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Article

Analysis of risk factors for agility dogs completing a dog walk agility exercise

Gemma Anthony [1], Scott Blake [1,*] and Roberta Ferro de Godoy [1,]

[1] Writtle University College. Chelmsford. CM1 3RR.UK

* Correspondence: scottblake247@gmail.com; Tel.: +447787-568581

Simple Summary: Dog agility is an increasingly popular activity among UK dog owners however, dogs taking part are at increasing risk of injury due to the demands placed upon their bodies, with a recent survey stating that 33% of 1627 competing agility dogs were currently injured. The most common reported injuries are to the shoulders, back and digits. The aim of this study was to determine whether dog speed, weight, age or experience places the canine forelimbs under greater strain when navigating a dog walk agility obstacle which may increase the risk of injury. This was achieved by measuring forelimb joint angulation and ground reaction forces (GRFs) whilst dogs negotiated the obstacle. Both carpal joint angle and elbow joint angle showed significant correlation with agility experience, whilst elbow joint angle demonstrated significant correlation with speed. None of the variables tested demonstrated a significant correlation with GRFs. Results suggest that inexperienced dogs appear to place more strain through the carpal and shoulder joints at the end of the dog walk whilst experienced dogs appear to place more strain through the elbow joint, correlating with existing studies that show that inexperienced agility dogs have a significantly greater risk of injury across all obstacles.

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 test for correlation between dog age, weight, speed, contact training method and agility experience and forelimb joint angulation and peak ground reaction forces (GRFs) over this obstacle. Dogs were filmed running across a Kennel Club (KC) standard dog walk whilst wearing reflective markers attached to specific anatomical points. A Tekscan Comformat and a Tekscan Walkway pressure mat were secured to the dog walk contact area and the ground at the end of the dog walk respectively. Joint angulation and peak forelimb GRFs were recorded and 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 increased flexion of the elbow joints and decreased extension of the carpus compared to inexperienced competitors. Higher speeds over the dog walk also resulted in significantly increased elbow joint flexion. Increased joint angulation and higher GRF's are associated with a higher risk of injury.

Keywords: biomechanics; kinetics; kinematics; angulation

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1. Introduction

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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 [1]. The obstacles found to be associated most frequently with injury were the jumps, A-frame and dog walk [1,2]. 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 [3,4,5,6,7] 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 [2].

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 [1,8].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 [3]. In agility competition the dog must strike a coloured area at the end of a dog walk obstacle with at least one paw (The dog walk is a raised plank approximately 1.2m high with fixed ramps at either end. The planks are a minimum of 3.66m in length and a maximum of 30.5cm in width). This study examined the effects on joint angulation and forelimb GRFs when tackling this equipment, as well as considering the impact of speed, weight, age and agility experience.

Results show that experienced agility dogs have significantly increased flexion of the elbow joint and significantly reduced extension of the carpal joint versus inexperienced agility dogs. The dog walk obstacle also created higher GRFs and more acute joint angulation than previously studied agility obstacles which leads us to conclude that further research is required to ascertain the long term health implications for dogs used in agility trials.

2. Materials and Methods

A research proposal was in February 2018 and subsequently approved in March 2018 by Writtle University College ethics committee reference 9830530/2018.
The study population consisted of ten large dogs and two medium dogs of various breeds aged between two and ten years old and weighing between 11.5 to 31 kilograms (KG).Each dog was graded by experience in accordance with the official Kennel Club agility grades, ranging from grade one to grade seven (Table 1).

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

Kennel Club Grade	Quantity
1	3
2	0
3	1
4	0
5	4
6	2
7	2

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 [9]. A pair of Brower timing gates were placed at the beginning and the end of the dog walk to measure the time taken by each dog to traverse the length of equipment. Two high speed video cameras 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 {10,4,7}. A 0.6 centimetre (cm) thick TekScan 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 yoga mat secured on top with tent pegs. 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 per cm^2 and had a maximal sample rate at 185Hz. A Tekscan COMFORmat to measure forelimb GRFs was secured to the contact area at the end of the dog walk plank with a yoga mat attached on top via duct tape to protect the pressure sensors from the dogs' claws. The dimensions of the Tekscan COMFORmat were 571.5 mm by 627.4 mm and the sensor panel was 471.4 mm by 471.4 mm. The mat contained 1027 sensors with a density of 0.5 sensors per cm^2, with the capacity to measure up to 34 kPa. It was connected to a laptop via wireless internet through a transmitter and the sampling rate was 100 Hz. Both mats were also secured to the ground with tent pegs and were calibrated before data collection.

