Sex determination from the metacarpals in a modern South African male and female sample

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Introduction

Violent crime is on the increase worldwide and South Africa is no exception. Some forensic cases may present with bodies in an advanced or complete stage of decomposition where only the skeleton is discernable. Various studies have been done to determine demographic characteristics from fragmentary or incomplete remains. Such information may be crucial in identifying the remains of a body as male or female. No studies on the use of the metacarpals (Figure 1) as an aid in determining the sex of an unknown individual has been carried out in South Africa.

Aims

The aim of this study was to determine if the dimensions of the metacarpals of the human hand can be used to determine sex of an unknown individual through the use of discriminant function formulae.

Figure 1: Dorsal (A) and palmar (B) views of metacarpals (MC) 1 to 5 of the right (R) hand. The labeling on the dorsal surface i.e. R1 to R5, was done to identify the bones during and after the maceration process. The number 6204 represents the cadaver number

Materials and Methods

A total of 200 sets of hand bones from each sex-race group (50 black males, 50 black females, 50 white males and 50 white females) were used. These hands were obtained from the Pretoria Bone Collection in the Department of Anatomy. The age of the individuals ranged from 21 to 81 years. A total of seven measurements were taken on each hand bone (Figure 2a and 2b), and for purposes of analysis the data from the two population groups were pooled.

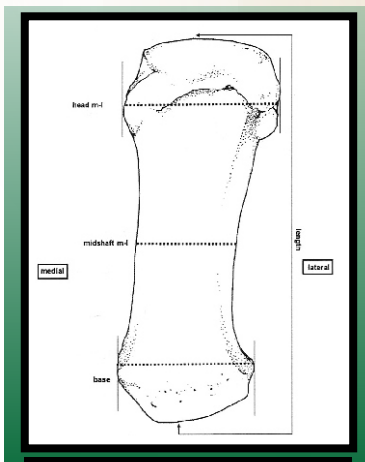

Figure 2a: Palmar view of the first metacarpal showing the length, mediolateral (m-l) measurements of the head, midshaft and base

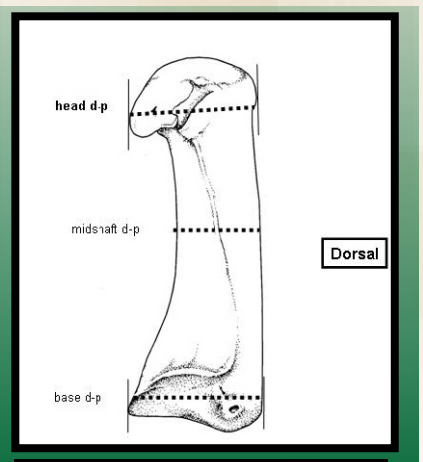

Figure 2b: Lateral view of the first metacarpal showing the length, dorsopalmar (d-p) measurements of the head, midshaft and base

All measurements were recorded to the nearest 0.01mm using a digital caliper. A discriminant function analysis was done using SPSS version 11.5. This analysis was carried out using all seven measurements for a stepwise procedure, afterwhich only the first selected variable was entered into a direct analysis. Canonical discriminant function coefficients were obtained for each measured variable in metacarpals one to five.

Results

Descriptive statistics comparing mean values of all seven dimensions for each metacarpal bone indicates that the values were significantly greater ($p<0.01$) in males than in females. Once this difference was established, a discriminant function analysis was done.

Table 1 shows the results obtained from the discriminant function analysis for all metacarpals. Only five of the seven variables were selected for metacarpal 1 in a stepwise analysis. A direct analysis was then run on the best selected variable for this metacarpal, namely the mediolateral measurement of the midshaft. Only three variables were selected for the second, third and fourth metacarpals. In these metacarpals, the anteroposterior measurement was the best selected variable which was then incorporated into the direct analysis. In the case of the fifth metacarpal, five variables were selected, with the anteroposterior measurement of the head listed as the best variable.

Table 2 displays the results for the canonical discriminant coefficients produced by the stepwise and direct analyses for all metacarpals. The unstandardized (raw) coefficient is used to calculate the discriminant score. This score is then compared to the sectioning point which is calculated by adding the group centroids for males and females and dividing by two.

