C. H. Lin,[1] *LL.M.; J. H. Liu,*[1] *Ph.D.; J. W. Osterburg,*[1] *M.P.A.; and J. D. Nicol,*[1] *M.S.*

Fingerprint Comparison. I: Similarity of Fingerprints

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ABSTRACT: Fingerprints from 61 pairs of male monozygotic twins (MZ), 47 pairs of female MZ, 40 pairs of same-sex male dizygotic twins (DZ), 44 pairs of same-sex female DZ, 4 pairs of opposite-sex DZ, and 28 brothers and 31 sisters of those twins are used for the study of fingerprint similarities. Similarities of fingerprint pattern, ridge count, and minutiae are evaluated for two population groups genetically related to each other in different degrees. It is concluded that fingerprint similarities, including pattern, ridge count, and possibly minutiae, between MZ individuals are significantly higher than those between other population groups, including DZ twins.

KEYWORDS: criminalistics, fingerprints, human identification, pattern, ridge count, minutiae, monozygotic twin, dizygotic twin

Earlier studies on papillary patterns of human fingers were reviewed by Bonnevie [*1*]. It was concluded as early as 1892 by Galton [*2*] that fingerprint patterns are inheritable. Wilder [*3*] further concluded in 1919 that monozygotic twins (MZ) were found to be strikingly alike with regard to the occurrence of patterns. However, he stated: "The correspondence in the friction-skin configuration is confined to the general plan of the surface as a whole and does not extend in the least to the fingerprint details, the 'minutiae' of Galton" [*3*]. These dermatoglyphic findings were later widely applied in studies of twins [*4,5*]. Based on the studies of inherited patterns and pattern sequences in ten fingers, a genetic theory was developed by Slatis et al [*6*]. Recently, an interesting minutiae-count study [*7*] on the calcar area of the sole indicated a higher correlation coefficient between monozygotic twins in comparison with dizygotic twins (DZ).

From a criminalist's viewpoint, the fact that there are no identical fingerprints has rendered the characterization of fingerprints the best method of personal identification. However, the similarity of fingerprints, especially those of twins, in pattern and ridge count and the possible similarity in minutiae may pose problems in the identification of incomplete, smudged, or vague latent fingerprints. On the other hand, inherited similarity may provide additional information to help adjudicate questions of paternity [*8*].

The purpose of this study is to examine the similarity of fingerprints (by pairs) in the following populations: MZ twins, same-sex DZ twins, opposite-sex DZ twins, same-sex siblings, opposite-sex siblings, and an unrelated population. The similarities compared include three classes of fingerprint characteristics: ridge pattern, ridge count, and Galton minutiae. Perhaps the most important question that needs to be answered is whether there is any

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[1]Graduate student, assistant professor, professor, and professor, respectively, Department of Criminal Justice, University of Illinois at Chicago Circle, Chicago, IL 60680.

similarity in the minutiae of fingerprints. If there are similarities, to what extent do they exist? Can these similarities lead to fingerprint misidentification, especially in regard to a partial fingerprint?

Experimental Procedure

The data base used for this study includes 196 pairs of MZ and DZ twins and 59 brothers and sisters of these twins (as classified in Table 1). For example, there are 44 pairs of same-sex female DZ twins and 4 pairs of opposite-sex DZ twins. With this data base, the possible types of comparison and the maximum number of pairing in each type without duplication or bias are shown in Table 2. There are eleven possible types of pairings. The maximum number of pairings is obvious for Type 1 through Type 5. The maximum number of other types of pairings is limited by the consideration that only one sibling can be selected for comparison. This consideration is based on the assumption that there may be similarities between the fingerprints of twins or other siblings. Once one of them is selected for com-

TABLE 1—*Data base used for fingerprint comparison.*

Zygotics	Number of Pairs	Number of Male Siblings[a]	Number of Female Siblings[a]
MZ			
Male	61	5	9
Female	47	9	9
DZ			
Same sex, male	40	4	5
Same sex, female	44	9	7
Opposite sex	4	1	1
Total	196	28	31

[a]The sibling whose age is nearest to that of the subject twin was selected for comparison.

TABLE 2—*Types and numbers of pairing of persons (not fingers).*

Relationship	Type	Maximum Possible Number of Pairings
MZ		
Male	1	61
Female	2	47
DZ		
Same sex, male	3	40
Same sex, female	4	44
Opposite sex	5	4
Sibling		
Same sex, male	6	10[a]
Same sex, female	7	17[a]
Opposite sex	8	34[a]
Unrelated population[b]		
Same sex, male	9	52[a]
Same sex, female	10	47[a]
Opposite sex	11	95[a]

[a]See Ref *9*.
[b]These samples were obtained by pairing fingerprints listed in Table 1.

parison, the use of the others would bias the result and degrade the randomness. A detailed description of the procedure used in arriving at the number of pairings listed in Table 2 is described elsewhere [*9*].

