Quantification of measurement of femoral head coverage and Norberg angle within and among four breeds of dogs

James L. Tomlinson, DVM, MVSci; and Jane C. Johnson, MA

Objective—To report values for percentage coverage of the femoral head (PC) and Norberg angle (NA) in 4 common breeds of dogs and to determine values for each that distinguish between normal and dysplastic hip status on the basis of Orthopedic Foundation for Animals (OFA) hip evaluation.

Animals—1,841 dogs 24 to 48 months of age that were Labrador Retrievers (455), Golden Retrievers (423), Rottweilers (418), or German Shepherd Dogs (418).

Procedure—Retrospective analysis of NA and PC measured from standard OFA ventrodorsal pelvic radiographs from 4 breeds of dog.

Results—Norberg angle ranged from 67.4 to 124.4° for Labrador Retrievers, 59.7 to 128.6° for Rottweilers, 70.2 to 119.4° for Golden Retrievers, and 56.3 to 121.3° for German Shepherd Dogs. The PC ranged from 6.5 to 79.9% for Labrador Retrievers, 5.7 to 79.5% for Rottweilers, 8.3 to 79.3% for Golden Retrievers, and 5.4 to 83.7% for German Shepherd Dogs. On the basis of logistic regression modeling for determining normal versus abnormal hip status for all 4 breeds, cutoff points for NA were < 105° and PC were < 50%.

Conclusions and Clinical Relevance—Results of our study indicate that cutoff points of NA of 105° and PC of 50% do not differentiate normal versus dysplastic hip status. Each of the 4 breeds had different values for NA and PC that distinguished normal from dysplastic hip status. (Am J Vet Res 2000;61:1492–1500)

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ip dysplasia is a common inherited disease of dogs that leads to osteoarthritis and various degrees of disability.1-3 Norberg angle (NA) has commonly been used as a variable to measure the degree of hip joint laxity in normal and dysplastic dogs in research studies.4-6 Norberg angle also has been used as one of the criteria for determining the hip status (normal or dysplastic) in some hip registries and breed club standards.1,13-15 A NA of 105° has been used as the number that distinguishes between normal and dysplastic hip status.14 A NA of 105° or greater has been considered to indicate normal status.15 Percent coverage of the femoral head (PC) is another reported variable for assessment of normal or abnormal status of the hip joint.6,12,14 Hip joints with 50% or greater coverage of the femoral head by the acetabulum have been considered to have normal status.12-14 To our knowledge, no definitive study to support a PC of 50% as distinguishing between normal and abnormal hip status exists in the literature. Values < 105° for NA and < 50% for PC have been described for dogs with normal hip status.6,9,12,20

The purpose of the study reported here was to establish values for PC and NA in 4 breeds of dogs and to determine the values of each that distinguish between normal and abnormal hip status on the basis of Orthopedic Foundation for Animals (OFA) hip evaluation. Our hypothesis was that cutoff points of 105° for NA and 50% for PC do not distinguish between normal and abnormal hip status. Our second purpose was to test the hypothesis that each breed has distinct values for NA and PC that separate dysplastic and normal hip status and grades of normal and dysplastic hip status. Our third purpose was to determine whether there were differences in NA and PC among OFA grades within a breed and among breeds.

Materials and Methods

Radiographs from 4 breeds of dogs were retrieved from the files of the OFA.1 Breeds evaluated were Labrador Retrievers, Golden Retrievers, Rottweilers, and German Shepherd Dogs. Only dogs radiographed between the ages of 24 to 48 months were included. All radiographs were from dogs that had been sent by private owners to OFA for evaluation. Each film was reviewed to ensure acceptable positioning for hip joint evaluation and clarity of radiographic detail of the pelvis and femurs. Acceptable positioning required that the whole pelvis and femurs be included on the radiograph. The femurs were positioned so that the femurs were parallel and extended, and each patella was centered in the trochlear groove of its respective femur with a symmetrical pelvis. Coxofemoral joints from each dog had been assigned to 1 of the 6 grades used by OFA grading system (normal, 1 = excellent; 2 = good, 3 = fair; abnormal, 4 = mild, 5 = moderate, 6 = severe). Three OFA consulting radiologists from a pool of 25 graded all radiographs. All reviewers of each radiograph had independently given the same pelvic radiograph the same OFA score. Dogs with unilateral hip dysplasia were not included in our study. The grade of normal or abnormal hip status was recorded along with age, breed, and sex of each dog.

