MONOZYGOTIC AND DIZYGOTIC TWIN BIRTH FREQUENCIES IN THE TOTAL, THE "WHITE" AND THE "COLORED" U.S. POPULATIONS

HERLUF H. STRANDSKOV AND EARL W. EDELEN
Department of Zoology, University of Chicago

Received February 25, 1946

HUMAN twins are generally thought to be of two types, monozygotic or one-egg pairs and dizygotic or two-egg sets. The evidence on the basis of which this conclusion has been drawn is somewhat indirect, but it is convincing. That dizygotic twins exist is suggested by the fact that some pairs are of opposite sex and different in many other characteristics which are known to have a genetic basis. That monozygotic twins occur is attested to by incompletely separated pairs and by the fact that more same sex twins appear than what one would expect if all were dizygotic.

If twin sets are of two types, it is of interest to determine the relative birth frequencies of each kind. This can not be done empirically, at least not readily, but the proportion of each type can be estimated fairly accurately. This has been done for most foreign twin populations and to some extent for that of the United States. At least statements appear in publications regarding the relative proportions of each kind in the U.S. twin population. For example, NEWMAN, who has long been considered an authority on twins in America, published a book in 1940 entitled "Multiple Human Births," in which he writes as follows: "We conclude that in the United States about one fourth of all twins born are one-egg twins." AREY (1940) in his widely used embryological textbook "Developmental Anatomy" does not refer specifically to the U.S. twin population, but he comments as follows: "Statistically about one fourth of all twins are identifiable as of the single egg type."

The senior author of the present paper has never been able to obtain close agreement with the statements quoted above whenever he has roughly analyzed a limited set of U.S. twin data. He has always obtained monozygotic percentages which are somewhat higher. Since this has been true and since there is considerable reason for having correct U.S. monozygotic and dizygotic birth percentages available in the literature, it seems desirable to derive the best estimates which are possible from an extensive set of U.S. twin records and to publish these. This we are doing in the present paper. In addition we are presenting certain statistical analyses of twin percentages which bring out information which is of some interest.

The data which we have chosen for consideration are the twin birth frequencies of the U. S. Birth Registration Area from 1922 to 1936 inclusive. These years were selected because we have already analyzed certain other aspects of the U.S. population for this 15-year interval, and therefore possess data for those years which are required for a twin frequency analysis (STRANDSKOV 1945a, 1945b).

The method we are applying for an estimation of monozygotic and dizygotic

twin birth frequencies was suggested originally by WEINBERG in 1902. It is generally known as Weinberg's differential method. It is based on the theory that sex in man is genetically determined and that ♀♀, ♀♂ and ♂♂ sets of dizygotic twin births should appear in a population in proportions given by the square of the birth sex ratio of the total population.

The actual calculation of the frequency of dizygotic twin births consists of equating the observed number of ♀♂ sets to the expected percentage, and estimating in this manner the total number of dizygotic twins born. All excess

TABLE 1

The estimated percentages of monozygotic twin births in the total U.S. twin population, that is, in the "white" and the "colored" twin populations combined.

YEAR	TOTAL NO. OF SETS OF TWINS BORN	NO. OF TWIN BIRTHS OF THE DIFFERENT SEX COMBINATIONS			ESTIMATED PERCENTAGE OF MONOZYGOTIC TWIN BIRTHS BASED ON:		
		♀♀	♀♂	♂♂	SEX RATIO OF TOTAL POPULATION	SEX RATIO OF TWINS	50:50 SEX RATIO
1922	21,163	6,911	7,098	7,154	32.855	32.902	32.921
1923	21,444	7,033	7,113	7,298	33.594	33.641	33.660
1924	22,751	7,327	7,575	7,849	33.344	33.392	33.410
1925	21,531	7,063	6,919	7,549	35.665	35.711	35.730
1926	21,739	7,122	7,056	7,561	35.020	35.066	35.084
1927	25,752	8,390	8,439	8,923	34.393	34.440	34.459
1928	26,786	8,663	8,878	9,245	33.648	33.693	33.720
1929	26,489	8,673	8,823	8,993	33.319	33.365	33.384
1930	26,128	8,513	8,748	8,867	32.972	33.018	33.037
1931	25,067	8,062	8,507	8,498	32.058	32.106	32.126
1932	25,081	8,043	8,570	8,468	31.594	31.641	31.661
1933	24,990	8,098	8,471	8,421	32.137	32.185	32.205
1934	25,993	8,523	8,612	8.858	33.671	33.717	33.736
1935	25,197	8,122	8,397	8,678	33.286	33.329	33.349
1936	25,569	8,394	8,388	8,787	34.327	34.370	34.389
Total	365,680	118,937	121,594	125,149	501.883	502.576	502.871
Mean	24,379	7,929	8,106	8,343	33.459	33.505	33.525

same sex twins are considered monozygotic. With the number of dizygotic and monozygotic twin births estimated, the percentage of each type is, of course, easily obtained.

