DISCRIMINANT ANALYSIS OF DEXTER CATTLE PHYSICAL MEASUREMENT DATA

J.A.L. Cavanagh, P.C. Thomson, I. Tammen, F.W. Nicholas and H.W. Raadsma
ReproGen, The University of Sydney, Camden NSW 2570 and Sydney NSW 2006

SUMMARY
Dexter cattle are a small breed of cattle originating in Ireland which have been bred worldwide for more than a century. There have been reports of mutant, aborted foetuses in this breed of cattle, described as chondrodysplastic foetuses (or "bulldog calves"). The affected foetuses display disproportionate dwarfism, a short vertebral column, marked micromelia, a large abdominal hernia, and a relatively large head with a retruded muzzle, cleft palate, and protruding tongue (Harper *et al.* 1998). Dexter chondrodysplasia is a single-locus disorder inherited in an incompletely dominant manner.

With the use of molecular techniques, the disease-causing gene has been identified (Cavanagh 2002). Over the course of the molecular study, 128 Dexter cattle were physically measured. With the recent development of the DNA test for Dexter chondrodysplasia, these 128 cattle were genotyped as normal or carrier animals. A discriminant analysis was performed using the measurement data and genotypes to determine which measurements more accurately separated normal and carrier animals. The best predictor was cannon bone length with 83 percent predictive accuracy. Further, a discriminant function was designed with an accuracy of 95 percent in separating normal and carrier animals.
Keywords: Dexter, cattle, chondrodysplasia, physical measurements

INTRODUCTION
Ever since the single-locus nature of Dexter chondrodysplasia was first recognised, there has been a need to distinguish heterozygotes from homozygotes. Given the early recognition that parents of affected calves tended to have shorter legs, breeders have very sensibly tried to identify carriers on the basis of leg length or some related measurement. However, in the absence of a definitive test for genotype, it was not possible to perform a rigorous test on the utility of physical measurements as an indicator of genotype. The best that could be done is a study (Symes, 1981) which is based on obligate heterozygotes and presumed homozygotes. Now that a definitive test for genotype exists, it is possible for the first time to rigorously test the utility of the different measurements. Although the DNA test removes the need for measurement assessment, it is of historical interest to assess the utility of the measurements.

MATERIALS AND METHODS
Measurements. A number of measurements were taken from 34 male Dexters and 94 female Dexters, including grade animals of various ages (data not shown). Measurements taken were the height of the animal at hip and wither, the girth, the length from wither to tail, cannon bone circumference and cannon bone length. The metacarpal index (MCI) was calculated by dividing the cannon bone length by the cannon bone circumference. These measurements are a subset of Symes' (1981) measurements. The 128 animals for which measurements were taken were also genotyped for

the chondrodysplasia mutation allowing measurement analysis based on actual genotype. Also recorded for each animal was sex and age.

Discriminant Analysis. Using discriminant analysis for each measurement, the proportion of animals correctly classified with respect to genotype solely on the basis of that measurement, was estimated. Secondly, a combined discriminant analysis on all seven measurements was conducted to determine the best linear function of the measurements in terms of proportion of animals correctly classified with respect to genotype. Finally, a stepwise discriminant procedure (Manly, 1994) was used to select the simplest function that still had effectively the same discriminating power as the best function of all seven measurements was determined.

RESULTS AND DISCUSSION

Discriminant Analysis. The data was graphed as a distribution for each genotype for each trait without adjusting for age or sex (graphs not shown). The results are summarised in Table 1 in which measurements are ranked according to their effectiveness in discriminating between genotypes.

Table 1. Effectiveness of measurements in discriminating between genotypes.

Trait	Number correct (out of 128)	Proportion correct
Cannon bone length	106	0.828
Metacarpal index (MCI)	98	0.766
Height (hip)	86	0.672
Height (wither)	81	0.633
Length	79	0.617
Cannon bone circumference	75	0.586
Girth	72	0.563

From the results in Table 1, the single trait with the most useful classification potential is cannon bone length (83%). The next best discriminator is MCI (77%). MCI is regarded by many breeders as the best discriminator, but for this dataset cannon bone length is a better predictor. The measurements at the bottom of this list have almost no predictive value, as 50% is equivalent to no predictive power.

The best discriminant function using all seven measurements was:
–86.9125 + 53.8631*MCI – 0.1195*Height.wither + 0.2601*Height.hip – 0.2306*Girth + 0.1728*Length + 3.2530*CB.circ – 0.9413*CB.length (proportion correct = 0.945).
This function is considerably more powerful (95%) than the best individual measurement (83%).
Using the stepwise procedure, the simplest function with the same discriminative power (95%) as the above function was:
–30.0648 + 0.1550*Height.hip – 0.2639*Girth + 0.1569*Length + 2.4728*CB.length.

