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Effectiveness of slow motion video compared to real time video in improving the accuracy and consistency of subjective gait analysis in dogs

D.M. Lane^{1,*}, S.A. Hill², J.L. Huntingford³, P. Lafuente⁴, R. Wall⁵ and K.A. Jones⁶¹Points East West Veterinary Services, Box 2696, Garibaldi Highlands, BC, V0N 1T0, Canada²Department of Military Psychology and Leadership, Royal Military College of Canada, Kingston, Ont, K7K 7B4, Canada³Essex Animal Hospital, 355 Talbot St N, Essex, Ontario Canada N8M2W3⁴Royal Veterinary College, Hawkshead Lane, North Mymms, Hatfield, AL9 7TA, UK⁵Center for Veterinary Pain Management and Rehabilitation, 10807 Kuykendahl Road, Suite 406, The Woodlands, TX 77382, USA⁶TOPS Veterinary Rehabilitation, 1440 East Belvidere Road, Grayslake, IL 60030, USA

Abstract

Objective measures of canine gait quality via force plates, pressure mats or kinematic analysis are considered superior to subjective gait assessment (SGA). Despite research demonstrating that SGA does not accurately detect subtle lameness, it remains the most commonly performed diagnostic test for detecting lameness in dogs. This is largely because the financial, temporal and spatial requirements for existing objective gait analysis equipment makes this technology impractical for use in general practice. The utility of slow motion video as a potential tool to augment SGA is currently untested. To evaluate a more accessible way to overcome the limitations of SGA, a slow motion video study was undertaken. Three experienced veterinarians reviewed video footage of 30 dogs, 15 with a diagnosis of primary limb lameness based on history and physical examination, and 15 with no indication of limb lameness based on history and physical examination. Four different videos were made for each dog, demonstrating each dog walking and trotting in real time, and then again walking and trotting in 50% slow motion. For each video, the veterinary raters assessed both the degree of lameness, and which limb(s) they felt represented the source of the lameness. Spearman's rho, Cramer's V, and t-tests were performed to determine if slow motion video increased either the accuracy or consistency of raters' SGA relative to real time video. Raters demonstrated no significant increase in consistency or accuracy in their SGA of slow motion video relative to real time video. Based on these findings, slow motion video does not increase the consistency or accuracy of SGA values. Further research is required to determine if slow motion video will benefit SGA in other ways.

Keywords: Canine, Lameness, Video, Diagnosis, Subjective.

Introduction

Kinetic and kinematic gait analysis are commonly used and accepted techniques for evaluating canine lameness (Hudson *et al.*, 2004; Quinn *et al.*, 2007; Waxman *et al.*, 2008; Katic *et al.*, 2009; Brown *et al.*, 2013; Kapatkin *et al.*, 2014). However, subjective gait analysis (SGA), the visual observation of a patient's movement in order to discern abnormalities that indicate musculoskeletal pain, is the most commonly performed procedure for evaluating gait in veterinary medicine (Katic *et al.*, 2009). It is considered a necessary element of orthopaedic or sports medical examinations (Malikides *et al.*, 2007; Millis and Mankin, 2014). Viewing the dog at both a walk and trot, from each side, and from directly in front and behind is recommended (Malikides *et al.*, 2007; Millis and Mankin, 2014).

Although SGA has the advantage of being an easily executed diagnostic technique, requiring no costly equipment or set-up time, there are limitations in interpreting the resulting data. Previous research

has demonstrated very strong intra-rater agreement for experienced observers evaluating the degree of lameness (Waxman *et al.*, 2008), but only strong inter-observer correlations for SGA (Quinn *et al.*, 2007).

SGA also appears to be a poor test for detecting minor shifts in weight or subtle degrees of lameness. Multiple researchers have concluded that subjective assessment of subtle lameness correlates poorly with objective measurements of gait such as kinetic and kinematic analysis (Evans *et al.*, 2005; Quinn *et al.*, 2007; Waxman *et al.*, 2008). According to Gillette and Angle (2008), rapid limb movement may hinder an observer's ability to visually detect subtle gait changes.

