Naturally Occurring Vitreous Chamber–Based Myopia in the Labrador Retriever

Donald O. Mutti,1,2 Karla Zadnik,2 and Christopher J. Murphy3

PURPOSE. To investigate whether myopia is present in a breed of domestic dog, the Labrador retriever, and how the ocular components are related to refractive error in this breed.

METHODS. Cycloplegic refractive error was measured in 75 Labrador retrievers by retinoscopy. Corneal and crystalline lens radii of curvature were measured in the right eyes of 57 of these dogs using a video-based keratophakometer, with axial ocular dimensions measured using A-scan ultrasonography.

RESULTS. Of the 75 dogs tested, 11 (14.7%) were myopic by at least −0.50 D in one eye, and 6 (8.0%) were myopic in both eyes (full range of refractive errors, +3.50 D to −5.00 D). Of the 57 dogs with ocular component measurements, seven (12.3%) were myopic by at least −0.50 D in the right eye. There was a significant negative correlation between refractive error and vitreous chamber depth (Spearman ρ = −0.42; P < 0.001). Myopic eyes had an elongated vitreous chamber depth (10.87 ± 0.34 mm for myopic dogs, 10.02 ± 0.40 mm for nonmyopic dogs; P < 0.0001, Kruskal-Wallis test). There was also a significant quadratic association between lens thickness and vitreous chamber depth (P < 0.005; R² = 0.11), indicating that thinner lenses occurred at both shorter and longer vitreous chamber depths.

CONCLUSIONS. Myopia in the Labrador retriever is analogous to human myopia in that it is caused by an elongated vitreous chamber. Thinner crystalline lenses found at longer vitreous chamber depths may be analogous to lens thinning documented in human ocular development. The Labrador retriever warrants investigation as a potential model of myopia that is naturally occurring rather than experimentally induced. (Invest Ophthalmol Vis Sci. 1999;40:1577-1584)
Breed of Dog (number of animals refracted)

- Alaskan Malamute (21)
- American Cocker Spaniel (16)
- Australian Shepherd (37)
- Basenji (16)
- Belgian Tervuren (8)
- Bernese Mountain Dog (11)
- Border Collie (7)
- Chesapeake Bay Retriever (13)
- Clumber Spaniel (5)
- Doberman (6)
- English Springer Spaniel (34)
- Field Spaniel (11)
- German Shepherd (36)
- German Shepherd Guide Dogs (53)
- Golden Retriever (67)
- Great Dane (5)
- Labrador Retriever (115)
- Miniature Dachshund (Smooth-Haired) (5)
- Miniature Poodle (18)
- Miniature Schnauzer (18)
- Mixed Breed (9)
- Norwegian Elkhound (6)
- Nova Scotia Duck Tolling Retriever (10)
- Papillon (5)
- Pug (7)
- Rottweiler (23)
- Samoyed (20)
- Schipperke (7)
- Shar-Pei (7)
- Shetland Sheepdog (22)
- Siberian Husky (15)
- Smooth-Coated Collie (49)
- Soft-Coated Wheaten Terrier (13)
- Other Terriers (34)
- Toy Poodle (42)

**Figure 1.** The average (±SD) refractive error of numerous breeds of domestic dogs screened by cycloplegic and noncycloplegic retinoscopy. The number of dogs examined for each breed is in parentheses. These data include all dogs measured and presented in our previous article reporting that German shepherd guide dogs have a lower prevalence of myopia than unselected German shepherds. Labrador retriever data include the 75 dogs reported within the present study.
TABLE 1. Ocular Component Values as a Function of Refractive Status

