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Metrical variation in the thumb, index, and middle finger among four samples of both sexes*

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Abstract. Metrical length and width parameters of the first through third ray metacarpals and phalanges are presented for four samples of adults of both sexes drawn from radiographs of the Ten State Nutrition Survey (1968–1970). Radiographic measurements were obtained with the aid of a digitizer and computer translation program. The establishment of ranges of variation among these samples allows their use in clinical diagnosis, for example of syndromes via pattern profile analysis. Proportional analyses of hand metrics can now be extended to include widths of the first three rays as well as lengths, and data for such a purpose are now available for American blacks, Mexican-Americans, and Oriental-Americans in addition to American white groups. Examples of intersample variation are given; the need to consider such variation in clinical contexts is emphasized.

Key words: Hand – Anthropometry – Variation – Ethnicity – Radiography

Introduction

As part of a larger project [13], parameters of length and width variation of the metacarpals and phalanges of the first three rays of the hand were determined for four samples of adults of both sexes. The information obtained should prove useful for skeletal radiologists attempting to diagnose clinical syndromes on the basis of hand segment proportions, particularly through the use of pattern profile analysis.

This research extends previous studies in two major ways. With the data presented here, investigations of hand proportions, including those using pattern profiles, can employ not only lengths, as has usually been done, but also widths. In addition, data are given for both sexes of four different groups, providing an indication of the variation evident across different samples or populations. The primary aim of this report is to present data on normal metrical variation that will be of aid in future basic and clinical research in these areas.

Materials and methods

Samples. The dataset consists of standard posteroanterior hand radiographs from the Ten State Nutrition Survey (1968–1970), on permanent loan to the University of Michigan's Center for Human Growth and Development. (Further methodological information beyond that provided here can be found in [13].) California, Massachusetts, and Washington were chosen as the states from which to sample due to considerations of sample size and composition of available radiographs. These three states have the largest number of radiographs of white females and males, and California yields

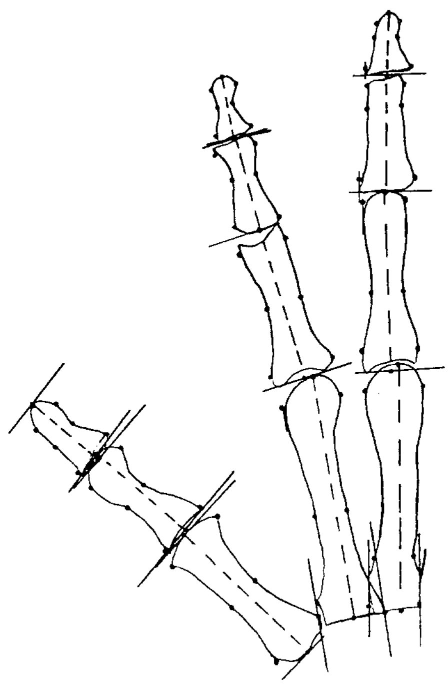

Fig. 1. Example of measurement points

* Based on research conducted at the University of Michigan

Table 1. Distribution parameters: American white females ($n=595$)

Distance	Mean	SD	Range	0.1	0.5	0.9	CV
LMC1	43.88	2.59	36.90–53.17	40.64	43.76	47.37	5.90
LPP1	30.84	1.88	24.80–38.24	28.57	30.71	33.25	6.10
LDP1	21.36	1.48	15.52–25.57	19.51	21.35	23.31	6.91
WbMC1	14.93	0.93	12.40–17.98	13.66	14.95	16.09	6.23
WmMC1	9.21	0.80	5.90–12.04	8.24	9.21	10.23	8.72
WhMC1	14.63	1.01	11.16–17.65	13.35	14.58	16.00	6.94
WbPP1	14.02	0.84	11.73–16.71	12.89	14.05	15.07	6.01
WmPP1	7.54	0.70	5.58– 9.96	6.71	7.52	8.44	9.23
WhPP1	11.12	0.73	8.66–12.92	10.16	11.14	12.06	6.53
WbDP1	11.09	0.78	8.57–14.03	10.08	11.10	12.08	7.02
WmDP1	5.31	0.73	3.12– 7.58	4.38	5.32	6.24	13.76
WtDP1	6.87	0.94	3.11– 9.84	5.73	6.86	7.97	13.75
LMC2	63.42	3.61	52.97–74.87	58.88	63.37	68.16	5.70
LPP2	39.39	2.15	33.42–46.71	36.63	39.38	42.11	5.46
LMP2	22.09	1.61	16.16–27.02	20.10	22.08	24.17	7.30
LDP2	15.84	1.14	11.96–18.90	14.44	15.85	17.32	7.18
WbMC2	17.36	1.05	13.72–20.63	16.11	17.30	18.76	6.06
WmMC2	7.79	0.61	6.11– 9.64	7.02	7.80	8.61	7.84
WhMC2	14.89	1.01	11.68–17.56	13.55	14.91	16.14	6.79
WbPP2	15.57	0.82	12.81–17.88	14.58	15.55	16.62	5.24
WmPP2	8.81	0.65	6.60–10.76	7.94	8.80	9.36	7.33
WhPP2	11.26	0.66	9.21–13.38	10.44	11.21	12.10	5.88
WbMP2	12.26	0.70	10.49–14.56	11.34	12.27	13.17	5.75
WmMP2	7.11	0.60	5.39– 9.09	6.32	7.11	7.90	8.43
WhMP2	9.20	0.52	7.73–11.05	8.51	9.17	9.92	5.66
WbDP2	9.28	0.58	7.30–11.33	8.52	9.28	10.01	6.28
WmDP2	4.57	0.57	3.10– 6.61	3.86	4.54	5.29	12.39
WtDP2	6.66	0.73	4.60– 9.44	5.73	6.64	7.52	10.89
LMC3	61.34	3.54	50.21–72.38	56.80	61.40	65.90	5.77
LPP3	43.42	2.33	37.54–51.61	40.51	43.40	46.41	5.37
LMP3	26.71	1.79	20.92–33.42	24.61	26.67	28.91	6.69
LDP3	16.90	1.15	13.12–20.16	15.49	16.90	18.44	6.82
WbMC3	13.37	0.90	10.45–16.80	12.26	13.37	14.55	6.70
WmMC3	7.73	0.63	5.54– 9.71	6.92	7.73	8.51	8.12
WhMC3	15.05	1.01	11.86–18.34	13.87	15.01	16.30	6.68
WbPP3	15.29	0.86	12.70–17.54	14.15	15.31	16.38	5.64
WmPP3	9.02	0.78	6.76–11.10	8.05	8.96	10.02	8.60
WhPP3	11.88	0.77	9.00–14.71	10.90	11.86	12.85	6.45
WbMP3	13.06	0.75	10.95–15.44	12.10	13.08	14.03	5.70
WmMP3	7.63	0.61	5.59– 9.36	6.82	7.62	8.39	8.03
WhMP3	9.95	0.53	8.28–12.09	9.31	9.93	10.65	5.36
WbDP3	10.11	0.60	8.28–12.02	9.38	10.04	10.91	5.94
WmDP3	5.03	0.54	3.38– 6.81	4.30	5.04	5.72	10.76
WtDP3	7.47	0.80	4.67– 9.97	6.48	7.43	8.50	10.67