A common method for reporting SGA is the use of a five point numerical rating scale (NRS) that divides the degree of lameness into categories (0=no lameness through 5=non-weight bearing lameness (Millis and Levine, 2014)). The NRS is a simple descriptive scale in which the examiners pick the level of lameness or the word that most describes the lameness they are

*Corresponding Author: Dr. David M. Lane. Points East West Veterinary Services, Box 2696, Garibaldi Highlands, BC, V0N 1T0, Canada. Tel.: 604-898-6630; Fax: 604-898-6633. E-mail: dlane@pointseastwest.com

Video ID#: _____

The subject's gait was:

Non-weight bearing lameness |-----| No lameness

Please indicate which limb(s) were affected (circle all that apply):

Left fore Left Hind Right Fore Right Hind No lameness

Fig. 1. Visual Analogue Scale completed by raters in this experiment to categorize the degree of lameness.

viewing. More accurate than the NRS is the Visual Analogue Scale (VAS) depicted in Figure 1. In this instance, the observer places a mark somewhere along a 10cm line to indicate the degree of lameness, with anchor points similar to those of NRS at either end of the scale. The VAS scale can be analyzed as a continuous scale because, unlike the NRS which has a few specific categories, the VAS scale has numerous possibilities and can reflect even small changes in lameness.

Objective measures of gait analysis often involve kinetic evaluation using either a force plate, or pressure plate or mat (Gillette and Angle, 2008; Oosterlinck *et al.*, 2011; Zink, 2013) or kinematic analysis involving three dimensional computer based analysis. Because of financial, spatial or temporal requirements of these technologies, both kinetic and kinematic analysis face barriers to widespread implementation in general practice. Therefore, there is value in finding other more accessible technologies to overcome the limitations of SGA. Slow motion video with the ability to repeatedly review animals walking and trotting may overcome some of the limitations of real time SGA. In addition, video images can be emailed to specialists or other practitioners for second opinion analysis.

Although many studies have employed digital video combined with kinematic markers and subsequent computer analysis (Agostinho *et al.*, 2011; Kim *et al.*, 2011; Bøddeker *et al.*, 2012; Gustås *et al.*, 2013; Miqueleto *et al.*, 2013), only one study documented the use of slow motion digital videography on its own (Waxman *et al.*, 2008). In that paper, each dog was filmed from a fixed camera angle of 30 degrees, and videos were made showing each dog walking at normal, and 50% normal speed. The dogs were not filmed while trotting. To our knowledge no studies have utilized slow motion video filming from the front, back, and sides of dogs, at both a walk and trot (as is recommended as part of a complete lameness exam) as part of their procedures when gathering SGA data.

Because there is a dearth of research on the use of slow motion video and its effects on the accuracy of SGA, further investigation is warranted. The purpose of our study was to determine if veterinary observers viewing videos of dogs walking and trotting in 50% slow motion would produce different SGA values than if viewing the same videos in real time. Our hypothesis

was that the veterinary observers would produce more accurate and consistent assessment of lameness when watching slow motion video relative to real time video.

Materials and Methods

Patient selection

The owners of 30 dogs volunteered to participate in this research after hearing about it through social media, newspaper and television articles. Fifteen dogs with naturally occurring lameness based on both history and physical exam findings, and fifteen dogs with no history or physical exam findings indicating lameness qualified for the study. The dogs ranged in age from 1.5 to 17 years (mean=6.25 years, SD=3.82). Fifteen were neutered males and 15 were spayed females. Their weights ranged from 2.9 kg to 45.0 kg with an average of 20.82 kg (SD=11.49). There were 10 mixed breeds, 3 Labrador Retrievers, 2 Whippets, 2 Belgian Malinois, 2 Golden Retrievers, and the remaining dogs were all purebreds with only a single representative.