<table>
<thead>
<tr>
<th>Ocular Component</th>
<th>Nonmyopes (n = 50)</th>
<th>Myopes (n = 7)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitreous chamber depth (mm)</td>
<td>10.02 ± 0.40</td>
<td>10.87 ± 0.34</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Anterior chamber depth (mm)</td>
<td>4.29 ± 0.36</td>
<td>4.16 ± 0.33</td>
<td>0.47</td>
</tr>
<tr>
<td>Lens thickness (mm)</td>
<td>7.85 ± 0.51</td>
<td>7.70 ± 0.56</td>
<td>0.26</td>
</tr>
<tr>
<td>Keratometer power (D)</td>
<td>36.94 ± 1.98</td>
<td>37.12 ± 2.45</td>
<td>0.67</td>
</tr>
<tr>
<td>Equivalent refractive index</td>
<td>1.535 ± 0.027</td>
<td>1.543 ± 0.027</td>
<td>0.55</td>
</tr>
<tr>
<td>Anterior lens radius (mm)</td>
<td>7.61 ± 0.55</td>
<td>7.94 ± 0.57</td>
<td>0.23</td>
</tr>
<tr>
<td>Posterior lens radius (mm)</td>
<td>8.12 ± 1.29</td>
<td>8.87 ± 0.93</td>
<td>0.14</td>
</tr>
<tr>
<td>Equivalent lens power (D)</td>
<td>48.26 ± 3.69</td>
<td>47.00 ± 4.43</td>
<td>0.45</td>
</tr>
</tbody>
</table>

P by Kruskal-Wallis.

Myopia in the Labrador Retriever

Methods

Although the Labrador retriever is emmetropic on average (Fig. 1), it was known from previous examinations that a cohort of dogs in the surrounding community (Madison, WI) were myopic. All dogs were brought by their owners for a Canine Eye Registry Foundation examination held at the School of Veterinary Medicine at the University of Wisconsin and were returned to their owners at the completion of the examination. Refractive error was measured in 75 Labrador retrievers by cycloplegic retinoscopy for both eyes, then ocular component dimensions of right eyes were measured in 57 of those 75 dogs using A-scan ultrasonography and a video-based keratophakometer (measuring corneal and lenticular radii of curvature in the horizontal meridian). Of the 75 dogs refracted by retinoscopy, 45 were female. The average age was 3.5 years (range, 0.13-10.5 years). For the 57 dogs with ocular component measurements, the average age was 3.1 years (range, 0.3-7.0 years), and 35 were female. Dogs were included in the ocular-component measurement phase of the examination after study procedures were explained, and written consent was obtained from the owner. All procedures adhered to the ARVO Statement for the Use of Animals in Ophthalmic and Vision Research and were reviewed and approved by the Animal Use Committee for the University of Wisconsin.

One drop of 1% cyclopentolate (Cyclogyl; Alcon, Fort Worth, TX) was instilled in each of the right and left eyes. Thirty minutes after drop instillation, streak retinoscopy was performed on each eye with handheld trial lenses in the horizontal and vertical meridians. Corneal and crystalline lens radii of curvature were measured on the right eye only using a portable, custom handheld video-based keratophakometer. The details of the design of this device are reported elsewhere.31

Purkinje images were photographed in the optimal focal plane for each pair with refocusing between viewing Purkinje III and IV, recorded on videotape, then digitized by a frame grabber (Data Translation, Marlboro, MA) with the separation between the center of each image in the pair measured by image-processing software (Image Analyst, ver. 7.22; Billerica, MA). This distance yields an equivalent mirror radius of curvature in air that may then be refracted through the optical elements preceding the reflecting surface, giving the radius of curvature in the eye and an equivalent refractive index that creates agreement between measured components and refractive error.25

Ocular axial dimensions (anterior chamber depth, vitreous chamber depth, and crystalline lens thickness) were measured on the right eye only by A-scan ultrasonography (model 820, Humphrey, San Leandro, CA), consisting of five readings using a handheld probe in semiautomated mode. The gates were altered to allow for the deeper anterior chamber, increased thickness of the crystalline lens, and shorter vitreous chamber in dogs. Distances were corrected for the different acoustic velocities reported for ocular tissues of the dog.32 Dogs were not sedated for ultrasound. Topical anesthesia was provided by 1 drop of 0.5% proparacaine. Statistical analyses were performed using statistical software (SAS JMP, ver. 3.1.5, SAS Institute, Cary, NC).