All possible pairings of fingerprints in the data base shown in Table 2 are used for pattern comparison. Fingerprints are classified into eight patterns [*10-12*]: plain arch (A), tented arch (T), ulnar loop (U), radial loop (R), plain whorl (W), central pocket loop (C), double loop (D), and accidental (X).

At the conclusion of the pattern comparison, those fingerprints having the same patterns in the corresponding fingers are selected for the comparison of ridge counts. The selected data base is shown in Table 3. Ridge counts are defined as follows [*10-12*]: plain arch and tented arch have no ridge count and are coded as zero; ulnar loops and radial loops are counted in accordance with the Henry System [*10*]; plain whorl, central pocket loop, and accidental are counted from the right delta for left-hand fingers and from the left delta for right-hand fingers; and double loop is counted from the delta to the core of the upright loop. If the two loops of a double loop are horizontal, the core that gives a lower ridge count is used. With the exception of plain and tented arches, all finger pairs having the same patterns are used in this comparison.

The last part of this study compares the similarity of minutiae in fingerprints. The criterion used in selecting a data base for this comparison is that only fingerprints having the same pattern and same ridge count from MZ groups will be considered. Since the major interest of this study is to investigate the highest possible level of fingerprint similarity (and, therefore, the possibility of fingerprint misidentification), only fingerprints from the MZ group are employed in this part of the study. This selection is based on a reasonable assumption that if there are going to be any identical (or closely related) fingerprints in terms of minutiae characteristics, they would most likely be found in the comparisons among an MZ twin population. The number of fingerprint pairs that meet this criterion are listed in Table 4. Because of the lengthy process of minutiae coding, only 38 pairs of fingerprints were arbitrarily selected and are listed in Table 5. For this comparison, minutiae are classified into nine types: ending ridge, short ridge, dot, fork, spur, double bifurcation, eye, broken ridge,

TABLE 3—*Number of fingerprint pairs with matching patterns (data base used for fingerprint ridge count comparison).*

	Number of Pairs of Fingerprints									
Relationship	A[a]	T[a]	U	R	W	C	D	X	Total	%
MZ										
Male	4	1	234	5	288	1	1	0	534	87.5
Female	2	0	208	2	207	0	2	0	413	87.9
DZ										
Same sex, male	0	0	112	3	125	0	4	0	244	61.0
Same sex, female	1	2	126	1	132	1	2	0	265	60.2
Opposite sex	0	0	9	0	8	0	0	0	17	42.5
Sibling										
Same sex, male	0	0	30	1	14	0	2	0	49	49.0
Same sex, female	2	0	52	0	31	0	1	0	86	50.6
Opposite sex	0	0	82	1	72	0	3	0	158	46.5
Unrelated population										
Same sex, male	0	0	111	1	150	0	1	0	263	50.6
Same sex, female	0	0	95	0	102	1	0	0	198	42.1
Opposite sex	0	0	191	1	236	0	0	0	428	45.1

[a]Patterns A and T are used for matching patterns but are not used for ridge count comparisons.

TABLE 4—*Number of pairs of fingerprints with the same pattern and ridge count (data base for minutiae comparison).*

Relationship	Number of Pairs of Corresponding Fingerprints							Pairs of Fingers Used[a]	%
	U	R	W	C	D	X	Total		
MZ									
Male	35	1	41	0	3	0	80	529	15.1
Female	27	0	33	0	1	0	61	411	14.8
DZ									
Same sex, male	14	0	12	0	0	0	26	244	10.7
Same sex, female	11	0	11	0	0	0	22	262	8.40
Opposite sex	0	0	0	0	0	0	0	17	0
Sibling									
Same sex, male	1	0	2	0	0	0	2	49	4.08
Same sex, female	4	0	2	0	0	0	6	84	7.14
Opposite sex	7	1	4	0	0	0	12	158	7.59
Unrelated population									
Same sex, male	6	0	12	0	0	0	18	263	6.84
Same sex, female	1	0	6	0	0	0	7	198	3.54
Opposite sex	11	0	15	0	0	0	27	428	6.31

[a]Patterns A and T were discarded because of undefined ridge count. For example, of the total 534 pairs of MZ males, we use only 529 since 4 A's and 1 T have no ridge counts and must be subtracted (534 − 4 − 1 = 529).

