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Diagnostic Efficiency of Fingerprint and Blood Group Differences in a Series of Twins *

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When dermatoglyphic methods were first introduced for the diagnosis of twin zygosity around 1930 they filled a great need. The ridges of the fingers and palms are determined early in gestation and are not altered by subsequent events. They can be evaluated without knowledge of the twins themselves and thus without bias from medical diagnosis or from other zygosity criteria. They lend themselves to quantitative as well as to qualitative methods of study, thus in principle offering hope of yielding positive evidence of monozygosity.

Discovery of the MN blood types in 1928 and of the Rh antigens after 1940 made blood typing superior to dermatoglyphics in twin diagnosis. Biochemical traits are determined at conception and they do not require quantitative evaluation or arbitrary definitions. Subsequent discoveries of additional simple traits have made theoretically possible the positive diagnosis of 98% of DZ twins (Juel-Nielsen et al, 1958). However, these methods are costly; some of the antisera are in short supply and few laboratories are equipped to do a large battery of the tests with high reliability. Since biochemical markers do not give any positive evidence of genetic identity, they permit no subdivision of similar twins into those that are surely MZ and those that may include the few residual DZ pairs. When errors are not excluded by replication of laboratory tests (Osborne, 1958), the DZ category may come to include a few MZ pairs. Finally, for a variety of reasons, blood can sometimes not be obtained from the subjects.

Perhaps as a reaction against the difficulties of serological twin diagnosis in large series of twins, there is now some return to subjective methods. Even mailed questionnaires are thought to be sufficiently reliable for some purposes (Cederlöf et al, 1961; Nichols and Bilbro, 1966). Yet interest in dermatoglyphics is being maintained by

* The data used in this analysis were collected in a cooperative study undertaken by the Department of Medical Genetics of the New York State Psychiatric Institute and the National Institute of Mental Health. Franz J. Kallmann initiated the research and provided guidance until his death in 1965. The New York State Schools provided reports of twin admissions, facilities for examinations and, in some instances, laboratory tests.

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observed sensitivity of these traits to early developmental disturbances and particularly to chromosomal aberrations. Use of dermatoglyphics in twin diagnosis probably will not be abandoned, and new methods may greatly increase the value of this approach.

MacArthur (1938) developed a complicated set of criteria in twin diagnosis based on palms as well as fingertips, but admitted that the palms seemed the less useful. Palms are also more difficult to print. Methods of analyzing fingerprints are still dominated by the techniques found useful in police identification of single individuals, namely, classification of patterns and counting of ridges. Since patterns and ridge counts are correlated and fail to classify the majority of twins conclusively, the early searches for other criteria could perhaps be renewed with profit.

The value of fingerprints in supplementing blood groups has been challenged with the argument that DZ twins who are alike in their biochemical markers may also be relatively similar in fingerprints (cf Osborne and De George, 1959, p. 35). This criticism may not be important. When many biochemical traits are used, DZ twins will always be found to differ, and when few traits are used, the multifactorial determination of the fingerprints and the small proportion of such factors likely to be linked with blood groups will produce little association between dermatoglyphic and serological similarity. Evidence is not available on this point.

Blood groups and dermatoglyphics were obtained in the course of a study of twins reported to the New York State Psychiatric Institute because of mental deficiency (Allen and Kallmann, 1962). Despite rather small numbers and incomplete blood typing information, these data offered some prospect of answering questions relevant to zygosity diagnosis. Any strong interdependence of correlation among the criteria of zygosity would probably become evident even in a limited series. Lesser degrees of correlation, with possible theoretical implications, could be detected in larger masses of information to which series like this can contribute.

Twin Material and Methods

Only same-sex twins were used in this analysis. Tab. I classifies the pairs in which both members were either blood-typed or fingerprinted. They are grouped according to serological differences and zygosity diagnosis and subdivided with respect to Caucasian race and with respect to Down's syndrome. Fingerprints were obtained in three pairs who could not be blood-typed and in 49 of the 50 sets in which blood group differences occurred, including two pairs from one set of same-sex DZ triplets. There were 51 definitely MZ sets, including the MZ pair from each of two DZ sets of triplets. Fifteen pairs with identical blood groups but with marked physical differences (partly pathological) are tentatively classified as doubtful DZ or MZ. Additional twins, including cases with Down's syndrome and pairs with similar blood groups not completely studied, were used in estimating blood group gene frequencies.

