A Study of Variations in the Frequency of Twin Births by Race and Socio-Economic Status

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ONE OF THE PROBLEMS concerning twinning is the existence of variation in the frequency of twin births in various ethnic and racial groups. Most recently, Guttmacher (1953) has reviewed the literature on this subject. Of the 12 countries from which data have been reported, Norway has the highest frequency of twin births, 14.5 per 1,000 total births, while Japan has the lowest, 6.5 per 1,000 total births. In the United States, differences in the frequency of twinning between the white and non-white segments of the population have been recorded by Hamlett (1935) and Strandskov and Edelen (1946). An analysis of the annual reports of the United States National Office of Vital Statistics has shown that the frequency of twin births in the white population was 11.3 per 1,000 total births as compared to 14.3 per 1,000 total births among the non-white population. Of additional interest is the observation that the frequency of monozygotic twins did not differ very much in the two population groups, being 3.9 per 1,000 among whites and 4.1 per 1,000 among non-whites, whereas the frequency of dizygotic twin births differed markedly, being 7.4 per 1,000 among whites as compared to 10.1 per 1,000 among non-whites. In general, it has been found that the differences noted between ethnic groups in the twinning tendency principally represent differences in dizygotic twin births with very little difference in monozygotic twin births (Komai and Fukuoka, 1936).

Since the frequency of dizygotic twins varies with maternal age and birth order, while that of monozygotic twins does not (Yerushalmy and Sheerar, 1940), the question must be raised as to whether the differences observed between white and non-white groups merely reflect, in whole or in part, possible differences in the maternal age and birth order patterns in these groups. It is also possible that the differences between the white and non-white populations in the United States may be a manifestation of the different socio-economic circumstances in which these two groups live. This report presents an analysis of data obtained from birth records in Baltimore in an attempt to study variations in the frequency of monozygotic and dizygotic twin births among white and non-white segments of the population and further to compare whites and non-whites after maternal age, birth order and socio-economic status have been taken into consideration. In addition, it will be possible to note whether or not there exist variations in the frequency of the two types of twin births by socio-economic status since the existence of such variations must be

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taken into consideration in evaluating the use of twin studies for testing genetic hypotheses.

METHOD OF STUDY

In Baltimore, during the period 1941 to 1948, there were recorded in the Baltimore City Health Department a total of 154,550 births, including live- and stillbirths. Of these, 41,013, or 26.5 per cent, were non-white births consisting almost entirely of Negro births. On the birth certificates the age of mother, birth order and race are routinely recorded, thus making it possible to adjust for these variables in making comparisons between different population groups. In addition, Baltimore is one of the metropolitan cities on which the Bureau of Census publishes information concerning characteristics of the census tracts. The census tract comprises a neighborhood of between 3,000 and 6,000 individuals who are relatively homogeneous with regard to certain population characteristics. For each census tract there are available certain socio-economic indices, such as median monthly rental, occupational data, home ownership, etc., by means of which the population may be classified into socio-economic groups. It is thus possible, by using information available on birth certificates in Baltimore, to study the variations in the frequency of twinning by race and socio-economic groups.

A limitation to this method of socio-economic classification should be briefly considered. Table 1 contains the frequency of first births and of births occurring to mothers under 25 years of age by race and a division of the population into fifths according to socio-economic level. From this table we can see that 73% of the non-white births are classified in the lower two socio-economic fifths. A majority of the remaining 27% non-white births, although classified in the higher categories, probably live in socio-economic circumstances that more closely approximate the lower two socio-economic fifths. This might occur when several blocks of non-white families are located in a census tract that is predominantly white and are, therefore, classified in one of the higher socio-economic groups although the socio-economic status of the non-white families may be more equivalent to that of the lowest socio-economic fifth in the general population. This results from a method of classifica-

TABLE 1.—FREQUENCY OF FIRST BIRTHS AND OF BIRTHS OCCURRING TO MOTHERS UNDER 25 YEARS OF AGE, BY RACE AND SOCIO-ECONOMIC FIFTHS

