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Effect of optical defocus on performance of dogs involved in field trial competition

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Objective—To measure the effect of induced myopia on field trial performance in dogs.

Animals—7 Labrador Retrievers and 1 Chesapeake Bay Retriever trained in field trial competition.

Procedures—Dogs were commanded to retrieve targets at 137.2 m (150 yards). Each dog participated in 3 trials while their eyes were fitted with 0- (plano), +1.50-, or +3.00-diopter (D) contact lenses, applied in random order. Retrieval times were measured objectively, and dog performances were evaluated subjectively by masked judges.

Results—Retrieval times were significantly faster with plano lenses than with +1.50- or +3.00-D lenses, but there were no significant differences in times between +1.50- and +3.00-D lenses. Masked judges assigned the best performance scores to dogs with plano lenses and the lowest scores to dogs fitted with +3.00-D lenses.

Conclusions and Clinical Relevance—Even mild myopic defocusing had a significant negative impact on both the subjective and objective assessments of dogs' performances. Dogs with demanding visual tasks or signs of visual deterioration should be evaluated retinoscopically to determine the refractive state because they may have ametropia. (*Am J Vet Res* 2012;73:546–550)

Light entering the eye is refracted, or bent, by the successive ocular structures that it passes on its way to the retina.[1] When light from optical infinity (ie, > 6 m) converges on the retina forming a well-focused image, the eye is defined as emmetropic. In a myopic eye, light from infinity converges in front of the retina. Myopia may be the result of excessive refractive power of the eye or abnormal elongation of the eye's axial length. Conversely, in a hyperopic eye, light from optical infinity converges behind the retina. Hyperopia may be the result of insufficient refractive power of the eye or abnormal shortening of the eye's axial length.

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Abbreviations

CI	Confidence interval
D	Diopter
HR	Hazard ratio

The magnitude of the refractive error in ametropic (ie, myopic or hyperopic) eyes is measured in D.[1]

Myopia may be regarded as the most prevalent ocular disorder in humans.[2] From 1999 through 2004, the prevalence of myopia among 12- to 54-year-old Americans was 41.6%.[3] In a survey[4] of students in Greece, myopia was found in 36.8% of 15 to 18 year olds, and a survey of schoolchildren in Singapore found a prevalence of 29.1% among 6 to 7 year olds.[5] High myopia (ie, refractive error > –6 D) is associated with an increased risk for several ocular diseases, including cataracts,[6] glaucoma,[7] and retinal detachment,[8] compared with the risk in emmetropic eyes.

Most cases of myopia in humans are due to excessive elongation of the axial length of the eye.[9] The etiology of the disorder in humans is multifactorial.[10] Numerous risk factors have been identified, most notably indoor work and work involving materials held close to the eyes (such as spending long hours reading),[11,12] but the disorder also has a strong genetic component,[2,13] making it more prevalent in certain ethnic groups and in children of myopic parents.[5,9,11,12]

As with any prevalent human disorder, there is a great impetus to identify a naturally occurring model of myopia in other animals. A large survey[14] revealed that the mean refractive state of dogs is emmetropic

(mean refractive error, –0.05 D). Several canine breeds and family lines within breeds were found to have mean refractive states indicative of myopia. For example, although the mean refractive state of Labrador Retrievers was emmetropic (defined as –0.5D < refractive error < +0.5D), there were discrete family lines of Labrador Retrievers, including entire litters, that were myopic. In that subset, which included 22% of the Labrador Retrievers evaluated, the mean refractive error was –1.48 ± 1.09 D (range, –5.00 to –0.50 D). Result of another study[15] showed a high incidence of myopia in Labrador Retrievers and demonstrated that the disorder has a strong genetic component in the breed. Ultrasonographic biometry of the eyes of ophthalmologically normal and myopic dogs representing 5 breeds (German Shepherd Dog, Collie, Miniature Poodle, English Springer Spaniel, and Labrador Retriever) revealed that only Labrador Retrievers develop myopia caused by dysregulated axial elongation of the globe.[16,17]

Optical defocus impacts visual acuity in dogs, with acuity decreasing in proportion to the degree of defocus (myopia or hyperopia).[18] Although visual acuity would be affected by myopia, the impact of myopia on performance in field trial conditions has not been previously determined. The purpose of the study reported here was to measure the effect of myopia on field trial performance in dogs.