L = length; W = width; b = base; m = middle; h = head; t = tuft; MC = metacarpal; PP = proximal phalanx; MP = middle phalanx; DP = distal phalanx; CV = coefficient of variation = (sd/mean) × 100. Measurements are in millimeters. Table from [13] 0.1 = 10th percentile; 0.5 = 50th percentile (median); 0.9 = 90th percentile

samples of considerable ethnic diversity. Large samples of radiographs of white females and white males form the primary subject, whereas smaller samples of black, Mexican-American, and Oriental males and females serve as comparison groups. (Further information on the Ten State samples appears in [13–16].) Adult individuals 25–40 years of age, inclusive, were measured. In the Oriental male sample, the small number of available radiographs necessitated widening the age range to 15–60 years. The Mexican-American sample was drawn solely from California; the Oriental sample includes individuals from California and Washington only.

Measurements. Measurements were made using a digitizer (Summagraphics; Model ID-TAB-14-TT; 0.1 mm resolution) and were translated to metric values via a computer program. A specially constructed lighting board with six 20-W warm-white General Electric fluorescent bulbs was placed underneath the digitizing board, and a white plastic sheet was placed on top of the digitizer, underneath the radiograph, to improve visual clarity.

Maximum length, from the lowest basal point to the farthest upper point of the head, is measured for metacarpal (MC)1 (see Fig. 1). The two basal processes may overlap the trapezium but are typically well seen even if they do so. MC2 is measured from the identation in the center of the base to the farthest upper point of the head. The basal processes of MC2 are often clear enough, but the indented point is easier to locate, and its use is consistent with previous radiographic studies. MC3 is measured from the center of the head to the base, excluding the styloid process. For all bones, lengths are obtained with reference to the longitudinal axis of the bone.

Distal phalanx (DP)1 length is measured from the tip to the

Table 2. Distribution parameters: American white males ($n=363$)

