Comparison of two canine registry databases on the prevalence of hip dysplasia by breed and the relationship of dysplasia with body weight and height

Frank H. Comhaire, MD, PhD, and Frédéric Snaps, DVM, PhD

**Objective**—To compare the results of 2 canine registries for classification of the hip joints for dysplasia by breed, and to relate the percentage of dysplastic dogs with body metric characteristics.

**Sample Population**—Data on the ranking order of hip dysplasia by breed from 2 registries for 156 dog breeds.

**Procedures**—The prevalence of hip dysplasia listed by the Orthopedic Foundation for Animals (OFA) and the breed mean score according to the list of the British Veterinary Association (BVA) Kennel Club Hip Dysplasia scheme were related to weight and height as well as the body mass index (BMI; kg/m²) by breed.

**Results**—The OFA ranking order and the percentage of dysplastic dogs were highly correlated with the BVA mean score (p = 0.74). A significant correlation was found between the prevalence of hip dysplasia and the BMI (r = 0.63). Receiver operating characteristic curve analysis revealed that the highest area under the curve, corresponding to the best discrimination, was at a BMI of 110 kg/m² with a criterion value of 15% dysplastic dogs (area under the curve, 0.89). Because the ratio of dogs in the positive and negative groups reflected the prevalence of the condition among breeds in the OFA database, the positive likelihood ratio was 9.32 and the negative likelihood ratio was 0.24.


**Abbreviations**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFA</td>
<td>Orthopedic Foundation for Animals</td>
</tr>
<tr>
<td>FCI</td>
<td>Fédération Cynologique Internationale</td>
</tr>
<tr>
<td>BVA</td>
<td>British Veterinary Association</td>
</tr>
<tr>
<td>BMI</td>
<td>Body mass index</td>
</tr>
</tbody>
</table>

Hip dysplasia is a hereditary predisposition to the development of degenerative joint disease early in the dog’s life. Both increased laxity and structural imperfections of the hip joint, for example, the lack of congruency of the laterocranial aspect of the acetabular rim with the femoral head, are thought to cause poor joint stability resulting in subluxation and degenerative joint disease. Because the genetic code of hip dysplasia has not been fully elucidated yet, the condition is detected through phenotypic evaluation by means of radiographic investigation.

Several methods exist for assessing the hip status on radiographs by use of the standard extended position, the flexed position, or both, with or without distraction. In the scheme of the OFA and the scheme of the FCI, hip status is graded into classes on the basis of descriptive criteria, whereas the BVA Kennel Club Hip Dysplasia scheme uses a numeric classification.

It is well known that degenerative disease of the hip joints develops earlier in life in individual dogs that are genetically predisposed and are overweight. However, little is known about the relation between the body dimensions (length and weight) of dogs of various breeds and the prevalence of hip dysplasia by breed. Also, no published data are found relating the ranking of breeds and the percentage of dysplastic dogs by breed in the OFA system, compared with the BVA mean score by breed.

The only possible strategy to reduce the prevalence of hip dysplasia is by eliminating dogs carrying this hereditary condition from breeding programs. In many European countries, systematic hip evaluation is not mandatory before breeding. There is little sense in imposing systematic radiographic evaluation of breeds with a low percentage of dysplastic dogs. In contrast, all dogs intended for breeding belonging to breeds with a high genetic burden for hip dysplasia should be ex-
amined. However, the percentage of dysplastic dogs by breed is not known for each breed. The purpose of the study reported here was to compare the results of 2 registries for classification of the hip joints for dysplasia and to relate the percentage of dysplastic dogs with the body metric characteristics by breed.

**Materials and Methods**

Data acquisition—Data on the ranking order of the prevalence of hip dysplasia by breed and the percentage of dysplastic dogs were obtained from the most up-to-date data set available on the Web site of the OFA (2007). The breed mean scores on January 1, 2006, were obtained from the BVA database. Height and weight per breed were taken as the highest values for male dogs as given in the FCI breed standard. For breeds that are not accepted by the FCI, these data were collected from the Web site of the respective breeds.

All information was introduced into the spreadsheet of the statistical program, and the ratio of weight to height (kg/m) was calculated. In addition, the BMI was calculated similarly to the Quetelet index applied to humans, by dividing weight (kg) by the squared shoulder height (m). Data on weight and height were available for 156 breeds, of which 146 were listed in the OFA statistics and 103 in the BVA database. For 102 breeds, both the OFA and the BVA data were included.