Serological information is not complete even on the typed pairs because each

Tab. I. Classification of the twin material

Group	Serological differences			Apparent zygosity	N.		
	ABO	Rh	Other		Caucasian	Non-Caucasian	Down's
I	diff.	same	mixed	DZ	8	1	1
II	diff.	diff.	mixed	DZ	6	1	0
III	same	diff.	mixed	DZ	17	4*	2
IV	same	same	diff.	DZ	8	5	3
V	same	same	same	DZ?	6	4**	2
VI	same	same	same	MZ?	4	1	0
VII	same	same	same	MZ	41	10*, **	3
VIII	?	?	?	?	3	0	0

* One set of DZ triplets is entered as 1 MZ pair and 1 DZ pair in the tables on blood groups; as 1 MZ and 2 DZ pairs in other tables.

** One set of triplets thought to be either MZ or DZ is counted as 1 MZ and 1 DZ pair, since the probable DZ comparisons are almost identical.

pair was typed sequentially, starting with the ABO and major Rh factors, until a difference appeared. Also, during the four years of data collection changes occurred in procedure and in available antisera.

Mean Values

The general probablity of discordance of DZ twins with respect to a simple trait depends on gene frequencies in the population of parents. In this material the parental gene frequencies must be estimated from the twins themselves. Each MZ pair was counted once and individuals of DZ pairs were given a weight of 0.67. Correct weights for DZ twins would vary with the blood group system according to genotype frequencies, dominance, and number of alleles, mainly between 0.67 and 0.75 (Finney, 1948; Fisher, 1940). Estimates were obtained by the method of Cepellini et al (1955) from the Caucasian twins, including cases of Down's syndrome. Frequencies of the three common Rh chromosomes were estimated after discarding six DZ individuals and 2 MZ pairs with rare phenotypes. In such a small sample, more elaborate procedures would not yield significantly different estimates. The following gene frequencies were obtained: $o = 0.72$, $A = 0.19$, $B = 0.09$; $R_1 = 0.48$, $R_2 = 0.19$, $r = 0.33$.

In the Caucasian twins, gene frequencies were 0.49 for Fy^a (Duffy), 0.618 for M and 0.382 for N. The proportion of MN heterozygotes was just half, not significantly greater than 47.2% expected under random mating. It cannot be concluded, how-

Tab. II. Mean values and certain intrapair variances of dermatoglyphic criteria of zygosity

	N.	Ridge count		Wendt score		Slater score	Nixon score
		Mean diff.	σ^2_w	Mean diff.	σ^2_w		
Caucasian							
DZ ♂♂	22	35.73	1016	10.45	79.2	+2.64	+3.43
♀♀	16	57.19	1822	8.69	60.1	+2.57	+3.72
MZ ♂♂	27	10.93	98.3	3.04	6.48	—1.71	—2.50
♀♀	16	7.81	50.1	2.12	3.62	—1.57	—2.56
Doubtful zygosity	13	32.23	772	8.62	63.0	+1.27	+1.45
Non-Caucasian							
DZ	10	50.5	1951	12.8	140	3.55	5.06
MZ	10	11.1	124	2.40	4.80	—1.83	—3.23
Down's syndrome (discordant)	8	21.6	373	4.67	13.7	0.36	—0.73

ever, that the population from which the twins were drawn is ethnically homogeneous.

Tab. II presents mean values of the dermatoglyphic criteria by race, sex and zygosity groups. Down's syndrome is excluded excepting in the last line. The differences between sexes and races are not statistically significant. Homogeneity regardless of sex will be assumed in subsequent analyses and in some instances, as noted, race also will be disregarded.