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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 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 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 length of time taken to move 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 and was analysed later using Quintic biomechanics software to identify the angles of the marked joints. Joint angles were recorded for the shoulder, elbow and carpus on both forelimbs and analysis was taken from the video frame captured at the point of maximum weight-bearing during the last stride of each forelimb on the dog walk. At the same time, the Tekscan COMFORMAT recorded GRFs for the forelimbs as they struck the contact zone at the end of the dog walk. Forelimb joint angles were also analysed from the video frame recorded as the forelimbs initially made contact with the ground after the dog walk at the point of maximum weight-bearing. The Tekscan Walkway pressure mat also recorded GRFs for the forelimbs as they struck the ground immediately after the dog walk. 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. The dog walk was repeated three times for each dog.

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 assess for correlation between joint angulation on the dog walk contact and ground and four independent variables: agility experience, speed, age and weight. The same correlation assessment was performed for forelimb GRFs, which were taken from the mean forelimb GRF recorded for the dog walk contact and the ground at the end of the dog walk. GRF recordings were taken from the peak pressure point of the first forelimb to strike both mats.

Agility experience was taken as the KC grade for each dog and speed was taken from the mean value recorded for the time taken for each dog to complete the dog walk. All data sets were assessed for normality prior to correlation testing using a Shapiro-Wilk test. For parametric data sets, Pearson's product-moment correlation was used to assess for significant correlation between variables. For non-parametric data sets, Spearman's rank-order correlation was used. Dogs were also sorted into two categories by dog walk contact training method: running and stopped. Significant differences in joint angulation and forelimb GRFs 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 Shaprio-Wilk test determined the data sets to be parametric or non-parametric.

3. Results

3.1. Joint angulation

3.1.1. Agility experience

All data sets for KC grade and joint angles on the dog walk contact and ground were found to be non-parametric following a Shapiro-wilk test. Therefore, Spearman's rank-order correlation was run to determine the relationship between joint angle and Kennel Club grade. A strong positive correlation between KC grade (Median=5) and carpal joint angle (Median=144.92) on the dog walk contact was found, which was statistically significant (r=0.579, n=12, p=0.048) (Figure 1). Carpal joint angle on the ground (Median=138.98) and KC grade (Median=5) was observed to have a weak positive correlation. However, this was not considered statistically significant (r=0.277, n=12, p=0.383)