Statistical analysis—Calculations of the arithmetic mean and SD, the median value, and the range (5th and 95th percentile values), and the geometric mean were determined. The distribution of height, weight-to-height ratio, and BMI was Gaussian. Distributions of the percentage of dysplastic dogs and of the BVA mean score were log-normal, and these variables were best described by the geometric mean and range. Correlations were calculated by use of the least squares method if the distribution of the data was normal, and the nonparametric Pearson rank correlation for data with skewed distribution, as indicated. Receiver operating characteristic curve analysis was used to determine the power of BMI to discriminate between breeds with high or low hip dysplasia prevalence, define criterion values, and calculate the sensitivity and specificity as well as the positive and negative likelihood ratios. Values of $P < 0.05$ were considered significant.

**Results**

The number of breeds with accurate data and their descriptive characteristics were determined (Table 1). The variability of the characteristics was large, as evidenced by the high values of SD and range, which corresponded with the important variability of body configuration found in dog breeds. Because of the high variability, the description of the results by means of the only the mean value was not valid; therefore, median and range (5th and 95th percentile values) were used.

The median percentage of dogs with dysplasia by breed was 12.1% (range, 2% to 44.8%). The median of the BVA mean score by breed was 13 points (range, 7 to 27.4 points). The median values of weight and height were 29.3 kg (range, 6.5 to 67.7 kg) and 0.61 m (range, 0.294 to 0.80 m), and the median BMI was 84.8 kg/m$^2$ (range, 52.2 to 137.4 kg/m$^2$).

Correlations relating to the percentage of dysplastic dogs, BVA mean score, weight, height, weight-to-height ratio, and BMI were determined (Table 2). Significant correlations were found between the percentage of dysplastic dogs and BVA mean score ($\rho = 0.74; P < 0.001$) and between weight and height ($\rho = 0.89; P < 0.001$). Significant correlations were also found between the percentage of dysplastic dogs and BVA mean score on

---

**Table 1**—Descriptive results of the population.

<table>
<thead>
<tr>
<th>Variables</th>
<th>No.</th>
<th>Mean ± SD*</th>
<th>Median (range)</th>
<th>Geometric mean†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dysplastic (%)</td>
<td>146</td>
<td>15.15 ± 12.85</td>
<td>12.1 (2.0–44.8)</td>
<td>11.08</td>
</tr>
<tr>
<td>BVA mean score</td>
<td>103</td>
<td>15.24 ± 7.11</td>
<td>13.0 (7.0–27.4)</td>
<td>13.96</td>
</tr>
<tr>
<td>Height (m)</td>
<td>156</td>
<td>0.569 ± 0.151</td>
<td>0.610 (0.294–0.800)</td>
<td>0.546</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>156</td>
<td>31.37 ± 18.44</td>
<td>29.3 (6.5–65.7)</td>
<td>25.71</td>
</tr>
<tr>
<td>Weight:height ratio (kg/m)</td>
<td>156</td>
<td>50.85 ± 21.09</td>
<td>48.4 (20.1–87.7)</td>
<td>45.42</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>156</td>
<td>89.41 ± 28.05</td>
<td>84.83 (52.2–137.4)</td>
<td>82.43</td>
</tr>
</tbody>
</table>

*Arithmetic mean. †Geometric mean given because certain variables present a log-normal distribution. No. = Number of breeds included in the statistics.

**Table 2**—Correlations between the variables studied.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Percentage of dysplastic dogs</th>
<th>BVA mean score</th>
<th>Height</th>
<th>Weight</th>
<th>Weight:height ratio</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFA rank</td>
<td>−0.86*</td>
<td>−0.74**</td>
<td>−0.06</td>
<td>−0.35*</td>
<td>−0.50**</td>
<td>−0.61*</td>
</tr>
<tr>
<td>Percentage of dysplastic dogs</td>
<td>0.74**</td>
<td>0.01</td>
<td>0.30*</td>
<td>0.48**</td>
<td>0.63*</td>
<td></td>
</tr>
<tr>
<td>BVA mean score</td>
<td>−0.06</td>
<td>−0.06</td>
<td>0.19*</td>
<td>0.37*</td>
<td>0.52*</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>−0.08</td>
<td>0.09*</td>
<td>0.71*</td>
<td>0.46*</td>
<td>0.69*</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>−0.06</td>
<td>−0.06</td>
<td>0.33*</td>
<td>0.46*</td>
<td>0.69*</td>
<td></td>
</tr>
<tr>
<td>Weight:height ratio</td>
<td>−0.06</td>
<td>−0.06</td>
<td>−0.06</td>
<td>0.33*</td>
<td>0.46*</td>
<td></td>
</tr>
</tbody>
</table>

*Significant ($P < 0.001$) correlation between variables. *Coefficient of correlation ($r$) calculated by the least squares method. *Correlation ($\rho$) calculated by the Pearson rank method.
the one hand, and weight as well as the ratios including weight, namely weight divided by height and BMI ($r = 0.63; P < 0.001$), on the other hand. Height was, however, neither correlated with the percentage of dysplastic dogs nor with the BVA mean score.

