EFFICIENCY OF GENETIC SYSTEMS FOR DIAGNOSIS OF TWIN ZYGOSITY

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A definition of efficiency is presented to aid a researcher in the choice of the genetic systems for the diagnosis of twin zygosity. An expression is given that produces a numeric value that indicates which systems do the most effective job of discriminating DZ twins from a sample of twin pairs. This definition of efficiency is illustrated with eight blood groups commonly used in twin zygosity diagnosis.

As more and more blood groups and other genetic markers become available for the diagnosis of the zygosity of a twin pair, it if often necessary to choose which genetic systems are best to use in the determination of a twin pair's zygosity. When members of a twin pair are discordant for a single blood group antigen or any other genetic marker, the pair is classified as DZ and the pairs that are concordant for all markers for the genetic systems tested are assumed to be MZ. In the case where the parental genotypes are not known, it is important to employ the genetic systems that most effectively classify the twins by zygosity.

One important aspect of chosing among the available genetic systems is the probability that a DZ twin is concordant for a specific marker. This probability is

$$P(\text{concordant}|\text{DZ}) = \left\{\left[1 + \sum_{i=1}^{N} p_i^2\right]^2 + \sum_{i \neq j}^{N} (p_i p_j)^2\right\}/4$$

where p_i is the frequency of the i-th allele in a system containing N alleles. The expression for $P(\text{concordance}|\text{DZ})$ has been derived by a number of authors for the specific cases of $N = 2$ and 3 allels (e.g., Neel and Schull 1954). For example, the case of $N = 2$ alleles with frequency p and $q = 1\text{-}p$ yields

$$\begin{aligned} P(\text{concordance}|\text{DZ}) &= \{[1 + p^2 + q^2]^2 + 2p^2q^2\}/4 \\ &= 1 - (1/2)\, pq(4\text{-}3pq) \end{aligned}$$

which is the result found in Neel and Schull (1954), Smith and Penrose (1955) and elsewhere.

It can be shown by means of Lagrange multipliers that $P(\text{concordance}|\text{DZ})$ takes on its minimum value when $p_i = 1/N$ for $i = 2, 3, \ldots, N$. This fact suggests a definition of efficiency for a specific genetic system as

$$\text{efficiency} = \frac{P(\text{discordance}|\text{DZ})}{\text{maximum } P(\text{discordance}|\text{DZ})} = \frac{1 - P(\text{concordance}|\text{DZ})}{1 - \text{minimum } P(\text{concordance}|\text{DZ})}$$

Table. *Efficiencies of* 8 *common blood group systems*

	Secretor (Le)	Kell (K)	Duffy (Fy)	ABO	A_1A_2BO	MNSs	Rh
Number of alleles	2	2	2	3	4	4	8
Minimum P (concordance | DZ)	0.5937	0.5937	0.5937	0.4630	0.4023	0.4023	0.3198
P (concordance | DZ)	0.5947	0.9050	0.5938	0.5933	0.5651	0.4351	0.4647
Efficiency	0.9977	0.2337	0.9997	0.7572	0.7277	0.9451	0.7870

and minimum $P(\text{concordance}|\text{DZ}) = (N(N+1)^2 + N-1)/4N^3$. This definition of efficiency is one measure of the distance between the actual gene frequency and the ideal situation (for discrimination purposes) where each allele in the system is equally frequent. The Figure shows the minimum probability of concordance as a function of the number of alleles in the genetic system. As the number of alleles increases, this probability approaches 0.25. The Table gives a comparison of 8 common blood groups where the gene frequencies are taken from Smith and Penrose (1955) for illustrative purposes. These frequencies apply to a specific population and any calculation of efficiencies depends on the marker frequencies p_i. Of course, these efficiencies will be obtained only in the case when all genotypes in a system are identified. Similar probabilities of concordance can be derived on the basis of genetic system phenotypes but no general expression of efficiency is possible for all cases.

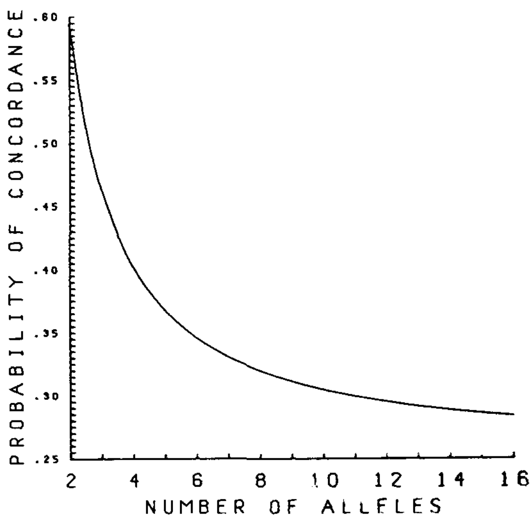

Figure. The minimum probability of concordance for the number of alleles 2-16.

The Table shows clearly that the more complex, multiple allele systems are not necessarily more efficient for determining zygosity, at least in this data set. For example, the Rh system is less efficient than several simpler blood group systems. Also, nothing is gained by differentiating between the A_1 and A_2 antigens in the ABO system.

REFERENCES

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