.022	58.52	82.47
LMC3	124	68.90	3.926	55.24	81.14
LMC4	124	58.87	3.325	48.67	69.43
LMC5	124	55.00	3.177	43.84	64.97
LPP1	124	33.00	2.267	24.65	38.61
LPP2	124	42.45	2.519	33.93	48.82
LPP3	124	46.74	2.541	39.25	54.67
LPP4	124	43.62	2.731	34.13	51.47
LPP5	124	34.56	2.137	27.98	40.60
LIP2	124	25.34	1.971	19.26	30.56
LIP3	124	30.93	2.184	24.03	37.44
LIP4	124	29.81	2.244	21.64	36.42
LIP5	124	21.37	2.265	16.10	31.03
LDP1	124	24.31	1.717	18.23	28.67
LDP2	124	18.58	1.497	14.44	21.99
LDP3	124	19.76	1.379	16.10	24.27
LDP4	124	19.76	1.363	16.26	23.63
LDP5	124	18.13	1.299	14.33	22.20

*All measurements in millimeters.

TABLE 2A—*Right hand summary statistics for females.**

Variable	N	Mean	Standard Deviation	Minimum	Maximum
RMC1	116	42.79	2.634	36.23	51.93
RMC2	116	64.99	3.986	55.41	75.84
RMC3	116	63.42	4.244	53.47	77.01
RMC4	116	54.32	3.702	44.31	64.93
RMC5	116	50.04	3.561	35.17	60.52
RPP1	116	29.51	1.921	24.07	35.17
RPP2	116	38.67	2.328	32.87	45.86
RPP3	116	42.80	2.571	36.34	50.14
RPP4	116	39.65	2.514	33.26	47.30
RPP5	116	31.59	2.055	26.02	37.04
RIP2	116	22.79	1.734	18.43	27.66
RIP3	116	27.60	2.159	19.86	33.27
RIP4	116	26.06	2.016	21.54	31.54
RIP5	116	18.31	1.844	13.05	22.97
RDP1	116	21.33	1.731	13.90	26.39
RDP2	116	16.25	1.278	12.38	19.89
RDP3	116	17.30	1.413	11.01	21.59
RDP4	116	17.32	1.438	13.09	22.60
RDP5	116	15.91	1.208	12.43	19.14

*All measurements in millimeters.

case of the foot, a function based on the distal first phalanx alone performs better than functions based on all of the metatarsals, or all of the proximal phalanges. Thus, it would seem that bones from the distal row should be used preferentially for sex determination when possible. However, as the central bones of the intermediate and distal phalanges can be difficult to position and side out of context (11), their use in sex determination may be limited to cases where bones are recovered in articulation.

Length Versus Robusticity Measures

A strong argument can be made for favoring length measurements when developing sexing techniques from the hands and feet. Length measurements differ substantively from the other measurements used to sex the hands and feet because they appear to be less influenced by lifetime activity. If a regression equation or discriminant function is to be widely applicable in a modern forensic context, the measures used to generate the function should be affected as little as possible by activity, so that the impact of activity-related differences between the population used to generate the function, and the subject(s) of forensic analysis, will be minimized. Most of the measures used in previous studies to assess sex from the hands and feet have been measures of breadth or height rather than length. Base width, base height, head width, head height, and midshaft diameters are all measures that may continue to change after puberty through appositional growth and bone modeling, potentially increasing the error associated with sexing techniques based on these dimensions.

TABLE 2B—*Right hand summary statistics for males.**

Variable	N	Mean	Standard Deviation	Minimum	Maximum
RMC1	133	46.86	3.444	23.50	55.06
RMC2	133	69.87	3.892	58.35	83.54
RMC3	133	68.35	3.657	55.42	79.36
RMC4	133	58.50	3.088	48.53	69.26
RMC5	133	54.54	3.066	43.69	65.30
RPP1	133	32.48	2.177	24.15	38.34
RPP2	133	41.94	2.280	33.48	49.40
RPP3	133	46.43	2.387	38.97	55.40
RPP4	133	43.40	2.281	35.71	52.04
RPP5	133	34.62	1.897	28.05	41.00
RIP2	133	25.35	1.996	19.27	31.31
RIP3	133	30.66	2.080	24.11	36.01
RIP4	133	29.33	2.063	22.81	34.44
RIP5	133	20.99	2.225	15.98	31.01
RDP1	133	23.90	1.838	17.48	27.59
RDP2	133	18.51	1.376	14.72	21.50
RDP3	133	19.66	1.348	16.04	23.00
RDP4	133	19.64	1.372	16.26	23.57
RDP5	133	17.96	1.215	14.59	21.73

*All measurements in millimeters.