Distance	Mean	SD	Range	0.1	0.5	0.9	CV
LMC1	48.67	2.78	41.54–57.32	45.36	48.55	52.43	5.72
LPP1	34.44	2.07	28.79–40.90	31.78	34.49	36.93	6.02
LDP1	24.17	1.61	16.73–28.83	22.28	24.24	26.20	6.68
WbMC1	17.53	1.16	14.68–21.47	16.03	17.49	19.03	6.61
WmMC1	10.65	0.93	7.96–13.86	9.53	10.54	11.99	8.71
WhMC1	17.26	1.29	14.26–21.82	15.70	17.20	18.96	7.48
WbPP1	16.16	0.99	13.91–19.03	14.84	16.14	17.40	6.10
WmPP1	8.73	0.75	6.88–11.35	7.79	8.68	9.77	8.64
WhPP1	12.92	0.92	10.32–16.04	11.77	12.92	14.06	7.15
WbDP1	12.85	0.97	10.40–15.68	11.59	12.85	14.13	7.53
WmDP1	6.18	0.85	3.72– 8.49	5.12	6.14	7.32	13.78
WtDP1	8.11	1.16	5.29–11.41	6.58	8.04	9.71	14.33
LMC2	69.51	3.94	58.58–82.10	64.76	69.45	74.48	5.67
LPP2	42.98	2.29	36.95–50.48	39.80	43.08	45.92	5.34
LMP2	24.47	1.69	19.64–29.90	22.36	24.47	26.51	6.91
LDP2	17.68	1.28	13.51–21.32	16.17	17.63	19.29	7.21
WbMC2	20.28	1.21	16.81–24.40	18.82	20.19	21.92	5.97
WmMC2	9.21	0.70	7.26–11.55	8.31	9.23	10.11	7.62
WhMC2	17.04	1.18	14.12–20.91	15.56	16.96	18.60	6.90
WbPP2	17.82	0.95	14.53–21.32	16.64	17.82	19.04	5.33
WmPP2	10.28	0.80	7.92–13.25	9.30	10.23	11.33	7.77
WhPP2	12.86	0.85	10.65–15.53	11.86	12.81	13.93	6.58
WbMP2	13.94	0.86	11.95–16.42	12.90	13.91	15.05	6.15
WmMP2	8.40	0.71	6.70–10.72	7.57	8.33	9.36	8.46
WhMP2	10.53	0.64	8.90–12.40	9.76	10.50	11.38	6.05
WbDP2	10.94	0.73	9.03–12.97	10.07	10.92	11.91	6.70
WmDP2	5.47	0.62	3.44– 7.18	4.69	5.45	6.30	11.38
WtDP2	8.02	0.87	4.94–10.76	6.94	8.02	9.07	10.81
LMC3	67.60	3.73	57.41–79.60	63.11	67.73	72.34	5.52
LPP3	47.69	2.49	40.57–54.80	44.60	47.50	50.94	5.22
LMP3	29.43	1.85	24.73–34.31	26.95	29.57	31.73	6.27
LDP3	18.94	1.31	15.34–22.58	17.33	18.87	20.69	6.94
WbMC3	15.52	0.98	12.92–18.63	14.32	15.46	16.77	6.31
WmMC3	8.98	0.69	6.94–11.08	8.04	9.00	9.82	7.72
WhMC3	17.58	1.07	14.03–20.24	16.20	17.64	18.93	6.10
WbPP3	17.64	0.95	14.44–21.10	16.49	17.57	18.81	5.41
WmPP3	10.72	0.89	8.41–13.97	9.52	10.67	11.93	8.28
WhPP3	13.60	0.87	10.91–16.14	12.52	13.61	14.60	6.37
WbMP3	14.95	0.84	12.50–17.08	13.88	14.96	16.09	5.60
WmMP3	9.01	0.72	6.75–11.50	8.10	8.98	9.90	8.01
WhMP3	11.50	0.67	9.48–13.68	10.73	11.41	12.36	5.80
WbDP3	11.92	0.72	9.57–14.00	11.07	11.88	12.83	6.07
WmDP3	6.06	0.63	4.46– 8.15	5.26	6.07	6.79	10.44
WtDP3	8.95	0.97	5.29–11.74	7.75	8.95	10.14	10.78

Table from [13]

point of intersection with the proximal phalanx (PP) below. (Recall that this phalanx is rotated in standard PA radiographic views; for a study of the effects of thumb rotation on measurement, see [13].) The length of DPs 2 and 3 is taken along the longitudinal axis from the tip to the point below which appears on a line of increased density representing the edge of the base. Maximum lengths of PPs and middle phalanges (MPs) are used. Although interarticular lengths of PPs could be reasonably well approximated, such approximation is not feasible for the intermediate phalanges. Thus, maximum lengths are taken for both.

Maximum widths are taken for bases and heads, and the minimum straight-across distance in between is taken as the measure of minimum width. A complication arises for the maximum base width of MC3, because the ulnar point is usually hidden behind MC4. For this width, the maximum clearly visible projection to the radial side is used as one point while the farthest point not covered by MC4 (the point of intersection of MC3 and 4) is the second point.

Results

Tables 1 through 8 give means and SDs for the 44 variables measured for samples of white females, white males, black females, black males, Mexican-American females, Mexican-American males, Oriental females, and Oriental males. Tables 1 and 2, those for the two large reference samples (white females and white males), also provide medians, 10th and 90th percentiles, ranges, and coefficients of variation ([SD/mean] $\times$ 100) for those variables.

Coefficients of variation of white female and white male distances range from 5.22 for the length of PP3 in males to 14.33 for tuft width of DP1 in males. The highest coefficients of variation are associated with middle and tuft widths of the DPs, presumably due at least

Table 3. Distribution parameters: American black females ($n=76$)

Distance	Mean	SD
LMC1	45.66	3.20
LPP1	32.50	2.48
LDP1	23.33	1.66
WbMC1	15.75	1.12
WmMC1	9.75	0.95
WhMC1	15.10	1.26
WbPP1	14.43	0.83
WmPP1	7.74	0.80
WhPP1	11.48	0.99
WbDP1	11.42	0.95
WmDP1	5.36	0.65
WtDP1	7.16	0.98
LMC2	66.41	4.12
LPP2	41.74	2.62
LMP2	23.18	1.89
LDP2	17.14	1.42
WbMC2	17.64	1.13
WmMC2	8.04	0.53
WhMC2	15.49	1.27
WbPP2	15.92	0.79
WmPP2	9.05	0.71
WhPP2	11.37	0.67
WbMP2	12.60	0.76
WmMP2	7.26	0.73
WhMP2	9.55	0.70
WbDP2	9.80	0.83
WmDP2	4.72	0.74
WtDP2	7.18	0.94
LMC3	64.83	3.96
LPP3	46.63	2.96
LMP3	28.48	2.11
LDP3	18.43	1.49
WbMC3	13.75	0.88
WmMC3	8.11	0.65
WhMC3	16.00	1.07
WbPP3	15.69	0.76
WmPP3	9.21	0.78
WhPP3	12.01	0.83
WbMP3	13.64	0.86
WmMP3	7.89	0.76
WhMP3	10.39	0.82
WbDP3	10.55	0.80
WmDP3	5.21	0.72
WtDP3	7.96	0.88