Zygosity Diagnosis in Down's Syndrome

Since it indicates a chromosomal anomaly, the 21-trisomy syndrome might be regarded as a zygosity criterion comparable to a blood group difference. However, there is at least one well documented report of discordance in apparently identical twins (Dekaban, 1965). Scrutiny of the eight same-sex discordant pairs in this series raises suspicion that they may not all be DZ. Five of the eight were alike in both the ABO and the Rh blood antigens; one of these pairs differed only in the P factor. Two pairs showed no difference in any blood factor but had pigmentary differences (Allen and Baroff, 1955), and upon skin grafting in the remaining pair the graft was rejected (Rogers and Allen, 1955). Fingerprints of these pairs also showed marked similarity, although the known influence of the syndrome on development of dermal patterns (Walker, 1957) would be expected to produce greater differences than those usually found in DZ twins. As shown in Tab. II, most of the mean differences and intrapair variances for the several measures of similarity are closer to those of MZ twins than to those of DZ twins. Even the faces of three pairs pictured

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by Allen and Baroff (1955) are strikingly alike, and seem as similar as might be expected in MZ pairs discordant for Down's syndrome.

Without cytological studies, no explanation can be given for the similarities within these pairs. If some are in fact a result of irregular fertilization or development, it is difficult to select the most probable instances; those pairs with the most similar fingerprints are not entirely similar in blood antigens. The whole series of twins with Down's syndrome of which they are a part already contained an excess of opposite-sex DZ twins (15/23 pairs instead of the expected 50%) and reclassification of even two of the same-sex pairs would leave a distribution that had barely a 0.05 probability. Because of the peculiar concentration of concordance in these twins, they are excluded from subsequent analyses.

Within-pair Correlation of Blood Antigens

Juel-Nielsen et al (1958) found complete agreement between the expected and observed frequency of serological identity in siblings, but the embryological and anatomical phenomena of twinning may affect the likelihood of serological identity in ways not possible in siblings. The rather suspicious distribution of differences in the twins with Down's syndrome described above, the excess of concordance with respect to ABO reported by Osborne and De George (1957) and the question of selective survival raised by these authors, call for an examination of concordance rates and verification of independence between blood groups and other traits in DZ twins. The analysis is seriously hindered because there was no absolute criterion of monozygosity in these twins such as a report of a single chorion (cf Essen-Möller, 1941). There is therefore a residue of DZ pairs that are inseparable from the least similar MZ pairs. Both the concordance rates and the test of independence of the factors are susceptible to error from inclusion of too many or not enough of the doubtful category.

A formula of Wiener and Leff (1940) uses population gene frequencies to predict the proportion of DZ twins that should be recognized as dissimilar by anti-A and anti-B antisera. Similar prediction with respect to the Rh system is sufficiently accurate for this small series if one disregards all but the three most common chromosomal configurations and assumes that all heterozygotes are recognizable with five Rh antisera. The system then resembles one with three alleles without dominance, and discordance is predicted approximately by a formula derived like that of Wiener and Leff:

$$P_{diff} = 2p^3(q + r) + 2q^3(p + r) + 2r^3(p + q) + \frac{5}{2}(p^2q^2 + p^2r^2 + q^2r^2) + 8pqr.$$

When these formulas are used with the gene frequencies mentioned above, they lead to the expectation that 0.34 of the Caucasian pairs in this series will be different in ABO groups; 0.53, in the Rh types. Among Caucasian pairs in groups I through V (Tab. I), the observed proportion of discordance was 0.31 (14/45) for ABO and

0.51 (23/45) for Rh. This does not suggest any substantial correlation between DZ twin partners in either the ABO or the Rh systems.

Despite full discriminating efficiency of the blood group systems individually, their collective efficiency in a battery of tests would be reduced if they were not fully independent. In the known absence of linkage, interdependence would require a rather complicated explanation, but a loose analogy is seen in the interaction of ABO and Rh factors with respect to erythroblastosis. In a recent report Edwards and Wingham (1967) have demonstrated the independence of a large number of marker loci in a more adequate series of DZ twins.

Tab. III shows the relation between ABO and Rh concordance in all pairs in groups I through V excepting cases of Down's syndrome. The races are combined

Tab. III. Tabulation of ABO concordance in relation to Rh concordance

		ABO blood groups		Total
		same	diff.	
Rh blood groups	same	22	9	31
	diff.	20	7	27
Total		42	16	58

because this comparison is not very sensitive to gene frequencies and the distribution of concordance in the Caucasians is not significantly different from that in the remaining twins. The table reveals no association.