Based on questionnaires completed by the owners using a five point NRS, each of the lame dogs had a history of experiencing “some” or “great” difficulty walking, trotting, jumping, negotiating stairs, rising from a lying position, or moving after either long rests or exercise. These signs were present for at least one month prior to the start of the experiment. Owner survey responses were used for determining patient eligibility, and were not factored into subsequent lameness assessments.

In addition to the historical information provided by owners, eligible dogs needed to have concurrent physical exam findings indicative of either unilateral or bilateral forelimb or hindlimb lameness (as determined by DL). Eligible forelimb lameness physical exam findings were confined to cases of chronic active elbow arthritis. Three patients had reduced elbow range of motion, pain on end feel, and palpable exostoses in order to qualify. One dog had bilateral elbow arthritis and two had unilateral elbow arthritis.

Eligible hindlimb physical exam findings included evidence of cruciate ligament disease as indicated by instability when performing either a cranial drawer or tibial thrust test (4 dogs with unilateral cruciate insufficiency, 3 dogs with bilateral cruciate insufficiency), bilateral medial luxating patellas with concurrent stifle pain (2 dogs), or bilateral hindlimb proprioceptive deficits as indicated by a markedly delayed or absent knuckling reflex (3 dogs). The video reviewers (RW, PL, KJ) were blinded to the examination findings.

All procedures were performed in accordance with the guidelines from the Canadian Council on Animal Care in Science. Owners signed a consent form prior to the collection of data.

Video collection and editing

Video footage was taken by a hand-held Canon EOS 7D camera filming at 30 frames per second. The videographer manually zoomed the lens on the dog in

order to have it fill most of the frame. Each dog was filmed on leash both walking and trotting a set distance on a paved parking surface behind a veterinary hospital. Dogs were walked and trotted by their owner or a designated handler. Twenty-eight of the 30 dogs were filmed with their owner acting as handler, the remaining two dogs were walked by a technician. Because the lens was zoomed in on the dog, the owner's upper torso was generally absent from the frame. At both walk and trot, each dog was filmed moving directly toward and away from the camera, and from each the left and right sides. The videographer filmed from fixed locations that remained unchanged throughout the experiment, one location for filming the dog from the side and one location for filming the dog moving toward and away from the camera.

One hundred twenty videos were made, four for each dog. The videos were edited using a standard software product (Corel Video Studio software, 1600 Carling Avenue, Ottawa, Ontario, K1Z 8R7, Canada). Each video file was edited to remove irrelevant footage, such as the owner asking the dog to sit before walking, or times when the dog began to canter instead of trotting. Sound was removed from all videos.

Four separate videos were made for each dog. The first video (RTW) captured the dog walking from each the left and right side, from the front (approaching the camera), and from the back (moving away from the camera). The second video (RTT) captured the dog trotting from each the left and right side, from the front, and from the back. Both the first and second videos played in real time.

The third video (SMW) used the same footage as the first video, except with the film slowed to 50% of the original speed. The fourth video (SMT) used the same footage as the second video, except with the film slowed to 50% of the original speed. Each video was then uploaded to a YouTube channel for the raters to access. Each dog travelled the same distance while being filmed (8 x 13m lengths), but due to differences in subject age, size, and degree of lameness, they travelled the distance at different speeds. The resulting videos were of different durations, depending on the speed the dog travelled the prescribed distance.

Duration of real time walk videos ranged from 26-92 seconds (M=50.87 sec, SD=16.77), real time trot videos were 19-49 seconds in duration (M=31.50 sec, SD=7.73), and their slow motion counterparts were approximately twice as long: Slow motion walk videos were 44-180 seconds long (M=99.60 sec, SD=35.50), and slow motion trot videos lasted 31-94 seconds (M=58.33 sec, SD=16.44).

Data collection

Three veterinary observers (RW, PL, KJ) with experience in gait analysis, physical rehabilitation and sports medicine volunteered to observe and grade

each of the 120 videos on a 100mm VAS scale with non-weight bearing lameness receiving a 0 score (far left of the line), and normal gait receiving a 100 score (far right of the line). Raters accessed the videos after being emailed a list of URLs. Video URLs were emailed in 4 batches. The order of videos in each batch was randomized using online randomization software (www.random.org), and the raters were instructed to observe the videos in the order in which they had been listed, which was identical for all three raters. This meant that all the videos in a given batch were reviewed before proceeding to the next batch.

