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Kinetics and kinematics of dog walk exercise in agility dogs of different experiences

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ABSTRACT

The injury rate in agility dogs is relatively high compared to the general population. No study to date has considered the biomechanical effects of the dog walk obstacle in agility trials, highlighting a research need. The aim of this study was to assess forelimb joint kinematics and peak ground reaction forces (PVF) over a dog walk agility obstacle and correlate with experience. Dogs were filmed running across a Kennel Club (KC) standard dog walk for kinematics analysis. Two pressure sensors were secured to the (1) dog walk contact area at exit and (2) ground at the end of the dog walk (landing area) for kinetics analysis. Forelimb joints angles and PVF at the contact zone at the walk exit and landing were analysed. A key finding is that the way a dog will move across the obstacle changes depending on their level of experience, with experienced dogs showing faster obstacle negotiation and increased flexion of the elbow joint compared to inexperienced competitors. Higher speeds over the dog walk also resulted in significantly increased elbow joint flexion. Another important finding is that PVF at landing are higher is dogs that are faster and also in dogs performing running technique in comparison to stopped technique,. Overall, dog walk obstacle created more forelimbs joint flexion and similar PVF in comparison with previously studied agility contact obstacles which leads us to conclude that further research is required to ascertain the long term health implications for dogs used in agility trials.

Keywords: agility; biomechanics; canine; obstacle

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INTRODUCTION

Dog agility is becoming increasingly popular amongst dog owners in the UK, with competitions, training classes and workshops held regularly all over the country. Dogs taking part in the sport are at an increased risk of injury due to the nature of the sport, as seen in a survey of 1627 agility dogs where 33% were currently injured (LEVY *et al.*, 2009). The obstacles found to be associated most frequently with injury were the jumps, A-frame and dog walk (CULLEN *et al.*, 2013; LEVY *et al.*, 2009). The dog walk is a walk plank of approximately 1.2 m measured from the ground to the top of the plank, with firmly fixed ramps at either end.

Several studies have researched the impact of jumping on the dog's body by studying landing forces and joint angulations of dogs over jump obstacles or A-frames (APPELGREIN *et al.*, 2018, 2019; BIRCH, E. *et al.*, 2015; BLAKE; DE GODOY, 2021; CULLEN *et al.*, 2016; PFAU *et al.*, 2011; WILLIAMS *et al.*, 2017) whilst none have considered the biomechanics of dogs over the dog walk obstacle which is considered one of the most common sources of injury in agility dogs (CULLEN *et al.*, 2013). Research has shown that the most common sites of injury in agility dogs are the shoulders, back and digits and that injuries are most likely to be soft tissue in nature (KERR; FIELDS; COMSTOCK, 2014; LEVY *et al.*, 2009).It is also believed that the greater the forces experienced by the limbs and the more acute the joint angles, the greater the strain placed upon the dog's body leading to a higher risk of injury (PFAU *et al.*, 2011).

This study aimed to examine forelimb joint angles and GRFs when agility dogs tackled the dog walk agility equipment, as well as considering the impact of speed, weight, age and agility experience. Data was collected at two points (1) at the end of the dog walk contact, referred during the manuscript as "contact"; (2) during landing on ground as the dog exited the dog walk, referred as "landing".

MATERIALS AND METHODS

Ethical approval

The data has been acquired according to modern ethical standards and according to guidelines set by The Animal (Scientific Procedures) Act 1986 (United Kingdom) and has been approved by the Animal Welfare and Ethics Committee of Writtle University College. The approval number was 98330530/2019. A written informed consent was obtained from the owners of the participants of the study. Veterinary consent was required to discount any current or underlying orthopaedic conditions that could hinder results.

Sample population

The study population consisted of ten large dogs and two medium dogs of various breeds aged 5.22±2.22 years old and weighing 20.07±5.91 kg. All were dogs who had previous agility experience. Each dog was graded by experience in accordance with the official UK Kennel Club agility grades, ranging from grade one to grade seven (Table 1). Progression through the grades is achieved by gaining a number of class wins at the relevant grade, with each grade requiring a higher number of wins. Kennel club grading would therefore be dependent on ability but would also infer relevant experience at a set level. Eight dogs performed the stopped contact technique and four dogs performed the running contact technique.