TABLE 3A—*Right foot summary statistics for females.**

Variable	N	Mean	Standard Deviation	Minimum	Maximum
RMT1	123	59.92	3.904	44.86	73.57
RMT2	123	71.51	4.534	57.81	84.22
RMT3	123	66.85	4.464	57.01	80.20
RMT4	123	65.70	4.308	56.52	76.88
RMT5	123	67.17	4.032	55.45	77.90
RPPP1	123	32.98	2.432	24.01	41.96
RPPP2	123	28.02	2.156	21.24	33.76
RPPP3	123	25.50	2.101	19.75	31.08
RPPP4	123	23.88	1.825	18.83	29.12
RPPP5	123	22.60	1.870	17.35	27.01
RPDP1	123	23.93	2.285	16.92	32.12

*All measurements in millimeters.

Activity-related change in limb bone dimensions appears to be greatest for midshaft diameters. In a study of the impact of body mass on measurements of the proximal femur, for example, Ruff et al. (12) found that diaphyseal cross-sectional size changes appreciably in response to increased mechanical loading. Similar results are reported by Lieberman et al. (13), who found that moderate exercise over a 3-month period significantly affected the diaphyseal cross-sectional geometry of limb bones in sheep, although it did not significantly affect the articular surface areas of these same bones. In the hands, studies by Lazenby (14,15) have demonstrated that the diaphyseal shapes of the metacarpals of older individuals are less circular than those of younger individuals, reflecting a lifetime of bone modeling caused by functional loading. Lazenby also found that females have less circular metacarpal shapes than males, reflecting differential loading by sex.

Activity-related change in the dimensions of the epiphyseal ends of limb bones appears to be less extreme than change in the diaphysis, but is still a potential concern when developing discriminant functions for use in a forensic context. In a study of the upper limb bone dimensions of tennis players, for example, Ruff et al. (16) found that the head of the radius averaged 5.6% broader on the side wielding the racket than on the opposing side, and epicondylar breadth of the humerus averaged 4.7% higher.

TABLE 3B—*Right foot summary statistics for males.**

Variable	N	Mean	Standard Deviation	Minimum	Maximum
RMT1	136	64.28	3.661	56.01	74.86
RMT2	136	76.60	4.254	65.83	91.41
RMT3	136	71.48	4.398	52.34	87.79
RMT4	136	70.36	4.727	51.12	85.54
RMT5	136	72.56	4.667	60.54	84.87
RPPP1	136	36.16	2.634	28.97	43.16
RPPP2	136	30.68	1.802	25.08	36.21
RPPP3	136	28.08	1.839	22.44	33.36
RPPP4	136	26.33	1.730	21.98	31.43
RPPP5	136	25.03	1.839	20.67	30.63
RPDP1	136	27.02	1.886	20.72	32.21

*All measurements in millimeters.

TABLE 4—*Left hand crossvalidation classification results.*

Variables	Female (%)	Male (%)	Pooled (%)
All	83.5	82.3	82.9
LMC1–LMC5	79.3	79.8	79.6
LPP1–LPP5	81.8	79.8	80.8
LIP2–LIP5	79.3	80.7	80.0
LDP1–LDP5	86.0	85.5	85.7
*LDP4, LDP5, LIP4	86.0	85.5	85.7
*LMC1, LMC5	80.2	79.8	80.0
*LPP1, LPP4	83.4	82.3	82.9
*LIP4	83.5	81.5	82.4
*LDP4, LDP5	84.3	86.3	85.3

*Stepwise selected variables.

Both differences were significant ($p < 0.001$) and in both cases the degree of asymmetry was greater for males than females.

If measures that are substantially affected by lifelong bone modeling are used to create discriminant functions, they will be less applicable to forensic subjects if activity levels change over time, particularly if these changes are not consistent between the sexes, or if a particular forensic subject had an atypical activity pattern. Furthermore, as suggested by Lazenby's research, differences between the mean age of the sample used to generate the functions, and the age of each individual being sexed by these functions, may influence the accuracy of sex determinations as well.