Area of the femoral head covered by the acetabulum for the right and left hip joints was measured in square millimeters by use of a digital scanner1 coupled to a microcomputer. The measurement was captured by use of a software measurement program.1 Area of the femoral head was measured 3 times for each hip joint. The femoral head was considered to be a circle, as viewed on the radiograph (Fig 1). The center of the femoral head was located, using a circle template. The circle that best fit the arc of curvature of the femoral head was...
selected. The diameter of each femoral head was recorded and the area of the femoral head calculated in square millimeters using the formula for area of a circle. The PC by the acetabulum was calculated and recorded by the software measurement program by dividing the area of the femoral head covered by the acetabulum by the total area of the femoral head and then multiplying by 100.

Norberg angle was measured for each hip joint of each dog (Fig 2). The angle was measured by use of a digital scanner coupled to a microcomputer and captured, using the measurement software program. Norberg angle was measured 3 times for each hip joint.

For statistical analysis, except for correlation analysis, the 3 measured values from each individual hip joint for NA and PC were averaged. Data were analyzed by grouping the data by low limb (LL) and high limb (HL) measurements. Low limb measurement was defined as the low value for NA and PC between the 2 hip joints of a dog for the variable being analyzed. High limb measurement was defined as the high value between the 2 hip joints of a dog for the variable being analyzed. Data were further grouped by breed, OFA grade, and by dysplastic or normal hip conformation. For correlation analysis, each measurement of the hip joint for NA and PC was used in the analysis making 6 measurements per dog. A value of \( P \leq 0.05 \) was considered significant.

Study 1—The mean, SD, median, and range for LL and HL measurements of NA and PC of the femoral head were calculated for each of the 6 OFA grades for the 4 breeds of dogs. To measure the strength of the relationship between NA and PC across grades and within grades for each breed, all 6 measurements from each dog were used to calculate Spearman correlation coefficients. A correlation coefficient > 0.7 was considered to indicate a strong correlation.

Study 2—The Jonckheere-Terpstra test, a nonparametric test used when the alternative hypothesis suggests a particular order of medians, was used to determine whether median NA and PC values were ordered in magnitude by grade. The HL and LL measurements were analyzed within each breed. If the results of the test were significant, the Dunn multiple comparison procedure was used to determine which pairs of grades had significant differences.

Study 3—A logistic regression model, using only LL measurements, was fitted to calculate the values of NA and PC that distinguished between normal and dysplastic hip status along with 95% fiducial limits. Fiducial limits were calculated with NA and PC individually and in combination. Using this model, sensitivity, specificity, false-positive rates, and false-negative rates were calculated.

Sensitivity was defined as what percentage of dogs, which were classified by OFA as having dysplastic hip status, were correctly predicted. Specificity was defined as what percentage of dogs, which were classified by OFA as having normal hip status, were correctly predicted. False-positive rate was defined as what percentage of dogs, which were classified by OFA as having dysplastic hip status, had normal status. False-negative rate was defined as what percentage of dogs, which were classified by OFA as having normal hip status, had dysplastic hip status.

Study 4—Using NA of 105° and PC of 50% as cutoff points of LL measurements for predicting whether a hip joint had normal or dysplastic status, sensitivity, specificity, false-positive rates, and false-negative rates were calculated on the basis of the actual assigned OFA classification for each breed. Values were calculated for NA and PC individually and for the combination of NA and PC.

Study 5—Logistic regression models were used to
decide whether age and sex were determinants of whether a dog was classified as having normal or dysplastic hip status based on LL measurements for each breed. The interaction of age and sex with NA and PC, using LL measurements for each breed, as a determinant of hip status was also evaluated.

Study 6—To test whether there were differences in values for NA and PC among breeds within an OFA grade, the Kruskal-Wallis test was used. If the results of the test were significant, the Dunn multiple comparison procedure was used to determine which pairs of breeds had significant differences.