Table 1. UK Kennel Club grade of dogs included in the study.

UK Kennel Club Grade	n=
1	3
2	0
3	1
4	0
5	4
6	2
7	2

Experiment set up

A Kennel Club standard aluminium and rubber dog walk was set up on a grass surface at a height of 1.2m in accordance with Kennel Club agility regulations (UK KENNEL CLUB, 2023). A pair of timing gates (Brower, Draper, USA) were placed at the beginning and the end of the dog walk to measure the speed performed by each dog to traverse the total length of equipment (10.58m). Two cameras (iPad, Apple, Cupertino, USA) were mounted on tripods opposite each other and adjacent to the end of the dog walk for video capture of the dogs for joint angle measurement. Video was captured at 1080p resolution and a frame rate of 240 fps. To enable the angles of the joints of interest to be measured, reflective markers were attached to specific anatomical locations on both forelimbs using a commercially available double-sided tape. They were placed on the dorsal border of the scapula, greater tubercle of the humerus, olecranon, carpus and metacarpophalangeal joint (BIRCH, EMILY; LEŚNIAK, 2013). A pressure mapping sensor attached to the end of the dog walk with double sided tape and covered by a 2mm foam mat was used to analyse peak vertical forces at the exit contact of the dog walk. The pressure mapping sensor (5330, Conformat, Tekscan, Norwood, US) had dimensions of 571.5 mm by 627.4 mm and consisted of 1024 pressure sensors at a density of 0.5 sensor/cm^2. A 0.6 centimetre (cm) thick pressure walkway pressure mat, consisting of two sensors mounted on a rigid platform was set up at the bottom of the dog walk, with the edge of the mat aligned flush with the end of dog walk contact and a thin rubber mat secured on top with tent pegs was used to collect kinetic data at the ground landing. The mat measured 148.5 cm by 58.4 cm with a sensor panel measuring 146.3 cm by 44.7 cm. The mat contained 4 sensors/cm^2 and had a maximal sample rate at 185Hz (Walkway, Tekscan, Norwood, USA). Sampling rate was 100 Hz for both pressure systems. The sensors were calibrated before starting data collection according to the manufacturer instructions (Figure 1).

Data collection

Once the anatomical markers were applied to each dog by a single researcher they were 'warmed up' by following the standard warm-up procedure used by the handler before normal agility training or competition. This consisted of 5 timed minutes of walk on a leash and a further two times minutes of trot on the leash. The same handler completed each warm up to maintain consistency. This minimised any risk of injury to the dogs and simultaneously allowed for the dogs to become accustomed to wearing the markers. Once warmed up, the dogs were