<u>Example:</u>
To calculate the discriminant score for the second metacarpal, each dimension of this bone is multiplied by its unstandardized coefficient (see Table 4). In the case of the second metacarpal where multiple variables have been selected, these are added or subtracted. The constant (see Table 4) is then added. The sectioning point for the second metacarpal is calculated as follows:
0.9064-0.8974 = -0.009/2 = -0.0045
Thus, if the discriminant score is >-0.0045 = Male, if <-0.0045 = Female

<u>If, for example, the dimensions of a second metacarpal are:</u>
Anteroposterior dimension of the base = 17.9 mm
Anteroposterior dimension of the midshaft = 9.8 mm
Mediolateral dimension of the base = 18.7 mm

<u>The calculation of the discriminant score is as follows:</u>
Discriminant score = (0.3046 x 17.9) + (0.5284 x 9.8) + (0.2756 x 18.7) + (-14.5365)
Discriminant score = 1.23

The score of 1.23 is above the sectioning point of -0.0045 (see Table 4), the individual would thus be classified as MALE. The further away the discriminant score is from the sectioning point, the more reliable is the estimation of sex.

The same steps are followed when a discriminant score needs to be calculated for a single variable. The single variable can also be compared to a demarking point which is calculated by adding the mean values of the male to that of the female and dividing this average value by two. If the dimension of the single variable is above the demarking point then it is classified as male, while a value below would be female.

Table 3 indicates the classification accuracy. The accuracies are high, ranging from 71.0% to 85.0% for males and 78.7% to 86.6% for females, dropping slightly on cross-validation.

Table 1: Discriminant function analysis of metacarpals 1 to 5 for South Africans

Function	Step	Variable	Wilk's lambda	Exact F-ratio	d.f
Metacarpal 1					
Stepwise	1	midshaft ml	0.610	125.780	1.197
	2	head ml	0.563	75.929	2.196
	3	base ml	0.537	56.142	3.195
	4	midshaft ap	0.514	45.769	4.194
	5	Length	0.498	38.878	5.193
Direct	1	midshaft ml	0.610	125.780	1.197
Metacarpal 2					
Stepwise	1	base ap	0.693	87.165	1.197
	2	midshaft ap	0.590	68.004	2.196
	3	base ml	0.549	53.409	3.195
Direct	1	base ap	0.693	87.165	1.197
Metacarpal 3					
Stepwise	1	base ap	0.627	116.972	1.197
	2	midshaft ap	0.575	72.568	2.196
	3	head ap	0.547	53.900	3.195
Direct	1	base ap	0.627	116.972	1.197
Metacarpal 4					
Stepwise	1	base ap	0.643	108.914	1.196
	2	base ml	0.547	53.611	3.194
	3	midshaft ap	0.529	42.958	4.193
Direct	1	base ap	0.641	110.344	1.197
Metacarpal 5					
Stepwise	1	head ap	0.667	97.384	1.195
	2	midshaft ml	0.592	66.738	2.194
	3	base ml	0.570	48.479	3.193
	4	midshaft ap	0.550	39.220	4.192
	5	Length	0.530	33.940	5.191
Direct	1	head ap	0.667	97.384	1.195

(ap=anteroposterior width measurement of the midshaft of the bone, ml=mediolateral width measurement of the midshaft, head and base of the bone, df=degrees of freedom)

Table 2. Canonical discriminant function coefficients of Metacarpals (MC) 1 to 5 for South Africans