The minor blood antigens were not regularly tested unless the pair was concordant in ABO and major Rh factors. The numbers are therefore even smaller than for the major factors, but the relations of MN and Duffy (Fy^a) to ABO and Rh are shown in Tab. IV. The expected concordance rates in the Caucasian pairs can be obtained

Tab. IV. Concordance for MN and Duffy in relation to ABO and Rh concordance

		ABO and Rh factors		Total
		Both alike	One or both different	
MN blood types	same	9 (6)	5	14 (6)
	diff.	5 (3)	2	7 (3)
Duffy blood types	same	9 (7)	5	14 (7)
	diff.	5 (0)	1	6 (0)

(Figures in parentheses are totals for non-Caucasian pairs; no such pairs were typed for MN or Duffy if discordant in ABO or Rh)

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from the observed gene frequencies by use of the formulas of Sutton et al (1955). The expected concordance is 61% of the DZ pairs with respect to MN, 78% with respect to Duffy. The observed rates are 67% and 70% in all the Caucasian twins, 64% and 64% in those having the same ABO and Rh blood types. Even the last

Tab. V. MN concordance in relation to Duffy concordance

		Duffy blood types			Total	
		same		diff.		
MN blood types	same	10	(6)	4	14	(6)
	diff.	3	(2)	2	5	(2)
Totals		13	(8)	6	19	(8)

(Figures in parentheses are totals for non-Caucasian pairs)

figure is not significantly deviant. This tends to exclude any strong interaction among the factors and offers new assurance that they are efficient in detecting DZ twins.

Finally, a small number of pairs were tested with both the MN and the Duffy antisera (Tab. V). The factors do not show significant interdependence. Three other antisera (S, K, P) were used too infrequently in the DZ twins to be considered here at all.

Relative Efficiency and Correlations among the Fingerprint Criteria

The conventional " total ridge count " has been used as a model for quantitative traits in twin diagnosis (Smith and Penrose, 1955; Richter and Geisser, 1960). Of the other measures that have been proposed in recent years, the pattern score of Wendt (1955) has the least dependence on ridge counts. The more complicated measures, actually linear discriminant functions, are basically those of Slater and Shields (1953) and Nixon (1956). These combine a comparison of complete ridge counts with separate comparisons of individual fingers of the twins. In a more recent publication Slater (1963) has proposed a modification of Nixon's index that yields a normal distribution by assigning greater weight to the total ridge count. In the present report the original Slater and Nixon functions are used.

Correlation coefficients among the four measures of twin similarity are presented in Tab. VI. Racial classification is disregarded here. The most striking feature of the data is the considerably higher correlations among the measures when they are applied to DZ twins. This is consistent with the fact that differences between MZ twins are relatively small and probably random, while differences between fraternal twins are largely genetic and hence affect primary dermatoglyphic variables in development, whatever these may be.

A second conclusion to be drawn from the table is that all these four measures are rather closely interdependent, especially in their representation of genetic differences. Probabilities based upon the several measures cannot be multiplied together like independent quantities in calculating the likelihood that twins are DZ. The two measures, ridge count and Wendt score, that would seem from their nature

Tab. VI. Correlations between dermatoglyphic measures of twin similarity

	DZ			MZ		
	Nixon score	Wendt difference	Ridge count difference	Nixon score	Wendt difference	Ridge count difference
Slater score	0.775	0.704	0.618	0.396	0.207	0.247
Nixon score		0.882	0.832		0.558	0.414
Wendt difference			0.655			0.178

to be most distinct, confirm this by having the lowest intercorrelation in the data from MZ twins and next-to-lowest in the data from DZ twins.