Socio-Economic Fifths	White Births			Non-White Births		
	No. of total births	Per cent first births	Per cent occurring to mothers under 25 years of age	No. of total births	Per cent first births	Per cent occurring to mothers under 25 years of age
1 (lowest)	21,091	37.1	50.8	14,683	29.1	61.7
2	17,376	40.2	49.5	15,151	33.8	65.9
3	23,840	44.5	48.1	8,056	31.8	57.4
4	23,650	50.1	42.2	2,635	38.8	56.4
5 (highest)	27,580	50.5	33.3	488	—	—
Total...........	113,537	45.1	44.0	41,013	31.8	60.2

tion based on average characteristics of individuals living in an area rather than on actual individual characteristics. However, an analysis of data based on census tract classification does provide suggestive leads that indicate the problems to be studied by more refined methods of investigation.

Because of the influence of maternal age and birth order on the frequency of dizygotes, it was necessary to see if the groups being compared were different with regard to these characteristics. Space does not allow a detailed presentation of these distributions, but in Table 1 there are presented the percentage of total births that had occurred to those mothers who were under 25 years of age and the percentage of first births by race and socio-economic fifths. From this table, we may note that among whites the percentage of first births increases from 37.1 per cent in the lowest socio-economic group to 50 per cent in the highest socio-economic group. On the other hand, the percentage of total births occurring among those mothers who were under 25 years of age decreases from 50.8 per cent in the lowest group to 33.3 per cent in the highest group. Among non-whites there is a suggestion of a similar pattern but it is less marked and more irregular.

In making comparisons between races and socio-economic groups, differences in maternal age and birth order distributions can be taken into account by a method of adjustment similar to that used for age adjustment in routine vital statistics practice. For each race the like-sexed and unlike-sexed twin frequencies were calculated for each birth order and maternal age group. The birth order groups used were 1, 2, 3, and 4 and over, and the maternal age groups in years of age were, under 20, 20–24, 24–29, 30–34, and 35 and over. The maternal age and birth order specific frequencies for like-sexed and unlike-sexed twin births were multiplied by the total white births in each maternal age and birth order class and expected numbers were obtained. For each racial group, these expected numbers were totaled and, when these totals were divided by the total white births, a maternal age and birth order adjusted frequency was obtained. Thus the non-white rates were adjusted to the white maternal age-birth order distribution. These rates are, therefore, comparable with each other and will not reflect differences in maternal age and birth order. An estimate of the frequency of monozygotic and dizygotic twins was obtained by applying Weinberg's Differential Method to these expected numbers of like- and unlike-sexed twins in each socio-economic class and racial group. In using Weinberg's method, the sex ratio was taken to be 1, since it was thought that use of the actual sex ratio would affect the results only slightly.

In order to carry out statistical tests of significance of the differences between the groups being studied, a method of statistical analysis recently proposed by Cochrane has been used (Cochrane, 1954). The twin frequencies within each maternal age-birth order category are computed and compared and the results of the comparisons from all of the maternal age-birth order groups are pooled for a combined test of significance. Allowance is thereby made for the effect of maternal age and birth order on the twin frequencies. We shall illustrate the use of this method by an example in which we compare the frequency of like-sexed twins among whites and non-whites. The necessary data for one particular maternal age-birth order category (under 20, birth order 1) are presented in Table 2. For this category we

TABLE 2.—FREQUENCY OF LIKE-SEXED TWIN BIRTHS OF FIRST BIRTH ORDER AMONG MOTHERS UNDER 20 YEARS OF AGE BY RACE

Race	Total	Like-Sexed Twin Births	
		No.	Frequency
White Births	8971	37	.0041 ($=p_w$)
Non-White Births	7255	41	.0057 ($=p_{nw}$)
All Births	16226	78	.0048 ($=p_t$)

calculate the frequency of like-sexed twins among whites, non-whites and for the total (p_w, p_{nw} and p_t). We then compute the difference between non-whites and whites ($d = p_{nw} - p_w$) with the direction of the difference being indicated. Thus, in this example $d = +.0016$. A weighting factor for this category is calculated from the numbers of the two groups, as follows:

$$\text{Weighting factor} = W_1 = \frac{n_w\, n_{nw}}{n_w + n_{nw}} = \frac{8971 \times 7255}{8971 + 7255} = 4{,}011.1$$

These computations are carried out for each of the maternal age-birth order categories. A weighted mean difference ($\bar{d}$) is then computed by summing these for all the categories, thus,

$$\bar{d} = \frac{\Sigma W d}{\Sigma W}$$

This has a standard error

$$S.E. = \frac{\sqrt{\Sigma W p_t q_t}}{\Sigma W}$$

The probability level of the difference is determined by computing $\bar{d}$/S.E. and referring to the tables of the normal distribution.