TABLE 5—*Number of pairs of fingerprints chosen as the data base for minutiae comparison.*

Pattern	Ridge Count						Total
	1-5	5-10	11-15	16-20	21-25	26-30	
U	4	2	7	2	1	0	16
R	1	0	0	0	0	0	1
W	0	0	9	8	1	0	18
C	0	0	0	0	0	0	0
D	0	0	0	1	1	1	3
X	0	0	0	0	0	0	0
Total	5	2	16	11	3	1	38

and angle ridge. Definitions, method of coding, and the comparison mechanism are detailed in Ref *13*.

Results and Discussion

In principle, there are three different ways [*4*] of comparison. Hands can be paired bilaterally (left and right hands of the same person), homolaterally (same-side hands of a pair), and heterolaterally (left of A with right of B, and right of A with left of B). It has been shown [*4*] that the degree of bilateral asymmetry is similar in MZ, DZ, and single-borns; that homolateral difference increases as the genetic relationship of the pairs decreases; and that heterolateral differences are greater but follow the pattern of homolateral difference. Since this study is based on determining the possibility of a criminalist's misidentifying fingerprints from two different individuals, homolateral comparisons are used for the comparisons of pattern and ridge count.

Pattern Comparison

The number and percentage of pairs of fingerprints found (by group) to have the same patterns are listed in the last two columns of Table 3. To read these results, one should refer to appropriate rows in the last column of Table 2. For example, there are 534 of 610 pairs (or 87.5%) of fingerprints in the male MZ group that match in pattern comparison.

The most significant result is the high degree of pattern similarity in MZ groups. Same-sex DZ groups also show significantly higher similarities. No significant difference in pattern similarities is observed in the comparison of other groups. The result obtained on the opposite-sex DZ group was unanticipated. However, this may merely be a result of the small population in this group.

Ridge Count Comparison

Except for A and T categories, all fingerprint pairs that have matched patterns (Table 3) are listed in Table 4 (second column from the right). These pairs are used for comparison of ridge count.

Results listed in the last column of Table 4 indicate that MZ groups have a significantly higher percentage of fingerprint pairs that match in ridge count. Since matches in both pattern and ridge count represent a high degree of similarity, it is reasonable to speculate that

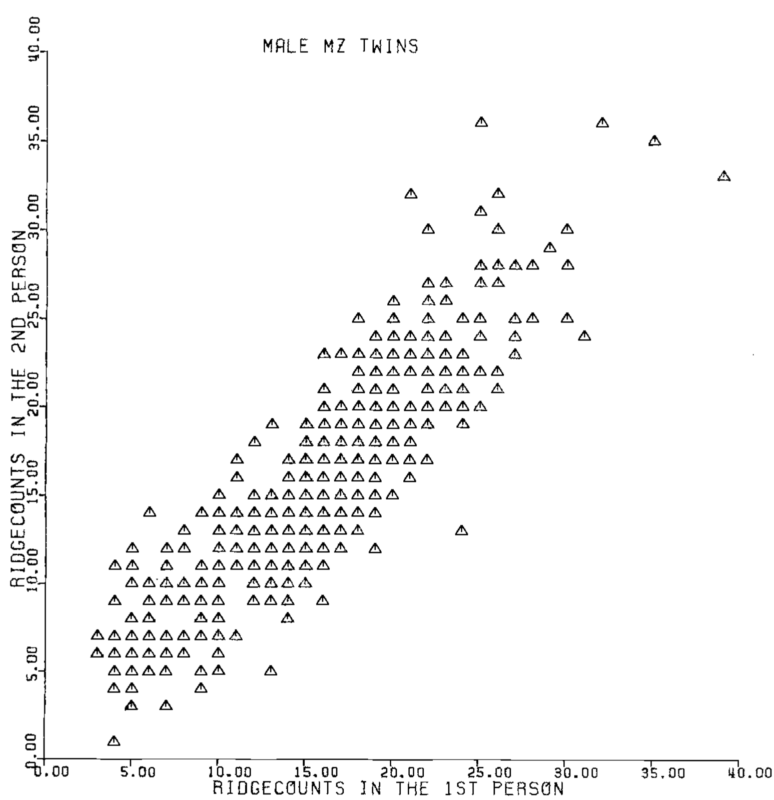

FIG. 1—*Ridge count correlation of fingerprints from male MZ twin group.*

the MZ group will be distinctly different from the other groups in other respects, for example in similarity of minutiae. A further comparison of ridge counts is made by plotting the ridge counts in corresponding fingers. Representative correlations are shown in Figs. 1 through 4. All correlation coefficients are listed in Table 6. It appears that correlation decreases in the following order:

1. MZ male and MZ female,
2. DZ same-sex male and DZ same-sex female,
3. DZ opposite-sex,
4. sibling same-sex male, sibling same-sex female, and sibling opposite-sex, and
5. unrelated population same-sex male, unrelated population opposite-sex, and unrelated same-sex female.