Length, on the other hand, may change slightly at the proximal and distal ends through functional loading and modeling, but any such change will be small relative to the total length of the bone. The main impact on length measures will be genetic and nutritional. Evidence from stature and growth studies of living humans suggest that bone length is influenced much more by genetics than by health and nutrition. For example, Garn et al. (17) showed that African American children are taller than Euro-American children despite lower socioeconomic status, and Steckel (18) found that even the harsh conditions of slavery led to less than a 4% reduction in standard height among African Americans of the 19th century. More recent investigation into the genetics of the tibia and femur has confirmed a strong association between genes and bone length (19).

Skeletal studies also support the notion that environmental factors play a relatively small role in determining bone length. Meadows Jantz and Jantz (20) documented the effect of improving health and nutrition on bone lengths in the United States between the 1830s and 1970s. Among Euro-Americans, Meadows Jantz and Jantz (20) found that lengths of the humerus, radius, ulna, femur, tibia, and fibula increased more among males than among females during the period. However, the magnitude of this change, when scaled to bone size, was relatively small. Male limb bones increased by *c.* 0.3–0.8% per decade, while female bones increased by only 0.05–0.3% per decade. Thus, the impact of improving health and nutrition on bone length over time appears to have been relatively small.

TABLE 5—*Right hand crossvalidation classification results.*

Variables	Female (%)	Male (%)	Pooled (%)
All	81.9	84.2	83.1
RMC1–RMC5	76.7	79.0	77.9
RPP1–RPP5	82.8	82.7	82.7
RIP2–RIP5	77.6	78.2	77.9
RDP1–RDP5	81.9	80.5	81.1
*RPP2, RPP4, RIP5, RDP2, RDP3	82.8	85.7	84.3
*RDP2, RDP3, RDP5	82.8	81.2	81.9
*RPP1, RPP2, RPP4	83.6	82.7	83.1

*Stepwise selected variables.

TABLE 6—*Right foot crossvalidation classification results.*

Variables	Female (%)	Male (%)	Pooled (%)
All	80.5	83.8	82.2
RMT1–RMT5	74.0	74.3	74.1
RPP1–RPP5	78.1	77.2	77.6
RDP1	80.5	78.7	79.6
*RMT4, RMT5, RDP1	82.9	82.4	82.7
*RMT4, RMT5, RPP4, RDP1	82.9	83.8	83.4

*Stepwise selected variables.

From a forensic perspective, the small degree of secular change in female bone lengths over many decades has important implications for sexing methods based on bone length. When a discriminant function is created using skeletons that are many decades old, the applicability of that function to more recent forensic subjects will depend on the amount of change in bone size over time. Increasing length in females is the only important factor in these cases, because larger females run the risk of being misclassified as males, while increasing length in males improves the probability that males in the sample will be classified into the correct category. Thus, when using length measures to create discriminant functions, it would appear that temporal differences between the reference population used to generate the function, and the observed population, become important only when the populations differ by many decades during a period of sustained secular change. It should also be noted that, because bone length is essentially fixed at around 20 years of age for each individual, the important periods of secular change are those that occur between the time the average person in the reference population used to generated the discriminant function reached the age of 20, and the time the unknown individual reached the age of 20.

Based on the above discussion, 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. In addition to the initial data published by Scheuer and Elkington (2), two studies have used the same measurements on at least the second metacarpal (3,9). These studies had in common the measurements interarticular length, base width, base height, head width, and head height. Scheuer and Elkington (2) took these measurements on recent British skeletons, Lazenby (3) took them on skeletons from a historic Anglican church in Ontario, Canada, and Burrows et al. (9) took them on modern Americans.

Comparing the mean measures for males and females from each sample with those reported by Burrows et al. (9), it would appear that the measures with the most stable relationship between the sexes are the length measures (Table 9). The mean lengths for Lazenby's historic Canadians are lower than for Burrows et al.'s modern Americans, but this difference is highly proportional between males and females (-4.2% and -3.9% of total length, respectively). The only other measure with such a proportional difference between the sexes is that for head height (-4.4% and -4.2% of total length). When the British skeletons from Scheuer and Elkington's study are compared with the modern Americans, the length measurements are again more stable between the sexes

TABLE 7—*Left hand discriminant functions with better than 80% correct classification.**,†

	Bone 1	Bone 2	Bone 3	Bone 4	Bone 5	Constant
1.	– 0.5717(IP4)					+22.8185
2.	– 0.1110(MC1)	– 0.4017(MC5)				+26.0704
3.	– 0.4004(PP1)	– 0.3337(PP4)				+26.4146
4.	– 0.8596(DP4)	– 0.7896(DP5)				+29.1934
5.	– 0.3004(IP4)	– 0.6944(DP4)	– 0.6107(DP5)			+31.5281
6.	– 0.2330(DP1)	+0.1166(DP2)	– 0.2384(DP3)	– 0.6150(DP4)	– 0.6572(DP5)	+30.1302