Results
Study 1—Mean age of dogs in each of the 4 breeds at the time the radiographs were taken for OFA evaluation were calculated (Table 1). Using LL and HL measurements, mean, SD, and median values, and range of values for NA and PC for each of the 6 OFA grades for the 4 breeds were summarized (Table 2-5). Norberg angle ranged from 67.4 to 124.4° for Labrador Retrievers, 59.7 to 128.6° for Rottweilers, 70.2 to 119.4° for Golden Retrievers, and 55.3 to 121.3° for German Shepherd Dogs. Percent coverage of the femoral head ranged from 6.5 to 79.9% for Labrador Retrievers, 5.7 to 79.5% for Rottweilers, 8.3 to 79.3% for Golden Retrievers, and 5.4 to 83.7% for German Shepherd Dogs.

Correlation coefficients, calculated using all 6 measurements from each dog, between NA and PC for each breed were calculated (Table 6). A correlation coefficient $>0.7$ was considered to indicate a strong correlation. For all 4 breeds, a strong correlation was found between NA and PC across all grades within a
breed (range, 0.86-0.90). Within a grade, only grade 5 for Labrador Retrievers had a strong correlation between NA and PC (0.70).

**Study 2**—Results of Jonckheere-Terpstra tests indicated that, in all 4 breeds, the median values for NA and PC were consistent with the ordering expected. The relationship of the 6 OFA grades within each breed for NA and PC were calculated. In general, going from grade 1 to 6, the values for each grade were significantly larger than the next. For Labrador Retrievers, Rottweilers, and German Shepherd Dogs, grade 1 and 2 were not significantly different for NA. For PC, grade 1 and 2 were not significantly different in German Shepherd Dogs. Grade 5 and 6 values for PC for Golden Retrievers were not significantly different.

**Study 3**—The calculated values for NA and PC from the logistic regression model, when considered together, that distinguish between normal and dysplastic hip status along with upper and lower fiducial limits were calculated. On the basis of PC, 42.2% (lower to upper limit; 40.3 to 44.2%), 42.7% (41.1 to 44.7%), 37.9% (36.2 to 39.6%), and 44.8% (42.8 to 48.3%) differentiated between normal and dysplastic hip status for Labrador Retrievers, Rottweilers, Golden Retrievers, and German Shepherd Dogs, respectively. On the basis of NA, 99.9% (lower to upper limit; 65.4 to 105°), 101.9%...
(99.9 to 104.9°), 92.6 (88.2 to 94.8°), and 100.3° (98.2 to 103.7°) differentiated between normal and dysplastic hip status for Labrador Retrievers, Rottweilers, Golden Retrievers, and German Shepherd Dogs, respectively.

Correctly classified, sensitivity, specificity, false-positive rates, and false-negative rates were determined, using the logistic regression model values versus the OFA assigned hip status (Table 7). On the basis of the values for PC and NA, 91.8 to 97.8% of the dogs were correctly classified for hip status. Sensitivity of the calculated values ranged from 91.4 to 97%. Specificity of the calculated values ranged from 92.3 to 98.4%. Golden Retrievers had the lowest values correctly classified, sensitivity, and specificity. False-positive rates ranged from 2 to 9.5%, whereas false-negative values ranged from 2.3 to 9.6%. Using NA or PC separately, values for correctly classified, sensitivity, specificity, false-positive rates, and false-negative rates were similar but typically somewhat lower than the values obtained by use of NA and PC combined.

Study 4—Using a rule of NA ≥ 105° and PC ≥ 50% as differentiating between normal and dysplastic hip status versus the OFA assigned hip status, the percentage of correctly classified, sensitivity, specificity, false-positive rates, and false-negative rates for normal or dysplastic hip status were determined (Table 8). Percentage of hip joints correctly classified by NA ≥ 105° and PC ≥ 50% versus the OFA assigned hip status ranged from 63.3 to 85.7%. Sensitivity for all 4 breeds was 100%. Specificity ranged from 19.7 to 74.4%. False-positive rates ranged from 23.3 to 50.5%, whereas false-negative values were all zero. Using NA or PC alone was less reliable in predicting hip status than using PC and NA together.

Study 5—The P values to determine the significance of sex, age, and combinations of sex and age with PC and NA for predicting hip status were determined by means of LL measurements (Table 9). Sex and the interaction of sex and NA were significant determinants of hip status for Rottweilers. For male Rottweilers, NA and PC were significant determinants of hip status. However, for female Rottweilers, only PC was significant; NA was not.

