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Author: E. Birch, J. Boyd, G. Doyle, A. Pullen

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The effects of altered distances between obstacles on the jump kinematics and apparent joint angulations of large agility dogs

E. Birch [a], J. Boyd [a,*], G. Doyle [b], A. Pullen [a]

[a] *School of Animal, Rural and Environmental Sciences, Nottingham Trent University, Southwell, NG25 OQF, UK*
[b] *School of Health, Sport and Bioscience, University of East London, Stratford, London, E15 4LZ, UK*

* Corresponding author. Tel.:+44 115 848 5345.
E-mail address: jacqueline.boyd@ntu.ac.uk (J. Boyd).

Highlights

- In contrast to equines, canine sport science has been poorly studied.
- As the distance between consecutive upright hurdles increases, so do the take-off and landing distances.
- Take-off and landing distances further alter with the dog's skill level.
- There are greater differences in jump kinematics when the distances between consecutive hurdles are shorter.
- Apparent joint angles alter for level of skill, with beginner dogs showing greater differences than advanced dogs.

Abstract

Canine agility is a rapidly growing sport in the UK. However, there is a paucity of scientific research examining jump kinematics and associated health and welfare implications of the discipline. The aim of this research was to examine differences in jump kinematics and apparent joint angulation of large (> 431 mm at the withers) agility dogs (n = 54), when the distance between hurdles was altered (3.6 m, 4 m and 5 m apart) and to determine how level of skill impacted upon jump kinematics.

Significant differences were observed for both the take-off ($P < 0.001$) and landing distances ($P < 0.001$) between the 3.6 m, 4 m and 5 m distances. Further differences were observed when level of skill was controlled for; take-off ($F[3,55] = 5.686$, $P = 0.002$) and landing ($F[3,55] = 7.552$, $P < 0.001$) distances differed at the 3.6 m distance, as did the take-off distance at the 4 m hurdle distance ($F[3,50] = 6.168$, $P = 0.001$). Take-off and landing speeds differed for hurdle distances ($P < 0.001$) and level of skill ($P < 0.001$). There were significant differences in apparent neck angle during take-off and landing ($P < 0.001$), lumbar spine angles during take-off, bascule and landing ($P < 0.01$), and in shoulder angles during the bascule phase ($P < 0.05$). The results indicate that agility dogs alter their jumping patterns to accommodate the spacing between hurdles, which ultimately may impact long term health and welfare due to altered kinematics.

Keywords: Canine; Biomechanics; Welfare

Introduction

Dog agility is a discipline whereby handlers navigate their dog around a set course, in the fastest time, without faults. The majority of obstacles are upright hurdles, set at a predetermined height in relation to the dog's height at the withers (Table 1). Dogs are further categorised by skill through a grading system (Table 2). In the UK, the majority of competitions are held under the auspices of The Kennel Club (KC).

Despite growing popularity, little research has examined jump kinematics of competitively trained agility dogs. Colborne (2007) suggested that canine kinematic studies were approximately 20 years behind human gait analysis and 10 years behind equine gait analysis. The minimum distance between hurdle fences varies between governing bodies and ranges from 3.6 m (KC)[1] to 5 m (Fédération Cynologique Internationale [FCI])[2]. What effect the distance between fences has upon the kinematics of agility dogs, and how this influences performance and potential injury risk is currently unknown. Much discussion is drawn from current equine literature due to the paucity of canine agility research (Powers, 2002; Colborne, 2007).

[1] See: The Kennel Club, 2013. Agility. http://www.thekennelclub.org.uk/activities/agility/ (accessed 2 February 2015)

[2] See: Fédération Cynologique Internationale, 2012. Agility regulations of the Fédération Cynologique International. http://www.fci.be/en/Agility-45.html (accessed 2 February 2015)

Birch and Lesniak (2013) demonstrated in agility dogs that as fence height increased flexion of the scapulohumoral joint and extension of the sacroiliac joint also increased. Pfau et al. (2011) found that there were higher vertical loads, peak forces and impulses in the front limbs upon landing over a hurdle than compared to a long jump.

