ARTICLE

Vision and Athletic Performance: Data from Agility Dogs

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ABSTRACT

Background: To explore the relationship between vision problems and athletic performance, we measured refractive error and binocular vision in highly trained canine athletes. This group offers the opportunity to examine vision effects pristinely, without any influence of corrective lenses or vision therapy. Such a study is impossible in humans, but can add insight about the influence vision has on athletic performance in general.

Methods: 210 dogs were recruited via word of mouth and examined at agility events in California, Texas, and Washington for cover test near and far, prism bar vergence near and far, Hirschberg and Bruckner tests for eye alignment, and retinoscopy. Owners and/or trainers categorized each dog as a good or poor jumper.

Results: 190 dogs qualified; 54 (28.4%) had binocular disorders and 136 (71.6%) did not. Among those without binocular problems, mean SE was +0.07 D for good jumpers and -0.82 D for poor jumpers; poor jumpers were significantly more myopic and had more astigmatism than good jumpers. However, because the distribution of refractive errors in our sample was broad (from -3.00 to +3.00 spherical equivalent), some myopic dogs were good jumpers and some emmetropic and hyperopic dogs were poor jumpers. Binocular vision problems had a separate and sometimes additive effect, with anisometropia and unilateral (constant) strabismus more strongly related to poor jumping than alternating strabismus. Regression analysis showed that binocular competence had relatively more weight in jumping than refraction.

Conclusions: Refractive error and binocular problems can affect jumping behavior in highly trained canine athletes. However, these vision problems are not predictive for any individual case, and as with human athletes, some individuals appear able to overcome physical attributes that for others are limiting. The results support the importance of vision, and in particular binocular and refractive problems, to athletic performance for humans as well as canines.

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INTRODUCTION

Animal models have long been used to explore and understand human behavior.[1] In the field of vision, dogs have become a valuable model for human myopia, providing data through their participation in experiments that would be difficult or impossible to carry out using human subjects.[2,3,4] Such studies rely on similarities in structure between canine and other retinas,[5] which are now deemed sufficient enough to allow dogs to become models in developing gene therapy for human childhood blindness.[6]

Sports vision is a uniquely human field.[7,8] Perhaps for this reason, animal models have not been exploited. However, like humans, animal athletes undergo years of training in their sport.[9] Dogs in particular can run and catch tennis balls with speed and accuracy, presumably using features of their forward-facing eyes to make appropriate judgments of both ball and body positions. Thus, examination of their behavior could provide insights for humans.

Agility is a recognized sport in which dog and human work together in a complex obstacle course that requires the dog to jump accurately and rapidly to achieve maximum performance,[10,11] – all tasks that involve vision. Training for agility often begins early in life;[11] some breeders expose puppies to course components even before weaning.[12]

Although owners and trainers generally believe that vision is important in the sport of dog agility, canine athletes rarely receive functional vision examinations during development or training. Trainers do recommend examination by a veterinary ophthalmologist,[13] but veterinary eye exams cover only basic eye health; refraction and tests for strabismus are rarely done. Unlike human athletes, dogs do not wear corrective lenses nor undergo corrective surgeries, and their owners do not typically know whether a functional vision problem exists. Agility dogs thus present a visually pristine population in which to study the possible effects of vision deficits on athletic training and performance. We can study the influence on performance of uncorrected myopia, for example, or of anisometropia or high astigmatism – which would be very difficult to study in a population of human athletes.