*Sectioning point = 0. Values greater than zero indicate female, values less than zero indicate male.
†Formula: Bone 1 product+Bone 2 product+Bone 3 product+Bone 4 product+Bone 5 product+Constant.
Note: Functions for PP1–PP5 and IP2–IP5 are not included because better functions were attainable using a subset of these bones.

than for the other measures, including head height. Thus, length measures appear to have a more stable relationship within the sexes of a population than do epiphyseal or diaphyseal measurements, probably because the latter are more influenced by lifetime activity. In a forensic context, where the lifetime activities of an unidentified individual are unknown, it is preferable to use metric methods based on length measurements, as they are least influenced by differences in daily activities, and most influenced by the local gene pool.

We do not mean to suggest that length alone will necessarily produce the highest classification results when developing a discriminant function. Using a combination of length, two midshaft dimensions, and two epiphyseal dimensions, Falsetti (4) produced functions for individual metacarpals from the Terry Collection that correctly classified the sexes 84–92% of the time. This compares with only 80% correct classification in the current study using length measurements of all five metacarpals in combination. Similarly, Robling and Ubelaker (6) used four epiphyseal and one midshaft dimension on individual metatarsals to produce functions from the Terry sample that correctly classified the sexes 87.5–93.5% of the time, compared with only 74% for all five metatarsals in the present study. Thus, addition of epiphyseal and midshaft measurements will improve the predicted classification rates of discriminant functions from the hands. However, because the population used to create discriminant functions will almost certainly differ both temporally, in terms of average year of birth, and in terms of lifestyle and activity levels, the functions with the broadest applicability will be those that minimize the impact of these differences. Falsetti's (4) study highlights the risk of applying functions using epiphyseal and diaphyseal breadth measures to other populations. When functions derived from the Terry Collection were applied to a known-sex forensic sample from University of New Mexico, the function with the best-expected result performed least well, misclassifying 22.5% instead of the expected 8%. Results were poorer still when the same functions were applied to modern British skeletons.

TABLE 9—*MC2 measurement differences by sex compared to Burrows et al. (2003).**

Measure	Lazenby (Female; %)	Lazenby (Male; %)	Scheuer (Female; %)	Scheuer (Male; %)
Interarticular length	+3.9	+4.2	+2.9	+4.3
M-L base width	– 0.1	+3.3	+6.4	+11.5
A-P base height	+1.9	+4.0	+1.6	+6.9
M-L head width	– 18.6	– 14.9	– 14.9	– 9.4
A-P head height	+4.2	+4.4	+0.6	+3.5

*Positive values indicate that Burrows et al.'s mean measures were larger.

Based on the discussion above, it appears that discriminant functions based on length measurements will be least impacted by activity-related variation, and therefore should be favored for sex determination, while diaphyseal breadth will be most impacted and should be avoided. Epiphyseal measures will be more impacted by lifetime activity than length measures, and should be used with caution until they have been more thoroughly examined from a forensic perspective. This study also demonstrates that length measurements from the hands and feet alone can be utilized to estimate the sex of unknown individuals, particularly in cases where remains are fragmentary, or so badly damaged that other elements are not reliable for sexing.

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TABLE 8—*Right side discriminant functions with better than 80% correct classification.**,†

	Bone 1	Bone 2	Bone 3	Bone 4	Bone 5	Constant
Right Hand:						
1.	– 0.3903(PP1)	+0.3400(PP2)	– 0.7022(PP4)	+27.5534		
2.	– 0.5310(DP2)	– 0.5077(DP3)	– 0.4955(DP5)	+27.0027		
3.	+0.4785(PP2)	– 0.6441(PP4)	– 0.1837(IP5)	– 0.6132(DP2)	– 0.4997(DP3)	+30.9616
Right Foot:						
1.	+0.1189(MT4)	– 0.2706(MT5)	– 0.6068(DP1)	+26.2755		
2.	+0.1995(MT4)	– 0.2528(MT5)	– 0.4380(PP4)	– 0.5055(DP1)	+27.9681	

*Sectioning Point = 0. Values greater than zero indicate female, values less than zero indicate male.
†Formula: Bone 1 product+Bone 2 product+Bone 3 product+Bone 4 product+Bone 5 product+Constant.
Note: Functions for manual PP1–PP5 and DP1–DP5 are not included because better functions were attainable using a subset of these bones.

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