The first batch of videos contained RTW footage, the second contained RTT, the third SMW, and the fourth contained SMT. Although raters were permitted to watch each video as many times as needed to provide a gait assessment, once they had marked their VAS score, they were not permitted to go back to review their assessments. As each batch was completed, the raters either emailed or faxed their responses back to the primary author for statistical analysis.

For each video, raters were also asked to identify which leg or legs (if any) were lame. A copy of the raters score sheet is provided as Figure 1. The raters were not informed of the hypothesis of this experiment.

Statistical analysis

Small sample size precluded the use of most inferential statistical tests of the hypothesis. Nonparametric measures of association were used instead (interpreted similarly to Pearson correlations – i.e. as values approach 1.0, strength of association increases). For this paper, values of 0.60-0.79 were considered strong, and values of 0.80-1.0 were considered very strong. Different types of variables require different nonparametric assessments, and we used Spearman's rho for variables measured on an interval scale, and Cramer's V for nominal variables. In addition, t-tests were employed to evaluate group differences in ratings because these tests are not adversely impacted by small sample sizes (Student, 1908).

Intra- and inter-rater agreement were measured by comparing the assessment of gait for real time and slow motion videos of dogs both walking and trotting. All tests were performed with 28 degrees of freedom, and were one-tailed.

To determine whether raters were accurately evaluating the performance of dogs in the videos, t-tests were performed using assigned group (lame/not lame) as the grouping (independent) variable. Lame dogs were expected to be scored lower than non-lame dogs at both walk and trot. Ratings were averaged across all raters, and mean ratings for real time and slow motion walk and trot were the dependent variables for this portion of the analysis.

In order to evaluate the accuracy of determining the source of lameness, the raters' assessments of which

limb or limbs was causing the lameness (Figure 1) were examined using Cramer's V (a measure of the strength of association between two nominal variables). Comparisons with the examination findings that were the basis for group assignment were similarly examined.

Results

Spearman's rho values for intra- and inter-rater agreement are presented in Table 1. All three raters showed strong to very strong intra-observer agreement when assessing the same gait in real time and in slow motion, with Spearman's rho values of ranging from 0.719 to 0.892 for walking, and 0.850 to 0.936 for trotting. Intra-observer agreement between real time walking and real time trotting was strong to very strong, ranging from 0.667 to 0.865. Intra-observer agreement between slow motion walking and slow motion trotting was very strong, ranging from 0.818 to 0.879. All p values were $p < .001$.

Agreement between observers when observing gait in real time showed strong agreement ranging from 0.612 to 0.737 for walking, and 0.713 to 0.796 for trotting. Inter-rater agreement was strong to very strong for slow motion video, ranging from 0.723 to 0.912 for walking, and 0.703 to 0.882 for trotting. The improved agreement for slow motion relative to real time was not statistically significant (evaluated using Fisher's Z-tests) for either intra- or inter-rater agreement.

Mean ratings for real time and slow motion walk and trot, standard deviations, and t-tests are presented in Table 2. The mean SGA scores for lame dogs walking and trotting in both slow motion and real time was almost 23 points lower than the mean SGA score for sound dogs (74.33 vs 97.01), but with greater variability in that scoring. The average standard deviation for lame dogs was 15.81 versus 3.74 for sound dogs.

The strength of association between raters' assessments of which leg or legs were lame, and with the physical exam assessment of which leg or legs were lame are presented in Table 3. Raters showed strong to very strong agreement with themselves when comparing real time and slow motion findings (0.700 to 0.875 for walking, 0.735 to 0.888 for trotting). Raters showed strong agreement with each other, with agreement in real time assessment ranging from 0.576 to 0.688 for walking, and 0.648 to 0.673 for trotting. Agreement on the source of lameness after watching slow motion video was very strong for walking, with a range of 0.819 to 0.859, and strong to very strong for trotting with a range of 0.753 to 0.830. Determination of which leg or legs were lame based on real time gait assessments showed strong association with physical exam findings, ranging from 0.617 to 0.753 for walking, and 0.631 to 0.704 for trotting. Slow motion video produced stronger agreement, ranging from 0.781 to 0.816 for walking, and 0.711 to 0.837 for trotting, although this improvement was not statistically significant (evaluated using Fisher's Z-tests).