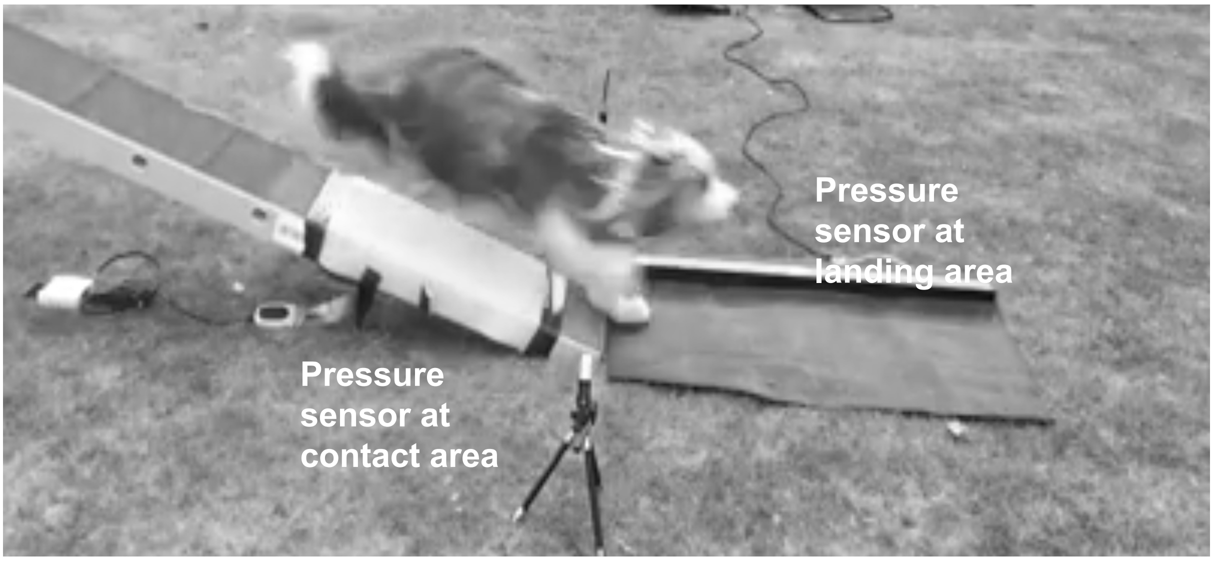

Figure 1. Set up of the experiment showing the positioning of the pressure sensors at the contact and landing area.

set up in a wait area 5 metres away from the beginning of the dog walk. The owner then released the dog and handled it over the dog walk as they would normally in training or competition. As each dog completed the equipment, they ran through the timing gates to provide an accurate value for the speed performed from one end of the dog walk to the other. Video recording was collected as the dog ran down the end of the dog walk. At the same time, the pressure sensors recorded GRFs for the forelimbs as they struck the contact zone at the end of the dog walk and as they landed on the ground immediately after the dog walk. The dog walk was repeated three times for each dog and all data sets for all dogs were collected over the course of a single day. The dogs were rewarded by the owner at the end of the exercise in the manner in which the owner would normally provide a reward.

Data analysis

Videos were analysed with a video analysis software (Quintic biomechanics v. 30, Quintics Consultancy, Birmingham, UK) to identify the angles of the marked joints. Joint angles were recorded for the shoulder, elbow and carpus on both forelimbs and analysis were taken from the video frames captured at (1) the point of maximum weight-bearing during the last stride of each forelimb on the dog walk, and (2) as the forelimbs initially made contact with the ground after the dog walk at the point of maximum weight-bearing.

The data collected from the pressure sensors were analysed by the dedicated softwares (Conformat Research and Walkway, Tekscan, Norwood, US) and peak vertical forces were recorded and normalised by the dog weight in Newtons.

Statistical analysis

A mean value was taken from the three values recorded for each joint on the left and right forelimb on the dog walk contact and on the ground. A mean value was then taken from the means calculated for the left and right forelimbs to provide an average angle for each joint across both forelimbs. These mean values were used to describe the kinematics of joints on the dog walk contact and ground landing. GRF recordings were taken from the peak pressure point of the first forelimb to strike both mats. A mean value was taken from the three trials for the PVF at the contact and landing. Furthermore, agility experience and speed were analysed in relation to the joints kinematics and PVF.

All statistical analysis were performed with SPSS (IBM Corp. Released 2021. IBM SPSS Statistics for Mac, Version 28.0. Armonk, NY: IBM Corp) and the confidence level was set as 95%. All data sets were assessed for normality prior to correlation testing using a Shapiro-Wilk test. Pearson's product-moment correlation was used to assess for significant correlation between speed and kinematics/kinetics variables. Spearman's rank-order correlation was used to assess association between kinematics/kinetics and KC level as this correlation was assessed between ordinal and continuous variables, so Spearman's was considered appropriate. Dogs were also sorted into two categories by dog walk contact training methods: running (n= 4) and stopped (n=8). Differences in forelimb joint kinematics and PVF between running and stopped contact training methods were tested for using either an independent sample t-test or a Mann-Whitney U test, depending on whether a Shapiro-Wilk test determined the data sets to be parametric or non-parametric.