Materials and Methods

Animals—Fourteen dogs were initially recruited for the study, but only 8 dogs completed the entire study and were used for data analysis. These included 7 Labrador Retrievers and 1 Chesapeake Bay Retriever (4 males and 4 females). Median age was 4 years (range, 2 to 8.5 years). All 8 dogs were professionally trained and active in the field trial competitive circuit. At the conclusion of the study, dogs underwent a comprehensive ophthalmic examination by a board-certified veterinary ophthalmologist (SRH or CJM), which included slit-lamp biomicroscopy and indirect ophthalmoscopy as well as refraction performed by 2 experienced scientists (RO and CJM) who used streak retinoscopy. No ocular abnormalities were found, and all dogs were judged to be emmetropic (defined as –0.5D < refractive error < +0.5D).

The use of animals in the study reported here was in compliance with guidelines outlined in the Animal Welfare Act and was approved by the Institutional Animal Care and Use Committee and the Clinical Trials Review Board of the University of California-Davis School of Veterinary Medicine. Dog owners consented to their dogs' participation.

Study design—The study was conducted during a 2-day period at Denverton Grounds, which is a training field owned by the California Retriever Training Association in Suisun, Calif. The area used consisted of flat terrain with low-lying vegetation and no water obstacles. The study was conducted during the daytime in photopic conditions, and the sky was clear.

The overall experimental design was for the dogs to retrieve plastic bumpers (targets) while their eyes were in each of 3 refractive states. Bumpers were launched by use of a remote-operated bumper launcher.[a] The launcher was camouflaged by vegetation to hide its actual location, and a white coat was placed next to it to simulate actual trial competition conditions. The launcher would beep 1 second prior to the bumper launch to attract the dog's attention toward the launch area.

Each dog completed 3 tests, with each test consisting of 2 runs. For the first run in each test, each dog was commanded to retrieve a bumper launched at a distance of 137.2 m (150 yards). For the second run in each test, the dog was commanded to retrieve a bumper launched at a distance of 182.9 m (200 yards). Two bumper launchers were used for these 2 runs and were placed in various locations to avoid a learning effect on the results of the second run. Once the dogs completed both runs of the first test, the 2 launchers were moved to different locations for the second and third tests. Distances from the dog staging area to the bumper launcher were measured by use of a laser range finder.[b]

For each of the 3 tests, each dog was fitted in both eyes with a different pair of soft contact lenses.[c] The refractive powers of the lenses used in the study were 0 (plano), +1.50, and +3.00 D. Therefore, both runs of each test were conducted with the dogs' eyes in different refractive conditions (emmetropia, –1.50- or –3.00-D myopia), the order of which was determined by use of a randomization table that was generated individually for each dog. Lenses were fitted in both eyes without topical anesthesia. At the end of each run, the presence of contact lenses in both eyes was confirmed. If a lens became dislodged from the eye during a run, the dog was disqualified from the study (because the dog could not be rerun on the course without a prior learning bias). All runs by all dogs were filmed with a video camera, and recordings were stored for subsequent analysis. For filming purposes, a 4.6-m (15-foot) tower was constructed to provide a view overlooking the entire training grounds.

Outcome measurements—The performance of the dogs was measured subjectively and objectively. The objective measurement was time (in seconds) elapsed from the release of the dog to its finding the bumper. However, in some runs, it became obvious to the dog trainer that the dog did not see the launch and landing of the bumper and was unable to find it. In such situations, the trainer intervened (ie, directed the dog to the bumper through use of whistles and arm gestures). In those runs, the time from the release of the dog to the beginning of the intervention was recorded. At the end of the study, 2 outcome measurements were used for analysis. First, time was recorded from the release of the dog until it found the bumper or until trainer intervention began. However, because this outcome might have been influenced by the period that the trainer waited before deciding to direct the dog to the bumper, a decision was made to also rank the recorded performance times for each dog during the 3 tests (from fastest to slowest). A run in which a dog received direction was automatically ranked as slowest, regardless of the time elapsed until the beginning of that intervention.

Dog performance was subjectively evaluated by 2 experienced, professional field trial judges who were

masked regarding the refractive state of the dogs' eyes in each test. Judges were asked to score the dog performances as they would be scored in competitions. At the end of the study, each judge was asked to compile scores in 2 formats: rank the 3 test performances from best to worst and rank the 8 dogs from best to worst.

Statistical analysis—The Friedman aligned rank test was used to determine whether the lens power (0, +1.50, or +3.00 D) differed for each dog's best, second-best, and worst performances separately for each observer. The null hypothesis was that there would be no effect of lens power on performance. The Kruskal-Wallis test for singly ordered categorical data was used to assess the relationship between the ordered lens power category and proportions of dogs that needed trainer direction and that were successful in retrieving the bumper.

