The influence of fence height on joint angles of agility dogs.

Emily Birch, a, Kirsty Leśniak, b, *

a Department of Animal and Land Sciences, Hartpury College, Hartpury, Gloucester, England, GL19 3BE
b Centre for Performance in Equestrian Sports, Hartpury College, Hartpury, Gloucester, England, GL19 3BE

* Kirsty Leśniak. Tel: +44 (0)1452 702488
E-mail address: Kirsty.lesniak@hartpury.ac.uk

Abstract

The Kennel Club (KC) and United Kingdom Agility (UKA) govern major dog agility competitions in the UK. Dogs are categorised into different jump heights depending on their withers height, with fence heights ranging from 300mm to 650mm for both organisations. Dogs fall into one of three height categories when competing under KC rules but one of four under UKA rules. The aim of this study was to investigate the potential influence of an additional height category for those dogs measuring over 430mm at the withers. Jump heights related to the possible percentage of body height that dogs of 430mm (7% lower) and 431mm (51% higher) would be asked to jump under UKA regulations without the addition of their fourth, Standard height. Joint angles were determined through Dartfish software from anatomical markers placed on the fore and hindlimb joints and at six points along the vertebral column.

As fence height increased, flexion of the scapulohumeral joint significantly increased for both the take-off ($P \leq 0.05$) and bascule phases ($P \leq 0.05$) of the jump. Resultant flexion increase is likely to have resulted in intensified stretching of the *Biceps brachii* and *Supraspinatus muscles*; potentially predisposing the onset of bicipital tenosynovitis, a condition commonly seen in agility dogs. The sacroiliac joint angle extended during take-off ($P \leq 0.05$) potentially predisposing to permanent nerve damage through repeated over-extension strains. From these findings it is suggested that although KC midi height fences are 450mm as opposed to 400mm as with UKA, the KC should potentially consider the introduction of a fourth height category in to their competitions to prevent risk of long term injury.

Key words: Dog, Agility, Kinematics, Joint, Heights

Introduction

An increasingly popular sport worldwide (Crufts, 2011) dog agility is governed in the UK by the Kennel Club (KC) and United Kingdom Agility (UKA); both associations holding mini, midi and full height classes. A fourth height between midi and full height, standard height, is offered by UKA but is not present under KC rules (UK Agility 2004; Kennel Club, 2012b). The potential for a fourth height has previously been discussed by the KC Agility Liaison Council but no changes have yet been agreed. The height a dog is required to jump depends on their height at the withers (Table 1).

Under KC regulations dogs measuring between 350 and 430mm at the withers are eligible for midi height (450mm) (Kennel Club, 2011); however a dog measuring just 1mm more, 431mm, must jump full height (650mm). For a dog of 431mm in height this is 51% greater than the dogs wither height. Those dogs of 430mm who are at the top of the height category for midi are jumping 7% lower than their wither height under UKA regulations but 5% higher than their wither height under KC regulations. This same dog would only have to jump 550mm under UKA regulations (UK Agility, 2004; Kennel Club, 2012b) and just 400mm under American Kennel Club (AKC) rules, which has five height categories (America Kennel Club, 2011); 250mm less than under KC rules. The additional height ranges offered by UKA and AKC illustrates their recognition of the need for more staggered height increases, potentially to reduce injury risk. Dogs only just measuring within the full height category are potentially at greater risk of injury due to the greater size jump in relation to their body height.

Commonly injured areas in agility dogs are the shoulders (bicipital tenosynovitis), the lumbar spine and the toes (O'Canapp 2007; Wernham et al, 2008). Levy et al (2009) identified that 33% of overall injuries to dogs were as a result of agility; of that, 58% were injured during competition. A-frames, bar jumps and the dog walk elements equated for two-thirds of reported injuries. The bar jump led to increased accelerative horizontal impulse and increased vertical loads, peak forces and impulses in the forelimbs (Pfau et al. 2010). The concussive landing forces from bar jumps are consequentially implicated in the prevalence of soft tissue injuries to the shoulders and back (Levy et al, 2009).