Minutiae Comparison

Table 7 summarizes the results of the comparison of minutiae using the data base listed in Table 5. With the matching mechanism described in Ref *13*, similarities in minutiae in two fingerprints are measured by numbers of minutiae matched or by the scores accumulated from these matches. The former measurement treats each type of minutia equally; the latter measurement gives different minutiae different weights depending on their frequency of occurrence.

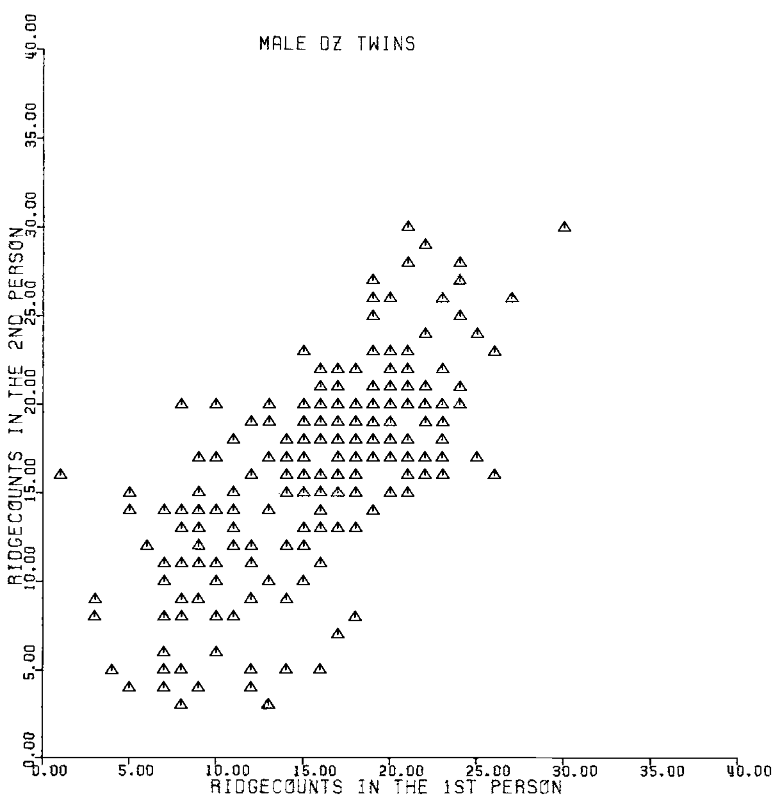

FIG. 2—*Ridge count correlation of fingerprints from male DZ twin group.*

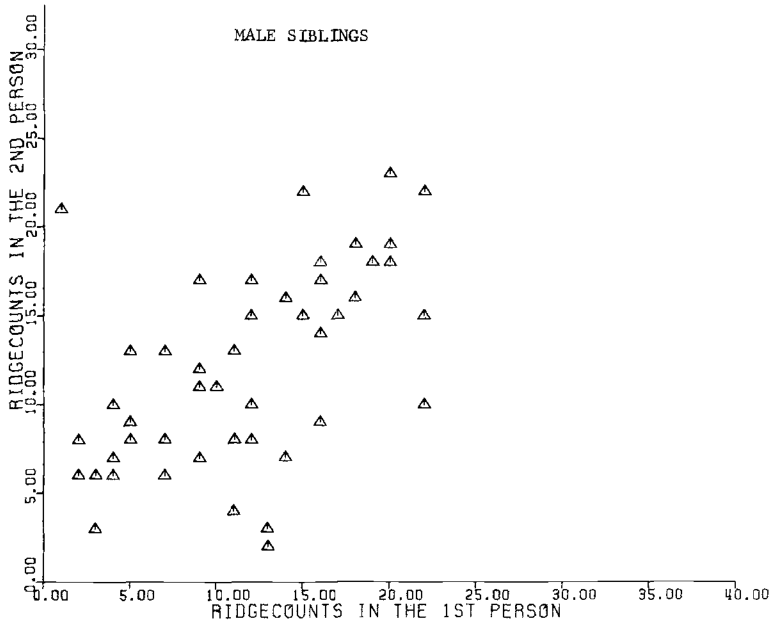

FIG. 3—*Ridge count correlation of fingerprints from male sibling group.*

TABLE 6—*Correlation of ridge count in corresponding fingers.*

Relationship	Number of Total Data	Number[a] of A and T	Number Used	Correlation Coefficient
MZ				
Male	534	5	529	0.89
Female	413	2	411	0.88
DZ				
Same sex, male	244	0	244	0.70
Same sex, female	265	3	262	0.71
Opposite sex	17	0	17	0.57
Sibling				
Same sex, male	49	0	49	0.49
Same sex, female	86	2	84	0.51
Opposite sex	158	0	158	0.48
Unrelated population				
Same sex, male	263	0	263	0.38
Same sex, female	198	0	198	0.29
Opposite sex	428	0	428	0.37

[a]Patterns A and T were not used because of undefined ridge count.