The problem of what to do with pairs of doubtful zygosity, mentioned in connection with correlations among blood antigens, is even more serious for the assessment of diagnostic effectiveness of dermatoglyphic traits, because these were used among other criteria in deciding which pairs with similar blood types were most likely DZ. Tab. VII summarizes the distributions when the 18 doubtful pairs in Groups V, VI and VIII are kept separate, which may exclude from the MZ series some MZ pairs with

Tab. VII. Proportion of twins classifiable by conventional dermatoglyphic criteria

	N.	Wendt score difference	Ridge count difference	Slater score	Nixon score
DZ pairs $P < 0.95$	49	0.51	0.57	0.69	0.78
MZ pairs $P < 0.95$	51	0.12	0.22	0.69	0.67
MZ and DZ optimum	100	0.79	0.80	0.90	0.88
Doubtful pairs $P < 0.95$	18	0.47*	0.28	0.72	0.83
All pairs optimum	115	0.75	0.77	0.83	0.83

* Based on 17 pairs

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large dermatoglyphic differences. The table does, however, show the *relative* effectiveness of the four methods in separating the twins into two groups. The first three rows give pairs whose diagnosis appeared definite. Rows 1 and 2 give the proportion of each type that was beyond 95% of the other type and row 3 shows the proportion that could be correctly classified by selection of a single optimal " cutting level ". Row four shows what proportion of the doubtful cases fell below 95% of DZ or above 95% of MZ.

There is a clear dichotomy of the methods, the two discriminant functions being about equally good and much better than the simpler measures. This superiority is obscured but not eliminated when, as in the fifth row, all pairs with known similar blood types are regarded as MZ.

Association between Concordance in Fingerprints and Concordance in Blood Antigens

In the diagnosis of MZ twins by exclusion of dizygosity (Essen-Möller, 1941; Smith and Penrose, 1955), empirical probabilities of dizygosity based on quantitative traits like dermatoglyphics are sometimes combined with theoretical probabilities based on mendelian traits. This presupposes independent variation of the separate criteria. If the genetic factors controlling fingerprints are numerous and have individually small effects, linkage of some of these factors with blood antigens would not greatly weaken the assumption of independence and could probably not be detected. But Holt (1961) has reported that the factors controlling fingerprints, though additive and quantitative in effect, appear not to be very numerous. It is therefore desirable to test for independence.

The sequential method of blood typing used in this study resulted in more extensive typing of some pairs than of others. It is possible, however, to compare dermatoglyphic findings in twins having two or more blood group differences with those in twins having only one difference after extensive typing, and with those in twins having only one difference after limited typing. Tab. VIII gives the numbers of

Tab. VIII. Classification of the twins by number of serological differences

Group	Caucasian	Non-Caucasian	Down's
A. Two or more differences	10*	1	0
B. One difference; extensively typed	9	5	3
C. One difference; incompletely typed	20	5	3

* One twin pair, not fingerprinted, omitted from Tables IX and X.

twin pairs falling in these three groups and Tab. IX compares them dermatoglyphically. Group A, with two or more blood group differences, shows the greatest intrapair differences in dermatoglyphics. This can be traced to two sources; first, group A contains two twin pairs with extraordinarily large intrapair differences (ridge count differences 165 and 133). Second, groups B and C contain six pairs in which one member has Down's syndrome, and it has been shown above that these pairs present a degree of similarity within pairs that is atypical of DZ twins in the series as a whole.

Removal of Down's syndrome and non-Caucasian twins has very little effect on the comparisons (table not shown). The pair with the largest ridge count difference remains, and accounts for a significantly large variance of ridge count differences

Tab. IX. Relation of dermatoglyphic similarity to number of blood group differences

N. of blood group differences		Ridge count difference	Wendt score difference	Slater score	Nixon score
A. Two or more differences	Mean	48.6	12.1	2.31	4.54
	Variance	3447	131	18.3	82.1
	σ^2w	2732	132		
B. One difference; extensively typed	Mean	39.0	8.94	2.73	2.77
	Variance	738	32.4	15.9	8.01
	σ^2w	1108	55.2		
C. One difference; incompletely typed	Mean	41.9	9.46	2.41	2.63
	Variance	945	54.6	9.25	24.6
	σ^2w	1332	71.1		

in group A ($F = 3.2$, $p<0.05$). But there is also a significantly low variance of Nixon scores in group B ($F = 3.7$, $p <0.05$). Group B is composed almost entirely of pairs that are concordant in the ABO factors, whereas groups A and C are partly concordant and partly discordant. Intra-pair variance is denoted by σ^2w.