Table after [13]

Table 4. Distribution parameters: American black males ($n=20$)

Distance	Mean	SD
LMC1	49.75	2.48
LPP1	34.97	2.19
LDP1	25.58	1.74
WbMC1	18.16	1.21
WmMC1	10.95	0.79
WhMC1	17.48	1.05
WbPP1	16.20	0.89
WmPP1	8.78	0.59
WhPP1	13.04	1.00
WbDP1	12.38	0.92
WmDP1	5.72	0.64
WtDP1	7.53	0.92
LMC2	71.15	3.59
LPP2	44.03	2.61
LMP2	24.60	1.76
LDP2	18.53	1.37
WbMC2	20.09	1.47
WmMC2	9.15	0.71
WhMC2	17.28	0.99
WbPP2	17.90	0.68
WmPP2	10.16	0.58
WhPP2	12.70	0.53
WbMP2	13.74	0.77
WmMP2	8.38	0.88
WhMP2	10.52	0.56
WbDP2	10.68	0.61
WmDP2	5.52	0.71
WtDP2	7.92	0.71
LMC3	69.71	3.45
LPP3	50.05	2.90
LMP3	30.21	2.18
LDP3	19.88	1.46
WbMC3	15.43	1.10
WmMC3	9.10	0.75
WhMC3	18.21	1.17
WbPP3	17.72	0.93
WmPP3	10.86	0.93
WhPP3	13.80	1.22
WbMP3	15.20	1.26
WmMP3	9.06	0.81
WhMP3	11.57	0.84
WbDP3	11.94	0.59
WmDP3	6.20	0.65
WtDP3	9.02	0.93

Table after [13]

in part to the small size of these measurements. Coefficients of variation for white females and white males are of similar magnitude.

Length and base width size-order relationships among component bones of the three rays are the same within all samples. Intersample variation is evident for absolute size-order middle width and head or tuft width relationships. If *t*-tests are used to find significant differences between sample pairs, white – black, black – Oriental, and black – Mexican-American pairs produce the greatest number of significant differences among female samples. Across female groups, the head width of MC2 is most often different. White – Oriental, black – Oriental, and Mexican-American – Oriental pairs show the greatest number of male sample differences. For male samples, the length of MC3 is most often different. In general, considering both sexes and all groups together, MC1 head width and PP1 widths are similar across samples, whereas MC3 length, MC3 head width, PP3 midwidth, and DP3 tuft width show the greatest number of differences.

Across all groups, males have a relatively longer thumb ray with respect to the index ray than do females, and their thumb PP is relatively longer with reference to the index PP. The male thumb also tends to be relatively longer than the female thumb in comparison with the index and middle fingers. Considering both sexes together, the length ratios MC3:PP3 and PP3:MC3+MP3 best separate different sample groups.

Discriminant analyses show base widths to be of

Table 5. Distribution parameters: Mexican-American females ($n=$ 25)

Distance	Mean	SD
LMC1	43.72	2.11
LPP1	30.59	1.47
LDP1	21.75	1.17
WbMC1	14.65	0.68
WmMC1	9.03	0.54
WhMC1	14.79	1.03
WbPP1	14.13	0.72
WmPP1	7.61	0.82
WhPP1	11.18	0.76
WbDP1	11.14	0.83
WmDP1	5.45	0.88
WtDP1	6.94	1.17
LMC2	62.42	2.66
LPP2	39.50	1.83
LMP2	22.03	1.37
LDP2	16.13	1.09
WbMC2	17.02	0.58
WmMC2	7.41	0.52
WhMC2	14.41	0.89
WbPP2	15.26	0.78
WmPP2	8.42	0.51
WhPP2	11.07	0.55
WbMP2	12.14	0.53
WmMP2	6.91	0.60
WhMP2	9.24	0.45
WbDP2	9.33	0.42
WmDP2	4.41	0.56
WtDP2	6.63	0.59
LMC3	60.88	2.65
LPP3	43.52	1.90
LMP3	26.41	1.28
LDP3	17.00	1.05
WbMC3	13.26	0.68
WmMC3	7.30	0.56
WhMC3	14.51	0.84
WbPP3	14.74	0.63
WmPP3	8.62	0.52
WhPP3	11.42	0.51
WbMP3	12.94	0.52
WmMP3	7.34	0.62
WhMP3	10.05	0.63
WbDP3	10.24	0.47
WmDP3	4.99	0.61
WtDP3	7.40	0.79

Table after [13]

Table 6. Distribution parameters: Mexican-American males ($n=$ 25)