Study 6—Using LL and HL measurements, com-

Table 7—Correctly classified, sensitivity, specificity, false positive rates, and false negative rates for predicting hip status (on the basis of predicted values for NA and PC from the logistic regression model) versus the OFA assigned hip status

<table>
<thead>
<tr>
<th>Breed</th>
<th>Correctly classified</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>False positive</th>
<th>False negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labrador Retriever</td>
<td>97.8%</td>
<td>97.0%</td>
<td>98.4%</td>
<td>2.0%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Rottweiler</td>
<td>95.0%</td>
<td>94.3%</td>
<td>95.7%</td>
<td>4.6%</td>
<td>5.3%</td>
</tr>
<tr>
<td>Golden Retriever</td>
<td>92.0%</td>
<td>91.4%</td>
<td>92.4%</td>
<td>9.5%</td>
<td>6.8%</td>
</tr>
<tr>
<td>German Shepherd Dog</td>
<td>91.8%</td>
<td>91.4%</td>
<td>92.3%</td>
<td>6.9%</td>
<td>9.6%</td>
</tr>
</tbody>
</table>

Table 8—105° Norberg and 50% coverage of the femoral head rule for predicting hip status

<table>
<thead>
<tr>
<th>Breed</th>
<th>Correctly classified</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>False positive</th>
<th>False negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labrador Retriever</td>
<td>85.7%</td>
<td>100%</td>
<td>74.4%</td>
<td>24.4%</td>
<td>0</td>
</tr>
<tr>
<td>Rottweiler</td>
<td>85.3%</td>
<td>100%</td>
<td>71.6%</td>
<td>23.3%</td>
<td>0</td>
</tr>
<tr>
<td>Golden Retriever</td>
<td>63.3%</td>
<td>100%</td>
<td>19.7%</td>
<td>50.5%</td>
<td>0</td>
</tr>
<tr>
<td>German Shepherd Dog</td>
<td>67.6%</td>
<td>100%</td>
<td>30.8%</td>
<td>37.5%</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Breed</th>
<th>105° Norberg angle</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>False positive</th>
<th>False negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labrador Retriever</td>
<td>87.7%</td>
<td>99.0%</td>
<td>78.7%</td>
<td>21.3%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Rottweiler</td>
<td>88.3%</td>
<td>97.7%</td>
<td>79.4%</td>
<td>18.4%</td>
<td>2.6%</td>
</tr>
<tr>
<td>Golden Retriever</td>
<td>55.32%</td>
<td>100%</td>
<td>19.9%</td>
<td>50.7%</td>
<td>0</td>
</tr>
<tr>
<td>German Shepherd Dog</td>
<td>71.0%</td>
<td>99.6%</td>
<td>38.8%</td>
<td>35.2%</td>
<td>1.3%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Breed</th>
<th>50% coverage of the femoral head</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>False positive</th>
<th>False negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labrador Retriever</td>
<td>87.0%</td>
<td>100%</td>
<td>76.8%</td>
<td>22.7%</td>
<td>0</td>
</tr>
<tr>
<td>Rottweiler</td>
<td>88.2%</td>
<td>99.6%</td>
<td>73.8%</td>
<td>22.0%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Golden Retriever</td>
<td>76.4%</td>
<td>100%</td>
<td>57.6%</td>
<td>34.8%</td>
<td>0</td>
</tr>
<tr>
<td>German Shepherd Dog</td>
<td>78.5%</td>
<td>100%</td>
<td>54.2%</td>
<td>28.8%</td>
<td>0</td>
</tr>
</tbody>
</table>

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Comparisons of NA and PC among breeds within an OFA grade were made (Table 10). For NA values, a discernible pattern of similarity was found between Labrador Retrievers and Rottweilers, especially in the 3 normal OFA grades of hip conformation. Except for grades 4 and 6, Labrador Retrievers and Golden Retrievers had significantly different values for NA. Rottweilers and Golden Retrievers had significantly different values for NA across all 6 OFA grades.

Using LL and HL measurements, comparison of values for PC within OFA grade 2 by means of HL measurements revealed no significant differences among breeds. Within OFA grade 2, comparison of values for PC by means of LL measurements revealed no significant differences among Labrador Retrievers, Golden Retrievers, and German Shepherd Dogs. Within OFA grade 3, Labrador Retrievers, Rottweilers, and German Shepherd Dogs had values for PC that were not significantly different from each other but that were significantly different from values for Golden Retrievers. Within OFA grade 4, German Shepherd Dogs had significantly different values than the other 3 breeds of dogs for PC. Using LL and HL measurements, no significant differences in values for PC were found between Labrador Retrievers and German Shepherd Dogs within OFA grade 5. No significant differences were found among the 4 breeds for PC within OFA grade 6. Labrador Retrievers and German Shepherd Dogs had PC that were similar across OFA grades. Rottweilers and Golden Retrievers had similar values for PC across OFA grades.