Receiver operating characteristic curve analysis of the power of BMI to discriminate between high or low prevalence of hip dysplasia by breed revealed an area under the curve varying between 0.78 and 0.89 for BMI values between 60 and 120 kg/m$^2$. The highest area under the curve, corresponding to the best discrimination, was at BMI value of 110 kg/m$^2$ and a criterion value of 15% of dysplastic dogs (area under the curve, 0.89; specificity, 91.7% with a 95% confidence interval of 73.0% to 98.7%; sensitivity, 77.7% with a 95% confidence interval of 69.2% to 84.7%). Because the ratio of dogs in the positive and negative group reflected the prevalence of the condition among breeds in the OFA database, the positive likelihood ratio was 9.32, and the negative likelihood ratio was 0.24. Similar results were found for the BVA mean score (area under the curve, 0.84).

Distribution plots and regression line of BMI versus the percentage of dysplastic dogs and of BMI versus the BVA mean score were developed (Figures 1 and 2, respectively). The relationship between the percentage of dysplastic dogs and BVA mean score was also determined (Figure 3).

**Discussion**

Genetic predisposition to hip dysplasia has been reported. Hip dysplasia may result in clinical expression as signs of degenerative joint disease, depending on external factors among which weight, and being overweight in particular, has been identified as an important risk factor among individual dogs. However, to our knowledge, no data are found concerning the relationship between the prevalence of hip dysplasia by breed and the general body dimensions of dogs of these breeds.

The prevalence of hip dysplasia in different breeds can be obtained from several sources, but the OFA database and the BVA mean score probably include the highest number of dogs. However, the BVA mean score is based on a numeric system, whereas the OFA classification uses descriptive classes that are rather similar to the system recommended by the FCI. Results of our study indicate that a good correlation exists between the results obtained in the 2 systems. The degree of correlation between the BVA mean score and OFA ranking is identical to that of the BVA mean score and the percentage of dysplastic dogs, which is because OFA ranking is based on the percentage of dysplastic dogs per breed. The high degree of correlation suggests that 55% ($R^2 = 0.74$) of the variability of the percentage of dysplastic dogs is explained by the variation of the BVA mean score. The good correlation also suggests that no major difference exists between the hips joints of US dogs included in databases of the OFA and those of dogs included in the BVA database. Our finding casts doubt on the importance of the suggested bias in the OFA database. Alternatively, it may be argued that a similar amount of bias could be present in both databases. Other methods aiming at the assessment of hip quality...
based on distraction under stress\textsuperscript{7,8} may be equally subjected to bias because radiographs of dogs with severe lesions may be withheld from assessment and registration. The University of Pennsylvania Hip Improvement Program registry attempts to overcome this bias by requiring its member veterinarians to submit all radiographic distraction studies that are performed.

The finding of a high correlation between weight and height in our study was expected because taller dogs tend to also be heavier. However, the percentage of dysplastic dogs was not correlated with height, whereas the percentage of dysplastic dogs had a significant correlation with weight. The weight-to-height ratio was correlated with both components of the ratio. Similarly, BMI was correlated with weight and with the weight-to-height ratio.

In our study, the percentage of dysplastic dogs by breed was highly correlated with BMI and the BVA mean score was correlated with BMI. As much as 40% ($R^2 = 0.63$\textsuperscript{7}) of the variability of the percentage of dysplastic dogs by breed was related to the variability of BMI. This finding is biologically meaningful but does not imply a causal relationship between hip dysplasia, which is genetically defined, and BMI.

From receiver operating characteristic curve analysis (data not shown), results from our study indicate that pivotal BMI at which the prevalence of hip dysplasia by breed increases over 15% is between 100 and 110 kg/m\textsuperscript{2}, with the latter BMI having the highest positive likelihood ratio. Exceptions to this finding were the Corgis, Petit Basset Vendean, and Black and Tan Coonhound (United States), which have a relatively low prevalence of hip dysplasia for their BMI, and the Pug, Boykin Spaniel (United States), and the Norfolk Terrier, which seem to have a higher hip dysplasia prevalence than expected from their BMI.

Regarding the positive relationship between BMI and the BVA mean score, exceptions are the Standard Schnauzer, Gordon Setter, Newfoundland, and Cane Corso with higher BVA mean score than expected for their BMI and the Bulldog with lower BVA mean score than expected from their BMI. These findings confirm previous observations of differences in breed susceptibility for hip dysplasia.\textsuperscript{20,21} Exceptions also underscore the limitations of the registry bases and of the BMI, while highlighting the multifactorial reasons for the radiographic expression of hip dysplasia.

In summary, results of our study indicate that breeds with high BMI have a high prevalence of hip dysplasia. This information may encourage relevant breed clubs to introduce systematic radiographic evaluation of the hip joints as part of their breeding strategy.

References