The first author is active in the sport of agility, and as an optometrist she has been asked by other owners and handlers whether vision problems could be responsible (in part) for poor jumping performance in dogs. The question arises naturally when one observes dogs on an agility course who are struggling – they seem to be having trouble judging where the obstacle (usually bars of a given height) is.[14] One correlate of poor jumping is "stutter-stepping," where the dog slows down, drops its head, and may take a series of unevenly spaced steps toward a jump. Another is a tendency to take off for the jump too soon, sometimes hitting the bar, especially with multiple bars in a spread jump.[12]

In general, training improves jumping ability. However, some dogs continue to exhibit these difficulties even after repeated training with various techniques. For them, no amount of training seems to change the dog's ability to plan the proper approach to jump on course. We hypothesized that dogs might either have a refractive error that would make a bar difficult to resolve, or that they had difficulties with binocular function, which would interfere with depth perception. In fact, Orfi et al.[15] demonstrated that blurring the vision of hunting dogs results in poor performance. Given the limited research in this area, our goal is not only to help those in the sport to better understand their dog's performance, but also to shed light on the role that a broad spectrum of functional vision problems might play in sports vision in general.

METHODS

Subjects

A total of 210 dogs were recruited through word of mouth via agility trainers in California, Washington, and Texas (Table 1). The site of testing varied with location. In California, nine

Table 1

Sample	N	Comments
Total Tested	210	In California (108), Washington (52), and Texas (50)
Eliminated from Sample	20	Pathology (7), Too Young (9), No Jumping Info (4)
Total Sample Analyzed	**190**	
Binocular Vision Problems	54	Due to Strabismus (32), Anisometropia (21), Both (1)
No Binocular Vision Problems	136	Including Hyperopes (49), Myopes (59), Emmetropes (28)

1- or 2-day sessions were carried out over 11 months in a recreational vehicle owned by one of the authors and located at or near agility training or events. In Washington, two 1-day sessions were carried out in a barn located on the property of an agility event. And in Texas, two 1-day sessions were carried out either in a darkened hotel room next to an agility event or at the home of one of the dog owners. Regardless of location, the dog's owner was always present and remained in control of the dog for the entire examination. The examiner (GD) was assisted by another individual (a co-author or other assistant familiar with dogs) who provided rewards and toys in order to maintain the animal's attention during testing.

Inclusion criteria for the study were (a) age at least 15 months, with at least one year of agility training (these are requirements for participation in sanctioned events); (b) active participation in agility trials; (c) sufficient agility training and trial experience to allow owners and instructors to determine the presence or absence of jumping problems; (d) no known ocular pathology. Of the 210 dogs, 20 were eliminated from the sample because they failed to meet one or more of these criteria, yielding a final sample size of 190 (Table 1).

Although 32 breeds made up the sample, more than half were Border Collies (n=106), reflecting the breed's popularity in the sport. The next most numerous breed was Shetland Sheepdog ("Sheltie," n=26), with the remaining breeds represented by 1 or 2 dogs on average. Although Shelties were significantly more astigmatic than Border Collies, we found no other differences with breed and thus all breeds were combined for this report.

Testing Procedures

Owners signed a permission slip after hearing a description of the study and the procedures to be used. They retained the top written portion of the form, which contained contact information for the investigators as well as a written description of the study goals. IACUC approval was not necessary, because the standard clinical testing procedures we used were unlikely to alter or influence the activity of the study animals.

The dog was either seated on the floor or on a couch where its head could be held steady by the owner or assistant as needed. The room was dimly illuminated for some tests (retinoscopy, Hirschberg, and Bruckner; see below); otherwise normal room illumination was used. Most of these highly trained dogs were obedient and able to hold still on command. Either the handler or an assistant used toys or treats as necessary to entice the dogs to focus attention at the desired testing distance. Testing techniques were modified from a typical toddler exam. While retinoscopy has been used in canines, e.g.,[4] to our knowledge this is the first attempt to evaluate binocular vision in dogs.

We attempted to collect data on each dog using the following tests, which generally took a total of 20 minutes. The target was either a small treat or a toy, depending on what held the dog's attention best. Photos were taken with iPhones.