Tab. X shows the dermatoglyphic findings in four subsamples of Caucasian DZ twins classified according to differences at the ABO and Rh loci, groups I through IV in Tab. I. Group III has the lowest mean values of all four measures. More striking is the high *variance* of most measures in group II and the low variance of most measures in group III. The variance of Slater's function in group III is extremely low compared with the other groups, giving an F of 6.1 ($p <0.001$). The reality of this difference is confirmed by reviewing the actual values; the range in group III was from —1.39 to +3.75, with only one of 17 values below —1; the range in the other three groups is from —2.21 to +10.12, with four of 21 values below —1 and ten values above +3.75.

There seems to be no good reason why group III should be different from all other groups. If groups I and II, differing at the ABO locus, are combined and compared with combined groups III and IV, difference in ABO is still associated with

greater mean differences in all measures but the differences in means are not significant. Differences in *variance* are significant at the 0.01 probability level with respect to ridge count differences and Slater's function, twins alike at the ABO locus again being more uniform; but these supposedly uniform twin pairs now include the two extreme Slater scores, —2.21 and +10.12.

Genetic linkage between the ABO locus and a gene with major effect on the fingerprints would account for the greater dermatoglyphic similarity within pairs in

Tab. X. Relation of dermatoglyphic similarity to the ABO and Rh systems

Blood group difference		Ridge count difference	Wendt score difference	Slater score	Nixon score
I. Different only in ABO	Mean	49.2	13.6	4.52	5.77
n = 8	Variance	1509	67.4	15.4	22.6
	σ^2_w	1873	122		
II. Different in ABO and Rh	Mean	61.4	11.4	3.28	5.36
n = 5	Variance	4381	87.3	14.1	59.8
	σ^2_w	3637	99.9		
III. Different only in Rh	Mean	38.3	7.88	1.38	2.37
n = 17	Variance	753	26.4	2.51	8.03
	σ^2_w	1087	43.5		
IV. Different in neither	Mean	43.8	8.63	2.38	2.50
n = 8	Variance	818	54.3	17.8	17.2
	σ^2_w	1315	60.9		

groups III and IV taken together. It would not explain the difference in variance of Slater scores between these two groups, which has an F of 7.1, again with a probability less than 0.001. Nor does a hypothesis of linkage find any support in the very limited additional sib-pair data provided by the material. One set of trizygotic triplets might be useful, but they were of mixed sex so that only two members were typed. Three families are represented by two sets of twins, but the parental ABO genotypes can be deduced in only one of these families. These families show no tendency for dermatoglyphic similarity to accompany similarity in the ABO genes beyond what occurred, probably by chance, within the twin pairs.

Efficient Use of Dermatoglyphic Data

The total ridge count is the sum of ten ridge counts, one (the larger if there are two) from each finger. A criterion commonly used in twin diagnosis is the difference of these sums. Similarly, Wendt (1955) devised a total pattern score that summed individual scores for all ten fingers, and compared these total scores in twins. However, the discriminant functions developed by Slater and Shields (1953) and by Nixon (1956) both achieve a better separation of MZ and DZ twins, in part, by

Tab. XI. Twin differences in Wendt score when hands are compared together and separately

Magnitude of the difference	Difference of sums			Sum of differences		
	DZ	MZ	Doubtful	DZ	MZ	Doubtful
0		3			3	
1		9	3		4	1
2	2	5	1	1	2	
3	2	6		2	6	1
4	2	4	3	2	2	3
5	3	1		2	5	1
6	2	1	2	2	5	1
7	1	1		1	1	
8	1		1	2		2
9-10	1		1	2	1	1
11-15	4		2	4	1	3
16-20	2		1	2		1
21+	3		2	3		2
Totals	23	30	16	23	30	16

Tab. XII. Twin differences in ridge count when hands are compared together and separately

Magnitude of the difference	Difference of sums			Sum of differences		
	DZ	MZ	Doubtful	DZ	MZ	Doubtful
0	1	2				
1		4			1	
2	1	5			2	
3	1	2	1		2	
4	1	1		1	1	
5		4			4	1
6-7	1	7		1	5	
8-9	1	7	2	1	5	2
10-12	4	4	2	2	4	2
13-15	3	6	1	6	5	1
16-19	2	4	1	2	11	1
20-29	6	3	6	6	8	4
30-39	3	1	1	4	1	2
40-49	5	1	1	6	1	2
50-59	3			3	1	
60-79	9		3	9		3
80	8			8		
Totals	49	51	18	49	51	18

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comparing separately the radial and ulnar sides of each finger for the twin pair. Since the total scores discard information about distribution of ridge counts or of patterns, it would seem possible that the simpler techniques of ridge count comparison or pattern score comparison might be improved merely by comparing hands or fingers separately. The relatively small numbers available in this study prevent a detailed or definitive investigation, but the apparent gain by use of separate scores for the left and right hands proves disappointingly small. A somewhat similar finding was reported by Lamy et al (1957).