Distance	Mean	SD
LMC1	49.01	2.45
LPP1	34.59	2.27
LDP1	24.72	1.49
WbMC1	17.43	1.10
WmMC1	10.58	0.90
WhMC1	17.32	1.23
WbPP1	16.11	1.02
WmPP1	8.63	0.84
WhPP1	12.83	0.83
WbDP1	12.78	0.63
WmDP1	5.99	0.64
WtDP1	8.07	0.92
LMC2	68.94	3.60
LPP2	43.48	2.84
LMP2	24.20	1.82
LDP2	17.91	1.48
WbMC2	19.92	1.30
WmMC2	9.01	0.64
WhMC2	16.88	1.33
WbPP2	17.70	0.94
WmPP2	9.99	0.54
WhPP2	12.79	0.72
WbMP2	13.71	0.71
WmMP2	7.99	0.51
WhMP2	10.44	0.63
WbDP2	10.82	0.71
WmDP2	5.37	0.54
WtDP2	7.69	0.68
LMC3	67.07	3.64
LPP3	48.49	2.98
LMP3	29.16	2.12
LDP3	19.03	1.30
WbMC3	15.47	1.12
WmMC3	8.75	0.51
WhMC3	17.39	1.02
WbPP3	17.46	0.96
WmPP3	10.48	0.53
WhPP3	13.69	0.90
WbMP3	15.05	0.58
WmMP3	8.70	0.69
WhMP3	11.49	0.75
WbDP3	11.89	0.74
WmDP3	5.85	0.55
WtDP3	8.49	0.83

Table after [13]

value in separating males from females. In general, lengths appear to be most useful for male sample differentiation, but base widths and midwidths appear to be as good as lengths for female sample differentiation.

By ranking coefficient of variation sequences from high to low, some indication of relative variabilities for these metrics can be gained. From the data of this investigation and those of Garn et al. [5], the PP-MC region of rays 2 and 3 appears least variable in length, whereas DPs and MP2 seem most variable in length. The second PP also tends to show low relative variation in minimum midshaft width and consequently low variation in slenderness, or in length divided by this width (see below).

Table 9 compares Parish's [8] measurements with those of Smith [13]. In addition, it includes values from Smith [13] for DP1 length, midwidth (Wm), and slenderness, DP2 and 3 midwidth and slenderness, and MP2 and 3 length, midwidth, and slenderness. Ranges for differences in mean lengths (SDs; CVs), mean minimum widths (SDs; CVs), and mean slenderness (L/Wm) values (SDs; CVs) for females (Parish – Smith) are −2.3 to 0.6 (−0.50 to 0.09; −0.9 to 0.6), −0.17 to 0.27 (−0.18 to −0.04; −2.0 to −0.6), and −0.40 to −0.05 (−0.17 to −0.04; −2.4 to −0.6), respectively. For males, corresponding ranges are −3.4 to −0.3 (−0.5 to 0.3; −0.7 to 1.3), 0.13 to 0.50 (−0.15 to 0.07; −1.8 to 0.6), and −0.57 to −0.17 (−1.0 to 0; −1.9 to 0.2).

Table 7. Distribution parameters: American Oriental females ($n=23$)

Distance	Mean	SD
LMC1	44.09	2.51
LPP1	31.16	1.87
LDP1	21.12	1.48
WbMC1	14.64	0.91
WmMC1	8.78	0.69
WhMC1	14.64	1.10
WbPP1	14.10	0.87
WmPP1	7.48	0.62
WhPP1	10.94	0.72
WbDP1	11.03	0.60
WmDP1	5.32	0.61
WtDP1	6.69	0.67
LMC2	62.22	3.20
LPP2	40.00	2.17
LMP2	21.99	1.51
LDP2	15.88	0.98
WbMC2	16.88	1.23
WmMC2	7.66	0.54
WhMC2	14.22	1.09
WbPP2	15.16	0.94
WmPP2	8.36	0.57
WhPP2	10.80	0.61
WbMP2	11.83	0.65
WmMP2	6.65	0.48
WhMP2	9.00	0.28
WbDP2	8.93	0.45
WmDP2	4.23	0.50
WtDP2	6.22	0.59
LMC3	59.84	3.35
LPP3	44.14	2.23
LMP3	26.38	1.75
LDP3	16.78	1.06
WbMC3	13.41	0.92
WmMC3	7.21	0.56
WhMC3	14.61	1.06
WbPP3	14.88	0.78
WmPP3	8.47	0.64
WhPP3	11.36	0.75
WbMP3	12.54	0.82
WmMP3	7.08	0.54
WhMP3	9.75	0.49
WbDP3	9.83	0.58
WmDP3	4.73	0.60
WtDP3	6.66	0.59

Table after [13]

Table 8. Distribution parameters: American Oriental males ($n=23$)

Distance	Mean	SD
LMC1	46.86	2.58
LPP1	32.89	1.75
LDP1	22.81	1.46
WbMC1	16.33	1.11
WmMC1	10.26	0.75
WhMC1	17.03	1.28
WbPP1	15.95	1.11
WmPP1	8.76	0.75
WhPP1	12.56	0.91
WbDP1	12.95	1.09
WmDP1	6.68	0.79
WtDP1	8.06	0.94
LMC2	66.19	3.75
LPP2	41.35	2.29
LMP2	23.06	1.46
LDP2	16.62	1.10
WbMC2	18.95	1.35
WmMC2	8.49	0.78
WhMC2	15.93	0.90
WbPP2	16.81	0.82
WmPP2	9.95	0.60
WhPP2	12.03	0.86
WbMP2	13.02	0.86
WmMP2	7.72	0.65
WhMP2	9.91	0.60
WbDP2	10.10	0.68
WmDP2	5.18	0.49
WtDP2	6.85	0.73
LMC3	63.99	3.73
LPP3	45.84	2.37
LMP3	27.57	1.75
LDP3	17.87	1.10
WbMC3	14.62	1.23
WmMC3	8.23	0.90
WhMC3	16.35	0.85
WbPP3	16.32	0.84
WmPP3	9.81	0.69
WhPP3	12.40	0.82
WbMP3	13.76	0.82
WmMP3	8.13	0.86
WhMP3	10.63	0.73
WbDP3	11.21	1.03
WmDP3	5.70	0.72
WtDP3	7.55	1.00

Table after [13]

It should be realized that there are some differences in measurement technique between the Parish and Smith studies.