Results

The average spherical equivalent refractive error was +0.55 ± 1.05 D for the right eye and +0.37 ± 1.20 D for the left eye, ranging from −5.00 D to +3.50 D of hyperopia. Dogs were generally isometropic, although there was a small, but statistically significant, difference between the spherical equivalent refractive error of the two eyes of +0.17 ± 0.47 D (right minus left; P < 0.0022, paired t-test). There was a significant negative association between the spherical equivalent refractive error and age in each eye, indicating a reduction in hyperopia with increasing age (right eye: Spearman correlation = −0.25, P = 0.030; left eye: Spearman correlation = −0.31, P = 0.007). The average refractive astigmatism was small in magnitude in each eye. The amount of astigmatism was statistically significant in the right eye at 0.11 ± 0.32 D (with-the-rule orientation, i.e., vertical meridian more myopic; P < 0.005, Wilcoxon signed-rank test), but not in the left eye at 0.08 ± 0.38 D (P < 0.10, Wilcoxon signed-rank test).

The overall prevalence of myopia among Labrador retrievers examined to date is 24.7% (54/219 eyes, Fig. 1). In the present study of 75 dogs refracted by cycloplegic retinoscopy, a myopic refractive error consisting of at least −0.50 D in each principal meridian occurred unilaterally in 17 eyes (11.3%; 8 right, 9 left), in at least 1 eye of 11 dogs (14.7%), and in both eyes of 6 (8.0%) of 75 dogs. The following analyses examine...
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FIGURE 2. The right eye spherical equivalent refractive error (Sph. Eq.) as a function of vitreous chamber depth for 57 Labrador retrievers. The four puppies in the study are indicated by open circles, and the mature dogs by points. The correlation is significant (Spearman $r = -0.42; P < 0.001$).

The associations between refractive error and ocular biometric data from the right eyes of 57 of these 75 dogs, including 7 animals (12.3%) with myopia in the right eye.

The only significant difference in ocular component values as a function of whether the eye was myopic or not was a longer vitreous chamber depth among myopic dogs ($P < 0.0001$; Kruskal-Wallis test). The mean values for ocular components as a function of refractive status are listed in Table 1. The association between an enlarged vitreous chamber and a more negative refractive error in these dogs can be seen in Figure 2. The scatterplot indicates that the relation is neither linear, nor has equal variance around a regression line over the range of vitreous chamber depth values. Therefore, a nonparametric correlation was calculated at $-0.42$ (Table 2; Spearman $r$; $P < 0.001$). As in human refractive error, the most important ocular component contributing to the range of refractive error in the Labrador retriever is vitreous chamber depth.

Significant correlations occur among a number of ocular components in the eye of the dog and are presented in Table 2. Derived variables such as the equivalent refractive index and the equivalent lens power are omitted, because any correlations are most likely an artifact of calculation from other component values. The human eye is characterized by negative correlations between the length of the eye and the following three variables: refractive error, lens power, and corneal power. $^{15,33}$ Vitreous chamber depth also has a negative correlation with refractive error and lens power in the dog. The sign on the correlation between vitreous chamber depth and the crystalline lens is positive, because lenses are described in terms of radii rather than power, but the positive correlation suggests that flatter lenses are associated with longer vitreous chambers, as in the human eye. The positive correlation between anterior and posterior lens radii suggests that they vary together, with flatter lens radii contributing to a shallower anterior chamber, perhaps through the positive association between a flatter anterior lens radius of curvature and greater lens thickness. The negative correlation between vitreous chamber depth and corneal power seen in humans did not reach statistical significance in this sample of Labrador retrievers. The correlation between corneal and lens power is significant in human eyes, but small ($-0.12$). $^{33}$ This correlation is much higher in dogs, with flatter, less powerful corneas associated with flatter and thicker lenses.