In presenting the results of this study, the data are presented in terms of adjusted rates of like- and unlike-sexed twins and of monozygotic and dizygotic twins for visual comparisons, and the actual statistical analysis is carried out by summing the comparisons made in each maternal age-birth order category and applying the test devised by Cochrane.

RESULTS

During the period 1941 to 1948, there had occurred 1,142 white twin births representing a frequency of 10.1 per 1,000 total births as compared to 529 non-white twin births with a frequency of 12.9 per 1,000 total births. The frequency of white monozygotic twin births was 4.4* as compared with 4.3 among non-whites, which is in agreement with previous observations in that there is very little difference between races with regard to monozygotic twinning (Guttmacher, 1953; Hamlett,

* In this report all frequencies are expressed as per 1,000 total births.

TABLE 3.—MATERNAL-AGE AND BIRTH ORDER ADJUSTED FREQUENCIES FOR MONOZYGOTIC AND DIZYGOTIC TWIN BIRTHS BY RACE

Race	Expected No. of		Monozygotic Twin Births*		Dizygotic Twin Births*	
	Like-sexed twin births	Unlike-sexed twin births	Expected number	Adjusted frequency (per 1,000)	Expected number	Adjusted frequency (per 1,000)
White Births	821	321	500	4.4	642	5.7
Non-White Births	1035	449	556	4.9	898	7.9

* Estimated by Weinberg's Differential Method.

1935; Strandskov and Edelen, 1946). However, the estimated frequency of dizygotic twins among whites was 5.7 as compared to 8.6 among non-whites, a difference which is also in general agreement with previous observations. In order to take the difference in the maternal age and birth order distribution of the births into account, the maternal age birth order adjusted frequencies were computed for whites and non-whites. The monozygotic non-white adjusted frequency was 4.9 as compared to 4.4 for the white births and the non-white dizygotic adjusted frequency was 7.9 as compared to 5.7 for the white births (See Table 3). Thus, the process of adjustment increased the difference in frequency for monozygotes while decreasing the difference for the dizygotes.

Tests for statistical significance were carried out by comparing the frequencies of like-sexed and unlike-sexed twin births and the estimated frequencies of monozygotic and dizygotic twins among whites and non-whites. The results are presented in Table 4. From this we note that the frequencies of like-sexed and unlike-sexed twin births are higher among non-whites and these differences are significant at probability levels of .02 and .01, respectively. After the monozygotic and dizygotic twin births are estimated and their frequencies compared, the probability levels change. For monozygotic twins, the frequency is still higher among non-whites but it is not statistically significant ($P = .11$). On the other hand a comparison of dizygotic frequencies indicates an increased frequency among non-whites and this difference is significant at a probability level of .004. In evaluating these results it is necessary to keep in mind the fact that there is a certain error associated with using Weinberg's method. In addition, in carrying out these significance tests for mono-

TABLE 4.—MEAN DIFFERENCE OF FREQUENCIES OF VARIOUS TYPES OF TWIN BIRTHS BETWEEN WHITE AND NON-WHITE BIRTHS

Type of Twin Birth	Weighted Mean Difference Per 1,000 Births (Non-Whites Minus Whites)	Standard Error of Mean Difference	Ratio: $\frac{\text{Difference}}{\text{S. E.}}$	P
Like-Sexed	+1.3*	0.56	2.32	.02
Unlike-Sexed	+0.9	0.36	2.53	01
Monozygotic	+0.7	0.44	1.59	.11
Dizygotic	+1.5	0.52	2.88	.004

* A plus sign indicates that frequency is higher among Non-Whites.

and dizygotes on each maternal age-birth order category, it was necessary to eliminate several categories where the number of unlike-sexed exceeded the number of like-sexed twin births, in which situation it is not possible to estimate the number of monozygotic and dizygotic twin births. It is, therefore, necessary to consider all of the data when interpreting these results. For example, we are interested in like-sexed differences since they afford an indication with regard to monozygotic frequencies. If like-sexed differences are not significant at the usual probability levels whereas the estimated monozygotic differences are significant, we can only consider the evidence as being suggestive. On the other hand, if both of these differences are significant, our confidence in the existence of such a difference is thereby increased. Thus from the comparisons made, it is possible to state that these two races definitely differ with regard to the frequency of dizygotic twins but that the difference with regard to monozygotic twins might be considered as being suggestive.