An exact Cochran-Mantel-Haenszel test on doubly ordered contingency table data that were stratified by individual dog was used to determine whether there was a relationship between lens power and ranking. Least squares linear regression was performed and Spearman rank correlation coefficients (ρ) were calculated to assess the association between lens power and trial run. A Cox proportional hazards regression model with robust variance estimation to account for replicates was used to compare retrieval times among the 3 lenses. Results are reported as HR and 95% CI. Values of $P < 0.05$ were considered significant for all analyses.

Results

Animals—Fourteen dogs were included in the study, but 6 were disqualified because of lens loss; therefore, only 8 dogs completed all lens trials and were used for data analysis. Because of time limitations, not all of the 182.8-m runs could be completed for all tests; therefore, the data for that distance were not analyzed.

Bumper retrieval—Under emmetropic conditions (plano lenses), no dogs required trainer intervention to find the bumper; all 8 dogs completed that test successfully. When their eyes were defocused by +1.50 D, 2 of 8 dogs required assistance, but all dogs successfully retrieved the bumper. When their eyes were defocused by +3.00 D, 3 of 8 dogs needed the trainer to intervene. One of these dogs could not locate the bumper despite the assistance; therefore, only 7 of 8 dogs retrieved the bumper. There was no significant difference among the 3 groups in terms of assistance required ($P = 0.13$) or retrieval completion ($P = 0.67$).

Timing outcomes—The HR used to compare the time required for bumper retrieval indicated that the time recorded when dogs wore the +3.00-D lenses was significantly ($P < 0.001$) greater than when they wore the plano (0-D) lenses (HR, 15.9; 95% CI, 6.0 to 42.0), as was the time recorded when they wore the +1.50-D lenses, but to a lesser extent ($P = 0.007$; HR, 8.7; 95% CI, 1.8 to 42.0). However, the HR used to compare the performance between dogs when wearing the +1.50-D lenses and when wearing the +3.00-D lenses revealed no significant ($P = 0.30$) difference (HR, 1.8; 95% CI, 0.6 to 5.6; **Figure 1**).

The Friedman aligned rank test revealed significant differences in timing ranking between performances with the plano and +1.50-D lenses ($P = 0.047$) and between performances with the plano and +3.00-D lenses ($P = 0.008$). There were no significant ($P = 0.50$) differences between timing rankings for when +1.50- and +3.00-D lenses were worn.

Subjective judge evaluation—The exact Cochran-Mantel-Haenszel test revealed a significant ($P = 0.050$) relationship between refractive power and rank for one of the judges ($\rho = 0.40$); least squares linear regression analysis identified a positive relationship between lens refractive power and rank after controlling for individual dog and observer ($P = 0.004$). The relationship neared significance ($P = 0.053$) for the other judge ($\rho = 0.45$); least squares linear regression revealed a positive relationship between lens refractive power and rank after controlling for individual dog and observer ($P = 0.044$). The relationship was significant ($P = 0.002$) when results for both judges were combined ($\rho = 0.42$); least squares linear regression identified a positive relationship between lens refractive power and rank after controlling for individual dog and observer ($P = 0.002$). That is, the higher the refractive power, the lower the ranking, so that the plano lens was associated with the best performances, the +1.50-D lens was associated with poorer performances, and the +3.00-D lens was associated with the poorest performances.