Tables XI and XII show the distribution of Wendt scores and ridge counts, respectively, when the two hands are compared together and separately. Tab. XIII summarizes the comparisons in terms of proportion of each type of twin classifiable by each method at the 0.05 probability level or, in the last row, by a single dividing point

Tab. XIII. Proportion of twins classifiable by two methods of using Wendt scores and ridge counts. Summary of Tables XI and XII

	Wendt scores		Ridge counts	
	Difference of sums	Sum of differences	Difference of sums	Sum of differences
DZ pairs $P < 0.95$	0.52	0.39	0.57	0.53
MZ pairs $P < 0.95$	0.40	0.30	0.22	0.33
Doubtful pairs $P < 0.95$	0.63	0.44	0.28	0.39
MZ and DZ optimum separation	0.83	0.77	0.80	0.78

chosen to give the best separation. The data require some explanation. Some pairs had to be omitted because Wendt scores were available only for both hands together. Pairs with Down's syndrome are excluded. All remaining pairs with blood group differences are included as DZ twins, while all pairs that were similar serologically and physically are counted as MZ. Exclusion of doubtful pairs from the MZ group tends to improve the apparent similarity within MZ pairs and explains the preponderance of high counts in the doubtful series. Nevertheless, the relative numbers classifiable by the difference of sums (hands taken together) and by the sum of differences (hands compared separately) provide an interesting comparison. The advantage of one method over the other is not statistically significant, but it appears that some precison may be gained in the case of ridge counts by comparing left hand with left and right hand with right. No such gain is indicated with respect to Wendt scores.

Conclusions

1. Data on 45 apparently DZ twin pairs, including some with no blood group differences, showed nearly the expected concordance rates with respect to ABO, Rh, MN and Duffy blood group systems. Coincidental concordance for any two

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systems also conformed. This tends to rule out selective survival or interdependence that might be peculiar to twins. However, because numbers are small, particularly in the MN and Duffy data, they exclude only gross deviations from expectation. Also, these were not normal individuals; at least one member of each pair was mentally subnormal.

2. Those DZ twin pairs concordant in ABO blood groups showed a significantly greater intrapair resemblance in fingerprints, and the magnitude of the differences was more uniform between pairs. Among the pairs concordant in ABO, *discordance* in Rh factors was associated with especially small variance and intrapair differences. Genetic linkage between fingerprints and blood groups would not explain these findings.

3. A small series of same-sex twins genetically nonidentical and discordant for Down's syndrome showed greater average similarity than is expected in DZ twins with respect to both blood groups and fingerprints. Some of them may represent an irregular type of uniovular twinning.

4. The four dermatoglyphic measures of intrapair resemblance used here had correlation coefficients between 0.61 and 0.88 in DZ twins, and between 0.18 and 0.56 in MZ twins.

5. Two linear discriminant functions were notably superior to total ridge count or Wendt pattern score in separating MZ and DZ twins by fingerprints alone.

6. The simpler measures of dermatoglyphic similarity could not be materially improved by comparing left and right hands separately. Modification of Wendt's method in this manner gave poorer results than his original method, suggesting that left-right differences in fingerprint patterns depend more on chance than on genetic control. Apparently the two hands together yield a better estimate of the underlying genetic parameters. However, the Slater and Nixon methods make good use of much more detailed information, and this supports the hope of achieving still further improvement in dermatoglyphic criteria of zygosity by careful selection of variables and weights.

Summary

Data obtained in a study of mentally defective twins permitted the examination of interdependence and efficiency of blood groups and fingerprints in zygosity diagnosis. After exclusion of Down's syndrome, the series consisted of 49 MZ pairs, 52 DZ pairs and 18 pairs of uncertain type.