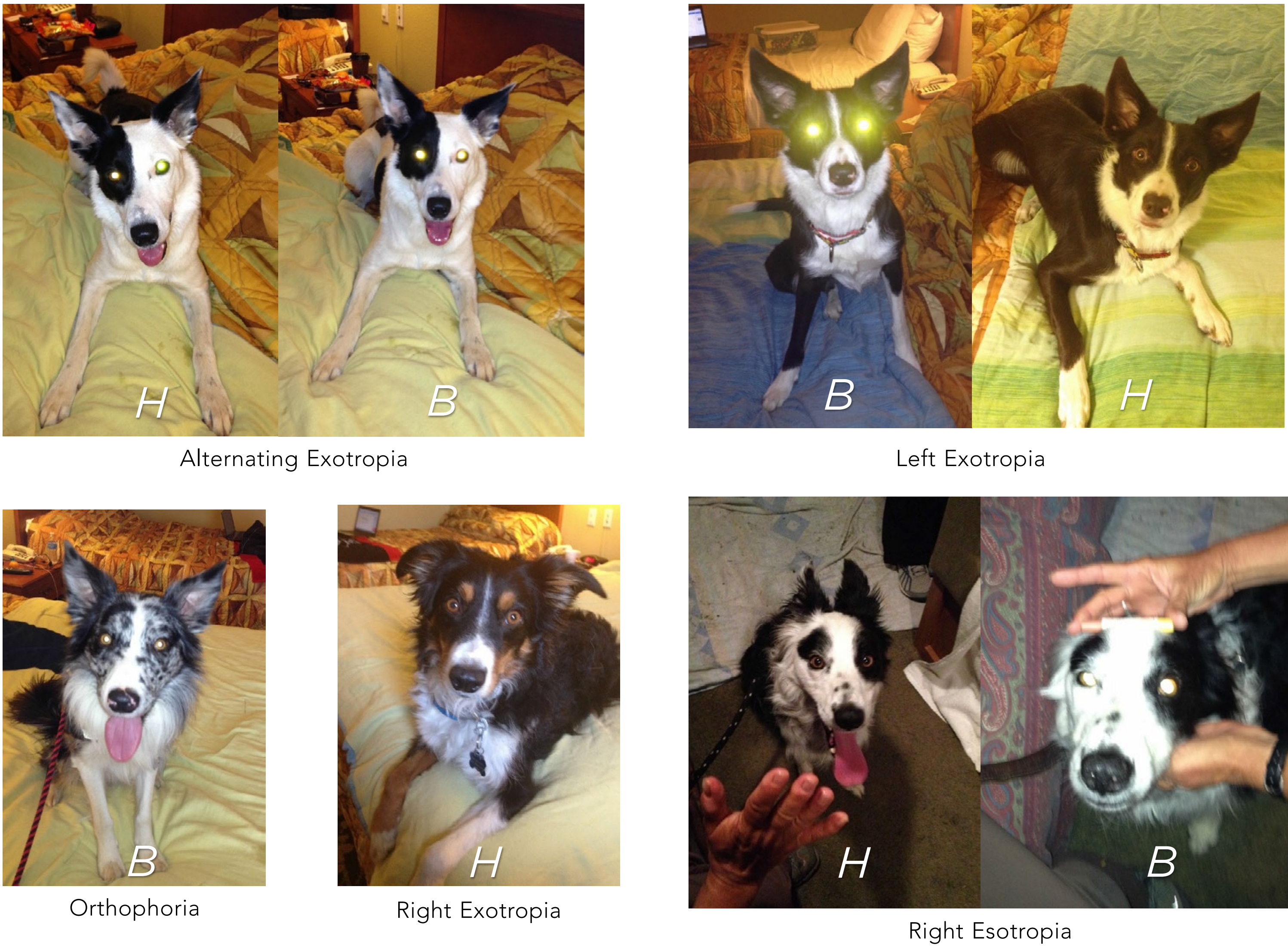

Figure 1

- Cover test at 6 feet and 16" for phoria and strabismus
- Prism bar vergence testing at 6 feet and 16"
- Retinoscopy with dog looking at target 6 feet away with undilated pupils,[4] to measure spherical and astigmatic error
- Hirschberg Test for eye alignment,[16] recorded via photo in primary gaze
- Bruckner Test for eye alignment and detection of anisometropia,[16] recorded via photo in primary gaze

Figure 1 illustrates some types of strabismus we observed. Othrophoria is clear in the bottom left, with even reflexes from both eyes. Uneven reflexes from the eyes show left and right exotropia, alternating exotropia, and right esotropia.