Discussion

Objective gait analysis can be divided into either kinetic or kinematic techniques. Force plate analysis has been accepted as the gold standard for the evaluation of lameness in humans and animals (Hudson *et al.*, 2004; Quinn *et al.*, 2007; Waxman *et al.*, 2008; Katic *et al.*, 2009; Brown *et al.*, 2013; Kapatkin *et al.*, 2014). It involves the measurement of ground reaction forces during ambulation with the data being subjected to computer analysis. Peak Vertical Force (PVF) and Vertical Impulse (VI) are the two most common and useful measurements when assessing canine locomotion from a kinetic standpoint (Quinn *et al.*, 2007). Force

Table 1. Strength of association (Spearman's rho) between ratings of videotaped performance for real time and slow motion walk and trot (N=30).

	2	3	4	5	6	7	8	9	10	11	12
Real time walk rater 1	0.795	0.892	0.796	0.645	0.716	0.697	0.805	0.612	0.595	0.659	0.539
Real time trot rater 1	--	0.853	0.936	0.763	0.796	0.814	0.834	0.641	0.713	0.814	0.630
Slow motion walk rater 1		--	0.829	0.714	0.819	0.780	0.867	0.659	0.604	0.723	0.594
Slow motion trot rater 1			--	0.766	0.808	0.821	0.882	0.691	0.747	0.798	0.703
Real time walk rater 2				--	0.865	0.867	0.773	0.737	0.627	0.749	0.706
Real time trot rater 2					--	0.944	0.910	0.686	0.760	0.849	0.733
Slow motion walk rater 2						--	0.879	0.718	0.779	0.912	0.755
Slow motion trot rater 2							--	0.639	0.755	0.839	0.762
Real time walk rater 3								--	0.667	0.719	0.668
Real time trot rater 3									--	0.865	0.850
Slow motion walk rater 3										--	0.818
Slow motion trot rater 3											--

Note: All p values are $p < 0.001$.

Table 2. Cell means, standard deviations, and t-tests comparing lame and non-lame conditions (N=30).

Variable	Lame condition mean (standard deviation)	Not lame condition mean (standard deviation)	t (df)	p
Real time walk	78.44 (14.24)	95.07 (5.39)	t (18)=-4.227	=0.001
Real time trot	71.91 (19.22)	97.18 (3.59)	t (15)=-5.005	<0.001
Slow motion walk	74.93 (13.75)	97.27 (3.40)	t (16)=-6.105	<0.001
Slow motion trot	72.02 (16.01)	98.53 (2.58)	t (15)=-6.332	<0.001

Note: Dependent variable is the average rating (across 3 raters) for each listed variable. The assumption of homogeneity of group variance was violated for all tests, and degrees of freedom have been adjusted as a result. Unadjusted df=28.

Table 3. Strength of association between rater assessments of location of lameness (Cramer's V) (N=30).

	1	2	3	4	5	6	7	8	9	10	11	12
Real time walk rater 1	--	0.887	0.875	0.818	0.619 ^A	0.714	0.789	0.714	0.688	0.665	0.791	0.788
Real time trot rater 1		--	0.789	0.795	0.646	0.673	0.719	0.670	0.632	0.648	0.742	0.688
Slow motion walk rater 1			--	0.877	0.673	0.710	0.819	0.728	0.639	0.645	0.859	0.783
Slow motion trot rater 1				--	0.670	0.713	0.830	0.753	0.692	0.726	0.889	0.830
Real time walk rater 2					--	0.771	0.724	0.688	0.576 ^B	0.624	0.646	0.590 ^A
Real time trot rater 2						--	0.899	0.888	0.555 ^B	0.667	0.731	0.700
Slow motion walk rater 2							--	0.874	0.584 ^A	0.619	0.847	0.786
Slow motion trot rater 2								--	0.574 ^A	0.678	0.763	0.753
Real time walk rater 3									--	0.677	0.700	0.711
Real time trot rater 3										--	0.708	0.735
Slow motion walk rater 3											--	0.888
Slow motion trot rater 3												--
Exam assessment	0.753	0.669	0.781	0.807	0.617 ^C	0.704	0.784	0.711	0.649	0.631	0.816	0.837