**Discussion**

Determination of hip status (normal vs dysplastic) and grade as determined by the OFA system is based on the evaluation of 9 criteria. For each dog evaluated, the worst hip joint determines the grade within normal or dysplastic hip status. It is possible for a dog to have one hip joint grade better than the other if a grade had been assigned for each hip joint separately. Dogs with unilateral hip dysplasia were not included in our study, as both hip joints were judged as normal or dysplastic by the OFA consulting radiologists. By OFA criteria, any hip joint that has osteoarthritis is auto-

**Table 9—P values* for the effect of age and sex on the determination of hip status for dogs by use of low limb measurements**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Labrador Retrievers</th>
<th>Rottweilers</th>
<th>Golden Retrievers</th>
<th>German Shepherd Dogs</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>0.05</td>
<td>0.003</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>PC</td>
<td>0.04</td>
<td>0.05</td>
<td>0.0004</td>
<td>0.003</td>
</tr>
<tr>
<td>Sex</td>
<td>0.19</td>
<td>0.02</td>
<td>0.23</td>
<td>0.44</td>
</tr>
<tr>
<td>Age</td>
<td>0.80</td>
<td>0.59</td>
<td>0.57</td>
<td>0.71</td>
</tr>
<tr>
<td>NA × Sex</td>
<td>0.22</td>
<td>0.006</td>
<td>0.65</td>
<td>0.37</td>
</tr>
<tr>
<td>PC × Sex</td>
<td>0.39</td>
<td>0.07</td>
<td>0.19</td>
<td>0.69</td>
</tr>
<tr>
<td>NA × Age</td>
<td>0.89</td>
<td>0.49</td>
<td>0.62</td>
<td>0.89</td>
</tr>
<tr>
<td>PC × Age</td>
<td>0.45</td>
<td>0.58</td>
<td>0.68</td>
<td>0.79</td>
</tr>
</tbody>
</table>

*P values for logistic regression model. P < 0.05 considered significant. See Table 2 for key. NA × Sex = Interaction of the Norberg angle and sex. PC × Sex = Interaction of the percent coverage of the femoral head and sex. NA × Age = Interaction of the Norberg angle and age. PC × Age = Interaction of the percent coverage of the femoral head and age.