Definitions and Data Analysis

We attempted to develop a grading scale for quality of jumping, but were not able to obtain sufficient environmental control (e.g., using the same course for all dogs) to implement it properly. In the future we would recommend developing such a scale, perhaps with trained observers and video clips. For this study, we defined "poor jumping" or "jumping problems" as persistent evidence of early takeoffs before a jump, stutter-stepping, hesitation, or any other jumping issue, as observed by the owner or outside observers who were experienced in agility training. A dog was classified as having no jumping problems if it exhibited none of these characteristics, according to the owner and expert observers. By these criteria, of the 190 dogs in our sample, 108 were reported to have no jumping problems, and were thus classified as "good jumpers" and 82 were reported to have jumping problems ("poor jumpers").

The following optometric definitions are used in this paper:

Emmetropia
Plano refraction +/- 0.50 D in both sphere and cylinder error

Hyperopia
Positive spherical refraction > + 0.50 DS

Myopia
Negative spherical refraction > - 0.50 DS

Astigmatism
Cylindrical refraction > - 0.50 DC

Astigmatic hyperope
Astigmatism and hyperopia

Astigmatic myope
Astigmatism and myopia

Anisometropia
1.00 D or greater difference in either sphere or cylinder error

Unilateral Strabismus
Constant deviation of one eye; determined by cover test and Bruckner and Hirschberg tests

Alternating Strabismus
Deviation that alternates between eyes; determined by cover test Bruckner and Hirschberg tests

Binocular Vision
Presence of strabismus (unilateral or alternating) or anisometropia

Data were analyzed descriptively by computing percentages of dogs with vision conditions in the entire sample and in those with jumping problems; chi square and binomial tests were used to assess significance for frequency and percentage data. T-tests were used to determine significance of differences between distributions of spherical and cylindrical error values across dogs. To determine relative impact of vision variables on good vs poor jumping, we used regression analysis followed by t-tests.

Table 2

Refraction	Good Jumpers n=87	Poor Jumpers n=49	p<
Spherical (DS)	+ 0.19	- 0.53	**.00001**
Cylindrical (DC)	- 0.25	- 0.64	**.001**
Spherical Equivalent (D)	+ 0.07	- 0.82	**.00001**