We know that there exist socio-economic differences between these two races. It was, therefore, considered desirable to see if the twin frequencies varied by socio-economic status since if there was such a variation it should be taken into consideration in comparing the two races. The twin frequencies for each socio-economic group and race are presented in Tables 5 and 6. In Table 5 they are unadjusted for maternal age and birth order whereas in Table 6 they are adjusted.

The white monozygotic and dizygotic adjusted frequencies are presented in the upper half of Table 6. From this we note that the monozygotic frequency among

TABLE 5.—FREQUENCY OF MONOZYGOTIC AND DIZYGOTIC TWIN BIRTHS, BY RACE AND SOCIO-ECONOMIC FIFTHS

Socio-Economic Fifths	No. of total births	Number of		Monozygotic Twin Births*		Dizygotic Twin Births*	
		Like-sexed twin births	Unlike-sexed twin births	Number	Frequency (per 1,000)	Number	Frequency (per 1,000)
White Births							
1 (lowest).........	21,091	131	76	55	2.6	152	7.2
2..................	17,376	124	50	74	4.2	100	5.8
3..................	23,840	190	65	125	5.2	130	5.5
4..................	23,650	163	58	105	4.4	116	4.9
5 (highest)........	27,580	213	72	141	5.1	144	5.2
Total...........	113,537	821	321	500	4.4	642	5.7
Non-White Births							
1 (lowest).........	14,683	134	61	73	5.0	122	8.3
2..................	15,151	139	71	68	4.5	142	9.4
3..................	8,056	58	33	25	3.1	66	8.2
4..................	2,635	14	9	5	—	18	—
5 (highest)........	488	8	2	6	—	4	—
Total...........	41,013	353	176	177	4.3	352	8.6

* Estimated by Weinberg's Differential Method.

TABLE 6.—MATERNAL-AGE BIRTH ORDER ADJUSTED FREQUENCIES FOR MONOZYGOTIC AND DIZYGOTIC TWIN BIRTHS, BY RACE AND SOCIO-ECONOMIC FIFTHS

Socio-Economic Fifths	Expected No. of		Monozygotic Twin Births*		Dizygotic Twin Births*	
	Like-sexed twin births	Unlike-sexed twin births	Expected number	Adjusted frequency (per 1,000)	Expected number	Adjusted frequency (per 1,000)
White Births						
1 (lowest)	645	377	268	2.4	754	6.6
2	783	346	437	3.8	692	6.1
3	922	311	611	5.4	622	5.5
4	762	266	496	4.4	532	4.7
5 (highest)	885	333	552	4.9	666	5.9
All White Births	821	321	500	4.4	644	5.7
Non-White Births						
1 (lowest)	1270	341	929	8.2	682	6.0
2	950	657	293	2.6	1314	11.6
3	953	351	602	5.3	702	6.2
4	—	—	—	—	—	—
5 (highest)	—	—	—	—	—	—
All Non-White Births	1035	449	556	4.9	898	7.9

* Estimated by Weinberg's Differential Method.

whites is lowest in the lowest economic fifth, and there is a suggestive pattern of increase with increasing socio-economic status. It must be admitted that the pattern of increase in frequency with increasing socio-economic status is not marked. On the other hand, the adjusted dizygotic frequency is highest in the lowest economic fifth and the frequencies decrease with increasing economic fifths until the highest socio-economic fifth, when it suddenly rises. The variations observed with regard to the adjusted dizygotic frequencies are not as great as those found in the case of the white monozygotes.