RESULTS

Joint kinematics

Carpal, elbow and shoulder angles measured at the two points: (1) the point of maximum weight-bearing during the last stride of each forelimb on the dog walk, and (2) as the forelimbs initially made contact with the ground after the dog walk at the point of maximum weight-bearing, are shown on table 2.

Table 2. Mean±SD of forelimb joints angles in degrees (n=12) at : (1) contact at the end of the dog walk, and (2) landing on ground from dog walk.

Point	Carpus	Elbow	Shoulder
Contact	149.26±10.76º	71.68±13.26º	98.16±9.64º
Landing	140.75±17.09º	81.33±18.69º	99.86±12.34º

Spearman's rank-order correlation was run to determine the relationship between joint angle and Kennel Club grade. For the elbow joint angle on the dog walk contact, a strong negative correlation was observed in relation to KC grade, which was found to be statistically significant (r=-0.608, n=12, p=0.036), therefore more experienced dogs showed a higher flexion at the elbow. The other joints angles did not show any significant correlation with the KC grade (p>0.05). KC grade was also found to be significantly correlated with speed, with more experienced dogs being faster than dogs with lower grades (r=0.763, p=0.004) by Pearson's rank-order test.

A Pearson's rank correlation was run to determine the relationship between each joint angle and speed. For the elbow joint, a moderate negative correlation was found between speed and elbow joint angle on the dog walk contact (r=-0.695, p=0.012), faster dogs flex more on elbow during the end of the dog walk.

An independent samples t-test was performed to test for a significant difference between the two categories of training method for each joint angle. All data sets were also tested for homogeneity between groups using Levine's test for equality of variances and the significance value recorded correspondingly. The results of the independent t-test showed that there was no significant difference between running contact trained dogs (n=4) and stopped contact trained dogs (n=8) for any of the joint angles measured (p>0.05).

Peak Vertical Forces (PVF)

The mean±SD PVF of the first forelimb to contact the pressure sensors at (1) the contact at the end of the dog walk, and (2) ground landing, are shown on table 3.

Table 3. Mean±SD of forelimb joints peak vertical forces (PVF) in N/N (n=12) at : (1) contact at the end of the dog walk, and (2) landing on ground from dog walk.

Point	PVF (N/N)
Contact	0.71±0.36
Landing	2.18±0.86

Following a Spearman's rank-order correlation test, there has been no significant association between experience and PVF at any point (p>0.05).

A Pearson's product-moment correlation was used to assess correlation between speed and PVF on the dog walk contact, which was non-significant (r=-0.028, n=12, p=0.931). However, a moderate positive significant correlation was observed for between speed and the PVF at landing (r=0.734, n=12, p=0.007).

Forelimb PVF for the dog walk contact and the ground were grouped by training method and assessed for normality using a Shapiro-Wilk test. Data for the running dog walk category was considered non-parametric for forelimb GRFs on both the dog walk contact and the ground. As a result, a Mann-Whitney U test was run to determine whether any significant difference was present between the forelimb GRFs of the two training methods. There was no significant difference found between the running contact group (n=4, Median=0.37 N/N) and the stopped contact group (n=8, Median=0.67N/N) for forelimb GRFs on the dog walk contact (U=2.337, p=0.126). However, the PVF at landing was significantly higher in the running group (Median=3.05 N/N) than on the stopped contact group (Median= 2.00 N/N) (U= 5.654, p=0.017) (Figure 2) .