**Table 10—Comparison of Norberg angle and percentage coverage of the femoral head among breeds**

<table>
<thead>
<tr>
<th>Value</th>
<th>Grade 1</th>
<th>Grade 2</th>
<th>Grade 3</th>
<th>Grade 4</th>
<th>Grade 5</th>
<th>Grade 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>LL (1,2 ≠ 3)</td>
<td>(1,2 ≠ 3)</td>
<td>(1,2 ≠ 3)</td>
<td>2 ≠ (1,3,4)</td>
<td>1 ≠ 2</td>
<td>(1,2) ≠ 4</td>
<td></td>
</tr>
<tr>
<td>LL (1,2 ≠ 4)</td>
<td>(1,2) ≠ 4</td>
<td>(1,2) ≠ 4</td>
<td>—</td>
<td>2 ≠ (1,3,4)</td>
<td>2 ≠ 3</td>
<td></td>
</tr>
<tr>
<td>LL (3)</td>
<td>(3)</td>
<td>3 ≠ 4</td>
<td>3 ≠ 4</td>
<td>—</td>
<td>1 ≠ 3</td>
<td>(1,3)</td>
</tr>
<tr>
<td>LL</td>
<td>P &lt; 0.001</td>
<td>P &lt; 0.001</td>
<td>P &lt; 0.001</td>
<td>P &lt; 0.001</td>
<td>P &lt; 0.001</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>HL (1,4)</td>
<td>(2)</td>
<td>(1,2) ≠ 3</td>
<td>(1,2) ≠ 3</td>
<td>2 ≠ (1,3,4)</td>
<td>(1,2) ≠ (3,4)</td>
<td>2 ≠ (3,4)</td>
</tr>
<tr>
<td>HL (3)</td>
<td>3 ≠ 4</td>
<td>3 ≠ 4</td>
<td>—</td>
<td>—</td>
<td>1 ≠ 2</td>
<td></td>
</tr>
<tr>
<td>HL</td>
<td>P &lt; 0.001</td>
<td>P &lt; 0.001</td>
<td>P &lt; 0.001</td>
<td>P &lt; 0.001</td>
<td>P &lt; 0.001</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>Percent coverage of the femoral head</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LL (1,2,3,4)</td>
<td>2 ≠ (1,4)</td>
<td>(1,2,4) ≠ 3</td>
<td>4 ≠ (1,2,3)</td>
<td>3 ≠ (1,4)</td>
<td>(1,2,3,4)</td>
<td></td>
</tr>
<tr>
<td>LL</td>
<td>(1,2)</td>
<td>(1,2)</td>
<td>—</td>
<td>2 ≠ 3</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>LL</td>
<td>(1,3,4)</td>
<td>—</td>
<td>—</td>
<td>(1,2)</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>LL</td>
<td>P = 0.06</td>
<td>P = 0.03</td>
<td>P &lt; 0.001</td>
<td>P &lt; 0.003</td>
<td>P &lt; 0.001</td>
<td>P = 0.12</td>
</tr>
<tr>
<td>HL (1,2,3,4)</td>
<td>(1,2,3,4)</td>
<td>(1,2,4) ≠ 3</td>
<td>4 ≠ (1,2,3)</td>
<td>(1,4) ≠ (2,3)</td>
<td>(1,2,3,4)</td>
<td></td>
</tr>
<tr>
<td>HL</td>
<td>P = 0.26</td>
<td>P = 0.07</td>
<td>P &lt; 0.001</td>
<td>P = 0.002</td>
<td>P &lt; 0.001</td>
<td>P = 0.07</td>
</tr>
</tbody>
</table>

1) Numbers in parentheses indicate no significant differences among dog breeds.

Indicates significant difference in values (P < 0.05) among breeds.

LL = Low limb measurement. HL = High limb measurement. 1 = Labrador Retriever. 2 = Rottweiler. 3 = Golden Retriever. 4 = German Shepherd Dog.
matically considered to be dysplastic unless documented evidence of a traumatic cause for the osteoarthritis exists.

Age is a factor in the reliability of hip status assigned by OFA. Accuracy of the assigned OFA hip status increases as the age of the dog at the time of evaluation of the hip joints increases. The accuracy of the assigned hip status in German Shepherd Dogs and Vizslas reported by Jessen was 95.4 and 92.5% at 24 months of age and 97.5 and 97.5% at 36 months of age, respectively. The mean age of dogs in our study was 5.4 to 6.9 months greater than the 24 month minimum age requirement of OFA, with a number of dogs being between 36 and 48 months of age. Accuracy of the assigned hip status by OFA (normal vs dysplastic) dogs in our study would be expected to be high on the basis of the mean age of dogs when the radiographs were taken. Accuracy of the assigned hip status in our study is also expected to be high because of the unanimous opinion of the 3 OFA consulting radiologists. Values for NA and PC for each grade for the 4 breeds was based on the actual OFA assigned grade and hip status (normal or dysplastic). Conclusions from our study are made on the assumption that the actual OFA assigned hip status and grade are accurate.

Results of our study provide reference values for NA and PC for the 3 normal grades and the 3 abnormal grades of hip conformation, as evaluated by OFA, for 4 breeds of dogs. Two of the breeds, Labrador retrievers and German Shepherd Dogs, are commonly used in hip dysplasia studies. Labrador Retrievers, Golden Retrievers, Rottweilers, and German Shepherd Dogs are the 4 breeds of dogs most commonly evaluated by OFA.