In order to apply the statistical test of significance to these data, it was necessary to create a dichotomy within each maternal age-birth order category. This was accomplished by combining the upper 2 economic fifths into one group and the lower 2 economic fifths into another. Thus, the twin frequencies in the upper economic two-fifths are compared with those in the lower. The results of these comparisons are presented in the upper half of Table 7. From this we note that the frequency of like-sexed twins is higher in the upper economic group and the difference between upper and lower economic strata is significant at a probability level of .03. On the other hand the frequency of unlike-sexed twins is lower in the upper economic group but the difference is not statistically significant. A comparison of the estimates of monozygotic twin frequencies in these groups indicates that it is higher in the upper economic group at a probability level of .0014. The dizygotic twin frequency is lower in the upper economic group and the difference is significant at a probability level of .02. It would appear from these comparisons that monozygotic twins are more frequent in the upper economic groups and that the significance level for this difference probably lies somewhere between .03 and .0014. On the other hand, the increased frequency of dizygotic twins in the lower economic groups can be considered only suggestive in line with the considerations previously discussed.

The non-white frequencies similarly adjusted are shown in the bottom half of Table 6. We note that the frequencies fluctuate markedly. The monozygotic frequency is highest in the lowest fifth with a rate of 8.2 and the lowest frequency is 2.6 in the second economic fifth, with no particular pattern of change with regard to socio-economic status. Frequencies for the fourth and fifth economic groups were not computed because of the small number of non-white births in these groups. The variations for dizygotes is as great as that found in the case of monozygotes. A major reason for these fluctuations is the smaller number of non-white births, which becomes particularly impressive when frequencies are computed for a particular maternal age- and birth order group. Among non-whites many of the maternal age-birth order specific frequencies are based upon less than a hundred births and so result in a great deal of sampling fluctuation.

In order to statistically analyze the variations in frequency between the socio-economic groups of the non-white population, it was necessary to combine the upper 3 economic-fifths into one group and to compare these with the lower 2 economic-fifths, since the number of births in the upper 2 economic-fifths were so small. The

TABLE 7.—MEAN DIFFERENCE OF FREQUENCIES OF VARIOUS TYPES OF TWIN BIRTHS BETWEEN UPPER AND LOWER ECONOMIC GROUPS BY RACE

Type of Twin Birth	Weighted Mean Difference Per 1,000 Births (Upper Fifths Minus Lower Fifths)	Standard Error of Mean Difference	Ratio: Difference / S.E.	P
White Births[2]				
Like-Sexed	+1.3[1]	0.61	2.13	.03
Unlike-Sexed	−0.6	0.39	1.54	.12
Monozygotic	+1.6	0.50	3.2	.0014
Dizygotic	−1.3	0.55	2.36	.02
Non-White Births[3]				
Like-Sexed	−1.6	1.00	1.60	.11
Unlike-Sexed	−0.2	0.73	0.26	.80
Monozygotic	−0.7	0.93	0.75	.45
Dizygotic	−2.0	1.13	1.77	.08

[1] A plus sign indicates that the frequency is higher in upper economic fifths, and a minus sign, that it is lower.

[2] Among whites, the comparison is between the upper economic two-fifths, and the lower two-fifths.

[3] Among non-whites the comparison is between the upper economic three-fifths and the lower two-fifths.

TABLE 8.—MEAN DIFFERENCE OF FREQUENCIES OF VARIOUS TYPES OF TWIN BIRTHS BETWEEN TOTAL NON-WHITE AND LOWER ECONOMIC GROUP WHITE BIRTHS

Type of Twin Birth	Weighted Mean Difference Per 1,000 Births (Total Non-White Minus Lower Whites)	Standard Error of Mean Difference	Ratio: Difference / S. E.	P
Like-Sexed	+2.0*	0.66	3.03	.0024
Unlike-Sexed	+0.9	0.46	1.96	.05
Monozygotic	+1.7	0.57	2.98	.0028
Dizygotic	+1.3	0.71	1.83	.07

* A plus sign indicates that the frequency is higher among Non-Whites than in the White lower economic two-fifths.

results of the analysis of the comparisons are presented in the lower half of Table 7. From this we note that none of the differences are sufficiently great as to ever reach a probability level of .05. The variations in the frequency of these various types of twin births among the economic groups of the non-white population are not statistically significant. From our earlier discussion of the method of economic classification used, this result is not unexpected.