Excessive joint movement may also be linked to agility injuries and are likely to result from increased fence heights. To date, no research exists regarding the impact of fence height, in relation to dog height on the kinematics of the jump. The aim of this study was to identify changes in limb and spinal joint angles in agility dogs over fences of two different heights, set in relation to their wither height. Angles were reviewed on approach, take off, bascule, landing and get away phases of the jump stride. Any increase in injury risk to dogs jumping excessively higher than their body height would be indicated, potentially supporting the need for the addition of a fourth height within current KC regulations. Joint flexion and extension was expected to become more exaggerated over the larger fence particularly during the take-off and landing phases. In accordance with previous injury related research, joint angles in the lumbar and shoulder regions were hypothesised to demonstrate changes of a greater magnitude.

Materials and Methods

The study population consisted of four German Shorthair Pointers, one Hungarian Visla, one Doberman, one Australian Kelpie and one mixed breed agility dog, chosen through convenience sampling. The dogs used were of similar agility competition experience and all competed within the full height category; wither heights ranged from 460mm to 720mm. Each dog had previously, or was currently, competing in agility competitions and none of the dogs were known to be suffering from any disorders including musculoskeletal conditions.

A lightweight plastic bar jump was used with modified wings enabling the jump to be set to any particular height in 1 cm increments. The jump heights were set specifically for each dog at 7% lower and 51% higher than the dog's height. These percentages were calculated by considering the height of fence in relation to withers height, that dogs at the top of UKA midi height would have to jump without the inclusion of the fourth, Standard height.

Markers were attached to specific anatomical points of the forelimbs (point of shoulder, elbow, carpus, and metacarpal pad), the hindlimbs (sacroiliac joint, base of tail, tuber coxae, stifle, tarsus and metatarsal pad) and vertebral column (external occipital protuberance, C2, T6, T13) (Gradner et al, 2007; Marsh et al, 2009). In the forelimb, angles were calculated on the cranial aspects of the elbow joint, and on the caudal/palmar aspect of the shoulder and carpal joints. In the hind limb, angles were calculated on the cranial/dorsal aspect of the hip and tarsal joints, and the caudal/palmar aspects of the stifle joint. Spinal angles were calculated from the ventral aspect of the spinal column.

The data were collected in an indoor equine arena on a Prowax surface. The fence was placed at the midpoint of the long side of the arena and the camera (JVC GY-HM700U HD; 60fps) positioned perpendicular to the fence at a distance of six metres. This distance enabled approach, take-off, bascule, landing and get away phases of the jump to be captured. The positioning of the fence with the arena wall to the left of the fence supported the dogs in attaining a right canter lead in both take-off and landing.

Owners warmed-up their dog for five minutes prior to data collection and were asked to follow their normal pre-competition warm-up protocol. The warm up period enabled each dog become accustomed to the feel of the markers (Leach, 2006). On completion of the warm up, each dog jumped the fence set at a height 7% lower than its height at the withers. The dog was set up four metres in front of the jump and the owner positioned four metres after the jump to ensure each dog had the same distance either side of the fence. A jump was deemed as unsuccessful if the dog ran under or around the jump, or knocked the pole down. If a dog had failed to complete the jump successfully five times then it would have been withdrawn from the study to ensure its welfare was not compromised. Once the lowest height was completed three times, the bar was raised in 10 cm increments until the calculated highest height (51% greater than height at withers) for each dog was reached. Dogs were recorded for three repetitions over the fences 7% lower and 51% higher than their height at the withers. The intermediate 10cm increments were only jumped once, successfully, at each increment and were not recorded.

From the anatomical markers, the angles of the spine at the base of the skull and the base of the neck, and the carpal, radio-humeral, scapulohumeral, tarsal, stifle, coxofemoral, sacroiliac and thoracolumbar joints were determined using Dartfish software. Angles were measured for approach (all four feet in contact with the ground during the final approach stride immediately prior to the forelimbs leaving the ground), take-off (forelimbs off the ground, immediately prior to the back feet leaving the ground), bascule (the midpoint over the jump), landing (initial forelimb contact with the ground) and get away phases (all four feet in contact with the ground immediately following landing). Take-off and landing distances from the base of the fence were also determined using Dartfish. Angles reported for each phase of the jump were maximal points of anatomical flexion or extension that occurred during that phase.

For each measured parameter at each phase over both heights of jump, mean values were determined for each dog from the three repetitions. These mean values for the joint angles, take-off distances and landing distances captured at the lower jump height were compared against those captured at the higher fence height for each phase of the jump under investigation to determine the existence of any difference resulting from the increase in fence height. Data were examined for statistically significant differences between the two fence heights using the Wilcoxon- Matched Pairs analysis.