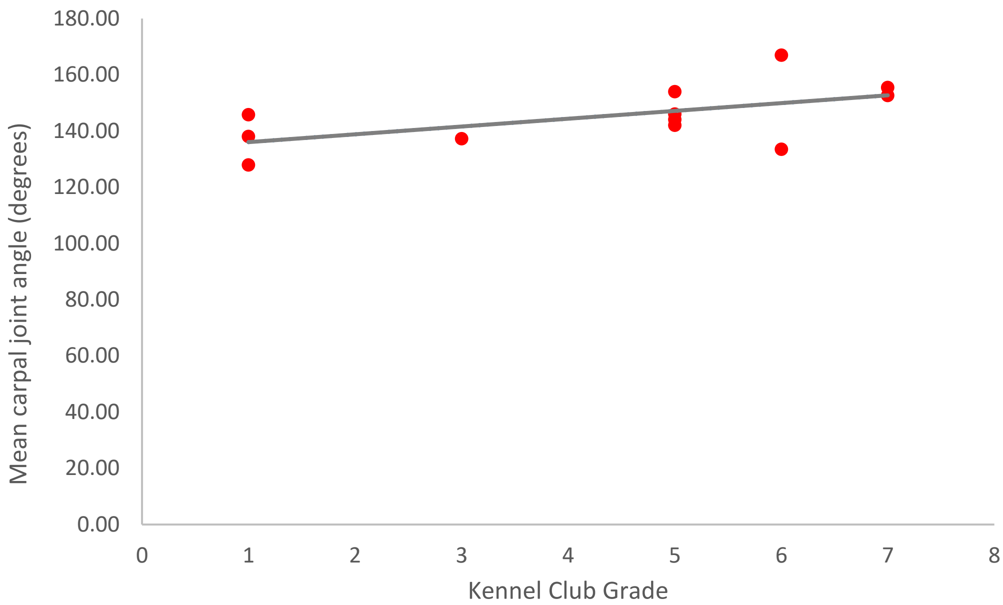

Figure 1. Correlation between Kennel Club grade and mean carpal joint angle on the dog walk contact

For the elbow joint angle on the dog walk contact (Median=68.82), a strong negative correlation was observed in relation to KC grade (Median=5), which was found to be statistically significant (r=-6.08, n=12, p=0.036) (Figure 3). A moderate negative correlation between elbow joint angle on the ground (Median=80.02) and KC grade (Median=5) was also observed, but this was not statistically significant (r=-0.493, n=12, p=0.103) (figure 2).

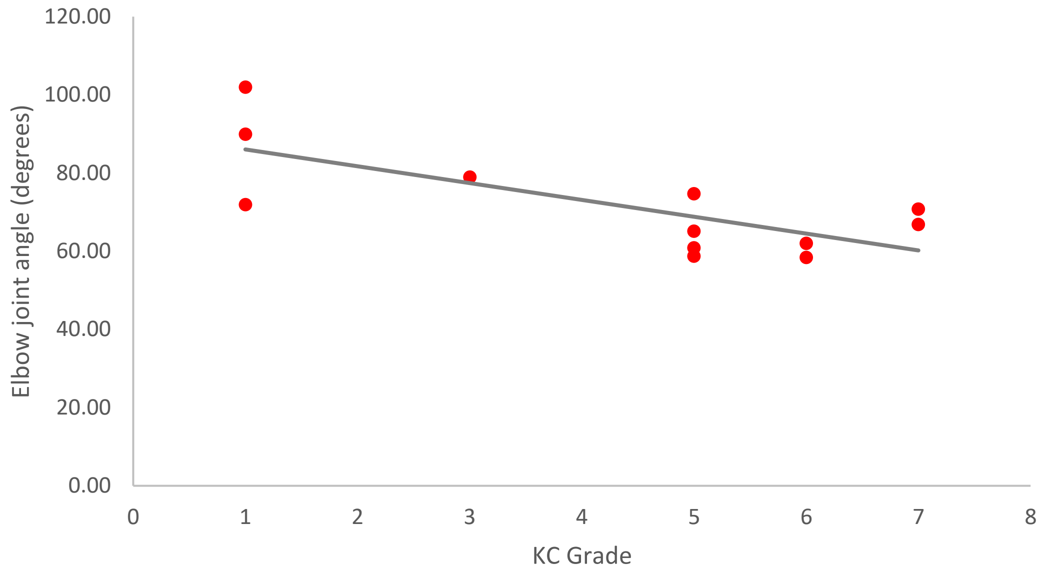

Figure 2. Correlation between Kennel Club grade and mean elbow joint angle on the dog walk

The shoulder joint angle for the dog walk (Median=97.34) and the ground (Median=97.61) were found to have a weak positive and moderate positive correlation with KC grade respectively, however no statistical significance was found for the shoulder joint angle on the dog walk (r=0.191, n=12, p=0.553) or the shoulder joint angle on the ground (r=0.309, n=12, p=0.328).