Although there is no significant linear correlation between vitreous chamber depth and lens thickness, examination of Figure 3 indicates that this relation is nonlinear—that is, that increasing vitreous chamber depths are associated with increasing lens thicknesses up to the point at which the longest vitreous chamber depths are associated with thinner lenses. The points in Figure 3 are best fit with the following quadratic equation:

$$\text{Lens thickness} = -0.51(\text{VCD})^2 + 10.3(\text{VCD}) - 44.4$$

where VCD is vitreous chamber depth.

Each coefficient in this model is significant ($P < 0.005$) with an adjusted $R^2$ of 0.11. The inclusion of higher order terms does not significantly improve the fit, nor are higher order terms indicated for any other relations between components.

The eye of the Labrador retriever grows rapidly. Of the 57 eyes, 4 belonged to puppies younger than 6 months (open circles in Fig. 2). Both the vitreous chamber depth (mean, 9.2

![Graph showing the relationship between vitreous chamber depth and lens thickness.](image)

**Table 2. Matrix of Spearman Correlation Coefficients between Ocular Components in 57 Labrador Retrievers**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Vitreous Chamber (mm)</th>
<th>Anterior Chamber (mm)</th>
<th>Lens Thickness (mm)</th>
<th>Sph. Eq. Refraction (D)</th>
<th>Keratometer Power (D)</th>
<th>Anterior Lens Radius (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitreous chamber (mm)</td>
<td>-0.076</td>
<td>-0.041</td>
<td>-0.14</td>
<td>-0.23</td>
<td>-0.17</td>
<td>-0.31†</td>
</tr>
<tr>
<td>Anterior chamber (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lens thickness (mm)</td>
<td>-0.041</td>
<td>-0.14</td>
<td></td>
<td>-0.23</td>
<td>-0.17</td>
<td>-0.31†</td>
</tr>
<tr>
<td>Spherical equivalent refraction (D)</td>
<td>-0.42*</td>
<td>0.17</td>
<td>0.13</td>
<td>-0.29†</td>
<td>-0.19</td>
<td>-0.53*</td>
</tr>
<tr>
<td>Keratometer power (D)</td>
<td>-0.24</td>
<td>0.043</td>
<td>-0.29†</td>
<td>-0.19</td>
<td>-0.40†</td>
<td>-0.47*</td>
</tr>
<tr>
<td>Anterior lens radius (mm)</td>
<td>0.28†</td>
<td>-0.31†</td>
<td>-0.024</td>
<td>-0.16</td>
<td>-0.47*</td>
<td>0.39‡</td>
</tr>
<tr>
<td>Posterior lens radius (mm)</td>
<td>0.34†</td>
<td>-0.41*</td>
<td>-0.024</td>
<td>-0.16</td>
<td>-0.47*</td>
<td>0.39‡</td>
</tr>
</tbody>
</table>

* $P < 0.001$.
† $P < 0.01$.
‡ $P < 0.05$.
mm) and the axial length (mean, 20.8 mm) of puppies are less than those of mature dogs. We looked for age-related trends in the mature eyes of the Labrador retrievers in the present study, excluding the four eyes of the dogs less than 6 months of age. As expected, anterior chamber depth showed a significant decrease with age (Fig. 4; Pearson $r = -0.32; P < 0.02$). Keratometer power, anterior and posterior lens radii of curvature, lens thickness, and vitreous chamber depth did not display age-related changes between 6 months and 7 years of age in these dogs ($P < 0.06$). The absence of age-related trends in lens thickness and vitreous chamber depth in mature dogs in this study may be because of the younger maximum age of dogs used in this study compared with those used previously (7 years compared with 13 years), breed differences between Labradors and Samoyeds, or a smaller sample size resulting from using only the right eye instead of both eyes of each dog.