This is the function that would be useful to breeders who are unable or unwilling to have the DNA test done. The distributions of the discriminant scores using the simplest function is illustrated in Figure 1.

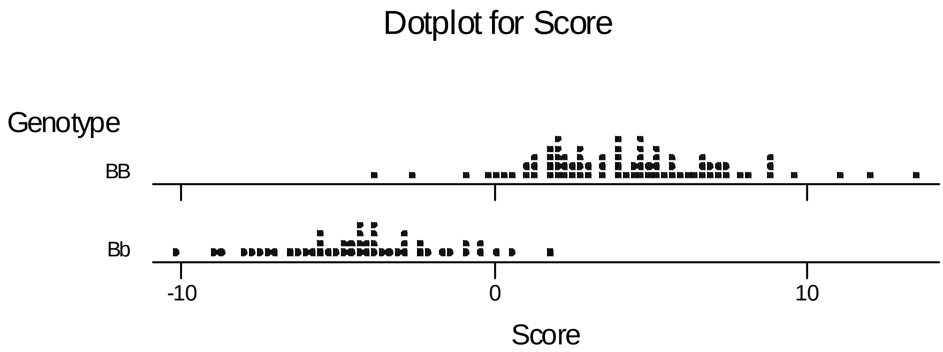

Figure 1. Dotplot showing the extent to which the discriminant function separates genotypes where BB represents the normal genotype and Bb represents carriers of chondrodysplasia.

It can be seen that with zero as the point of discrimination, the two functions would have correctly classified all but four of the homozygotes and all but two of the heterozygotes. This is the origin of the 95% figure quoted above (i.e. (4 + 2)/128 = 95%).

Further analysis using a regression model (data not shown) indicated that animals less than 3 years old are not necessarily fully grown in height. This suggests that if the discriminant analysis was conducted using predicted asymptotic height, or some other appropriate age adjustment, there would be increased discriminatory power.

As previously mentioned, the physical measurements taken on the cattle in this study are a subset of Symes' (1981) measurements. Only measurements taken by the authors were analysed in this study, to ensure consistency. As some of the measurements are difficult to take, such as length of the cannon bone, it was important to stay consistent within our own measurements, and therefore, not include those taken by other scorers.

The discriminant analysis allows us to determine how valuable the measurements are in predicting the genotype of an animal. The discriminant analysis showed that cannon bone length has a good ability to predict genotype (83%), followed by MCI (77%) and height (average 65%). The remaining three measurements had a predictive value less than 62%. Nicholas *et al.* (1996) analysed measurement data collected by Symes (1981). Symes selected carriers based on those animals that had produced affected calves, and non-carriers based on those that had normal calves only. Nicholas *et al.* found that the best genotype predictor was leg length (72%), closely followed by cannon bone length (70%), MCI (66%) and height (66%). The other ten measurements all gave predictive scores less than 57%. Unfortunately leg length was not able to be measured in this study, nor was chest depth (from which Nicholas *et al*. (1996) calculated leg length by subtracting chest depth from height), due to the lack of suitable equipment. Both studies showed the utility of cannon bone length, followed by MCI and then height, but in the present study the predictability for cannon bone length and MCI was markedly higher.

When Nicholas *et al.* (1996) combined measurements together in a discriminant function analysis; the best predictive result was 75%. However, when four measurements were grouped together in a discriminant function analysis in the present study, namely hip height, girth, length and cannon bone length, a predictive score of 95% was shown. The predictive power of 95% is superior to the predictive power of 75%, and is extremely good for predicting the genotype of an animal given physical measurements. Symes' (1981) study measured 114 females of which 11 were known carriers. The present study included 94 females (29 tested as carriers) and 34 males (12 tested as carriers). Although the overall number of animals was similar, it is possible that Symes did not identify all carriers in the group. The only animals identified as carriers were those that had produced affected calves. It is highly likely that there would have been carrier animals that had not yet produced an affected calf and would have therefore been classified as non-carriers. It is this probable misclassification that may have made the data from the present study more powerful in determining predictive ability of the measurements.

The ability to genotype accurately all animals that were measured in the present study provided powerful data for the discriminant analysis. Although it would be interesting to gather more measurement data, it is unlikely to occur, as a DNA test is now available. The measurement data is not required to indicate the likelihood of an animal being a carrier for those animals that will be DNA tested. If DNA testing was not available, measurement analysis would be a good indicator of carrier status. There would be a certain degree of incorrect classifications which could lead to the birth of affected calves which the industry is trying to avoid. DNA testing is a more accurate predictor of carrier status, and is available for the industry.

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