In view of the differences in twin frequencies among white economic groups and since the socio-economic circumstances of the vast majority of the non-white population in Baltimore are more equivalent to the white lower economic groups, it appears necessary to take this into consideration in comparing the white and non-white twin frequencies. It appears reasonable to compare the non-white total frequencies with those in the white lower economic two-fifths. Thus we note that the total non-white adjusted monozygotic frequency is 4.9 as compared to the adjusted white frequencies of 2.8 and 3.4 in the two lower economic fifths and the total non-white adjusted dizygotic frequency is 7.9 as compared to the adjusted white frequencies of 6.6 and 6.1 for the lower two economic fifths.

The comparison of total non-white frequencies with white lower economic group frequencies was analyzed for statistical significance. The results are presented in Table 8. We note that the frequencies for all twin types are higher among non-whites than among whites. The difference of like-sexed and monozygotic twin frequencies is significant at probability levels of .0024 and .0028. On the other hand the unlike-sexed and dizygotic frequencies are different at probability levels of .05 and .07. Apparently the slight excess of unlike-sexed and dizygotic twins in the white lower economic groups as previously noted is sufficient to diminish the differences between the races to borderline statistical significance. From this comparison it appears that the monozygotic twin frequency is higher among non-whites than among whites when maternal age, birth order and socio-economic status are taken into consideration, whereas the dizygotic frequency is questionably higher.

DISCUSSION

The findings of this study suggest that the frequency of white monozygotic twin births is lower in the lower socio-economic segments of the population, while that of white dizygotic twin births is higher in the lower socio-economic segments with this latter difference being of borderline statistical significance. These differences are present after adjusting for the variations in maternal age and birth order distributions between socio-economic segments. A comparison between whites and non-whites indicates that the frequency of monozygotes and dizygotes is higher among non-whites, after taking into account the effects of maternal age, birth order and socio-economic status; but the difference in dizygotic frequency is only of borderline statistical significance.

Before discussing possible explanations and implications of these findings, it is important to consider some limitations of the data. The comparisons of frequencies are made on the basis of adjustment for maternal age and birth order. It would have been more desirable to make direct comparisons of specific frequencies for each maternal age and birth order group between the various groups rather than in terms of an adjustment process. Unfortunately, the numbers were too small to permit this, particularly when broken down into different maternal age and birth order categories. The method of statistical analysis employed does not directly suffer from this limitation but, here again, it would have been preferable to compare frequencies directly without resorting to the pooling of the data for combined tests of significance.

Another possible limitation results from the use of Weinberg's method to estimate the frequency of monozygotic and dizygotic twin births. An aforementioned difficulty results from the use of census tracts as a means of economic classification. This is not the ideal method and cannot replace a classification by individual characteristics. But it is an inexpensive means of studying socio-economic differences which could indicate the need for more definitive studies. Despite these limitations, we think that the results are sufficiently suggestive to warrant the drawing of some inferences and the carrying out of more definitive studies to test these findings further.

The most surprising result was the variation in frequency of white monozygotic twin births among the different socio-economic groups. Even though statistical analysis indicated that this difference was highly significant (probability levels of less than .01), our interpretation is cautiously conservative in that we consider it as being not definitely established but highly suggestive requiring confirmation by other studies. The results are sufficiently suggestive to at least warrant an attempt at an explanation, however speculative it might be. One plausible explanation is that the difference may reflect higher abortion rates in the lower socio-economic groups. Since the frequency of abortions among monozygotic twins is probably higher than for single pregnancies, an increased abortion rate in lower economic groups would result in a lower frequency of monozygotic twin births. It would be necessary to obtain some reasonable estimates of abortion rates in these population groups to test this hypothesis. One difficulty with this hypothesis is that, since the frequency of abortions for dizygotic twin pregnancies is probably also higher than for single pregnancies we would expect that the frequency of dizygotic twin births by socio-economic groups would follow a pattern similar to that found for monozygotic twin births. However, since the frequency of abortions among dizygotic pregnancies is also probably less than for monozygotic pregnancies, the variation of frequency should not be as great as that noted for the monozygotes. Much depends upon the relative differences between the frequency of abortions among monozygotic, dizygotic and single pregnancies. For example, if the frequency of abortion among monozygotes is much higher than among dizygotic and single pregnancies, while the abortion risk of dizygotic pregnancies is only slightly higher than of single pregnancies, we would not expect that the frequency of dizygotic twin births would be influenced to any great extent by varying abortion rates in different population groups. Unfortunately, the necessary data concerning abortion rates are not available. The only information that suggests that the differences in abortion rates may be in the above direction is that stillbirth frequencies are highest among monozygotes, less frequent among dizygotes and least among single births (Yerushalmy and Sheerar, II, 1940). It is obvious that the basic difficulty with any hypothesis is that we are actually interested in the frequency of twin pregnancies and not of twin births, since the latter are the end result of a period of intra-uterine existence during which many events may occur. At present, we have no good estimate of the frequency of occurrence of such events as abortions and consequently can only offer speculative hypotheses. Another explanation for the suggestive socio-economic differences which may be less probable is that the socio-economic segments may be composed of different ethnic groups which may have different twin frequencies. These possibilities must be kept in mind in any interpretation of the differences found.