Note: All p values are p≤0.001 except where noted with superscripts (defined as ^Ap≤0.01, ^Bp≤0.02, ^Cp≤0.002).

plates, however, do not measure the successive events in locomotion, the distribution of weight over the foot or proper stride length data in small dogs (Lascelles *et al.*, 2006). In addition, computerized gait analysis by force plate is not readily available in a clinical setting. Pressure plates can also be used as an alternative to force plate for the evaluation of canine gait. Pressure plates allow for simultaneous and continuous analysis of foot strikes and are accurate for small and large dogs. Asymmetry indices, paw contact area, PVF and VI of both hind legs can be measured by these systems (Oosterlinck *et al.*, 2011). Pressure plate systems have been validated as reliable indicators of canine lameness (Oosterlinck *et al.*, 2011).

Pressure mat walkways consist of a mat with many pressure sensors. As a dog walks over the mat, graphics of the pressure distribution in the paw appear on a computer screen and can be used for analysis (Gillette and Angle, 2008). These systems can provide the clinician with gait time and distance, vertical force as a percentage of body weight and quantify high and low pressure areas on the paw. They are portable, can be attached to a laptop computer, have been validated as

a tool for lameness diagnosis in large and small dogs (Kim *et al.*, 2011) and are more affordable than force plates (Lascelles *et al.*, 2006).

Another technique to objectively measure gait involves kinematic analysis (Gillette and Angle, 2008; Zink, 2013). Kinematic analysis can be either subjective or quantitative. Subjective kinematic analysis is simply observation of the animal and scoring with a NSR or VAS scale. Quantitative kinematic analysis quantifies positions, velocities, accelerations and angles of anatomic points in space (Millis and Levine, 2014). Three-dimensional motion analysis equipment is used to calculate linear and angular velocities, and the movement of planes in space (Zink, 2013). Three dimensional kinematic data collection provides the greatest amount of information, but involves complex preparation and as such tends to be employed only by research facilities (Colborne, 2004; Griffon, 2008). These systems are too costly for general practice. However, two dimensional analysis can be undertaken. Reflective markers are placed on anatomical locations, videoaped, and then specialized software can be used to measure the linear displacement (Zink, 2013). This

system can also be costly and has other limitations including the lack of normal values for dogs of different breeds and phenotypes, and the need to adjust data to account for artifacts created by skin gliding over landmarks and creating artificial marker movement (Agostinho *et al.*, 2011; Kim *et al.*, 2011).

Previous research undertaken by Waxman and colleagues examining real time SGA demonstrated very strong intra-rater agreement ($r^2 = 0.89 - 0.93$) for experienced observers evaluating the degree of lameness (Waxman *et al.*, 2008). These values were similar to our findings for both real time and slow motion video. Unfortunately, our hypothesis that slow motion video footage would increase the consistency of SGA was not supported by our data. Raters showed strong to very strong agreement with themselves when assessing the degree of lameness in both real time and slow motion thus indicating that slow motion video offered no demonstrable advantage over real time video.

When dogs are being treated for lameness by more than one clinician, agreement between different observers on degree of lameness is key to reliability (Rutherford, 2002). Other researchers have demonstrated strong ($r = 0.73 - 0.77$) inter-observer correlations for SGA (Quinn *et al.*, 2007). These values are similar to our findings for both slow motion and real time video. Although the level of inter-rater agreement was higher for slow motion videos compared to real time videos, this difference was not statistically significant. This lack of significance may be a reflection of the small sample size. Because observers showed strong agreement with each other, demonstrating an increase in consistency becomes more difficult without a larger sample of dogs. Further research is required to determine if this is the case.

