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Short Note

Is Weinberg's Differential Rule Valid?

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Weinberg's differential method, whereby the frequency of dizygotic twins in a population is obtained by doubling the number of opposite-sexed pairs, might not be valid. Data are presented indicating a higher frequency of same-sexed than opposite-sexed pairs among samples of dizygotic twins ascertained at birth, thus favoring the hypothesis that, contrary to the method's fundamental assumption, the sexes of the two twin zygotes be not independent.

Key words: Weinberg's method, Sex determination, Dizygotic twinning, Autosomal markers, Ascertainment at birth

Weinberg's differential rule states that among a sample of T twin pairs containing U unlike-sexed pairs, the estimated number of monozygotic pairs is almost exactly T – 2U. The assumption underlying this rule is that among dizygotic (DZ) pairs, the sex of one twin is independent of the sex of the other, and that, therefore, among DZ pairs there are almost exactly equal numbers of same-sexed and of opposite-sexed pairs (the difference from equality being occasioned by the fact that the sex ratio is not exactly 0.5). In 1974 Bulmer read a paper to the First International Congress on Twin Studies in which he reviewed the evidence against Weinberg's rule and concluded that it is not strong. I have published a note [11] drawing attention to data which impugn the rule. Since then, Bulmer's paper has been published in this journal [1]. Accordingly I want to offer an up-to-date summary of the data (of three sorts) which tend to suggest that there is a flaw underlying the rule.

I have suggested [5] that (a) the sexes of the zygotes in DZ pairs are not independent, and (b) consequently, contrary to Weinberg's rule, there are more same-sexed than opposite sexed DZ twin pairs. The first two lines of evidence come from these points.

THE EVIDENCE AGAINST THE RULE

1. It has been suggested independently by Guerrero [3] and James [6] that the sex of a human zygote may be related to the time of its formation within the menstrual cycle. Further data supporting the notion have been presented by Guerrero [4], James [7–10, 14, 15] and Rostron and James [21] and have been reviewed by James [12]. Roberts has given a mathematical formulation for the gravitational separation of X and Y spermatozoa [19], and has suggested that this may be the basis for much of the observed variation of human sex ratio – in particular for the data relating sex ratio to the time of insemination [20]. If this hypothesis were correct (and the evidence for it now seems strong) then presumably the sexes of the two zygotes in DZ pairs would not be independent, and there would be a flaw in Weinberg's rule.

2. Weinberg's rule is most convincingly tested by data on the autosomal markers of a large sample of twins ascertained and blood-typed at birth. Within such data, one has to confine one's attention to those pairs known to be DZ on the basis of autosomal markers alone. (Opposite-sexed pairs concordant for autosomal markers have to be omitted to compensate for the same-sexed pairs concordant for autosomal markers which are lost, never being recognised as DZ).

The Table summarises published data of this sort. It will be seen that there are appreciably more same-sexed than opposite-sexed pairs. Comparable unpublished data have been kindly made available to me by Professor J. H. Edwards (Birmingham University), Dr S. Selvin (New York State Department of Health) and Professor M. Lewis (Winnipeg); when pooled, they point in the same direction.

To make a conservative test of the assumption underlying Weinberg's rule, I have suggested [11] that (on the null hypothesis that the assumption is true) the expected proportion of opposite-sexed paris among DZ pairs is

$2(m-m^2-v)$

TABLE. Twin Pairs (Ascertained and Blood-Typed at Birth) Known to be DZ on the Basis of Autosomal Markers Alone

	Number of twin pairs		
Authors	Same sex	Opposite sex	
Potter [18]	79	71	
Walsh and Kooptzoff [24]	38	22	
Corney et al [2]	84	88	
Nylander [16]	383	318	
Say et al [22]	62	44	
Nylander and Corney [17]	79	66	
Total	725	609	$\chi^2 = 7.74, P < 0.01$
Expected frequency	674.2	659.8	

Notes: The first four sets of data above were included in Bulmer's paper [1]. Bulmer's fifth set of data was from the Birmingham Twin Survey as provisionally reported by Strong and Corney [23]. It is important to note that, by the time the numbers cited by Strong and Corney had doubled, that survey too was showing an appreciable excess of same-sexed pairs.

There seems to be no heterogeneity in the above data. And (especially when the unpublished Birmingham Twin Survey data are included) there seems to be no difference between Caucasian and Nigerian data.

where the probability of births being male has a mean m and variance v. Parameter estimates that might reasonably be inserted in this expression are m = 0.514 [8] and v = 0.0025 [7]. Using these values, the expected frequencies of same- and of opposite-sexed pairs in the Table are 674.2 and 659.8. The chi-squared value calculated on these expected and the observed frequencies is 7.74, $P < 0.01$.

3. Bulmer [1] was impressed by the fact that in one large sample of sheep twins, Weinberg's rule seemed to be obeyed. However I have noted [13] that when this sample is pooled with others, and when account is taken of the occasional MZ pair, the distribution of the combinations of the sexes seems not to be binomial. This finding is in conformity with findings on the litters of other species [10]. Taken together, these findings throw doubt on the validity of Weinberg's rule in a number of species.

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