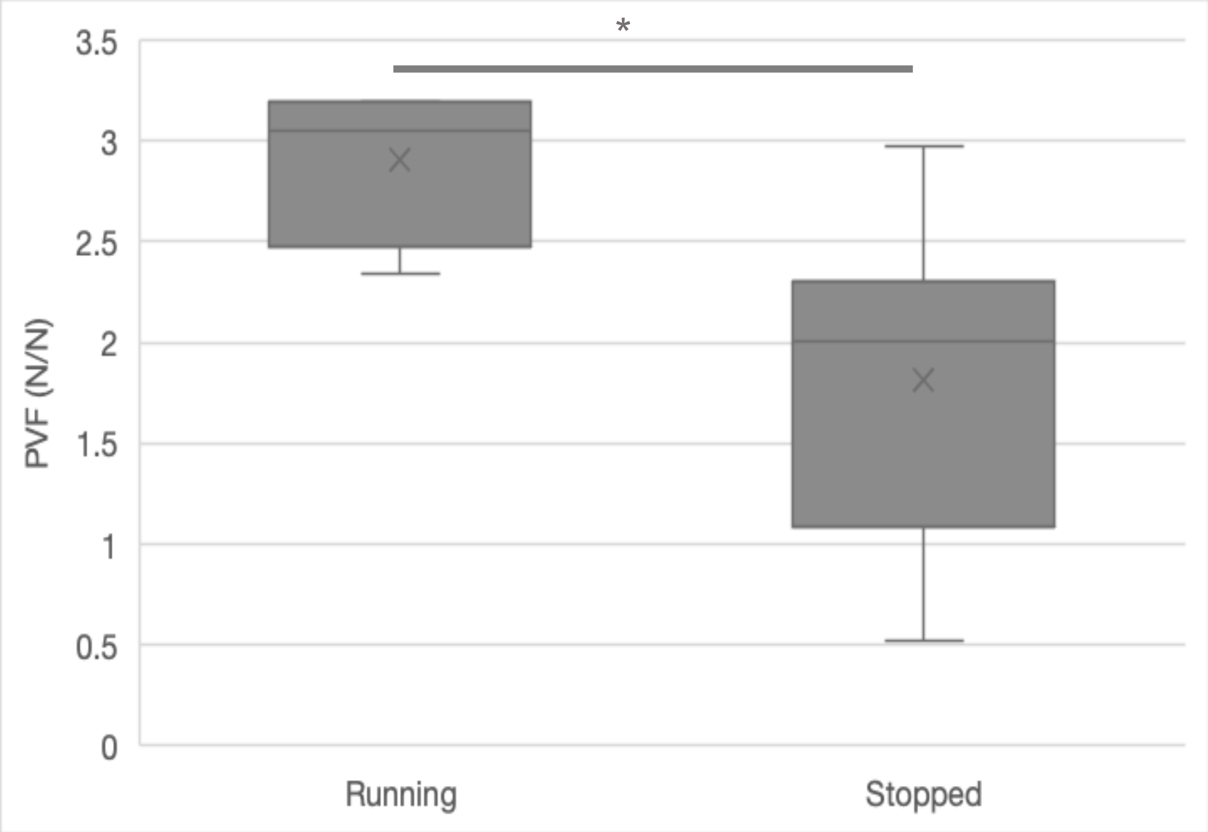

*Figure 2. Peak vertical force (PVF) in N/N during ground landing from the dog walk obstacles in agility dogs performing running (n=4) and stopped contact (n=8) technique. The bottom and top of the box are the first and third quartiles, the band inside the box is the second quartile (the median), and the 'x' is the mean. The lines extending vertically from the boxes (whiskers) indicate the minimum and maximum of all of the data. * represents significant differences between groups (p<0.05).*

DISCUSSION

A key finding is that the way a dog will move across the obstacle changes depending on their level of experience, with experienced dogs showing faster obstacle negotiation and increased flexion of the elbow joint compared to inexperienced competitors. Higher speeds over the dog walk also resulted in significantly increased elbow joint flexion. Another important finding is that PVF at landing are higher is dogs that are faster and also in dogs performing running technique in comparison to stopped technique,.