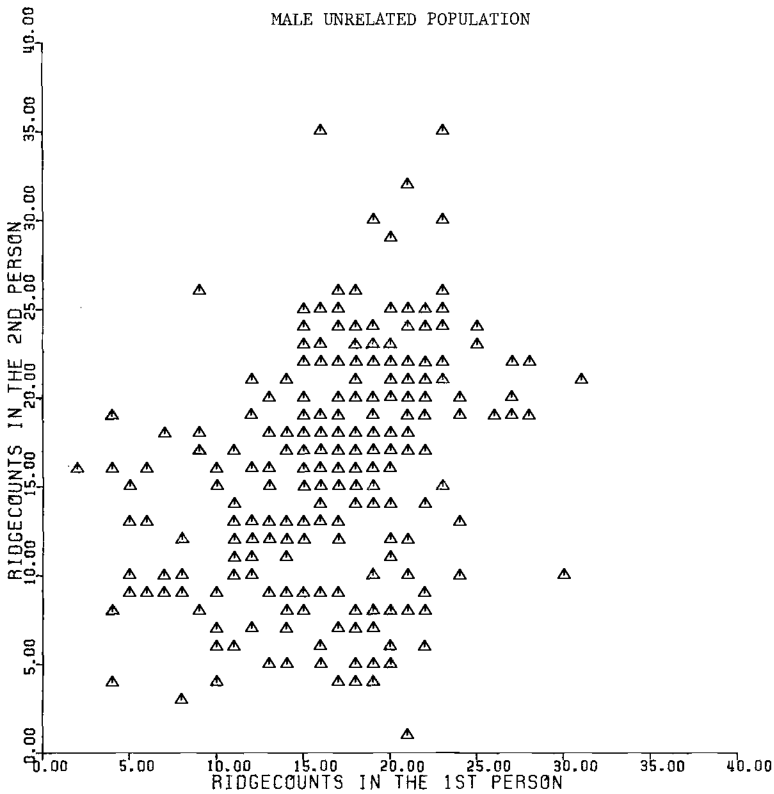

FIG. 4—*Ridge count correlation of fingerprints from male unrelated population group.*

The entries in the second column of Table 7 are the numbers of minutiae coded for each fingerprint. These numbers also represent the maximum possible numbers of minutiae that can be matched. The maximum possible matching scores depend on types of minutiae coded and are listed in the third column of Table 7.

The similarity of minutiae measured by the number of minutiae matched are recorded in Columns 4 through 6 of Table 7. Entries in Column 4 are the numbers of minutiae matched when compared to their twin. Entries in Columns 5 and 6 are the average and standard deviation, respectively, obtained by comparing to the remaining 74 fingerprints in the data base. The average values are then compared to the results obtained for the values of the twin. Because the 74 fingerprints belong to 37 pairs of twins, they are separated into two groups of 37 for the calculation of average and standard deviations. Columns 7 through 9 are parallel to Columns 4 through 6, but matching scores are used as the basis of measurement. Entries in the last column of Table 7 are the score rank of the twin in relation to the remaining 74 fingerprints.

The last column of Table 7 indicates that the following pairs of fingerprints are highly similar: 3-4, 9-10, 23-24, 33-34, 43-44, 49-50, 57-58, 59-60, 67-68, 69-70, 73-74, and 75-76. Visual comparison, in addition to the (matching) scores, indicates that the most similar pair is fingerprints 9 and 10. These two fingerprints are shown in Fig. 5.

Number of minutiae (Column 5) and matching score (Column 8) obtained from the two groups of 37 fingerprints are not statistically different from each other. However, the data of these (two) parameters obtained by comparing twins are significantly different from that ob-