Levy et al. (2009) reported that 33% of agility dogs had sustained an injury, with 58% of injuries occurring during competition, mirroring findings in equine studies (Singer et al., 2008). Shoulder injuries are commonly reported in agility dogs[3] and specialised rehabilitation veterinary practices[4] are being set up to accommodate canine athletes[5]. Neck, shoulder and back injuries were found to be most common, often occurring whilst jumping hurdles (Cullen et al., 2013a, b). These preliminary findings again are similar to those that are seen in equine studies (Clayton and Barlow, 1989). Research is needed to examine the impact of such activities on the health, welfare and longevity of agility dogs.

Work examining equine jump kinematics suggests that fence type and height both impact upon limb placement during the take-off and landing phases, and alter joint angles (Clayton and Barlow, 1989; Powers and Harrison, 1999; Hole et al., 2002). Jumping techniques in untrained, loose schooled horses differ, with 'good' jumpers being able to more accurately judge the optimum take-off distance (Powers and Harrison, 2000). In addition, successful horses were found to take off further from the fence than unsuccessful horses

[3] See: O'Cannapp, S., 2007. Shoulder conditions in agility dogs. Focus on Canine Sports Medicine. http://www.akcchf.org/assets/files/canine-athlete/Biceps-injury.pdf. (accessed 2 February 2015)

[4] See: Smart Clinic, 2014. Welcome to SMART vet Wales. http://www.smartvetwales.co.uk./ (accessed 2 February 2015)

[5] See: Pet Rehab, 2013. Pet rehab fitness training. http://pet-rehab.co.uk/fitness-training/ (accessed 2 February 2015)

during a puissance competition (Powers, 2002). Wejer et al. (2013) reported that equine jump kinematics were also altered by experience and training, whilst Rodrigues et al. (2014) found a decrease in jumping efficiency when the number of jumps increased. Anatomically, equines and canines differ, but it is reasonable to postulate that changes between hurdle distance will affect canine jump kinematics.

The aims of this study were to examine how (1) the distance between hurdles alters the take-off and landing distances; (2) the level of skill affects take-off and landing distances; (3) the apparent shoulder, lumbar spine and neck angles alter between different hurdle placement, and (4) the level of skill affects these apparent joint angles.

Materials and methods

The study gained full ethical approval from Nottingham Trent University Animal, Rural and Environmental Sciences Ethical Review Group (ARES60, 2 October 2012) prior to data collection. Fifty-four large dogs (Table 1), competing at The KC International Agility Festival, were recruited to the study on a volunteer basis (Table 3). No dogs were withdrawn from the study following an initial veterinary screen for injuries. The test comprised of nine hurdles (650 mm high) in three sets of three; one set 3.6 m apart (KC minimum distance), one set 4 m apart (FCI minimum distance for small dogs) and one set 5 m apart (FCI minimum distance for large and medium dogs). A high definition video camera (JVC GC-PX10 HD, 300fps) was sited 3 m away from the second hurdle of each set (Fig. 1). Handlers ran their dogs as they would in normal competition with dogs being withdrawn from subsequent analyses if they failed to complete all nine hurdles.

Dogs were classified into levels of skill by the grade within which they were currently competing (Table 2). Beginner dogs competed in grades 1 and 2 (*n* = 7), novice dogs in grade 3 (*n* = 10), intermediate dogs in grades 4 and 5 (*n* = 17), advanced dogs in grades 6 and 7[6] (*n* = 20).

Downstream data analysis was conducted using Dartfish software[7] with the base of the hurdle wing (0.48 m) used to calibrate distances (Fig. 2). Take-off was determined as the frame immediately prior to the dog leaving the ground and measured from the toe of the trailing hind limb to the hurdle wing (Powers and Harrison, 1999). Landing was determined as the frame where the dog first contacted the floor and was measured from the back of the carpus of the leading forelimb to the hurdle wing (Powers and Harrison, 1999).