In table 1 are presented the total number of twin sets born each year from 1922 to 1936 inclusive, the number of ♀♀, ♀♂ and ♂♂ pairs, and, in the first of the last three columns of the table, the estimated yearly percentages of monozygotic births based on the birth sex ratio of the total population. This sex ratio, as presented previously by STRANDSKOV (1945b), is 48.431 percent ♀ : 51.569 percent ♂.

An examination of this third from the last column of table 1 reveals that for each of the 15 yearly twin populations, the estimated percentage of monozy-

gotic births among all twin births is close to 33⅓ percent rather than 25 percent as given by NEWMAN, AREY and others. For the total twin population of 365,680 sets, for the 15 year interval, the estimated percentage is 33.43. Thus it is evident that it is much more accurate to say that about one-third of all U.S. twin births are monozygotic rather than one-fourth as generally quoted. The difference is sufficiently great to warrant a correction in standard reference and textbooks. GREULICH (1934) and HAMLETT (1935) obtained somewhat similar percentages, but they did not emphasize the discrepancy and did not

TABLE 2

The estimated percentages of monozygotic twin births in the "white" U.S. twin population.

YEAR	TOTAL NO. OF SETS OF TWINS BORN	NO. OF TWIN BIRTHS OF THE DIFFERENT SEX COMBINATIONS			ESTIMATED PERCENTAGE OF WHITE MONOZYGOTIC TWIN BIRTHS BASED ON:		
		♀♀	♀♂	♂♂	SEX RATIO OF TOTAL POPULATION	SEX RATIO OF TWINS	50:50 SEX RATIO
1922	18,947	6,176	6,304	6,467	33.388	33.435	33.456
1923	19,143	6,298	6,298	6,547	33.133	34.180	34.200
1924	20,263	6,552	6,659	7,052	34.205	34.250	34.274
1925	19,460	6,412	6,173	6,875	36.490	36.536	36.557
1926	19,598	6,425	6,309	6,864	35.550	35.595	35.616
1927	22,581	7,334	7,357	7,890	34.773	34.817	34.839
1928	23,052	7,499	7,555	7,998	34.383	34.431	34.453
1929	22,647	7,422	7,504	7,721	33.665	33.709	33.731
1930	22,123	7,224	7,316	7,583	33.793	33.838	33.861
1931	21,095	6,782	7,074	7,239	32.860	32.908	32.932
1932	21,056	6,790	7,102	7,164	32.471	32.518	32.542
1933	20,741	6,721	6,926	7,094	33.147	33.190	33.214
1934	21,590	7,135	7,054	7,401	34.585	34.632	34.655
1935	21,279	6,911	6,983	7,385	34.301	34.344	34.367
1936	21,655	7,104	7,059	7,492	34.736	34.782	34.805
Total	315,230	102,785	103,673	108,772	512.480	513.165	513.502
Mean	21,015	6,852	6,911	7,251	34.165	34.211	34.233

present a detailed analysis. NEWMAN'S estimate is based on the data of NICHOLS published in 1907.

Although WEINBERG suggested that the sex ratio of the population as a whole should be used as a base in the estimation of monozygotic and dizygotic twin birth frequencies, some investigators have argued that it is more appropriate to use the birth sex ratio of the twin population itself. This sex ratio could be sufficiently different from that of the total population to give significantly different estimated percentages. To find out whether or not this is true for the U.S. twin population, we have estimated the monozygotic birth percentages based on this ratio. For the total twin population in question the birth sex

ratio is 49.151 percent ♀ : 50.849 percent ♂. The estimated monozygotic percentages are given in the second from the last column of table 1. From an inspection of this column it will be seen that these percentages differ very little from those derived by using the sex ratio of the population as a whole. In fact, the mean of the two columns are so similar that for all practical purposes it is immaterial whether one employs the birth sex ratio of the total U.S. population or the birth sex ratio of the twin population itself.

Another possible sex ratio to use is the theoretically expected 50:50 ratio. It has been widely employed by investigators, because it is the easiest and the simplest to apply. In the last column of table 1 are shown the monozygotic

TABLE 3

The estimated percentages of monozygotic twin births in the "colored" U.S. twin population.