Of the four independent variables tested for correlation with joint kinematics, only two were found to have a significant correlation: agility experience, and speed. Elbow joint flexion was found to be higher in more experienced and faster dogs. This suggests that there is a difference in biomechanics between inexperienced and experienced agility dogs when navigating the dog walk contact. One possible reason for this could be that dogs increase in speed with more experience, which is supported by the significant positive correlation observed between speed and KC grade. With experience, dogs have further training and skills adaptations, allowing them to perform the task in a faster speed, but at expenses of more flexed joints, possibly increasing the risk of injuries. This findings agree with previous findings regarding other agility obstacles as A-frame (WILLIAMS *et al.*, 2017) and jump (BIRCH, E. *et al.*, 2015), with experienced dogs showing higher speeds and more flexion on joints on those obstacles too. Along with generally navigating the dog walk more slowly, less experienced dogs had an observed tendency to look towards their handler when navigating the contact area, creating a more upright posture and thus increasing carpal extension (although not significant) and reducing elbow flexion. Contrastingly, more experienced dogs appeared to perform the behaviour more independently and at higher speeds, producing a lower, more crouched posture and thus reducing carpal extension and increasing elbow flexion. As a result of the biomechanical differences between experienced and inexperienced agility dogs, it could be expected that different joint areas would be more prone to injury on the dog walk between the two groups. More specifically, the results from this study suggest that the carpal joint and associated soft tissues are potentially more susceptible to increased strain in inexperienced dogs, whereas the elbow joint and associated soft tissues are placed under more strain in experienced dogs.

Contrary to expectations the angle of the shoulder joint showed no significant correlation with any of the independent variables tested. This was of interest as previous literature has stated that the shoulder is one of the most common sites of injury in the agility dog (CULLEN *et al.*, 2013; LEVY *et al.*, 2009). It may be the case that other obstacles place increased strain on the shoulder and therefore account for the high incidence of injury in the area. Previous research (BIRCH, E. *et al.*, 2015) found that shoulder joint angle was significantly affected by changes in jump distances, suggesting that bar jump obstacles are a likely factor in the high risk of shoulder injuries in agility.

Interestingly the mean shoulder joint angle on the dog walk contact was found to be 98.15 ± 2.78° and 99.86 ± 3.56° on the ground at the end of the dog walk whilst a previous study reported the lowest mean shoulder joint angle during jump landing as 110.81°(BIRCH, E. *et al.*, 2015) – a difference of over ten degrees. And we should also consider that shoulder flexion angle during normal trot is 104.5°(LORKE *et al.*, 2017). It could therefore be surmised that the dog walk contact results in greater flexion of the shoulder joint than jump landing, and even higher flexion than standard trot, leading to increased strain through the shoulder and subsequent increased injury risk. Previous research has reported that during jump take-off the lowest mean shoulder joint angle was 71.28° (BIRCH, E. *et al.*, 2015) which is almost thirty degrees lower than the mean shoulder joint angles reported in this study.

The mean elbow joint angles in this study were 71.68 ± 13.26° and 81.33 ± 18.69° respectively, which are considerably more acute than the lowest mean elbow joint angle reported during landing from a jump previously (BIRCH, E. *et al.*, 2015), but, as with the shoulder joint, the mean elbow angle reported during jump take-off was more acute than that reported in this study. The increased stress associated with this equipment seems even more severe if we compare with standard trot elbow flexion angles, which are in average 83.2° (LORKE *et al.*, 2017). Further research comparing joint flexion between the several agility obstacles within the same population would be required to definitively determine if one had more of an impact on joint flexion and subsequent associated soft tissue strain than the other. Future studies may also consider examining joint angulation at different points along the dog walk to provide a more complete analysis of the effects of the equipment on the dog's body.

With regards PVF, we found that faster dogs and dogs performing running contact technique displayed a higher PVF at the ground landing, with no significant findings at PVF on contact. This was not surprising as a stopped contact technique leads to deceleration on the down plank of the dog walk prior to reaching the contact, whilst running contact continue at a more consistent speed. This would explain the higher PVF recorded as at higher speeds, greater force would be expected to be exerted through the forelimbs in order to stop at the end of the dog walk contact. Furthermore, the results from this study also indicate that the forelimbs of agility dogs may experience similar force on the ground landing from the dog walk than during A-frame contact (APPELGREIN *et al.*, 2019) , potentially indicating an increased risk of injury associated with the dog walk. Further research comparing forelimb PVF between agility obstacles within the same population would be needed to determine whether the dog walk poses a significantly increased risk of forelimb injury than the jumps.