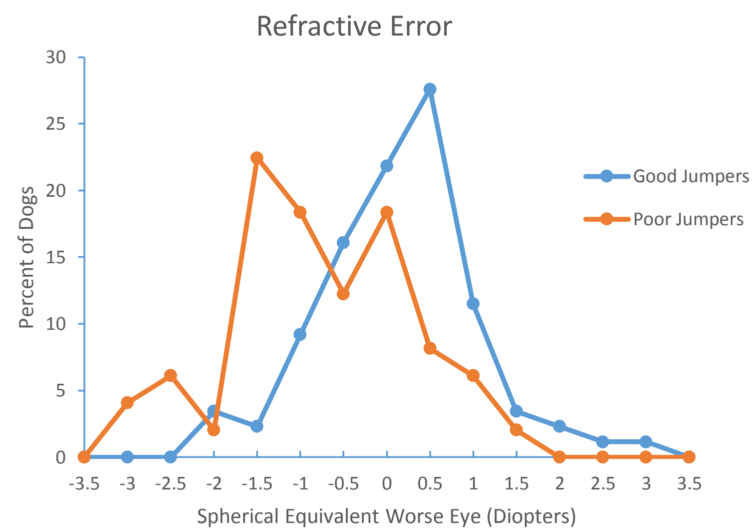

Figure 2

RESULTS

To examine the incidence of refractive error, we first present results from the 136 dogs without strabismus (Table 2). The mean refraction for good jumpers was +0.19 D spherical and -0.25 D cylinder, for a spherical equivalent of +0.07. Thus good jumpers were emmetropic, on average. Poor jumpers, in contrast, were slightly myopic on average (-0.53 DS) with -0.65 D cylinder and spherical equivalent of -0.82 D. The differences between good and poor jumpers were highly significant in every refractive category (Table 2).

Figure 2 shows the full distribution of refractive errors for good jumpers and poor

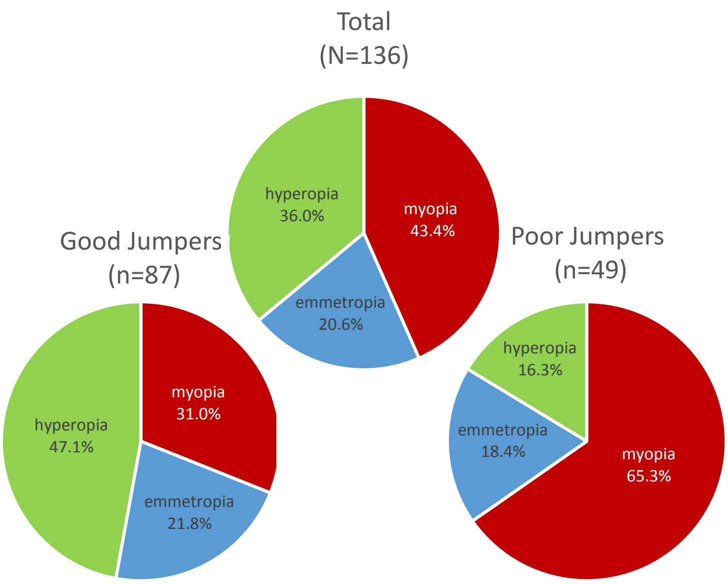

Figure 3

jumpers, illustrating that each is very broad. The trend toward myopia for poor jumpers is clear, as is the tendency toward hyperopia for good jumpers. But being myopic certainly does not preclude good jumping. For example, some dogs with spherical equivalent -1.0 D or more were good jumpers, while some dogs with spherical equivalent +1.0 or more were poor jumpers. Even though they are very broad, the distributions are statistically different by 2-tailed t-test (p (t) < .003).

Figure 3 shows the data in terms of proportions of dogs with a given type of refraction according to whether they were good or poor jumpers. In the total sample of 136 dogs without binocular vision problems, 28 (21%) were emmetropic by our definition of +/- 0.50 D. Of the remainder, 59 (43%) were myopic and 49 (36%) were hyperopic. When the dogs were separated into good and poor jumping categories, the proportion of emmetropes remained about the same (18% in poor jumpers and 22% in good jumpers). However, the relative proportion of myopes and hyperopes differed. The proportion of good jumpers who were hyperopes increased to 47% relative to the total sample, and the proportion who were myopes decreased to 31%. For poor jumpers the opposite occurred: a large proportion of poor jumpers were myopes (65%), while the proportion of hyperopes was low (16%). The changes in proportion between the total sample and the subsamples according to jumping behavior were highly significant (chi square goodness of fit = < 0.00001).