Results

For six of the eight dogs, significantly increased extension ($P \leq 0.05$) was recorded at the base of the neck between the 7% lower jump ($\bar{x}$ = 208.10°; SD±6.99) and 51% higher jump height ($\bar{x}$ 213.55°; SD±7.43) during the approach phase. When the data was reviewed with outliers removed ($\bar{x}$± 2SD), one of the two dogs which did not demonstrate extension at the base of the neck was excluded for the angles of the tarsus and the base of the neck, and this dog was the cross breed. The result of its exclusion was that the base of the neck no longer demonstrated a significant difference in angle; however the tarsus angle demonstrated a significant increase in extension ($P \leq 0.05$) during take-off as the fence height increased.

During the take-off phase, significantly increased extension of the hock ($P \leq 0.05$) and the sacroiliac region ($P \leq 0.05$) were identified from the lowest to the highest height. However, significantly increased flexion was recorded for the radio-humeral ($P \leq 0.05$) and scapulohumeral ($P \leq 0.05$) joints and the base of the neck ($P \leq 0.05$) (Table 2). No statistically significant differences were found between the take-off distances for the two heights of jumps.

Greater flexion was recorded for the scapulohumeral joint ($P \leq 0.05$) and the radiohumeral joint ($P \leq 0.05$) angles during the bascule phase from the lowest ($\bar{x}$ = 107.95°; SD±5.93; $\bar{x}$ = 52.09°; SD±18.13 respectively) to the highest height fence ($\bar{x}$ = 88.25°; SD±9.33; $\bar{x}$ = 39.04°; SD±15.40 respectively).

No significant changes in flexion or extension of any joints were recorded between the two heights of fence during the landing or get away phases, however landing distance increased significantly with an increase in fence height ($P \leq 0.05$).

Discussion

Although few changes were recorded for joint angles during the approach phase, the increased extension at the base of the neck indicated that on the approach the dogs were raising their heads. Although this change was not significant with the outlier removed, the means demonstrated a trend for this extension across six of the seven remaining dogs and the P-value was close to the significance level (P=0.063). This change in head position is potentially to better determine the height of the fence (Zinc and Daniels, 1996); however, as a consequence it puts this region of the spine in extension.

During take-off the base of the neck moved from the extended orientation seen in the approach phase, to a more neutral, or slightly flexed orientation; with significantly greater flexion when the higher fence was jumped compared to the lower fence. This flexion, and the concurrent extension of the sacroiliac region, results in the spinal column appearing visually straighter. This alignment would support the transfer of energy required during take-off and also the increase in vertical trajectory needed to get over the taller fence. This increase in vertical trajectory is also reflected by the increase in tarsal joint extension for the larger fence where greater vertical propulsion is required.

Very little research into the biomechanics of dog agility exists and none have investigated the kinematic effects of fence heights on joint angles. Much research however has been undertaken in jumping horses and such research has identified that during the take-off phase the equine sacroiliac joint angle increases when jumping higher fences compared to those of a smaller height, and the lumbar spine consequently becomes more extended (Dyson and Murray 2003). Sacroiliac joint injuries are a common cause of nonspecific hindlimb lameness in horses (Tucker et al, 1998) and show jumping horses are at a significantly greater risk of developing sacroiliac joint disease (Dyson and Murray 2003). Significant damage to the sacroiliac joint can lead to permanent nerve damage and, in smaller species such as dogs and cats, severe damage can result in the joint needing to be pinned (Johnson and Dunning, 2005). The significant increase in extension of this region due to the higher jump height within the current study indicates that injury to this region is a significant concern in dogs being required to jump fences which are substantially greater than their withers height.

In addition to the spinal extension, simultaneous and significant flexion in the scapulohumeral and radiohumeral joint angles was observed within the take-off phase. These alterations demonstrate increased flexion, and therefore tucking-up, of the forelimbs to support clearance of the fence. This significant forelimb flexion originating from the scapulohumeral and radiohumeral joints remains during the bascule phase. Increased flexion of the scapulohumeral joint compounds the strain on the highly tendinous *Biceps brachii* which runs over the dorsum of the joint. Repeated strain of this structure has been linked to bicipital tenosynovitis, a condition common in agility dogs (O'Cannapp, 2007). The potential for damage to this structure in agility dogs, in addition to a failure to appropriately diagnose and rehabilitate the injury, can lead to permanent degeneration of the tendon.