Same-sex pairs discordant for Down's syndrome seemed to include some pairs of uniovular or irregular origin, but this could not be investigated cytologically. Concordance appeared to occur independently in different blood group systems. However, DZ twins concordant in the ABO blood groups were significantly more similar in their fingerprints than were other pairs, and the within-pair differences were more uniform.

Linear discriminant functions designed for zygosity diagnosis make much better use of dermatoglyphic information than do simpler measures, and the latter could not be much improved by comparing left and right hands separately.

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RIASSUNTO

I dati ottenuti da uno studio eseguito su gemelli affetti da disturbi mentali hanno dato la possibilità di esaminare l'interdipendenza e l'efficacia dei gruppi sanguigni e delle impronte digitali nella diagnosi di zigotismo. Il campione era costituito da 49 coppie di gemelli MZ, 52 DZ e 18 di zigotismo incerto.

Inoltre, fra otto coppie dello stesso sesso, discordanti per la sindrome di Down, sembravano esservene alcune di origine monovulare o irregolare, ma non è stata possibile una dimostrazione citologica. Le concordanze sembravano presentarsi indipendentemente nei differenti sistemi di gruppi sanguigni, e tuttavia i gemelli DZ concordanti per i gruppi ABO erano significativamente più simili di altre coppie riguardo alle impronte digitali, e le differenze tra i due membri di una stessa coppia erano più uniformi.

La funzione discriminante lineare elaborata per la diagnosi di zigotismo utilizza le informazioni dermatoglifiche meglio dei mezzi normali che non è stato possibile migliorare neanche paragonando separatamente la mano destra e la mano sinistra.

RÉSUMÉ

Les données obtenues d'une étude faite sur des jumeaux ayant des défauts mentaux, ont donné l'opportunité d'examiner l'interdépendance et l'efficacité des groupes sanguins et des empreintes digitales dans le diagnostic de zygotisme. La série se composait de 49 couples de jumeaux MZ, 52 de jumeaux DZ et 18 de jumeaux dont le zygotisme était incertain.

En plus, huit couples du même sexe, discordants pour le syndrome de Down, semblaient comprendre quelques couples d'origine monovulaire ou irrégulière, mais ceci n'a pas pu être investigué cytologiquement. La concordance a paru se présenter indépendamment dans de différents systèmes de groupes sanguins. Pourtant, les jumeaux DZ concordants pour les groupes ABO étaient significativement plus similaires dans leurs empreintes digitales que d'autres couples, et les différences entre les deux jumeaux du même couple étaient plus uniformes.

La fonction discriminante linéaire élaborée pour le diagnostic de zygotisme utilise mieux les informations de dermatoglyphie que les moyens simples, que l'on n'a pas pu beaucoup améliorer, en comparant séparément la main gauche et la main droite.

ZUSAMMENFASSUNG

Ergebnisse, die während einer Untersuchung von geistig defekten Zwillingen erhalten wurden, ermöglichten es, die Abhängigkeit und den Wert von Blutgruppen und von Fingerleisten für die Diagnose der Eiigkeit zu beurteilen. Die untersuchte Gruppe, unter Ausschluss des Downschen Syndromes, bestand aus 49 EZ und 52 ZZ Paare und aus 18 Paare, bei denen die Eiigkeit zweifelhaft war.

Einige der diskordanten gleichgeschlechtlichen Paare mit dem Downschen Syndrome waren anscheinend von eineiiger oder unregelmässiger Herkunft, was aber nicht zytologisch untersucht werden konnte. Konkordanz schien unabhängig bei verschiedenen Blutgruppensystemen aufzutreten. Zweieiige Zwillinge mit einer Konkordanz in den ABO Gruppen zeigten jedoch bedeutend mehr Ähnlichkeit in ihren Fingerleisten als andere Paare, und die Intra-Paar-Differenz war gleichartiger.

Die linearen Trennfunktionen für die Eigkeitsdiagnose ermöglichen einen viel besseren Gebrauch der Hautleisten, als andere, einfachere Methoden, welche auch durch isoliertes Vergleichen von rechter und linker Hand nicht viel verbessert werden könnten.

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