Another interesting finding was that the frequency of monozygotic twin births was higher among non-whites than among whites, particularly when maternal age, birth order and socio-economic status were considered. It is difficult to postulate a biological explanation for this difference. An extension of the same kind of reasoning that was used above with regard to socio-economic differences in the case of monozygotes would imply that the racial differences might be a result of a lower abortion rate among non-whites. This does not seem very probable, but in the absence of actual estimates of such rates, the possibility must be kept in mind. If variation in environmental circumstances does not adequately account for the findings, it may be necessary to postulate the existence of genetic differences between these two races with regard to the monozygotic twinning tendency.

Of additional interest was the finding that the dizygotic twin frequency was higher among non-whites than among whites after the effects of maternal age and birth order had been taken into account. However, when the comparison between these two races was limited to comparable socio-economic groups, the difference in frequencies diminished from high to borderline statistical significance. This result is difficult to evaluate particularly since no marked differences were noted between the socio-economic groups of the white population. But it does raise the question as to whether the differences in dizygotic twin frequencies in various ethnic groups noted by other investigators are at least partially a result of environmental factors.

IMPLICATIONS WITH REGARD TO TWIN STUDIES

Admittedly, any biological explanations for the findings are purely speculative. However, these observations do have some practical implications with regard to the utilization of twin studies as a means of testing genetic hypotheses. It would appear that a higher percentage of monozygotic twins would be in the upper socio-economic groups as compared to a group of dizygotic twins. If twin comparisons are being made to test a genetic hypothesis of a trait that is correlated either positively or negatively with socio-economic status, the comparisons in concordance frequencies between monozygotes and dizygotes may either overestimate or underestimate to some extent the true difference in concordance frequencies. If, in addition to these socio-economic differences, one considers the findings of other investigators, indicating that the monozygotes and dizygotes differ with regard to stillbirths rates, family size, and influence of maternal age, etc. the question must be raised as to their comparability. This becomes particularly important when these attributes are independently associated with the trait being studied, since it imposes certain restrictions on the inferences that can be drawn from twin studies. Some of these problems have been recently reviewed by Price, (1950).

An indication of some of these difficulties can be illustrated by the following simple mathematical model:

Let p_m = proportion of affected monozygotic twins among all monozygotic twins in the population, and

q_m = proportion of unaffected monozygotic twins among all monozygotic twins in the population, and

$p_m + q_m = 1$.

Likewise for dizygotic twins,

p_d = proportion of affected dizygotic twins among all dizygotic twins in the population, and

q_d = proportion of unaffected dizygotic twins among all dizygotic twins in the population, and

$p_d + q_d = 1$.

Then, p_m^2 = frequency of monozygotic pairs with two affected members, $2p_mq_m$ = frequency of monozygotic pairs with one affected member, and q_m^2 = frequency of monozygotic pairs with no affected members. This binomial distribution would hold true in a similar fashion for dizygotic twin pairs.