Grading of hip joints for hip status (normal vs dysplastic), using the OFA system, is based on the status of the worst hip joint. Values for NA and PC by means of LL measurements in our study are probably more accurate in determining the cutoff values for an OFA hip grade than HL measurements. Using LL measurements, none of the grade 3 mean values for NA or PC of the 4 breeds were > 105° or 50%, respectively. Grade 1 and 2 mean values for NA and PC of Labrador retrievers and Rottweilers were > 105° and 50%, respectively, however, only grade 1 mean value for NA of Golden retrievers and German Shepherd Dogs was > 105° by use of LL measurements. Other studies have questioned the validity of 105° for NA and 50% for PC as cutoff points for distinguishing between normal and dysplastic hip status. Considerable overlap of the maximum value, using HL measurements, of the dysplastic grades versus the minimum value, using LL measurements, of the normal grades were found in our study. Because of the overlap of the values for NA and PC between normal and dysplastic hip status, use of NA and PC as sole determinants of hip status may not be justified. The most likely explanation for dogs with a dysplastic hip status that had higher values for NA and PC than dogs with normal hip status (but lower values for NA and PC) is that dogs with dysplastic hip status had radiographic signs of osteoarthritis. By OFA guidelines, a dog with osteoarthritis of the hip joint is automatically considered to have dysplastic joints if trauma or another disease condition has not cause the osteoarthritis. Depth of the acetabulum and prominence of the cranial aspect of the acetabular rim also contribute to these measurements. An appreciation of the variation in pelvic bone shape is gained after review of large numbers of pelvic radiographs. Another explanation for the overlap of values for PC and NA between hip joints with dysplastic and normal status is the lack of sensitivity of these measurement techniques in determining maximum hip joint laxity.

Norberg angle and PC had a strong correlation across OFA grades in our study. As NA increased or decreased, the PC increased or decreased proportionally for highest to lowest values. Within an OFA grade, NA and PC did not correlate strongly except for OFA grade 5 for Labrador retrievers. We expected to find a strong correlation between NA and PC within an OFA grade. The small range of values for PC and NA within a grade may have contributed to the lack of correlation. The combination of small range of values along with the natural variation in the shape of the acetabulum could account for the lack of correlation. Variations in shape of the acetabulum that can be seen include notching of the dorsal acetabular rim and the prominence of the cranial aspect of the dorsal acetabular rim. Notching of the acetabulum would potentially contribute to a small PC. Prominence of the cranial aspect of the dorsal acetabular rim affects NA. The more prominent the cranial aspect of the dorsal acetabular rim, the greater the NA will be. No apparent reason was found for correlation within grade 3 of Labrador Retrievers for NA and PC. Lack of sensitivity of NA and PC in detecting joint laxity may also account for lack of correlation of NA and PC within a grade.

In our study, an order of magnitude of values for NA and PC generally were found when going from grade 1 to 6. Grade 1 and 2 for NA were the most consistent exception to following an order of magnitude. Not finding a distinct difference between NA for grade 1 and 2 in our study is consistent with Swenson's statement that "it becomes more and more difficult to differentiate the quality of dogs the better they are." What is most important in the order of magnitude is that the median values for grade 3 were always significantly larger than the median values for grade 4 for NA and PC. Determining a significant difference between median values for grade 3 and grade 4 is important, because these 2 grades distinguish between normal and dysplastic hip status.

Based on the logistic regression model, using the measurements made from radiographs from the actual OFA hip status, PC of 50% was not an accurate cutoff point for differentiating between normal and dysplastic hip status. In addition, NA of 105° is higher than any of the predicted values for NA found in our study and, therefore, does not appear to be an appropriate number to distinguish between normal and dysplastic hip status. One of the premises of the OFA hip grading system is that a dog should only be judged against other members of its breed. Our predicted values for NA and PC support the premise that each breed potentially has different values for NA and PC and, thus, should be judged individually as a breed.
The use of NA and PC values to predict hip status versus the actual OFA assigned hip status was compared in our study. The predicted values for NA and PC would correctly assign a dog as having dysplastic or normal hip status versus the OFA assigned hip status in most cases. This analysis demonstrates the reliability of the predicted values for NA and PC. Using these measurements for determining hip status does not take into account whether the dog has osteoarthritis, however. Using a combination of the predicted values for NA and PC from the model to determine the correct hip status of a dog is more accurate than using either NA or PC individually. False-positive rates indicate that some dogs would be unnecessarily eliminated from the breeding pool on the basis of the predicted OFA score of the model. False-negative rates are of concern, because some potentially dysplastic dogs would be kept in the breeding pool on the basis of the predicted OFA score. The most likely reason that some dogs were assigned an actual OFA dysplastic grade, even though the NA and PC were in the nondysplastic range as predicted by the model, was the presence of radiographically detectable osteoarthritis. Golden Retrievers and German Shepherd Dogs appear to be harder to accurately classify than Labrador Retrievers and Rottweilers on the basis of NA and PC. Values for correctly classified (normal or dysplastic) were lower, whereas values for false-positive and false-negative rates were higher for Golden Retrievers and German Shepherd Dogs than for Labrador Retrievers and Rottweilers. The overall high values for correctly classified, sensitivity, and specificity coupled with low values for false-positive and false-negative rates indicates good consistency in subjective evaluation of hip status.