The link between the increase in height of the fence and increase in scapulohumeral joint flexion reinforces some concerns that within KC competitions, dogs that only just meet the full height category could be putting excess strain on their soft tissues through jumping fences that are large in comparison to their body height. The lack of a clavicle in the dog results in the shoulder muscles playing an important role in passive as well as athletic movement (Budras et al, 2007) and are consequently required to stabilise, generate, absorb and transfer forces to accomplish movement in the forelimbs (Farrow, 2005; Giacomo et al, 2008). Damage to these muscles will negatively impact the muscles efficiency at recoiling and pulling the leg forward (Budras et al, 2007). Further research is needed to investigate the incidence of injuries in agility dogs in relation to their height and the height classification in which they are competing in an effort to avoid permanent damage through degeneration.

Interestingly, the increased flexion in the forelimbs during the bascule phase is not reflected in the hindlimbs nor are there significant differences in the angles measured within the vertebral column. This indicates that the increased upward trajectory and the increased forelimb flexion to ensure clearance are satisfactory up to this point of the jump sequence to ensure clearance of the fence.

Pfau et al's (2010) findings suggest that differences in joint angles should have been expected on landing over the bar fence due to the more acute landing angle and higher vertical loading forces identified within their investigation of agility dog injuries in relation to fence type. The lack of significant differences found during the landing and get away phases of the current study may be influenced by the low sampling rate within this study (60Hz), potentially preventing maximal angled from being detected. However, it also illustrates how research in this area could benefit from the concurrent use of force plates alongside angle data to accurately determine the influence of various fence heights on biomechanical adaptations of the landing phase. Differences in the landing distances and angulations could also be related to the speed of approach and this is therefore another area where further research is needed. Within competition dogs would have a longer approach and would be encouraged to complete the fence in a hurdling form of jump at a higher speed and may also be encouraged to turn on landing. These factors are, however, likely to increase the risk of injury rather than decrease it.

Although no changes in the angles of joints were observed, the landing distances increased significantly with the increase in fence height. This again contradicts the findings by Pfau et al (2010) who suggest a more acute landing angle with the bar fence; however their investigation compared fence types rather than fence heights and this may account for the difference in results. The results from the take-off phase of the current study suggest that greater propulsive forces are employed to jump higher fences. The increased power required to clear the jump may propel the dog further over the fence and thus account for the longer landing distance.

The tallest dog used in the study measured 720mm to the withers and as such the higher jump (51% greater than height at withers) for this dog was 1090mm. A dog of this height would not normally be asked to jump a fence of this size, and during competition would be asked to jump a maximum of 650mm. This is a difference of 440mm; 9cm greater than the wither height of the smallest dogs in this category. This discrepancy demonstrates how much higher, as a percentage of body height, a dog of 431mm would be expected to jump during competition, and as such how much the risk of injury is increased.

Study Limitations

As has been identified in equine kinematic studies (van Weeren et al., 1992; Sha et al., 2004), movement of the skin over the bony landmarks used for marker placement within results in biological errors in measurement; particularly within full retraction, or protraction, of the limb. Correction models have been calculated for some anatomical landmarks in the horse; however there are currently no similar correction models for canine kinematic investigations. Such biological noise is likely to have influenced the measurements within this study.

To further understand the findings of this investigation force measurements would have ideally been taken on take-off and landing; this would have enabled further comparisons to be drawn with this study and the findings of Pfau *et al*. (2010) who looked at take-off and landing forces over different fence types.

Although the sample size could be considered as small, it was comparable to most equine kinematic investigations where sample sizes can be as few as four or five horses. The generalizability of the current findings would however be enhanced through the inclusion of a wider range of breeds and anatomical types within the study population. This would, as a consequence, require the need for a larger sample size to be used.

Conclusion

The findings demonstrate that an increase in fence height results in significant changes to the excursions of joints in the forelimb and vertebral column, areas already identified in previous agility dog research as the most commonly injured. These findings indicate that agility dogs that are required to jump fences excessively higher than their own with height are potentially being put at a greater risk of developing injuries such as bicipital tenosynovitis or sacroiliac strain. Those dogs likely to be at most risk within the current height categories are those just above the KC midi category (431mm) and are require to jump full height (650mm) which is 51% bigger than their wither height and 200mm higher than the midi height category. Further research is needed to confirm injury location and prevalence in relation to the height of the dog and the height category they are competing at. Should a relationship be found, it would support findings from the current study and add emphasis to the suggestion that fence height categories, where dogs are required to jump large fences in comparison to their body size, need to be reviewed to support injury prevention.