3.1.2. Speed

All data sets for time taken to complete the dog walk and joint angles on both the dog walk contact and the ground were found to be non-parametric following a Shapiro-wilk test. Therefore, Spearman's rank-order correlation was run to determine the relationship between each joint angle and the time taken to complete the dog walk. A moderate negative correlation was found between time taken to complete the dog walk (Median=2.72) and carpal angle on the dog walk contact (Median=144.92) however, this was found to be not statistically significant (r=-0.343, n=12, p=0.276) and no correlation was found between time taken to complete the dog walk (Median=2.72) and carpal angle on the ground (Median=138.98).

A weak positive correlation between shoulder joint angle on the dog walk (Median=97.34) and time taken to complete the dog walk (Median=2.72) was observed but this was not statistically significant (r=0.175, n=12, p=0.587). No correlation was found between shoulder joint angle on the ground (Median=97.61).

3.1.3. Age

Following a Shapiro-Wilk test, carpal joint angle on the dog walk (Mean=146.87 ± 2.93) and carpal joint angle on the ground (Mean=140.75 ± 4.93) in relation to age of dog (Mean=4.82 ± 0.57) were considered parametric. Therefore, Pearson's product moment correlation was run. No correlation was found between dog age (Mean=4.82 ± 0.57) and carpal joint angle on the dog walk (Mean=146.87 ± 2.93) and a weak negative correlation was found between dog age (Mean=4.82 ± 0.57) and carpal joint angle on the ground (Mean=140.75 ± 4.93) but this was not statistically significant (r=-0.205, n=12, p=0.522).

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A Shaprio-Wilk test determined the elbow joint angle on both the dog walk and the ground to be non-parametric and therefore Spearman's rank-order correlation was run. No correlation was found between dog age (Median=5) and elbow joint angle on the dog walk (Median=68.82) or elbow joint angle on the ground (Median=80.02).

3.1.4. Weight

A Shapiro-Wilk test was performed and dog weight (Mean=20.57 ± 1.83) and carpal joint angle on the dog walk contact (Mean=145.29 ± 3.11) and ground (Mean=140.75 ± 4.93) were found to be parametric. Therefore, Pearson's product-moment correlation was performed and a moderate positive correlation was found between both carpal joint angle on the dog walk contact (Mean=145.29 ± 3.11) and carpal joint angle on the ground (Mean=140.75 ± 4.93) and dog age (Mean=20.57 ± 1.83). This was not statistically significant for carpal joint angle on the dog walk (r=0.387, n=12, p=0.214) or carpal joint angle on the ground (r=0.447, n=12, p=0.145).

Data for the elbow joint angle on the dog walk contact (Median=68.82) and the ground (Median=80.02) was determined to be non-parametric, so Spearman's rank-order correlation was performed. Both joint angles were found to have a weak negative correlation with dog weight (Median=20.5) but this was not significant for either the dog walk contact (r=-0.238, n=12, p=0.457) or the ground (r=-0.105, n=12, p=0.746).

Shoulder joint angle data was determined to be parametric and Pearson's product-moment correlation was performed. No correlation was found between shoulder joint angle on the dog walk contact (Mean=98.15 ± 2.78) or the ground (Mean=99.86 ± 3.56) and dog weight (Mean=20.57 ± 1.83).

3.1.4. Training method

The data sets were tested for normality using a Shapiro-Wilk test and were found to be parametric. As a result, 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 and stopped contact trained dogs for any of the joint angles measured (p=0.05)

3.2. Ground reaction forces

3.2.1. Agility Experience

Following a Shapiro-Wilk test, data for KC grade was determined to be non-parametric and therefore all GRFs were assessed for correlation with KC grade using Spearman's rank-order correlation. GRFs on the dog walk contact (Median=12.12) were found to have a weak negative correlation with KC grade but this was not considered significant (r=-0.133, n=12, p=0.680). GRFs on the ground at the end of the dog walk were found to have a moderate negative correlation with KC grade but this was also not significant (r=-0.324, n=12, p=0.304).