We found binocular disorders in 54 dogs, 22 with anisometropia and 33 with strabismus; one dog had both conditions. Table 3 shows that these conditions existed in both good and poor jumpers, but tended to predominate in poor jumpers. Of the 22 dogs with anisometropia, 7 were good jumpers and 15 poor jumpers (top row, Table 3, p<.05, binomial test). We observed a total of 20 unilateral strabismics, 5 of whom were good jumpers and 15 poor jumpers. Interestingly, of the 13 alternating strabismics, 9 were good jumpers and only 4 were poor jumpers. Nonetheless, statistically speaking, strabismus of any type was significantly associated with poor jumping behavior (p<.05, chi square test for each category: unilateral, alternating, and no strabismus). Finally, although

Table 3

Binocular Balance		**Good Jumpers**		**Poor Jumpers**	
		N	**%**	**N**	**%**
Anisometropia		7	6.9	15	18.3
No Anisometropia		101	93.1	67	81.7
Total		108		82	
Strabismus					
	Unilateral Esotrope	1	0.9	5	6.1
	Unilateral Exotrope	4	3.7	10	12.2
	Alternating Esotrope	0	0.0	0	0.0
	Alternating Exotrope	9	8.3	4	4.9
	Total Strabismus	14	13.0	19	23.2
No Strabismus		94	82.0	63	76.8
Total		108		82	

Table 4

Binocular Vision Problems	**Good Jumpers** n=108	**Poor Jumpers** n=82
No (n=136)	87 **64%**	49 **36%**
Yes (n=54)	21 **39%**	33 **61%**

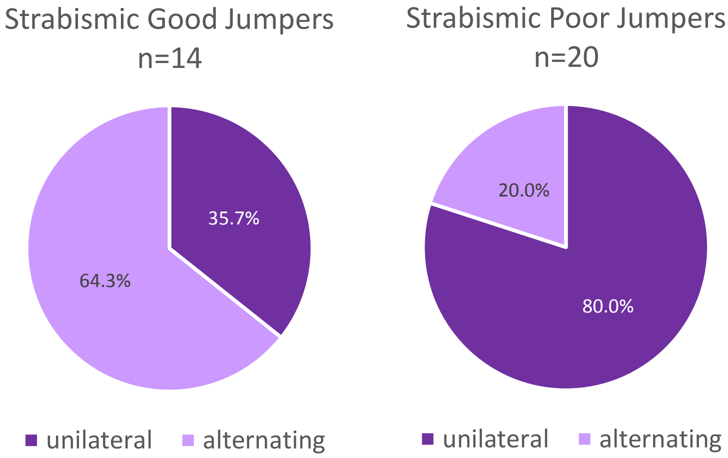

Figure 4

we collected vergence measurements, we found no statistically significant differences relative to jumping behavior.

Table 4 shows that binocular vision is an important contributor to jumping behavior. We compared the 136 animals with no binocular vision problems from the previous analysis to the 54 we found with binocular vision problems of any type. Of the dogs with binocular vision problems, 61% were poor jumpers and 39% were good jumpers. Of the dogs without binocular vision problems, 64% were good jumpers and 36% were poor jumpers – an almost complete reversal. This relationship was statistically significant by chi square (p<.002).

Table 5

Refraction	No BV Problems n=136	BV Problems n=54
Spherical (DS)	-0.07	-0.42
Cylindrical (DC)	-0.39	-0.63
Spherical Equivalent (D)	-0.25	-0.67

The type of strabismus was also related to good or poor jumping (Figure 4): good jumpers among the dogs with binocular vision problems tended to be alternating strabismics (64%), while poor jumpers who were strabismic tended to be unilateral (80%).

Table 5 shows that dogs with binocular vision problems were, on average, more myopic than those without (p<.03 for each category of refractive error, 2 sample t-tests with 2-tailed probability). The cohort of 136 dogs without binocular vision problems were emmetropic by our definition (SE = -0.25 D).

Table 6 is the result of a regression of spherical equivalent refraction and presence or absence of binocular vision problems on jumping behavior, in an attempt to discern weighting factors for each. The regression was statistically significant, meaning that at least one of the variables is related to jumping behavior. Subsequent t-tests showed that both spherical equivalent (p < .001) and binocular vision (p < .01) were significant contributors to the regression, and the weighting factors for the regression equation (Table 6) indicate that the effect of having a binocular vision problem is greater than that of refraction. The adjusted R square value of 0.11 indicates that about 11% of the variability in jumping category is due to the presence of these variables.