The raters consistently scored lame dogs with lower values relative to sound dogs, but showed considerable disagreement in assessing the degree of lameness, as indicated by a wide standard deviation in the distribution of scoring values. Conversely, the raters scored sound dogs with values approaching 100 and showed stronger agreement as indicated by a much smaller standard deviation in scoring. In general, the raters showed a good ability to distinguish between the lame and sound dogs. Slow motion video did not increase the raters' ability to distinguish lame versus sound dogs.

Raters showed strong agreement with each other in determining which limb or limbs was the source of lameness when viewing slow motion video of dogs either walking or trotting. When the raters responses were compared to the physical exam findings, the associations were stronger for slow motion assessments compared to real time assessments, but this increase did not achieve statistical significance. This lack of significance may reflect an inadequate sample size.

Further research with a larger population of lame dogs is required to confirm that slow motion video truly does not increase the accuracy of identifying the source of lameness.

Gillette & Angle's theory that SGA detection of lameness might be more difficult in short limbed dogs with rapid leg movement (Gillette and Angle, 2008) was not tested as part of this research due to inadequate sample size. Further experimentation would be required to determine if correlations exist between the accuracy of determining the affected limb using slow motion video, and either limb length or limb speed. Repeating the experiment with a larger sample size, and recording leg lengths for further analysis would help answer this question.

Similarly, small sample size prevented the division of lame dogs in this study into the categories of unilateral or bilateral lameness. It would take further research using a larger sample size of unilaterally and bilaterally affected dogs to determine if slow motion video affects the accuracy of observers to distinguish the source of lameness when more than one side is affected.

The lack of any objective measurement device to determine the degree of lameness is a major flaw in this experimental design, as SGA was compared to subjective physical exam findings. Neither kinetic nor kinematic technology was used in this study as this equipment was not available to the researchers, which underscores the need for more accessible technology.

Although NRS is a common way to report SGA findings, VAS is believed to be more nuanced, allowing the observer to record more subtle differences. It also creates interval data instead of nominal data which allows for greater flexibility in statistical analysis (Hudson *et al.*, 2004; Quinn *et al.*, 2007). Because of these advantages, a VAS scale was selected over a NRS scale in this study. A SGA using a VAS scale without using video was not performed in this study because the reviewers were at remote locations and so this was not possible.

Because this technology was not available, the researchers were unable to objectively categorize the degree of lameness within the dog sample. Multiple researchers have previously reported that subjective scoring methods are not reliable in assessing mild lameness, although agreement increased as lameness grade worsened (Evans *et al.*, 2005; Quinn *et al.*, 2007; Waxman *et al.*, 2008). This finding is consistent in the equine literature as well (Keegan *et al.*, 2010; Viñuela-Fernández *et al.*, 2011). Although the VAS scale used has been reported to be more precise than a numerical scale because it measures lameness on a continuous spectrum (Hudson *et al.*, 2004; Quinn *et al.*, 2007), it has been suggested that this may not be true with subtle lameness (Holton *et al.*, 1998). Therefore, it is the dogs with subtle lameness conditions that would benefit

most from widely accessible technology that improves the accuracy or consistency of SGA. Because this study did not attempt to categorize the degree of lameness expressed by the dogs, it is unknown if any of the dogs in this study had subtle lameness issues. Further research is required to determine if slow motion video SGA is beneficial when applied specifically to cases of subtle lameness as defined by objective measurement techniques.

Based on these findings, slow motion video does not increase the consistency or accuracy when determining the source of lameness. Further research is required to determine if slow motion video without concurrent computer analysis is of value in increasing the accuracy of SGA, and for assessing cases of subtle lameness.

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Conflicts of interest

This research was privately funded and the authors declare there are no conflicts of interest.

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