Ocular components are rarely measured in vivo in the dog, and all reported crystalline lens radii have been from in vitro data, to our knowledge. We use in vivo phakometric and ultrasonographic data to construct a schematic eye for the Labrador retriever (Table 3, Fig. 5). With the sole difference between myopic and nonmyopic eyes being an elongated vitreous chamber depth, average values for each ocular component are used with the average value for a nonmyopic vitreous chamber depth in this model. The eye having an average myopic vitreous chamber depth is presented for comparison in Figure 5. Modeled ametropias compare well with measured average nonmyopic and myopic refractive errors of +0.86 D and −2.07 D, respectively.

### Table 3. Parameters of a Schematic Eye for the Labrador Retriever Based on In Vivo Measurements

<table>
<thead>
<tr>
<th>Refractive indices</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornea (single surface)</td>
<td>1.3375</td>
</tr>
<tr>
<td>Aqueous</td>
<td>1.3333</td>
</tr>
<tr>
<td>Crystalline lens</td>
<td>1.5361</td>
</tr>
<tr>
<td>Vitreous</td>
<td>1.3333</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Distances from anterior cornea (mm)</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Anterior lens</td>
<td>4.27</td>
</tr>
<tr>
<td>Posterior lens</td>
<td>12.10</td>
</tr>
<tr>
<td>Retina</td>
<td>22.12</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Radii of curvature (mm)</th>
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</thead>
<tbody>
<tr>
<td>Cornea</td>
<td>9.13</td>
</tr>
<tr>
<td>Anterior lens</td>
<td>7.65</td>
</tr>
<tr>
<td>Posterior lens</td>
<td>−8.20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distances from principal planes (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary nodal point</td>
<td>8.22</td>
</tr>
<tr>
<td>Secondary nodal point</td>
<td>8.95</td>
</tr>
<tr>
<td>First principal plane</td>
<td>3.75</td>
</tr>
<tr>
<td>Second principal plane</td>
<td>4.48</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distances from principal planes (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary focal distance</td>
<td>−13.42</td>
</tr>
<tr>
<td>Secondary focal distance</td>
<td>17.89</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equivalent power of the eye (D)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>+0.86</td>
<td></td>
</tr>
<tr>
<td>−2.07</td>
<td></td>
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</table>

### Discussion

We have shown that myopia in the Labrador retriever is caused by an elongated vitreous chamber and not by excessive crystalline lens or corneal power. This is a key feature of human myopia and other experimental models. Myopia has been previously reported in the Labrador retriever, although it was associated with retinal detachment and skeletal abnormalities. Ophthalmoscopy, which is part of the Canine Eye Registry Foundation examination, and a physical examination showed no retinal disease or skeletal abnormality in any of the dogs reported here. Seven dogs, one of which was myopic (−0.75 D), had fine, punctate lens opacities. The vitreous chamber was significantly longer in myopic dogs, even if these seven dogs with opacities were excluded ($P < 0.0003$; Kruskal-Wallis test).

One limiting factor is that the association between myopia and excessive overall axial elongation of the eye present in human myopia was not seen in the Labrador retriever (Fig. 6; Spearman $r = −0.15; P < 0.26$). The absence of this association was noted in a previous report on myopia in German
shepherds. This finding may indicate that myopia is different in the eye of the dog, perhaps involving a process in which the lens thins and/or moves forward without excessive overall growth. Results from this study support lens thinning and longer vitreous chamber depths rather than anterior movement of the crystalline lens as the source of the myopia in the Labrador retriever. There is a nonlinear association between lens thickness and vitreous chamber depth (Fig. 3), yet no significant association between anterior chamber depth and lens thickness, between anterior chamber depth and vitreous chamber depth, between the spherical equivalent refractive error and either anterior chamber depth or lens thickness (see Table 2), or between the spherical equivalent refractive error and the sum of these two variables (Spearman $r = 0.18; P < 0.18$).