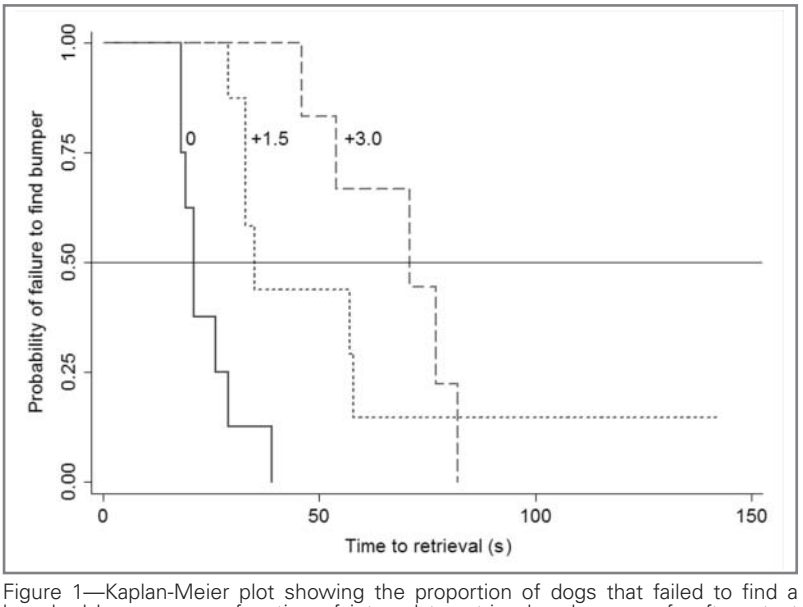

Figure 1—Kaplan-Meier plot showing the proportion of dogs that failed to find a launched bumper, as a function of interval to retrieval and power of soft contact lenses with which they were fitted (0, +1.50, and +3.00 D). Dogs that failed to find the bumper by the end of the study were censored.

Discussion

Findings of the present study suggested that even a mild degree of myopia, equivalent to –1.50 D (the degree of myopia is expressed in terms of the power of the spherical lens that would be needed to correct it), has a significant effect on behavior-based vision testing in retriever breeds of dogs, impacting their ability to locate targets at a distance of 137.2 m. This effect was detected subjectively by professional judges who were unaware of the dogs' visual acuity and objectively by measurement of retrieval performance times.

Over the years, several behavior-based tests have been developed to assess various aspects of visual function in dogs. These include behavior-based testing of color vision,[19] contrast sensitivity,[20] and visuospatial discrimination.[21] Two behavior-based tests were recently developed to quantitatively evaluate the ability of dogs to navigate obstacle courses in various lighting conditions, allowing behavioral assessment of ocular rod and cone function.[22,23] However, to date, no behavior-based test has been developed to assess visual acuity in dogs. Currently, these assessments are conducted by use of electrophysiological methods through recording of pattern electroretinograms[24] and pattern visual-evoked potentials,[18,25] which record the functional responses of the retina and visual cortex, respectively, to alternating patterns of various sizes and can thus be used to determine the smallest pattern detected by the visual system.[26] Use of functional magnetic resonance imaging has been proposed, although not evaluated, for this purpose.[27] On the basis of such methods, it has been estimated that the visual acuity of dogs, measured by use of the Snellen fraction (in which 20/20 is the reference [gold] standard of optimal human acuity), ranges between 20/50 and 20/140, with approximately 20/75 being the likely mean.[1,28,29]

Visual acuity is affected by numerous ocular factors. These include the anatomy of the retina because a high concentration of cones and associated ganglion cells contributes to high visual resolution.[1,28,29] One of the reasons for the poor visual resolution of dogs versus other species is that the canine area centralis, which is the retinal area that subserves the highest visual acuity, is populated by a relatively low concentration of cones (23,000 cones/mm^2)[30] and ganglion cells (14,400 cells/mm^2).[31] The presence of a tapetum lucidum, which increases light scatter in the eye, also has a negative impact on visual resolution.[32]

Additionally, optical factors, including optical aberrations and accommodative power, have a substantial effect on visual acuity. However, the most important optical factor to affect visual acuity is the refractive state of the eye and the extent of its ametropia, if any. Electrophysiological recordings in dogs have shown that 1 D of induced myopia will reduce visual resolution in an emmetropic dog by 1 cycle/degree, from 20/75 to 20/85.[18] Similar results have been obtained in electrophysiological studies of defocused monkeys[33] and humans.[34]

Based on the results of these electrophysiological studies[18,33,34] and the Snellen fraction conversion charts,[35] the predicted visual acuity of the dogs of the present study was 20/92 and 20/120 when induced with myopia of –1.50 and –3.00 D, respectively. As our results demonstrated, despite the small sample size, such a reduction in visual resolution had a significant negative impact on the dogs' performance as judged both subjectively and objectively. Considering that the refractive state of dogs' eyes may change with age in some breeds,[14] presumably because of age-related changes in the lenses of the eye,[14,36] loss of emmetropia should be added to the list of differential diagnoses for deterioration in visual performance of dogs. Furthermore, results of the present study demonstrated the importance of refraction screening and selection for emmetropia in dogs with demanding visual tasks, such as field-trial dogs and guide dogs for the blind, given that they may have ametropia.

a. Thunder T-1000, Thunder Equipment, Wampum, Pa.
b. YardagePro Sport 450, Bushnell, Overland Park, Kan.
c. Proclear, CooperVision, Fairport, NY.

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