Table 6

Regression Statistics	
Multiple R	0.346891
R Square	0.120333
Adjusted R Square	0.110925
Standard Error	0.468253
Observations	190

ANOVA

	df	SS	MS	F	Significance F			
Regression	2	5.608799	2.804399	12.79026	6.22E-06			
Residual	187	41.00173	0.219261					
Total	189	46.61053						

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.331265	0.04087	8.1053	6.7E-14	0.250639	0.41189	0.250639	0.41189
Refraction	-0.11485	0.030171	-3.80664	0.000191	-0.17437	-0.05533	-0.17437	-0.05533
Binocular Vision	0.203013	0.076356	2.658757	0.008523	0.052382	0.353644	0.052382	0.353644

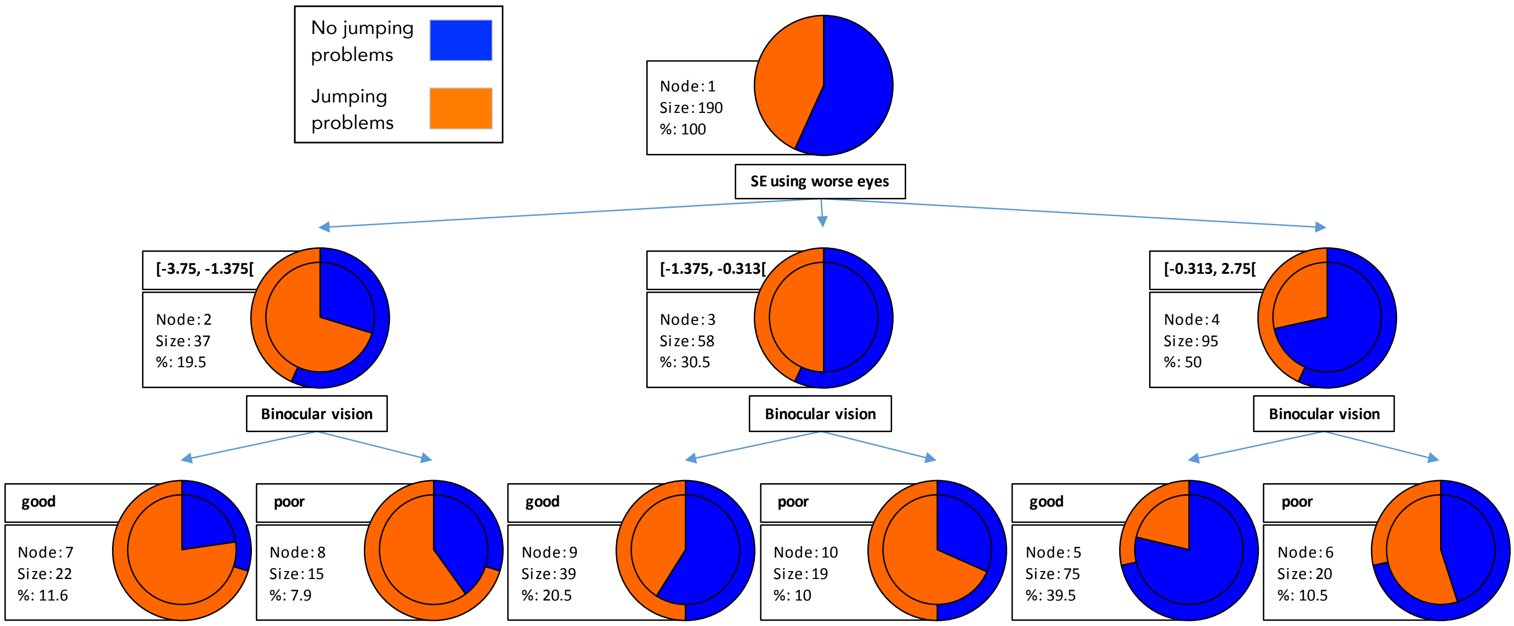

Figure 5

Further analysis (Figure 5) showed that myopia between -1.375 D and -3.75 D was predictive of jumping problems while emmetropia and hyperopia were predictive of no jumping problems (Figure 5). However, when binocular vision problems were present, more than 50% of emmetropes and hyperopes had jumping problems. It thus appears that if either myopia or poor binocular vision are present, they can be associated with jumping problems, and that if myopia is relatively low (between -0.313 and -1.375) then the effect of poor binocular vision is additive: it is more likely that a dog will have jumping problems when poor binocular vision is combined with low myopia.

DISCUSSION

This study demonstrates that refractive state and binocular vision contribute to the quality of jumping behavior in canine athletes. Specifically, myopic astigmatism and unilateral strabismus are associated with poor jumping. These factors have been implicated by previous studies in human athletes,[7,8] and generally assumed by coaches and clinicians to be important. This study is the first to examine a sample of canine athletes with no visual correction, and who consequently have a wide range of vision difficulties.

A main finding is that although near-sightedness and poor binocular control are related to poor jumping performance, the predictive value for any individual dog is limited: only about 11% of the variability in jumping behavior is due to the vision factors we measured (Table 6), and the distribution of refractive errors among both good and poor jumpers are broad. Thus, some dogs with myopia were good jumpers, and dogs with emmetropia or hyperopia could certainly be poor jumpers. Clearly, many other factors are involved in determining the outcome for any given dog, such as reaction time or body conformation and even higher-level perception – which we did not measure in our study. On the other hand, as an athlete, knowing that more than 10% of one's performance relies on one sensory system indicates that maximizing the input from that system is important.