YEAR	TOTAL NO. OF SETS OF TWINS BORN	NO. OF TWIN BIRTHS OF THE DIFFERENT SEX COMBINATIONS			ESTIMATED PERCENTAGE OF "COLORED" MONOZYGOTIC TWIN BIRTHS BASED ON:	
		♀♀	♀♂	♂♂	SEX RATIO OF TOTAL POPULATION	SEX RATIO OF TWINS AND 50:50 RATIO
1922	2,216	735	794	687	28.294	28.339
1923	2,301	735	815	751	29.118	29.161
1924	2,488	775	916	797	26.326	26.367
1925	2,071	651	746	674	27.909	27.958
1926	2,141	697	747	697	30.173	30.220
1927	3,171	1,056	1,082	1,033	31.725	31.757
1928	3,734	1,164	1,323	1,247	29.084	29.138
1929	3,842	1,251	1,319	1,272	31.286	31.338
1930	4,005	1,289	1,432	1,284	28.439	28.489
1931	3,972	1,280	1,433	1,259	27.795	27.845
1932	4,025	1,253	1,468	1,304	27.006	27.056
1933	4,249	1,377	1,545	1,327	27.230	27.277
1934	4,403	1,388	1,558	1,457	29.185	29.230
1935	3,918	1,211	1,414	1,293	27.769	27.820
1936	3,914	1,290	1,329	1,295	32.039	32.090
Total	50,450	16,152	17,921	16,377	433.378	434.085
Mean	3,363	1,077	1,195	1,091	28.892	28.939

estimates based on this ratio. By examining these percentages it will be apparent that they also are very close to those obtained by using the birth sex ratio of the population as a whole. In fact they are so close that the general usage of a 50:50 ratio is justified. This statement holds, at least, for the estimation of the percentage of monozygotic births within U.S. twin populations.

It may be desired by some to have on hand the estimated yearly dizygotic percentages. We have these available and have made use of them in our statistical analyses, but we shall not publish them in full. They can, of course,

be obtained directly by subtracting the estimated yearly percentages of monozygotic births from 100 percent. For the total 15 year period the estimated dizygotic percentage based on the sex ratio of the population as a whole is 66.57.

The monozygotic percentages presented in table 1 are those for the total U.S. twin population. From a genetic point of view it is of interest, to find out if racial differences exist. Twin birth data are not presented in the U.S. census

TABLE 4

Estimated monozygotic and dizygotic birth percentages among U.S. twin births based on the sex ratio of all births in the population in question. The data are for the years 1922 to 1936 inclusive.

POPULATION	TOTAL NO. OF TWIN SETS BORN DURING 15 YEAR INTERVAL	ESTIMATED PERCENTAGES OF	
		MONOZYGOTIC SETS	DIZYGOTIC SETS
Total	365,680	33.432	66.568
"White"	315,230	34.156	65.844
"Colored"	50,450	28.908	71.092

records for all the racial sub-groups of the U.S. population for the period under consideration, but they are available for what the Bureau of the Census calls the "white" and the "colored" U.S. populations. The "white" population probably consists almost exclusively of members of the Caucasoid stock, but the "colored" population is a mixture of Negroid, Mongoloid and Caucasoid. It is, however, largely Negroid. Therefore an estimate of its monozygotic birth frequency will be fairly representative of the U.S. Negroid stock.

The estimated percentages of monozygotic births in the "white" U.S. twin population from 1922 to 1936 inclusive are shown in table 2. Those for the "colored" are presented in table 3. As before, the estimated yearly percentages of dizygotic births are not published, but the estimates for the total 15 year period are listed in table 4.

With the yearly monozygotic and dizygotic percentages estimated for the total, the "white" and "colored" U.S. twin populations, it is of interest to compare the means of these different populations to see whether or not they are significantly different. This can be done by applying the standard formula for a test of the significance of the difference between two means:

$$t = \frac{\Delta}{\sqrt{\frac{\Sigma(x_1 - \bar{x}_1)^2 + \Sigma(x_2 - \bar{x}_2)^2}{N_1 + N_2 - 2} \times \frac{N_1 + N_2}{N_1 N_2}}}$$

The t values for the pairs of percentage means which have been compared, together with the probabilities of the t values, are shown in table 5. If we examine this table, we find that significant differences between the means of some of the populations do occur. Of particular interest are the significant differences between the means of the "white" and the "colored" twin populations. The

monozygotic percentage of the "white" twin population is significantly higher than that for the "colored," and, as follows, the dizygotic percentage of the "white" twin population is significantly lower than that for the "colored."