Results of our study indicate that using NA ≥ 105° and PC ≥ 50%, either individually or in combination, to predict whether a dog has normal or dysplastic hip conformation will err toward calling a dog dysplastic when its hip conformation is normal on the basis of actual OFA grading. Using these criteria, sensitivity and false-negative rates were high and low, respectively. Specificity and false-positive rates were lower and higher, respectively, than desirable. Using the values of NA ≥ 105° and PC ≥ 50% as distinguishing between normal and dysplastic hip status will, in a high percentage of dogs, correctly predict those with dysplastic hip status. However, these values will incorrectly classify dogs with normal hip status as being dysplastic in a high number of dogs. The incorrect assignment of a dysplastic hip status on the basis of NA of 105° and PC of 50% as cutoff points would unnecessarily eliminate a large number of dogs from the breeding pool. In the Golden Retriever breed, as an example, only 19.7% of dogs with normal hip status as assigned by OFA were predicted to have normal hip status by use of a NA of 105° as a cutoff value. However, using these values for NA and PC as cutoff points between normal and abnormal hip status in selection of which dogs to breed, may be an effective means to decrease the incidence of hip dysplasia in a breed by selecting for those dogs with the most congruent hip joints.

Neither age nor sex, when evaluated individually, contributed to whether a dog was judged as normal or dysplastic, except in Rottweilers. Age was most likely not a determinant of hip status, because the dogs evaluated in this study had reached an age where the likelihood for change in the hip status with time was low. Sex and the interaction of NA and sex were significant determinants of hip status in Rottweilers. Male Rottweilers were more likely to be judged as being dysplastic than were females when NA was the same. We have no explanation for this finding in Rottweilers.

A premise of OFA hip evaluation is that the hip conformation of a dog is judged against the characteristics of that specific breed and not against another breed or against dogs of all breeds. Evaluation of NA and PC across the 4 breeds in this study supports the premise that individual breeds may vary in hip conformation. As an example, Labrador Retrievers and Golden Retrievers had values for NA and PC across the OFA grades that generally were different from one another even though these breeds have similar body conformation. Labrador Retrievers and Rottweilers, breeds with much different body conformation, generally had similar values for NA and PC across OFA grades. Other studies support the premise that each breed of dog should be judged individually for the criteria of having either normal or dysplastic hip status.25-27

On the basis of OFA grading of hip status, results of our study indicate that a NA of 105° and a PC of 50% do not represent the cutoff points that most accurately distinguish normal from dysplastic hip status in Labrador Retrievers, Rottweilers, Golden Retrievers, and German Shepherd Dogs. Values for PC that may more accurately distinguish normal and dysplastic hip status than 50% are 42.2% for Labrador Retrievers, 42.7% for Rottweilers, 37.9% for Golden Retrievers, and 44.8% for German Shepherd Dogs. For Labrador Retrievers and Rottweilers, these values would be expected to correctly classify these 2 breeds 98 and 94.7%, respectively. Golden Retrievers and German Shepherd Dogs would be correctly classified 88.9% of the time. Values for NA that may more accurately distinguish normal and dysplastic hip status than 105° are 99.9° for Labrador Retrievers, 101.9° for Rottweilers, 92.6° for Golden Retrievers, and 100.3° for German Shepherd Dogs. For Labrador Retrievers and Rottweilers, these values would be expected to correctly classify hip status 96.3 and 92.7% of the time, respectively. Golden Retrievers and German Shepherd Dogs would be correctly classified as to hip status 89.6% and 89.7% of the time, respectively. Using a combination of NA and PC would correctly classify hip status 92 to 98% of the time, depending on the breed. Using the maximum values determined in our study for NA and PC as distinguishing normal from dysplastic hip status is more conservative and would error on the side of calling some dogs with normal hip status by OFA evaluation dysplastic. Using a NA of 105° and or a PC of 50% as cutoff points would err on the side of designating a larger number of dogs as being dysplastic than would be classified as dysplastic by OFA grading criteria.

Orthopedic Foundation for Animals, 2300 Nifong Boulevard, Columbia, Mo.
References