Discussion

Various syndromes are associated with changed morphology or proportions in the hand (see [10]). Pattern profile analysis is a particularly useful technique for examining the changes in proportions that occur in such syndromes. In its usual form, lengths of metacarpals and phalanges are plotted, employing standard deviation units, relative to age and sex norms. The plot produced provides a graph of relationships among the bones [2–4, 6, 7, 9, 11, 12]. The data presented here can be used to generate that portion of the standard pattern profile plot which involves rays 1–3. However, they can also be used to produce another style of plot (Figs. 2, 3) that includes 44 variables, 11 lengths and 33 widths from the first three hand rays. (Rays 4 and 5 were not measured for the purposes of the larger investigation but could also be of use.)

When pattern profiles are generated employing the 44 length and width variables for the eight samples discussed here, plus two volunteer samples, base widths and head widths generally separate sexes of the same groups better than midwidths, tuft widths, and lengths.

Table 9. Comparative measurements: Parish [8] and Smith [13]

Distance	Parish[a]								Smith							
	Females				Males				White females				White males			
	Mean	SD	Range	CV	Mean	SD	Range	CV	Mean	SD	Range	CV	Mean	SD	Range	CV
LMC1	42.40	2.30	37.00–49.00	5.40	46.20	3.10	40.00–54.00	6.70	43.88	2.59	36.90–53.17	5.90	48.67	2.78	41.54–57.32	5.72
WmMC1	9.04	0.71	7.50–11.00	7.90	10.93	0.88	9.50–13.00	8.10	9.21	0.80	5.90–12.04	8.72	10.65	0.93	7.96–13.86	8.71
SMC1	4.71	0.42	4.00– 5.90	8.90	4.24	0.36	3.50– 5.10	8.50	4.79	0.46	3.58– 6.78	9.50	4.60	0.40	3.42– 5.84	8.69
LPP1	28.50	1.60	25.00–33.00	5.60	31.00	1.70	27.00–35.00	5.50	30.84	1.88	24.80–38.24	6.10	34.44	2.07	28.79–40.90	6.02
WmPP1	7.71	0.63	6.00– 9.50	8.20	9.16	0.73	7.50–10.50	8.00	7.54	0.70	5.58– 9.96	9.23	8.73	0.75	6.88–11.35	8.64
SPP1	3.72	0.34	3.00– 4.50	9.10	3.40	0.30	2.80– 4.10	8.80	4.12	0.42	3.00– 5.75	10.16	3.97	0.35	3.09– 5.04	8.78
LDP1									21.36	1.48	15.52–25.57	6.91	24.17	1.61	16.73–28.83	6.68
WmDP1									5.31	0.73	3.12– 7.58	13.76	6.18	0.85	3.72– 8.49	13.78
SDP1									4.10	0.63	2.63– 6.38	15.45	3.98	0.58	2.32– 6.34	14.60
LMC2	64.00	3.10	58.00–73.00	4.80	68.60	3.40	63.00–78.00	5.00	63.42	3.61	52.97–74.87	5.70	69.51	3.94	58.58–82.10	5.67
WmMC2	7.90	0.57	6.50– 9.00	7.20	9.34	0.77	8.00–11.00	8.20	7.79	0.61	6.11– 9.64	7.84	9.21	0.70	7.26–11.55	7.62
SMC2	8.13	0.60	6.90– 9.70	7.40	7.41	0.59	6.40– 9.10	8.00	8.18	0.68	6.50–11.22	8.28	7.58	0.59	5.87– 9.36	7.80
LPP2	38.10	1.80	34.00–42.00	4.70	41.00	2.00	37.00–46.00	4.90	39.39	2.15	33.42–46.71	5.46	42.98	2.29	36.95–50.48	5.34
WmPP2	9.08	0.52	8.00–10.50	5.70	10.78	0.65	9.50–12.00	6.00	8.81	0.65	6.60–10.76	7.33	10.28	0.80	7.92–13.25	7.77
SPP2	4.20	0.25	3.70– 4.90	6.00	3.80	0.22	3.40– 4.40	5.80	4.49	0.34	3.51– 5.66	7.65	4.20	0.32	3.33– 5.20	7.73
LMP2									22.09	1.61	16.16–27.02	7.30	24.47	1.69	19.64–29.90	6.91
WmMP2									7.11	0.60	5.39– 9.09	8.43	8.40	0.71	6.70–10.72	8.46
SMP2									3.12	0.30	2.14– 3.99	9.47	2.93	0.27	2.23– 3.74	9.34
LDP2	15.84	1.23	13.00–19.00	7.80	17.25	1.43	12.50–20.00	8.30	15.84	1.14	11.96–18.90	7.18	17.68	1.28	13.51–21.32	7.21
WmDP2									4.57	0.57	3.10– 6.61	12.39	5.47	0.62	3.44– 7.18	11.38
SDP2									3.51	0.45	2.28– 5.39	12.77	3.27	0.40	2.40– 4.50	12.14
LMC3	61.70	3.10	56.00–70.00	5.00	66.50	3.20	59.00–75.00	4.80	61.34	3.54	50.21–72.38	5.77	67.60	3.73	57.41–79.60	5.52
WmMC3	7.87	0.53	7.00– 9.00	6.70	9.22	0.71	7.50–10.50	7.70	7.73	0.63	5.54– 9.71	8.12	8.98	0.69	6.94–11.08	7.72
SMC3	7.87	0.53	6.70– 9.40	6.70	7.25	0.55	6.30– 9.10	7.60	7.98	0.70	6.29–11.06	8.75	7.56	0.62	5.83– 9.65	8.22
LPP3	42.00	2.00	38.00–46.00	4.80	45.60	2.20	41.00–51.00	4.80	43.42	2.33	37.54–51.61	5.37	47.69	2.49	40.57–54.80	5.22
WmPP3	9.16	0.60	8.00–10.50	6.60	11.18	0.77	9.00–13.00	6.90	9.02	0.78	6.76–11.10	8.60	10.72	0.89	8.41–13.97	8.28
SPP3	4.59	0.31	4.00– 5.40	6.80	4.10	0.29	3.50– 5.20	7.10	4.85	0.44	3.68– 6.74	9.17	4.47	0.37	3.37– 5.63	8.35
LMP3									26.71	1.79	20.92–33.42	6.69	29.43	1.85	24.73–34.31	6.27
WmMP3									7.63	0.61	5.59– 9.36	8.03	9.01	0.72	6.75–11.50	8.01
SMP3									3.52	0.30	2.64– 4.71	8.50	3.28	0.28	2.49– 4.36	8.40
LDP3	17.15	1.23	14.00–20.00	7.20	18.64	1.53	13.00–21.00	8.20	16.90	1.15	13.12–20.16	6.82	18.94	1.31	15.34–22.58	6.94
WmDP3									5.03	0.54	3.38– 6.81	10.76	6.06	0.63	4.46– 8.15	10.44
SDP3									3.39	0.39	2.39– 4.80	11.57	3.16	0.35	2.39– 4.57	10.98