In using twins for studying a genetic hypothesis, the investigator selects an index twin with the condition being studied and then determines whether or not the other member of the twin pair is affected. He then subdivides his twin pairs according to whether or not they are monozygous or dizygous and for each of these types, he determines the percentage concordance, that is, the percentage of twin pairs in which both members are affected. The percentage concordance for monozygotes is compared with that for dizygotes and if significantly greater it is interpreted as being due to the influence of inheritance. Utilizing the terms of the binomial distribution, as derived above, it can be demonstrated that differences in concordance percentages may reflect differences between p_m and p_d.

In binomial terms, the percentage concordance for monozygotes can be expressed as follows:

$$\frac{p_m^2}{2p_mq_m + p_m^2} = \frac{p_m^2}{p_m(2q_m + p_m)} = \frac{p_m}{2q_m + p_m}$$

Similarly for dizygotes the percentage concordance can be expressed as,

$$\frac{p_d}{2q_d + p_d}$$

A comparison of these two ratios indicates that if p_m is greater than p_d, the percentage concordance for monozygotic twin pairs will be greater than the concordance for dizygotes. Thus a higher concordance percentage for monozygotes does not necessarily indicate genetic differences, since it may reflect differences between p_m and p_d. An example of such a situation was considered in a recent report of a study of epilepsy (Lilienfeld, and Pasamanick, 1954). In this investigation maternal and fetal factors such as certain complications of pregnancy and prematurity were found to be associated with epilepsy. It is thus possible that the greater prevalence of prematurity and perhaps other pregnancy factors among monozygotic than among dizygotic twin births may account, in whole or in part, for the greater concordance of epilepsy found in monozygotic twins.

One way of dealing with this problem is to determine the prevalence of a particular trait among monozygotic twins and among dizygotic twins rather than to start out with an index twin who is affected. Then one could determine if the concordance percentage is greater than is to be expected on a chance basis. Comparisons can then be made between monozygotic and dizygotic twins. If this is not done, one cannot be certain that the greater concordance among monozygotic twins is not a manifestation, at least in part, of an increased prevalence of the trait resulting from the characteristics of monozygosity.

SUMMARY

A study of the frequencies of mono- and dizygotic twin births born in Baltimore during 1941 to 1948 indicated that there is an increased frequency of both mono- and dizygotic twin births in the non-white population as compared to the white population, after adjustment for the influence of maternal age, birth order and economic status was made. An additional finding that can be considered as suggestive at present is that monozygotic twin births are less frequent in the lower socio-economic segments of the population. This finding requires confirmation by additional studies. Some possible explanations for these differences and their implications with regard to utilizing twin studies for testing genetic hypotheses are briefly discussed.

REFERENCES

COCHRANE, W. G., 1954, Some Methods for Strengthening the Common Chi-Square Tests. *Biometrics*, 10: 417–451.

GUTTMACHER, A. F., 1953, The Incidence of Multiple Births in Man and Some of the Unipara. *Obstet. & Gyn.*, 2: 22–35.

HAMLETT, G. W. D., 1935, Human Twinning in the United States. Racial Frequencies, Sex Ratios, and Geographical Variation. *Genetics*, 20: 250–257.

KOMAI, T. AND FUKUOKA, G., 1936, Frequency of Multiple Births Among the Japanese and Related Peoples. *Am. J. Phys. Anthrop.*, 21: 433.

LILIENFELD, A. M. AND PASAMANICK, B., 1954, Association of Maternal and Fetal Factors with the Development of Epilepsy. 1. Abnormalities in the Prenatal and Paranatal Periods. *J. Am. M. Ass.*, 155: 719–724.

PRICE, B., 1950, Primary Biases in Twin Studies. Am. J. Hum. Genet., 2: 293–352.

STRANDSKOV, H. H. AND EDELEN, E. W., 1946, Monozygotic and Dizygotic Twin Birth Frequencies in the Total, the "White" and the "Colored" U. S. Populations. *Genetics*, 31: 438–446.

YERUSHALMY, J. AND SHEERAR, E., 1940, Studies in Twins. 1. The Relation of the Order of Birth and Age of Parents to the Frequency of Like-Sexed and Unlike-Sexed Twin Deliveries. *Human Biol.*, 12: 95–113.

YERUSHALMY, J. AND SHEERAR, E., 1940, Studies in Twins. II. On the Early Mortality of Like-Sexed and Unlike-Sexed Twins. *Human Biol.*, 12: 247–263.