3.2.2. Speed

Speed was measured by the time taken to complete the dog walk and assessed to be non-parametric using a Shapiro-Wilk test. As a result, Spearman's rank-order correlation was used to assess correlation between time taken to complete the dog walk (Median=2.72) and GRF on the dog walk contact (Median=12.12) and on the ground (Median=36.63). A moderate positive correlation and a weak positive correlation was observed for both variables respectively. This was not considered

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significant for either GRF on the dog walk contact (r=0.490, n=12, p=0.106) or GRF on the ground (r=0.140, n=12, p=0.665).

3.2.2. Age

A Shapiro-Wilk test determined dog age and GRF on both the dog walk contact and the ground to be parametric. Therefore, Pearson's product-moment correlation was used to test for correlation between the variables. A weak negative correlation was found between dog age (Mean=5.25 ± 0.68) and forelimb GRF on the dog walk contact (13.92 ± 2.07) but this was not considered statistically significant (r=-0.150, n=12, p=0.642). No correlation was found between dog age (Mean=5.25 ± 0.68) and forelimb GRF on the ground at the end of the dog walk (Mean=40.51 ± 4.29).

3.2.3. Weight

Data for dog weight and forelimb GRF on the dog walk contact and the ground were determined as parametric by a Shapiro-Wilk test. Therefore, Pearson's product-moment correlation was performed, and a strong positive correlation was found between dog weight (Mean=20.57 ± 1.83) and forelimb GRF on the dog walk contact (Mean=13.92 ± 2.07). However, this was not considered statistically significant (r=0.523, n=12, p=0.081). No Correlation was found between dog weight (Mean=20.57 ± 1.83) and GRF on the ground at the end of the dog walk (Mean=40.51 ± 4.29).

3.2.4. Training method

Forelimb GRFs 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 (Median=6.32) and the stopped contact group (Median=15.81) for forelimb GRFs on the dog walk contact (P=0.154). Nor was there any significant difference between the running contact group (Median=53.24) and the stopped contact group (Median=35.00) for forelimb GRFs on the ground at the end of the dog walk (P=0.073).

4. Discussion

Of the four independent variables tested for correlation with joint angulation, only two were found to have a significant correlation; agility experience and speed. Carpal joint angle and elbow joint angle were both found to show significant correlation with agility experience and elbow joint angle demonstrated significant correlation with dog speed. 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 time taken to complete the dog walk and elbow joint angle. 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 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

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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 [1,2]. 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 [4] 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 degrees and 99.86 ± 3.56 degrees 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 degrees [4] – a difference of over ten degrees. It could therefore be surmised that the dog walk contact results in greater flexion of the shoulder joint than jump landing, leading to increased strain through the shoulder and subsequent increased injury risk. Previously during jump take-off it was reported the lowest mean shoulder joint angle as 71.28 degrees [4] 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 degrees and 81.33 ± 18.69 respectively, which are considerably more acute than the lowest mean elbow joint angle reported during landing previously [4], but, as with the shoulder joint, the mean elbow angle reported during jump take-off was more acute than that reported in this study. Further research comparing joint flexion between the two 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.

No significant correlation was observed between dog body weight and any of the joint angles measured, nor was there any correlation with age. It would be expected that heavier dogs would present with more acute joint angles due to increased loading, whilst increased age would be expected to be associated with increased agility experience and, subsequently, speed, so these variables may have potentially confounded the results.

With regards GRFs none of the variables tested in this study demonstrated significant correlation on the dog walk or the ground. This was a surprising but may have been influenced by several factors. A number of dogs exhibited deceleration on the down plank of the dog walk prior to reaching the contact whilst others appeared to continue at a more consistent speed. This would impact the GRFs 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. Despite a lack of significant findings, correlation was observed between forelimb GRFs and some of the variables which may prove significant in a larger study population. Despite this, the results from this study still indicate that the forelimbs of agility dogs may experience greater force on the ground at the end of the dog walk than during jump landing, potentially indicating an increased risk of injury associated with the dog walk. Further research comparing forelimb GRFs between the two 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.

5. Conclusions

This is the first study of its kind 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

Author Contributions:

Conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, visualization; G Anthony.; writing—review and editing, S Blake.; supervision, R de Godoy.;

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