Apparent neck angle was measured as that formed between the top of the skull, C2 and the top of the scapula. The lumbar spine angle was taken between T13, the top of the ilium and the base of the tail. The shoulder angle was that measured between the top of the scapula, top of the humerus and the elbow. Angles were examined for the take-off, landing and bascule (determined as the midpoint over the hurdle) phases of the jump (Powers and Harrison, 1999; Weigel and Millis, 2014) (Fig. 2).

Inter-observer reliability was examined using Pearson's correlation with repeated measure analysis of variance (ANOVA) and effect size (Cohen's *d*) examining differences between conditions. Tukey post-hoc tests determined where the differences lay.

Results

[6] The Kennel Club, 2013. Agility Grading Structure with Win/Points Progression Criteria for 2013. Available at: http://www.thekennelclub.org.uk/media/271056/aggradingstructure13.pdf (accessed 15 February 2015)
[7] See: Dartfish, 2014. http://www.dartfish.com/en/ (accessed 2 February 2015)

Data showed a strong positive correlation (take-off and landing distances $r[96] = 0.992$, $P < 0.001$; apparent joint angles $r[432] = 0.865$, $P < 0.001$) between two independent researchers indicating a high level of inter-observer reliability.

Take-off and landing distance and speed between the 3.6 m, 4 m and 5 m distances.

Significant differences were seen in take-off distance between the three distances ($F[2,159] = 25.079$, $P < 0.001$) with dogs taking off significantly closer to the hurdle in the 4 m distance compared to the 3.6 m ($P = 0.007$) and 5 m distances ($P < 0.001$) (Fig. 3). An effect size of 0.75 was found, suggesting a moderately important difference between the conditions. Furthermore, there was a significant difference in take-off speed between the three distances ($F[2,159] = 37.133$, $P < 0.001$). Dogs jumped faster in the 3.6 m distance compared to the 4 m distance ($P = 0.007$) and slower compared to the 5 m distance ($P < 0.001$), whilst dogs jumped significantly slower than in the 4 m distance compared to the 5 m distance ($P < 0.001$) (Fig. 4).

Further significant differences were found for landing distance between the three distances ($F[2, 159] = 46.601$, $P < 0.001$). Dogs landed significantly further away from the hurdle in the 5 m distance compared to the 3.6 m ($P < 0.001$) and 4 m distances ($P < 0.001$) (Fig. 3). An effect size of 1.46 was found suggesting an important difference between the conditions. Furthermore, significant differences in landing speed were seen between the three distances ($F[2,159] = 70.258$, $P < 0.001$). Dogs jumped faster in the 3.6 m distance compared to the 4 m distance ($P < 0.001$) and slower than in the 5 m distance ($P < 0.001$). Dogs jumped significantly slower in the 4 m distance compared to the 5 m distances ($P < 0.001$) (Fig. 4).

Take-off and landing distances across levels of skill.

Significant differences were seen in the take-off distances during the 3.6 m distance ($F[3,55] = 5.686$, $P = 0.002$) with beginner dogs taking off nearer to the hurdle compared to intermediate dogs ($P = 0.002$). Furthermore landing distances differed significantly ($F[3,55] = 7.552$, $P < 0.001$) with beginner dogs landing nearer the hurdle compared to novice ($P = 0.003$) and intermediate dogs ($P = 0.004$). Advanced dogs landed nearer to the hurdle compared to novice ($P = 0.017$) and intermediate dogs ($P = 0.017$) (Fig. 5). There was a significant effect of skill on the take-off ($F[3,50] = 9.416$, $P < 0.001$) and landing speed ($F[3,50] = 8.876$, $P < 0.001$) during the 3.6 m distance. Beginner dogs were slower than novice ($P = 0.013$) and intermediate dogs ($P < 0.001$) during take-off and slower than intermediate ($P < 0.001$) and advanced dogs ($P = 0.045$) during landing.

Take-off distances differed significantly at the 4 m distance ($F[3,50] = 6.168$, $P = 0.001$). Advanced dogs took off further away from the jump compared to beginner ($P = 0.005$) and novice dogs ($P = 0.009$). No significant differences were observed for landing distances or take-off and landing speed at the 4 m distance.