Wm = minimum midshaft width; S = slenderness (L/Wm); CV = coefficient of variation
Table from [13]
[a] From left-hand tables

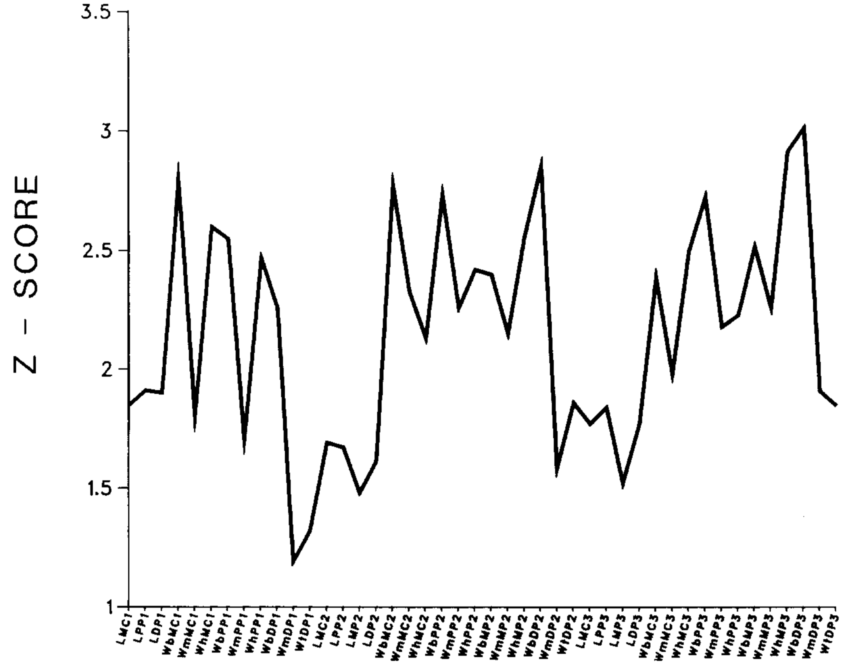

Fig. 2. An example of a type of pattern profile that can be drawn from the data of Smith [13]. In this case, American white males are plotted with reference to American white females. White males are from 1.2 to 3.0 Z-scores larger than white females, with several base widths forming prominent high points in the pattern. From Smith [13]