TABLE 7—*Results of minutiae comparison.*

1	2	3	4	5	6	7	8	9	10
			No. of Minutiae Matched			Scores of Matching			
				With Others[b]			With Others[b]		
Print No.[a]	No. of Minutiae Coded	Maximum Possible Score	With Twin	Avg[c]	SD[c]	With Twin	Avg	SD	Score Rank of Twin
1	79	115.318	26	19.6	6.48	30.566	25.100	5.901	15
				20.5	8.61		24.150	6.525	
2	70	98.234	22	18.8	7.85	30.566	22.560	6.127	12
				20.1	6.65		23.346	5.575	
3	83	128.856	31	21.7	6.79	38.306	24.488	6.234	1
				21.5	6.50		25.007	5.736	
4	75	106.436	31	22.7	5.38	37.739	24.649	5.774	3
				21.3	7.32		26.477	5.561	
5	43	55.359	19	18.0	8.36	24.376	18.070	4.494	12
				17.4	7.56		19.315	5.081	
6	52	72.982	18	18.1	7.52	22.376	18.177	4.810	21
				17.8	7.57		20.719	5.403	
7	65	92.738	31	20.4	4.10	41.317	23.197	5.117	2
				21.5	3.85		24.761	5.126	
8	94	137.932	32	26.4	5.46	40.593	30.961	7.029	13
				28.5	7.08		34.176	9.406	
9	106	167.144	38	22.1	6.41	50.475	25.414	8.147	1
				22.1	6.40		25.752	8.187	
10	74	104.138	38	24.0	5.71	50.475	26.989	6.584	1
				25.2	5.87		29.098	6.961	
11	92	123.436	24	27.1	7.10	27.793	30.696	7.681	52
				28.6	6.95		32.234	8.096	
12	56	76.835	25	19.8	4.66	28.809	22.925	5.433	16
				21.4	4.17		24.923	5.164	
13	94	129.027	35	28.1	7.04	40.749	32.252	7.828	13
				29.4	6.25		33.795	7.421	
14	77	110.908	35	25.1	6.19	40.747	29.137	7.529	4
				25.1	5.97		29.023	7.325	

15	58	80.502	23	14.5	4.73	28.502	17.543	5.788	5
				15.6	5.12		19.308	6.604	
16	86	119.303	24	26.2	5.93	30.085	31.005	6.663	41
				26.3	5.53		29.760	6.387	
17	102	128.220	41	27.9	7.33	45.493	30.980	7.455	4
				28.0	7.21		30.520	8.392	
18	119	171.172	38	27.6	6.79	42.446	32.067	7.720	9
				28.5	7.01		33.004	8.509	
19	46	56.847	23	17.6	4.72	23.926	19.892	4.627	20
				18.4	3.95		20.299	4.772	
20	60	84.906	24	19.6	3.69	24.941	22.595	4.969	30
				20.7	3.94		24.151	5.006	
21	56	71.824	22	19.5	3.83	26.202	21.471	4.435	18
				20.2	5.04		21.974	5.876	
22	51	71.730	22	17.4	3.54	26.202	19.001	3.488	7
				18.7	3.71		21.021	4.765	
23	81	116.723	36	23.4	6.58	44.575	27.316	7.310	3
				26.0	6.19		30.230	8.092	
24	79	109.253	37	23.1	4.60	45.591	27.444	5.289	1
				24.6	4.54		29.206	5.825	
25	37	50.330	11	13.6	3.28	13.141	15.384	3.918	58
				14.2	3.06		15.467	3.659	
26	34	43.431	8	11.7	3.15	9.109	12.764	3.512	66
				12.2	2.58		13.673	3.005	
27	55	79.043	16	16.3	3.96	17.384	18.141	4.617	43
				16.9	3.87		19.333	4.608	
28	37	45.707	14	13.4	4.00	15.353	14.329	4.456	27
				13.8	3.49		15.284	3.936	
29	63	93.295	21	19.1	4.69	29.449	22.401	6.308	14
				19.0	4.95		22.189	6.812	
30	48	69.777	22	15.9	3.63	30.464	18.607	5.148	4
				17.7	3.78		21.361	5.281	
31	83	126.978	24	23.6	5.31	30.770	28.306	7.448	27
				23.0	5.05		28.087	7.259	
32	84	114.920	27	27.8	6.01	32.832	31.728	7.165	34
				28.1	5.52		32.381	7.100	
33	84	127.554	44	22.1	5.89	61.055	26.058	7.422	1
				22.1	5.30		26.009	7.016	