The significant influence of vision variables on jumping behavior suggests that certain treatment options, as for humans, might be appropriate to try on dogs. Contact lenses would correct refractive errors, and binocular vision could improve with correction and/or vision therapy.[17] To our knowledge neither contact lens correction nor vision therapy has yet been tried in dogs. An area for investigation is how long it would take for dogs to adjust or adapt to the new refraction presented by contact lenses. Another is how to design vision therapy protocols appropriate for dogs.

Vision in general, and especially resolution ability (high acuity) has long been a desirable quality in human athletes.[7,8] This work supports the application of corrective lenses, especially in cases of myopia and/or astigmatism. Such use has been shown to improve performance, and programs that train dynamic acuity (resolution while a target is moving) – can be effective.[18,19] In addition, vergence facility and other near-point skills are associated with athletic ability,[20] and poor binocular control has been associated with clumsiness in humans.[21] Thus it seems reasonable to expect that dogs with strabismus might also misjudge space. Our results strongly suggest that good binocular vision is desirable for good agility performance in dogs. The findings are consistent with the use of vision therapy or visual skills training to correct strabismus and improve binocular function for maximum athletic performance in humans.

Finally, the close interaction between vision and the ability to perform demanding physical tasks supports the importance of providing treatment (i.e., glasses and/or vision therapy) to children when disorders are detected. In particular, children with poor binocular control, like dogs with poor binocular control, may not fully benefit from athletic training if they are hindered by the inability to provide sharply focused and coordinated information from both eyes to the brain.

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Maureen Powers, who holds a Ph.D. in Psychobiology from the University of Michigan, was Professor of Psychology in Neuroscience at Vanderbilt University where she founded and directed the Vanderbilt Vision Research Center. Her primary research interest in the relation between basic visual function and behavior, in humans and animals. She is currently Senior Scientist at Gemstone Foundation.

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Gina Day earned the O.D. from SCCO, after having served in the Air Force. She established her own private practice in Larkspur, California, where she provides vision therapy. She and Dr. Powers have also collaborated in studies of the effectiveness of vision therapy for post-refractive patients who still experience blur.