In a previous paper (STRANDSKOV 1945a) we showed that the percentage of twin pregnancies among all pregnancies is significantly higher in the U.S.

TABLE 5

The t values and their probabilities obtained by comparing the means of the estimated percentages of monozygotic births among twin births in the total, the "white," and the "colored" U.S. populations from 1922 to 1936 inclusive.

POPULATIONS COMPARED*	*t* VALUE	PROB. LESS THAN
"White" vs. Total	1.82	.1
Total vs. "colored"	8.61	.001
"White" vs. "colored"	10.12	.001

* In each instance the population with the larger mean percentage is shown first.

"colored" population than it is in the "white." (The respective percentages for the 15 year interval in question are 1.433 and 1.129.) With the number of monozygotic and dizygotic births estimated for each year for both the "white" and the "colored" population, it is, of course, possible to calculate the monozygotic and dizygotic pregnancy percentages for each population and, consequently, to decide whether the higher twin pregnancy percentage in the "colored" population is due to more monozygotic pregnancies, to more dizygotic, or to more of both types. The monozygotic and dizygotic pregnancy percentages for the total, the "white," and the "colored" U.S. populations for the 15 year interval are shown in table 6. The t values obtained from a comparison of the means of the yearly pregnancy percentages of the different populations are presented in table 7.

TABLE 6

The estimated percentage of monozygotic and dizygotic twin births or pregnancies among all pregnancies in the total, the "white," and the "colored" U.S. population from 1922 to 1936 inclusive.

POPULATION	TOTAL NO. OF SINGLE AND PLURAL PREGNANCIES	ESTIMATED MONOZYGOTIC PREGNANCIES		ESTIMATED DIZYGOTIC PREGNANCIES	
		NO.	%	NO.	%
Total	31,487,413	122,253	.388	243,427	.773
"White"	27,923,410	107,669	.386	207,561	.743
"Colored"	3,564,003	14,584	.409	35,866	1.006

If we examine tables 6 and 7, we find that both the monozygotic and the dizygotic twin pregnancy percentages are significantly higher for the "colored" population than they are for the "white." Hence we may conclude that the

significantly higher total twin pregnancy frequency in the "colored" population is due, not only to more dizygotic twin pregnancies, but also to more monozygotic.

Since we have found racial differences in the percentage of monozygotic pregnancies as well as in the percentage of dizygotic pregnancies, it is appropriate to consider the probable causes of these differences. Are the responsible factors environmental, genetic, or in part both types? It is not possible on the

TABLE 7

The t values and their probabilities obtained by comparing the means of the estimated percentages of monozygotic and dizygotic pregnancies among all pregnancies in the total, the "white" and the "colored" U.S. populations from 1922 to 1936 inclusive.

POPULATIONS COMPARED*	t VALUE	PROB. LESS THAN
A. Monozygotic percentages		
Total vs. "white"	.64	.6
"Colored" vs. total	2.51	.02
"Colored" vs. "white"	3.46	.01
B. Dizygotic percentages		
Total vs. "white"	4.12	.001
"Colored" vs. total	22.56	.001
"Colored" vs. "white"	26.80	.001

* In each instance the population with the larger mean percentage is shown first.

basis of the present data to come to any final decision with respect to this question, but it is possible to point out a few facts which present some evidence in favor of one point of view or another. If we compare the observed variance of each distribution of 15 yearly percentages of monozygotic and dizygotic pregnancies in both the "white" and the "colored" populations with the variance expected due to chance, we find that for all of the distributions considered, the observed variance is significantly larger than the variance expected due to chance. This is shown by the F values in table 8. (For a discussion of the statistics F see FISHER 1935 and SNEDECOR 1939). Since the observed variance is significantly larger for the more or less racially homogeneous populations, as well as for the mixed groups, it seems logical to conclude that environmental factors can and do affect the incidence of occurrence of both monozygotic and dizygotic twinning in man. It does not seem likely that genetic factors varied sufficiently within the "white" or the "colored" population during the 15 year interval to be responsible for all or even most of the excessive observed variance.