TABLE 7—*Continued.*

1	2	3	4	5	6	7	8	9	10
			No. of Minutiae Matched			Scores of Matching			
				With Others[b]			With Others[b]		
Print No.[a]	No. of Minutiae Coded	Maximum Possible Score	With Twin	Avg[c]	SD[c]	With Twin	Avg	SD	Score Rank of Twin
34	100	144.346	42	27.7	7.68	59.024	32.876	9.585	1
				28.4	6.40		33.847	7.775	
35	60	83.642	25	21.6	4.68	32.131	24.603	6.150	8
				20.9	5.55		24.667	6.746	
36	63	88.431	24	21.2	4.90	31.116	24.522	5.712	14
				23.2	5.75		27.199	7.724	
37	55	70.935	31	21.5	4.41	35.859	23.442	5.048	2
				21.2	4.82		23.471	5.554	
38	70	90.324	28	23.8	4.72	32.812	26.308	5.020	13
				24.8	5.78		27.516	6.715	
39	69	99.415	26	21.8	5.09	35.026	25.012	6.127	7
				21.7	5.23		25.374	6.120	
40	75	103.407	26	24.7	4.89	34.119	28.683	6.172	19
				25.6	5.35		28.795	5.858	
41	93	116.483	31	27.3	6.60	33.223	29.641	7.427	25
				27.8	6.69		29.859	7.394	
42	85	114.251	32	26.2	5.89	34.239	29.283	6.863	17
				25.9	5.83		28.747	6.139	
43	87	110.730	48	28.9	7.90	53.589	32.272	7.437	1
				30.2	5.87		33.945	6.795	
44	102	131.727	46	33.3	6.32	51.558	37.418	7.051	3
				34.4	7.39		38.532	9.274	
45	91	116.105	38	29.7	7.61	41.429	33.058	8.544	16
				29.9	8.05		33.169	8.974	
46	74	96.259	39	24.5	5.88	42.445	26.450	6.465	1
				25.7	5.47		27.702	5.781	
47	54	76.892	26	18.1	5.32	28.525	20.535	6.124	11
				19.1	4.94		21.914	6.016	

48	77	103.884	25	26.4	6.74	27.509	30.022	7.871	47
				27.0	5.68		30.771	7.478	
49	98	129.304	39	29.8	6.53	45.327	33.328	7.230	3
				30.1	6.57		33.867	7.717	
50	91	127.384	42	27.2	5.81	48.374	30.427	6.386	1
				28.2	6.84		32.415	8.010	
51	69	104.813	26	22.0	5.30	33.033	25.662	6.426	13
				22.2	6.33		25.935	8.196	
52	62	89.663	26	19.0	4.75	32.126	21.864	6.393	4
				19.3	4.87		22.600	6.173	
53	73	95.371	23	22.5	5.05	26.937	25.545	6.236	39
				24.8	6.18		27.572	7.273	
54	64	83.092	24	20.8	4.83	27.953	22.601	5.519	24
				22.2	5.22		25.004	6.205	
55	67	88.004	24	23.2	5.70	26.643	26.099	6.290	41
				24.2	5.08		27.695	6.022	
56	61	88.834	24	21.5	4.63	27.211	24.750	5.485	26
				21.4	4.63		24.606	5.681	
57	108	149.353	48	29.0	6.64	53.884	32.859	7.371	1
				29.0	7.87		32.614	8.659	
58	128	173.185	48	30.7	8.67	53.884	34.253	9.990	4
				31.2	8.92		34.869	10.612	
59	69	82.917	44	19.7	7.62	47.372	21.339	8.388	1
				20.2	7.72		21.680	8.376	
60	102	133.438	44	28.0	8.69	47.372	31.646	10.002	5
				28.0	7.64		31.923	9.109	
61	67	85.414	29	24.4	5.96	32.591	27.019	6.686	21
				24.9	6.24		28.286	7.250	
62	59	80.361	28	23.1	4.93	31.575	26.575	5.909	17
				24.1	5.14		27.929	6.261	
63	68	85.557	32	23.2	6.36	37.175	25.873	7.273	6
				24.1	6.37		26.914	7.543	
64	72	96.737	32	24.1	5.08	37.175	27.567	6.193	8
				25.9	5.67		30.649	6.792	
65	68	84.651	31	21.9	6.63	35.154	24.338	7.590	6
				22.2	6.23		25.050	7.009	
66	94	127.110	29	27.1	6.00	33.123	30.609	6.846	31
				28.2	6.32		31.942	7.369	

TABLE 7—*Continued.*

1	2	3	4	5	6	7	8	9	10
			No. of Minutiae Matched			Scores of Matching			
				With Others[b]			With Others[b]		
Print No.[a]	No. of Minutiae Coded	Maximum Possible Score	With Twin	Avg[c]	SD[c]	With Twin	Avg	SD	Score Rank of Twin
67	56	72.312	33	19.4	5.12	39.049	22.032	6.032	1
				19.6	4.60		22.387	5.466	
68	71	93.520	33	23.5	5.94	39.049	26.173	7.051	4
				24.4	5.18		27.591	6.017	
69	66	96.536	30	20.1	4.84	38.426	24.460	6.154	2
				21.1	5.50		26.655	7.420	
70	75	108.847	29	21.3	4.47	37.410	25.024	5.612	3
				21.8	5.19		26.662	6.692	
71	85	116.983	35	27.0	6.28	41.549	30.715	6.954	8
				29.0	6.63		33.174	7.455	
72	79	115.262	32	21.2	6.33	38.503	24.573	7.578	7
				23.3	6.67		27.519	7.873	
73	91	120.607	43	23.7	6.78	52.068	26.485	7.598	1
				24.4	7.19		27.935	8.528	
74	77	108.703	41	20.2	5.70	50.037	23.739	7.027	1
				21.1	6.61		25.006	7.720	
75	109	152.210	44	24.7	8.46	54.848	27.911	9.630	2
				25.3	9.03		28.923	10.491	
76	103	149.680	46	25.5	6.62	56.880	30.350	7.971	1
				26.7	6.51		32.039	7.756	