Function	Step	Variable	Unstandardized coefficient	Standard coefficient	Structure coefficient	Group centroids
MC1 Stepwise	1	Midshaft ml	0.2861	0.3016	0.7962	M=0.9935
	2	head ml	0.2566	0.3384	0.5470	F=-1.0036
	3	base ml	0.2121	0.2879	0.5766	
	4	Midshaft ap	0.3822	0.3239	0.6573	
	5	Length	0.0982	0.2730	0.5938	
		(Constant)	-18.3415			
		Sectioning point	-0.0051			
Direct	1	Midshaft ml	0.9485	1	1	M=0.7910
		(Constant)	-11.5287			F=-0.7980
		Sectioning point	-0.004			
		Demarking point	Males>12.15>Females			
MC2 Stepwise	1	base ap	0.3046	0.4350	0.7338	M=0.8974
	2	Midshaft ap	0.5284	0.5153	0.7301	F=-0.9094
	3	base ml	0.2756	0.4294	0.7093	
		(Constant)	-14.5365			
		Sectioning point	-0.0045			
Direct	1	base ap	0.7002	1	1	M=0.6585
		(Constant)	-11.5789			F=-0.6652
		Sectioning point	-0.0034			
		Demarking point	Males>16.53>Females			
MC3 Stepwise	1	base ap	0.3324	0.4219	0.8462	M=0.9015
	2	Midshaft ap	0.4283	0.3942	0.7375	F=-0.9106
	3	head ap	0.4124	0.4216	0.8353	
		(Constant)	-15.5067			
		Sectioning point	-0.0046			
Direct	1	base ap	0.7879	1	1	M=0.7628
		(Constant)	-13.1813			F=-0.7705
		Sectioning point	-0.0039			
		Demarking point	Males>16.72>Females			
MC4 Stepwise	1	base ap	0.4163	0.4200	0.8003	M=0.9174
	2	base ml	0.4627	0.4861	0.6529	F=-0.9361
	3	Midshaft ap	0.5275	0.4849	0.7145	
		(Constant)	-14.5196			
		Sectioning point	-0.0094			
Direct	1	base ap	0.9635	1	1	M=0.7409
		(Constant)	-12.2514			F=-0.7484
		Sectioning point	-0.0038			
		Demarking point	Males>12.33>Females			
MC5 Stepwise	1	Midshaft ml	0.3723	0.3096	0.7072	M=0.9291
	2	base ml	0.2954	0.3909	0.6371	F=-0.9386
	3	Midshaft ap	0.4657	0.4411	0.7288	
	4	Length	0.1157	0.3786	0.5560	
		(Constant)	-16.4791			
		Sectioning point	-0.0048			
Direct	1	Midshaft ml	1.1567	1	1	M=0.6995
		(Constant)	-13.7773			F=-0.7067
		Sectioning point	-0.0036			
		Demarking point	Males>11.91>Females			

ap=anteroposterior width measurement, ml=mediolateral width measurement

Table 3. Sexing accuracy using metacarpals 1 to 5. Percentage of correct group membership and cross-validation

Function		N (Total)	Male Count	%	Female Count	%	Average Accuracy
Metacarpal 1							
Stepwise	Original	199	85/100	85.0	85/99	85.9	85.4
	Cross-validated	199	84/100	85.0	85/99	85.9	84.9
Direct-MC1 midshaft ml	Original	199	75/100	75.0	78/99	78.8	76.9
	Cross-validated	199	75/100	75.0	78/99	78.8	76.9
Metacarpal 2							
Stepwise	Original	199	76/100	76.0	83/99	83.8	79.9
	Cross-validated	199	76/100	76.0	82/99	82.8	79.4
Direct-MC2 base ap	Original	199	71/100	71.0	80/99	80.8	75.9
	Cross-validated	199	71/100	71.0	80/99	80.8	75.9
Metacarpal 3							
Stepwise	Original	199	80/100	80.0	83/99	83.8	81.9
	Cross-validated	199	79/100	79.0	83/99	83.8	81.4
Direct-MC3 base ap	Original	199	72/100	72.0	84/99	84.8	78.4
	Cross-validated	199	72/100	72.0	83/99	83.8	77.9
Metacarpal 4							
Stepwise	Original	198	80/100	80.0	85/98	86.7	83.3
	Cross-validated	198	77/100	77.0	85/98	86.7	81.8
Direct-MC4 base ap	Original	199	78/100	78.0	79/99	79.8	78.9
	Cross-validated	199	78/100	78.0	79/99	79.8	78.9
Metacarpal 5							
Stepwise	Original	197	78/99	78.8	84/98	85.7	82.2
	Cross-validated	197	78/99	78.8	84/98	85.7	82.2
Direct-MC5 head ap	Original	199	76/99	76.8	82/98	83.7	80.2
	Cross-validated	199	76/99	76.8	82/98	83.7	80.2

Discussion

The first metacarpal had the largest F-ratio indicating that this is the most dimorphic bone in the metacarpal series, and it also had the highest accuracies. The average accuracies of classification found in this study are comparable to those found by others. 1,2 This indicates that these measurements can be used with a fair degree of accuracy to determine the sex of an unknown individual. Generally, an analysis with multiple variables yields better classification accuracies than using a single variable.

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