At the 5 m distance, significant differences in the take-off ($F[3,50] = 3.453$, $P = 0.023$) and landing speeds were seen ($F[3,50] = 4.679$, $P = 0.006$). Beginner dogs were slower than advanced dogs during the take-off ($P = 0.038$) and landing phases ($P = 0.01$) and novice dogs were slower than advanced dogs during the landing phase ($P = 0.05$) (Fig. 6). There were no differences in take-off and landing distances at the 5m distance.

Apparent joint angle differences between the 3.6 m, 4 m and 5 m distances

During the take-off phase of the jump there was a significant difference in the neck angle between the three distances ($F[2,153] = 11.728$, $P < 0.001$). A more acute neck angle was observed in the 3.6 m and 4 m distance, compared to the 5 m distance ($P < 0.001$). Further significant differences were seen during the landing phase of the jump ($F[2,153] = 18.692$, $P < 0.001$) again with there being a more acute neck angle during the 3.6 m and 4 m distances, compared to the 5 m distance ($P < 0.001$) (Table 4).

Lumbar spine angle differed significantly between the three distances during (1) the take-off phase of the jump ($F[2,153] = 7.889$, $P = 0.001$), with an increased extension in the 4 m distance compared to the 3.6 m distance (P = 0.004) and the 5 m distance ($P = 0.001$); (2) the bascule phase of the jump ($F[2,153] = 6.248$, $P = 0.002$) demonstrating an increased flexion in the lumbar spine during the 5 m distance compared to the 4 m distance ($P = 0.001$), and (3) the landing phase of the jump ($F[2,153] = 65.091$, $P < 0.001$), demonstrating an increased flexion during the 4 m distance compared to the 3.6 m distance ($P = 0.028$) and 5 m distance ($P < 0.001$) (Table 4).

Shoulder angles differed significantly during the bascule phase of the jump ($F[2,153] = 3.326$, $P = 0.039$) with an increased flexion of the shoulder joint at the 4 m distance compared to the 5 m distance ($P = 0.05$). No significant differences were observed during the take-off or landing phases of the jump (Table 4).

Apparent joint angle differences across levels of skill.

At the 3.6 m distance, significant differences were seen in neck angles during the bascule phase of the jump ($F[3,55] = 7.262$, $P < 0.001$) with advanced dogs demonstrating a more obtuse neck angle compared to novice ($P = 0.001$) and intermediate dogs ($P = 0.005$). Lumbar spine angles differed significantly during the take-off phase ($F[3,55] = 3.149$, $P = 0.032$) with novice dogs demonstrating an increased flexion compared to advanced dogs ($P =$

0.032). Shoulder angles differed significantly during the bascule phase of the jump ($F[3,55] = 5.237$, $P = 0.003$) with beginner dogs showing an increased extension compared to intermediate ($P = 0.021$) and advanced dogs ($P = 0.017$). No significant differences were seen during the 4 m distance.

At the 5 m distance, significant differences were seen in the neck angles during the bascule phase of the jump ($F[3,55] = 2.954$, $P = 0.04$) with advanced dogs showing a greater flexion compared to novice dogs ($P = 0.023$). Lumbar spine angles differed significantly during the take-off phase of the jump ($F[3,55] = 3.653$, $P = 0.018$) with advanced dogs demonstrating an increased flexion compared to novice dogs ($P = 0.038$). Shoulder angles differed during the take-off ($F[3,55] = 3.053$, $P = 0.036$) and landing ($F[3,55] = 3.857$, $P = 0.014$) phases of the jump. There was increased flexion of the shoulder angle for advanced dogs compared to novice dogs during the take-off phase ($P = 0.023$) and an increased extension of the shoulder angle for novice dogs compared to advanced dogs during the landing phase ($P = 0.01$).