[a]Numbers 1 and 2, 3 and 4, 5 and 6, and so on, are pairs of twins.
[b]Two groups of 37 fingerprints are used in the calculation of average and standard deviation. See text.

FIG. 5—*Fingerprints 9 and 10: the best matching prints of twins.*

tained by comparing other fingerprints in the data set. This is shown by the significant differences between entries in Columns 4 and 5 and between entries in Columns 7 and 8. For example, in comparing Person 1 with his twin (Person 2), there are 26 minutiae matched with a score of 30.566; the corresponding values obtained in comparison with the two groups (who are twins to each other) of 37 persons are 19.6, 25.100 and 20.5, 24.150.

These results demonstrate, in most cases, that minutiae similarities between same-pattern and same-ridge count fingerprints from MZ twins are significantly higher than minutiae similarities between random pairs of fingerprints. Whether these similarities are associated with pattern and ridge count or result from a genetic relationship is not clear at this stage. Further study will be directed toward the comparison of minutiae in same-pattern and same-ridge count fingerprints of MZ groups with those of a random population. This proposed study will separate the pattern ridge count parameter from the genetic relationship parameter.

It is also clear that although fingerprints may have a high degree of similarity, as shown in Fig. 5, variations in minutiae distribution still permit their differentiation.

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References

[1] Bonnevie, K., "Studies on Papillary Patterns of Human Fingers," *Journal of Genetics*, Vol. 15, No. 1, 1925, pp. 1-111.

[2] Galton, F., *Finger Prints*, Da Capo Press, New York, Reprint Edition, 1965.

[3] Wilder, H. H., "Physical Correspondence in Two Sets of Duplicate Twins," *Journal of Heredity*, Vol. 10, 1919, pp. 410-420.

[4] MacArthur, J. W., "Reliability of Dermatoglyphics in Twin Diagnosis," *Human Biology*, Vol. 10, No. 12, 1938, pp. 12-35.

[5] Lin, R-S., Chiu, F-Y., and Chen, K-P., "A Preliminary Twin Study in Taiwan II. Dermatoglyphic Aspect and Zygosity-Testing," *Journal of the Formosan Medical Association* (Taipei, Taiwan), Vol. 68, No. 4, 1969, pp. 28-35.

[6] Slatis, H. M., Katznelson, M. B-M., and Bonne-Jamir, B., "The Inheritance of Fingerprint Patterns," *American Journal of Human Genetics*, Vol. 28, No. 3, 1976, pp. 280-289.

[7] Okajima, M., "Frequency of Epidermal-Ridge Minutiae in the Calcar Area of Japanese Twins," *American Journal of Human Genetics*, Vol. 19, No. 5, 1967, pp. 660-673.

[8] Brown, T. B., "New Thoughts on Fingerprints—Practical Applications," *Journal of the Forensic Science Society*, Vol. 4, No. 1, 1963, pp. 18-23.

[9] Lin, C. H., "The Similarity of Fingerprints and the Development of a Single Fingerprint Filing and Searching System," Master's thesis, University of Illinois at Chicago Circle, Chicago, 1981.

[10] Federal Bureau of Investigation, *The Science of Fingerprints*, U.S. Government Printing Office, Washington, DC, 1977, pp. 4-85.

[11] Moenssens, A. A., *Fingerprint Techniques*, Chilton Book Co., New York, 1971, pp. 64-93.

[12] Field, A. T., *Fingerprint Handbook*, 2nd printing, Charles C Thomas, Springfield, IL, 1971, pp. 9-17.

[13] Liu, J. H., Lin, C. H., Osterburg, J. W., and Nicol, J. D., "Fingerprint Comparison. II: On the Development of a Single Fingerprint Filing and Searching System," *Journal of Forensic Sciences*, Vol. 27, No. 2, April 1982, pp. 305-317.

Address requests for reprints or additional information to
Juei H. Liu, Ph.D.
Department of Criminal Justice
University of Illinois at Chicago Circle
Box 4348
Chicago, IL 60680