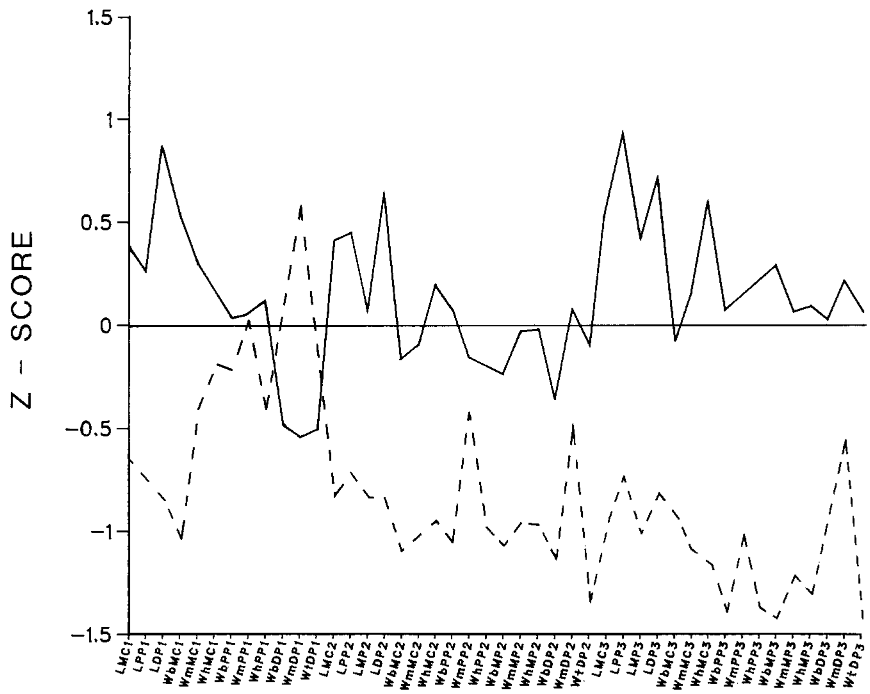

Fig. 3. In this pattern profile American black (*solid line*) and American Oriental (*dashed line*) males are plotted with reference to American white males. Note that the hands of black males are not only larger than those of Oriental males but also show many patterning differences from them

For example, in Fig. 2 a pattern profile for white males is shown. The values obtained from the white male sample are plotted in Z-scores against those from the white female sample. The males range from 1.19 to 3.02 SD units above the females. The least difference occurs in the midwidth of DP1; the greatest, in the base width of DP3. Base widths of MCs 1 and 2, PPs 2 and 3 and DPs 2 and 3, together with the width of the head of MP3, form prominent high points, indicating variables of greatest difference between the sexes. Lengths of MPs 2 and 3, midwidths of DPs 1 and 2, and tuft width of DP1 are low points.

The variables best separating white females from other female groups and white males from other male groups depend upon the particular groups being compared. Furthermore, relationships among the male groups differ from those among the female groups. That is, variables best separating a female sample from the white female reference are not the same in all cases as those best separating the respective male sample from the white male reference. The pattern profiles most alike for females with reference to white females are those of Orientals and Mexican-Americans; those most different, again with reference to white females, are of the volunteers and Mexican-Americans. The patterns most alike among the males, with respect to white males, are for the Mexican-American and black groups, while those most different are for Oriental and black groups. Also, for both sexes, the best differentiating variables come from a variety of length and width metrics.

These results indicate that although there are similarities in the ways that groups divided by sex pattern against one another, there is also a large degree of variation; thus there are no universally applicable rules. Individual groups must be analyzed on a case-by-case basis. These results further indicate that variables useful for some discriminations are of lesser value in others.

Why should investigations of hand proportions add widths to the battery of measurements? The clinical usefulness of width metrics has yet to be fully tested, but it may well prove that for some conditions width metrics are diagnostically as useful as or more useful than lengths or that a combination of length and width metrics provides the best clinical measure. Research employing these widths should be conducted to pinpoint the most useful variables for common syndromes.

In fact, some use of length-width proportions has been in effect for more than 2 decades. Parish [8] measured radiographic lengths and widths of the 1 through 5 MCs and PPs plus the lengths of DPs 2–5 in a study designed to provide a standard methodology of measurement for use in clinical work. Even before that time, a figure termed the "relative slenderness" of a bone was being used diagnostically, based on the observation that when a metacarpal or phalangeal length is divided by its shaft width, a relatively constant value results for each bone for normal individuals (see [8]). Poznanski [10], using Parish's data, notes that slenderness ratios are significantly abnormal in Marfan's syndrome but that the typical length pattern profile displays little deviation from normal except for relatively short DPs in combination with relatively large hand bones. It is suggested as an example that a pattern profile including widths might provide increased diagnostic power for this syndrome.

For the best results, the ethnicity of the samples should match those of the patients being evaluated. It has already been realized that clinical diagnosis via pattern profiles needs to take into account population differences in hand proportions (e.g., see [1]). For example, in Fig. 3 the black and Oriental male samples are plotted with reference to white males. A short DP of the thumb is seen in many disorders [10], so we may profitably examine this bone. Note that the length of DP1 for Oriental males is below the white reference, with a Z-score of -0.84, while that for black males is above this reference, with a Z-score of 0.88. The total range here is 1.72 SD units. In contrast, note that the range for base width of DP1 is smaller – only 0.58 units – and that for this variable black males are somewhat below the white reference while Oriental males are slightly above. Thus, DP thumb length and overall shape differ by population group. Also, as previously discussed, DPs, while absolutely long in Marfan's syndrome, are relatively short. Since DPs in the black sample are relatively long, if a black individual were plotted with a white sample as the reference group, a proportionately greater reduction would be needed to make this evident.

In summary, pattern profiles that incorporate widths and are population-specific are expected to increase diagnostic precision. The large white female and male groups reported here can be used as normal references against which to compare white female and white male patients. The black female sample is reasonably large and is an adequate reference sample for black females for most purposes. The other groups have smaller sample sizes, so their use as standards is not fully justified. However, they do provide an indication, used in conjunction with the larger white male and female samples, of the sorts of sample differences to be expected when evaluating patients of American black, Mexican-American, and Oriental-American extraction. Further research should be conducted to investigate the degree to which intersample differences affect diagnostic results.

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