Although we are inclined to think that we have evidence which suggests that environmental factors can and do affect the incidence of occurrence of both monozygotic and dizygotic twinning in man, we are not of the opinion that environmental factors are responsible for all of the observed racial differences in monozygotic and dizygotic pregnancy percentages. That dizygotic twinning in man has some genetic basis is generally accepted on the basis of

pedigree analyses. Hence it would not be surprising to find a racial difference as large as that observed due to heredity. Whether or not all of the observed racial difference in dizygotic twinning is due to genetic factors, our data do not permit us to say, but we are inclined to think that much of it is. That monozygotic twinning in man has some genetic basis is less certain. In fact most investigators question it. We do know, however, that monozygotic twinning or quadrupling among lower animal forms such as the armadillo is genetically determined. Hence it would not be unreasonable to suspect that monozygotic

TABLE 8

The F values or the extent to which the observed variance of each of twelve different distributions of monozygotic and dizygotic percentages is greater than the variance expected due to chance.

DISTRIBUTIONS ANALYZED	F* VALUE	PROB. LESS THAN
A. Monozygotic births among:		
1. twin births	13.20	.01
2. "white" twin births	9.86	.01
3. "colored" twin births	4.95	.01
4. pregnancies in total population	8.01	.01
5. pregnancies in "white" population	5.81	.01
6. pregnancies in "colored" population	4.88	.01
B. Dizygotic births among:		
1. twin births	13.20	.01
2. "white" twin births	9.86	.01
3. "colored" twin births	4.95	.01
4. pregnancies in total population	12.65	.01
5. pregnancies in "white" population	7.55	.01
6. pregnancies in "colored" population	2.72	.01

* In each instance the observed variance is greater than the variance expected due to chance. (F. 1.69 has a probability of .05 and F. 2.07 a probability of .01.)

twinning in man might be partially influenced by heredity. Our observed racial difference in the incidence of occurrence of monozygotic twinning is relatively small and could presumably be due entirely to racially different environmental factors, but we are of the opinion that it is due in part to a rôle played by heredity.

SUMMARY

The proportions of monozygotic and dizygotic twin births among all twin births in the total, the "white," and the "colored" U.S. populations from 1922 to 1936 inclusive, are estimated. It is found that the respective monozygotic percentages are 33.46, 34.17, and 28.89. The racial difference is statistically significant.

Although the "colored" population has a significantly lower proportion of monozygotic births among twin births, it has a significantly higher percentage of twin births among all births. The percentages are 1.43 for the "colored" population and 1.13 for the "white."

The greater percentage of twin births among all births in the "colored" population is due not only to more dizygotic births but also to more monozygotic. The respective "colored" and "white" dizygotic percentages are 1.01 and 0.74. The respective monozygotic percentages are 0.41 and 0.39. Both of these racial differences are statistically significant.

The observed variance of each distribution of 15 yearly twin percentages is compared with the variance expected due to chance. For all of the twelve distributions considered, the former is found to be significantly larger than the latter. This suggests that environmental factors can and do affect the incidence of occurrence of both monozygotic and dizygotic twinning in man.

Although it is thought that environmental factors do affect the incidence of occurrence of dizygotic twinning in man, the conclusion is reached that much of the observed racial difference in the percentage of dizygotic pregnancies among all pregnancies is due to hereditary differences.

The observed racial difference in the percentage of monozygotic pregnancies among all pregnancies is small and could presumably be due entirely to racial environmental differences. Yet we are inclined to think that the data suggest a partial rôle played by hereditary factors.

LITERATURE CITED

AREY, L. B., 1940 Developmental Anatomy. Philadelphia: W. B. Saunders Co.

Births, Stillbirths and Infant Mortality. Statistics for the Birth Registration Area of the United States. Bureau of the Census.

FISHER, R. A., 1935 Statistical Methods for Research Workers. Edinburgh: Oliver and Boyd.

GREULICH, W. W., 1934 Heredity in human twinning. Amer. J. Phys. Anthrop. **19**: 391–431.

HAMLETT, G. W. D., 1935 Human twinning in the United States. Racial frequencies, sex ratios, and geographical variations. Genetics **22**: 250–257.

NEWMAN, H. H., 1940 Multiple Human Births. New York: Doublebday, Doran and Company.

NICHOLS, J. B., 1907 The numerical proportions of the sexes at birth. Amer. Anthrop. Assoc. Mem. **1**: 245–300.

SNEDECOR, G. W., 1938 Statistical Methods. Ames: Collegiate Press Inc.

STRANDSKOV, H. H., 1945a Plural birth frequencies in the total, the "white" and the "colored" U. S. populations. Amer. J. Phys. Anthrop. N.S. **3**: 49–55.

1945b Birth sex ratios in the total, the "white" and the "colored" U. S. populations. Amer. J. Phys. Anthrop. N.S. **3**: 165–175.

WEINBERG, W., 1902 Beitrage zür Physiologie und Pathologie der Mehrlingsgeburten beim Menschen. Pflügers Arch. **88**: 346–430.