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper

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Table 1: Jump category and fence height depending on height at withers for both UK Agility and Kennel Club competitions.

<table>
<tr><th>Height at withers</th><th>UK Agility</th><th>Kennel Club</th></tr>
<tr><td>≤ 350mm</td><td>Mini - 300mm</td><td>Mini - 300mm</td></tr>
<tr><td>351-430mm</td><td>Midi – 400mm</td><td>Midi – 450mm</td></tr>
<tr><td>431-500mm</td><td>Standard – 550mm</td><td rowspan="2">Full – 650mm</td></tr>
<tr><td>>500mm</td><td>Full – 650mm</td></tr>
</table>

Table 2: Mean (±SD) values for all joint angles at each phase of the jump (Significant differences in mean values in bold).

Phase of jump	Approach		Take Off		Bascule		Landing		Get away	
Fence height	7% lower	51% higher	7% lower	51% higher	7% lower	51% higher	7% lower	51% higher	7% lower	51% higher
Hock	118.5 (±9.0)	122.2 (±14.1)	**134.5 (±14.7)**	**151.6 (±5.2)**	86.2 (±10.7)	78.8 (±21.6)	70.6 (±9.5)	76.8 (±16.1)	134.7 (±12.1)	132.9 (±18.6)
Stifle	107.3 (±8.8)	105.9 (±4.1)	104.8 (±7.6)	110.4 (±5.5)	50.0 (±12.0)	44.4 (±10.6)	51.5 (±9.9)	50.2 (±10.7)	131.6 (±17.2)	136.6 (±24.6)
Hip	90.5 (±4.2)	86.4 (±6.8)	119.9 (±4.4)	122.1 (±5.3)	97.8 (±11.9)	92.8 (±12.9)	81.5 (±12.9)	82.4 (±10.9)	97.3 (±11.5)	93.5 (±8.0)
Sacroiliac	154.6 (±4.3)	155.3 (±6.0)	**179.4 (±5.3)**	**186.6 (±6.2)**	173.2 (±7.0)	174.6 (±7.7)	158.9 (±12.0)	163.4 (±10.4)	141.8 (±11.1)	144.8 (±7.5)
Thoracolumbar	165.1 (±8.9)	165.7 (±9.3)	183.3 (±4.7)	184.5 (±5.6)	193.0 (±5.9)	194.2 (±5.5)	193.2 (±6.4)	201.2 (±7.0)	166.3 (±8.7)	166.9 (±10.4)
Base of neck	**208.1 (±6.9)**	**213.6 (±7.4)**	**168.2 (±8.8)**	**162.1 (±6.5)**	182.4 (±9.6)	177.7 (±10.8)	211.9 (±12.5)	216.1 (±17.1)	182.2 (±19.5)	177.6 (±17.5)
Base of skull	178.7 (±5.7)	181.2 (±7.6)	170.4 (±5.2)	174.9 (±9.4)	176.6 (±4.4)	173.9 (±6.0)	183.0 (±11.0)	184.1 (±8.4)	172.9 (±9.9)	177.9 (±13.8)
Radiohumeral	126.8 (±9.5)	128.9 (±9.7)	**44.5 (±18.6)**	**23.2 (±13.2)**	**52.1 (±18.1)**	**39.0 (±15.4)**	112.3 (±14.6)	119.3 (±10.9)	90.5 (±25.9)	95.4 (±23.8)
Scapulohumeral	98.1 (±8.9)	98.3 (±9.1)	**83.9 (±12.4)**	**72.3 (±8.1)**	**107.9 (±5.9)**	**88.3 (±9.3)**	118.0 (±14.5)	125.6 (±13.2)	104.1 (±8.0)	99.4 (±9.2)
Carpal joint	197.9 (±18.3)	196.2 (±25.9)	90.1 (±24.5)	89.5 (±24.7)	136.1 (±22.9)	124.5 (±18.7)	212.3 (±5.3)	207.4 (±14.2)	208.2 (±13.5)	224.1 (±14.0)