Discussion

The large sample size and high level of inter-observer reliability in this study, with all dogs tested under field conditions, increases its ecological validity (Feeney et al., 2007; Hogy et al., 2013). The take-off distance/speed and landing distance/speed significantly increased when consecutive jump distances were at 5 m compared to 3.6 m and 4 m. If the dog cleared the jumps at the same height irrespective of condition, the longer jump distances would suggest a flatter trajectory, which would likely reduce vertical ground reaction forces. More skilled dogs took off and landed further away from the hurdle, at a greater speed when compared to less skilled dogs. This suggests that experienced dogs may be more adept at deciphering the optimum take-off point for the jump, as has been seen in equines (Powers and Harrison, 2000; Powers, 2002).

Beginner dogs jumped slower than higher skilled dogs in both the 3.6 m and 5 m distances, illustrating how speed may be a contributing factor for dogs moving up competitive grades or, arguably, how speed will increase with skill. Whilst take-off and landing speed did not differ significantly during the 4 m distance, take-off and landing distance did vary, with higher skilled dogs taking off and landing further away from the hurdle. Thus, larger impulses would need to be produced due to the dogs increased time in the air. In contrast, at the 5 m distance, speed increased with skill, whilst take-off and landing distances did not differ, suggestive of smaller impulses in higher skilled dogs due to less time in the air. Previous studies examining canine jump kinematics found that there was an increased speed, coupled with shallower landing angles when the height of the obstacle decreased (Pfau et al., 2011; Birch and Lesniak, 2013). Whereas the height of the jumps did not alter in our study, we found similar results with dogs increasing their speed but with shallower landing angles over the hurdles placed 5 m apart.

Apparent neck, shoulder and lumbar spine joint angles differed significantly, which suggests, at least potentially, why injuries occur more commonly in these locations (Levy et al., 2009; Cullen et al., 2013a, b). The increased flexion of the neck in the 3.6 m and 4 m distances may be due to the dogs landing closer to the next hurdle so having to lift their head in preparation for take-off over the third hurdle. Indeed, all dogs ‘bounced’ between the hurdles in the 3.6 m distance but not in the 4 m and 5 m distances. Inclusion of distances to test jumping ability of dogs at low skill levels is in stark contrast to equine show jumping competitions, which commonly include a combination of hurdles set at bounce strides, to test ability at advanced levels[8].

Back angles differed between the three distances, but there was no demonstration of an increased extension of the lumbar spine, as has been previously seen in other agility research (Birch and Lesniak, 2013), possibly due to the height of the hurdle being consistent at all three distances. Shoulder angles at the 4 m distance were significantly more flexed during the bascule phase of the jump in comparison to the 5 m distance and may reflect reduced take-off and landing distances, creating a smaller, steeper jumping arc. The lack of a clavicle results in shoulder muscles playing an important role not only in athletic, but also passive movement. Consequently, repeated hyperflexion and extension of this joint could be detrimental to the health and welfare of the dog, and might explain why shoulders present as a common location for injury in agility dogs (Budras et al., 2007; Giacomo et al., 2008; Cullen et al., 2013a, b).

When controlling for skill, the greatest number of differences were seen at the 3.6 m distance, mirroring differences in take-off and landing distances and supporting the notion that dogs may find hurdles spaced at this distance more challenging. In support of this, 11 dogs were removed from analysis due to not completing the obstacles correctly. All of these incidents occurred at either the 3.6 m or 4 m distances, nine of which were beginner or novice dogs. This supports the notion that jump kinematics differ for the distance between hurdles and for level of skill.

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[8] See: Fédération Equestre Internationale. London 2012 Olympic games – jumping preview. http://www.fei.org/news/london-2012-olympic-games-jumping-preview (accessed 15 February 2015)

Conclusions

This study illustrates how canine jumping style and speed differs with distance between hurdles as well as with levels of skill. Skilled dogs appear to be more adept at deciphering optimum jump kinematics than less skilled dogs. Overall, as the distance between hurdles increases, the differences in jump kinematics of skilled and less skilled decreases, suggesting that reduced obstacle distances should be restricted to higher skilled dogs, analogous to equine show jumping competitions. Whilst arbitrary regulations may historically have been acceptable, there is now a distinct need for more scientific research in this area.