This was the first study to examine the kinematics and kinetics of agility dogs on the dog walk. Whilst the relatively small sample size of the study population has its limitations, a significant difference in the kinematics of experienced and inexperienced agility dogs over the dog walk contact was found. This suggests that inexperienced dogs may be at risk to different types of injuries than experienced dogs when completing the dog walk, further evidenced by the increased flexion observed through the elbow joint in faster dogs, which is generally associated with increased experience. To minimise the risk of injury in inexperienced dogs, it may be beneficial for these dogs to spend more time training for the dog walk contact on considerably lower equipment. It would also be advisable to minimise the number of repetitions of the dog walk during training, certainly if at its full height, to reduce strain on the elbow and shoulder joints. Furthermore, it is worth noting that PVF observed in this study are similar to the reported in agility dogs at A-frame contact and dogs performing at higher speeds and running contact experience higher PVF at landing phase, therefore the dog walk agility exercise should not be overlooked as a potential cause of injuries.

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DECLARATION OF CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest. This research has not received any funding.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

AUTHORS' CONTRIBUTION

GA participated in study conception and design, data collection, data evaluation and writing the manuscript. RFG assisted in study design and supervision, statistical analysis and writing the manuscript. SB participated in statistical analysis and writing the manuscript. All author contributed to the article and approved the submitted version.

References

APPELGREIN, Carla *et al.* Kinetic Gait Analysis of Agility Dogs Entering the A-Frame. *Veterinary and Comparative Orthopaedics and Traumatology*, v. 32, n. 02, p. 097–103, 31 mar. 2019.

APPELGREIN, Carla *et al.* Reduction of the A-Frame Angle of Incline does not Change the Maximum Carpal Joint Extension Angle in Agility Dogs Entering the A-Frame. *Veterinary and Comparative Orthopaedics and Traumatology*, v. 31, n. 02, p. 077–082, 13 fev. 2018.

BIRCH, E. *et al.* The effects of altered distances between obstacles on the jump kinematics and apparent joint angulations of large agility dogs. *The Veterinary Journal*, v. 204, n. 2, p. 174–178, maio 2015.

BIRCH, Emily; LEŚNIAK, Kirsty. Effect of fence height on joint angles of agility dogs. *The Veterinary Journal*, v. 198, p. e99–e102, dez. 2013.

BLAKE, S.; DE GODOY, R. Ferro. Kinematics and kinetics of dogs completing jump and A-frame exercises. *Comparative Exercise Physiology*, v. 17, n. 4, p. 351–366, 15 jun. 2021.

CULLEN, Kimberley L. *et al.* Survey-based analysis of risk factors for injury among dogs participating in agility training and competition events. *Journal of the American Veterinary Medical Association*, v. 243, n. 7, p. 1019–1024, 1 out. 2013.

CULLEN, Kimberley L. *et al.* The magnitude of muscular activation of four canine forelimb muscles in dogs performing two agility-specific tasks. *BMC Veterinary Research*, v. 13, n. 1, p. 68, 7 dez. 2016.

KERR, Zachary Y.; FIELDS, Sarah; COMSTOCK, R. Dawn. Epidemiology of Injury Among Handlers and Dogs Competing in the Sport of Agility. *Journal of Physical Activity and Health*, v. 11, n. 5, p. 1032–1040, jul. 2014.

LEVY, I. *et al.* A preliminary retrospective survey of injuries occurring in dogs participating in canine agility. *Veterinary and Comparative Orthopaedics and Traumatology*, v. 22, n. 04, p. 321–324, 18 dez. 2009.

LORKE, Malin *et al.* Comparative kinematic gait analysis in young and old Beagle dogs. *Journal of Veterinary Science*, v. 18, n. 4, p. 521, 2017.

PFAU, Thilo *et al.* Kinetics of jump landing in agility dogs. *The Veterinary Journal*, v. 190, n. 2, p. 278–283, nov. 2011.

UK KENNEL CLUB. *Agility Regulations 2023*. . [S.l: s.n.], 2023.

WILLIAMS, J.M. *et al.* The effect of the A-frame on forelimb kinematics in experienced and inexperienced agility dogs. *Comparative Exercise Physiology*, v. 13, n. 4, p. 243–249, 5 out.

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