The finding of thinner lenses associated with longer vitreous chamber depths has a parallel in human myopia. Lens thinning occurs in human refractive development in early childhood up to the age at which the prevalence of myopia begins to increase. Thinner lenses are associated with myopic refractive errors throughout childhood. It is hypothesized that the crystalline lens is stretched and thinned as the eye grows both equatorially and axially. Determining whether thinner crystalline lenses occurring at longer vitreous chambers in the Labrador retriever are caused by a similar mechanism requires further study.

If thinning of the crystalline lens is caused by or simply accompanies an excessive length of the vitreous chamber because of excessive growth, then myopic dogs may be suitable for testing regimens that attempt to control myopia by curbing excessive growth. Even though the axial length may not be excessive, the longer vitreous chamber depth may represent growth that is greater than optimal. The two animals with higher amounts of myopia had longer than average axial lengths. A larger sample of moderately myopic dogs would help to establish the role of overall axial growth in the development of myopia. Breeding for myopia may be one strategy to increase the sample of myopic dogs, as would studying breeds with a higher prevalence of myopia, such as the toy poodle. It is of interest to note that in our ongoing studies of dogs we have identified entire litters of myopic puppies in which one or both of the parents was myopic. Attempts to breed for this trait would determine how the heritability of myopia in dogs compares with humans and establish its utility as a naturally occurring model of myopia.

Axial distances for the Labrador retriever compare well with results from unspecified breeds and the Samoyed. The largest difference between published values and our results occurred for crystalline lens radii of curvature. Sivak and Kreuzer report that the in vitro lens radii of curvature for six specimens in each of two investigations was 6.60 mm to
The underlying assumption of evaluations of the biochemistry of using the chick in certain experimental situations. IOVS, glial cells by a factor of 7, a visual acuity of approximately 20/75, and a calculated depth of field of up to 0.33 D. The correlation is not significant (Spearman r = —0.15; P < 0.26).

7.29 mm for the anterior surface and 6.32 mm to 6.72 mm for the posterior surface, a nearly symmetric biconvex lens with the anterior surface flatter than the posterior surface. Our phakometric measurements indicate that the lens is more asymmetric, with the anterior surface being steeper than the posterior surface (Tables 1 and 3). This is opposite to the asymmetry present in the human biconvex lens where the anterior surface is the flatter. Interestingly, the drawing of the canine eye in Schiffer et al. displays a lens with a flatter posterior than anterior radius.

Anatomic differences also exist between dog and human eyes. Adult dogs have deeper anterior chamber depths by 0.5 to 1.3 mm, thicker lenses by approximately 4 mm, shorter vitreous chamber depths by 6 mm to 7 mm, and shorter overall axial lengths by 1 mm to 2 mm than adult human eyes. Other anatomic and functional comparisons may be made according to a recent review. A higher percentage of dog photoreceptors are rods, their binocular visual field is less at 30° to 60°, they possess a limited accommodative amplitude of 2 D to 3 D, and they have a horizontally oriented "visual streak" of peak retinal sensitivity instead of a fovea, a lower number of ganglion cells by a factor of 7, a visual acuity of approximately 20/75, and a calculated depth of field of up to 0.33 D. The significance of these differences is unknown, but the human and dog eye are probably no more dissimilar in anatomy and accommodative mechanism, for example, than the human and chick eye.

Dogs are certainly more difficult to use in research than chicks. Experimental myopia in the chick has been a successful paradigm in part because chicks are small and relatively easy to house in the laboratory, and myopia can be induced rapidly. A different animal model would have to supply new and important information to replace the efficiency of using the chick in certain experimental situations. The underlying assumption of evaluations of the biochemistry of experimental myopia has been that pharmaceuticals that affect induced myopia may be good candidates for arresting developmental myopia in children. Evaluating the effects of such pharmaceuticals in a naturally occurring model of myopia may be just such a situation, providing important information on the efficacy of agents to alter ocular growth under normal visual circumstances, conditions more similar to those experienced by children at risk for myopia. Myopia in the dog warrants further evaluation of its potential to serve as a natural model of juvenile myopia.

References