Conflict of interest statement

Jacqueline Boyd and Gary Doyle are both members of The Kennel Club Activities Health and Welfare Sub Group. None of the other 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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Fig. 1. The layout of the upright hurdles used in the study. A, B and C are camera locations and illustrate the camera's field of view ensuring the take-off and landing phase of the jump is recorded. Broken lines identify direction of travel, with each dog being stopped and restarted between each set of three hurdles.

Fig. 2. Illustration of Dartfish analysis. (A) Illustration of measurement of apparent joint angles. (B) Mean take-off and landing distance for the 3.6 m hurdle distance. (C) Mean take-off and landing distance at the 5 m hurdle distance. Take-off and landing distances were calibrated for Dartfish analysis using the foot of the hurdle (0.48 m).

Fig. 3. Mean take-off and landing distances. * Significant difference between take-off and landing distance ($P < 0.05$).

Fig. 4. Mean take-off and landing speed over the three hurdle distances. * Significant differences between take-off and landing speed ($P < 0.05$).

Fig. 5. Mean take-off and landing distances for different levels of skill. * Significant differences for the take-off and landing distances for different levels of skill ($P < 0.05$).

Fig. 6. Mean take-off and landing speed for the different levels of skill. * Significant differences in take-off and landing speed for different levels of skill ($P < 0.05$).

Table 1

Jump height categories under Kennel Club regulations.

Category	Height to the withers	Jump height
Small	< 350 mm	350 mm
Medium	351 mm - 430 mm	450 mm
Large	> 431 mm	650 mm

Table 2

Level of skill as defined under Kennel Club regulations.

Grade	Ability	Progression
1	Beginner	All dogs and handlers with no previous wins in agility
2	Beginner	All dogs and handlers who have won one agility class or three jumping classes at grade 1
3	Novice	All dogs who have won one agility class or three jumping classes at grade 2. Or all dogs with handlers who have previously won out of grade 1 and 2
4	Novice	All dogs who have won one agility class or three jumping classes at grade 3.
5	Novice	All dogs who have won one agility class or three jumping classes at grade 4.
6	Advanced	All dogs who have won three classes, with at least one of which being in agility at grade 5.
7	Advanced	All dogs who have won four classes, two of which must be in agility at grade 6.

Table 3

Sample demographics

Breed	Percentage	Mean age (years)
WSD/WSD crosses/BC	80%	6
Retriever/Retriever cross	9%	6
Sight hounds	6%	5
Others (e.g standard poodle, GSD)	5%	4

WSD, working sheepdog; BC, Border collie; GSD, German shepherd dog.

404 **Table 4**

405 Mean apparent joint angles for the 3.6 m, 4 m and 5 m hurdle distances

Distance	Neck angle (°)			Back angle (°)			Shoulder angle (°)		
	3.6 m	4 m	5 m	3.6 m	4 m	5 m	3.6 m	4 m	5 m
Take-off	175.3 ± 1.74 [a]	176.06 ± 1.25 [b]	184.5 ± 1.38 [a, ,b]	174.26 ± 1.07 [a]	180.3 ± 1.19 [a, b]	173.71 ± 1.03 [b]	71.92 ± 1.63	71.28 ± 1.41	72.9 ± 1.6
Bascule	173.67 ± 1.58	172.76 ± 0.94	174.9 ± 1.39	173.68 ± 1.1[a]	177.86 ± 1.38 [b]	170.52 ± 0.84 [a, b]	77.41 ± 2.09 [a]	76.67 ± 1.88 [b]	85.5 ± 2.68 [a ,b]
Landing	147.77 ± 2.62 [a]	151.4 ± 1.98 [b]	168.3 ± 1.95 [a, b]	173.91 ± 1.29 [a, b]	158.18 ± 1.22 [b, c]	178.55 ± 1.13 [a ,c]	114.74 ± 1.5 [a]	110.81 ± 1.35 [a]	112.67 ± 1.43

406

407 [a,b,c] significant differences of $P < 0.05$