The effect of the A-frame on forelimb kinematics in experienced and inexperienced agility dogs

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Abstract

Limited research has evaluated the kinematics of agility dogs over different equipment despite the growing popularity of recreational and competitive agility. A-frames are associated with a higher risk of injury; these risks could be related to how dogs approach the equipment. We hypothesised that forelimb (FL) and spinal kinematics would differ throughout the different phases of negotiating the A Frame: incline, apex, decline, and between experienced and inexperienced agility dogs. Eight agility dogs of mixed breed and age, all trained on the A-frame participated in the study. Participants were divided into two groups: inexperienced dogs (ID: <4 years training; n=4) and experienced dogs (ED: >4years training; n=4), and undertook 3 runs over the A-frame. Reflective markers were placed on each dog's carpus (Ca), radiohumeral (RH) and scapulohumerus (SH) joints, Atlas, C3 and L3. Video footage was transferred to Dartfish™ to enable FL joint angles to be calculated for the approach (last stride), incline (FL contact), apex (FL over), decline (FL touchdown and FL departure). The range of movement (ROM) for spinal markers was also calculated. Wilcoxon signed rank analyses, with Bonferroni correction applied ($P<0.02$), indicated if kinematics differed for ED and ID between the phases. Similar kinematic patterns were observed through all phases for C3 and L3, however a greater ROM was found for ED: C3 and ID: L3. For atlas, ED stayed in flexion for all phases whilst ID movement varied: approach-incline extension, incline-apex: flexion, apex to decline extension followed by flexion. No significant differences in FL joint angles existed ($P>0.02$). No significant differences in kinematic measures were seen between Ed and ID dogs in any phases of the A-frame. ED demonstrate consistent movement patterns; ID vary their head and neck position more, and exaggerate their apex jump. Rounding the A-frame apex could encourage a less-extreme technique in ID.

Keywords: dog agility, canine, injury, performance, kinematics

Short Communication

Introduction

Canine agility is a fun and active sport for dogs and their owners, which has become increasingly popular since the first show in 1978 (Kennel Club, 2014a). Agility Dogs are trained and encouraged to manoeuvre themselves over various pieces of equipment set out on a course at speed (Leach, 2006; Kennel Club, 2014b). Generally, within agility 32% of dogs will experience an injury related to their sport; furthermore, inexperienced dogs, defined as those with less than 4 years' agility experience, appear to be at greater risk of injury than their experienced counterparts (Cullen et al., 2013). Despite this, limited research has assessed the biomechanics of dogs participating in canine agility. To date the majority of studies have examined dogs jumping hurdles, revealing that dogs experience high vertical forces in the forelimb and overstretching of the shoulder and spinal joints when jumping, potentially exposing them to repetitive strain disorders such as bicipital tenosynovitis and supraspinatus tendinopathy (Birch and Lesniak, 2013; Pfau et al., 2011). Injury surveys suggest that the A-frame is responsible for more injuries than hurdles (Cullen et al., 2013). Levy et al. (2009) suggested that 27% of overall agility injuries involved the A-frame warranting investigation into how dogs negotiate this piece of equipment.

The A-frame (Plate 1) is a common piece of equipment used within canine agility courses. It is a contact piece of equipment and consists of two 2.74 metre (m) (9 foot) ramps combining to a height of 1.75m (5 foot 9 inches) to give an 'A' shape and includes incline, apex and decline phases (Kennel Club, 2014c). The A-frame angle can be reduced to teach inexperienced dogs how to complete it correctly. Dogs are required to run up the A- Frame incline, cross over the apex and run back down the decline. Contact obstacles also integrate zones at the ends touching the ground which dogs are required to touch with their feet to complete the equipment correctly (Leach, 2006). Dogs injured on the A-frame tend to present with spinal and shoulder injuries predominately, but can also experience carpal and phalangeal injury (Cullen et al., 2013; Levy et al., 2009). Injury acquisition has been anecdotally associated with extension and flexion in the spine throughout the incline-apex-decline phases as well as the increased loading and extension of the forelimb, and increased deceleration (braking) forces observed in downhill locomotion, potentiated by the faster speeds that are encouraged in experienced dogs during agility competition (Lee, 2010).

Although not examined in agility dogs, the effect of gradient on galloping has been investigated in racehorses. Self et al. (2012) found that racehorse speed decreases during downhill running possibly due to an increase in forelimb weight bearing. This loading pattern results in a higher duty factor (the ratio of stance duration to stride duration) compared to vertical locomotion, and creates a longer loading period as well as increasing FL impulse and peak limb force, generating a greater propensity for injury. Duty factor increases were also observed during galloping on an incline; therefore running in both incline and decline conditions generate increased loading in the limbs (Self et al., 2012). The gradients encountered by agility dogs on the A-frame generally exceed those encountered by racehorses, and if similar patterns of loading occur within dog as horses, this could explain the increased incidence of injury associated with A-frames (Cullen et al., 2013; Levy et al., 2009). Running speed and the experience of animals could also affect biomechanical efficiency on gradients; we hypothesised that inexperienced dogs would not display the same kinematic patterns as experienced agility dogs who had acquired defined and efficient motor skill patterns from multiple years of training and competition practice. Therefore, this study aimed to evaluate the effect of the A-frame on forelimb and spinal kinematics in experienced and inexperienced agility dogs.

Method

Eight agility dogs, of mixed breed (Collie n=3; Labrador retriever n=2, Flat coat retriever n=1, Cross breed n=1) and age (3.25±1.81 years), and their owners were recruited via convenience sampling from an agility club in the South West of the United Kingdom; combinations ranged from those who took part in agility for fun to regular agility competitors. For participation in the study all dogs were required to be fit with no known medical conditions by their owner to ensure the safety and welfare of the dog. Dogs were grouped according to experience as defined by Cullen et al. (2013): experienced dogs (ED) (n=4) had four or more years of agility practice even if the dog had not previously competed and inexperienced dogs (ID) (n=4) had less than 4 years' experience in training or competition. All dogs were required to have previously received A-Frame training to participate within the study.

Reflective markers (20mm) were placed on each dog's carpus (Ca), radiohumeral (RH) and scapulohumeral (SH) joints, atlas (C1), cervical vertebra 3 (C3) and lumbar vertebra 3 (L3). Markers were attached to dogs by the same experimenter and were secured with insulation tape. Owners were asked to warm up their dogs by either undertaking a 5-minute walk around the paddock or using their own warm up methods for 5-minutes (mixed exercises involving recall). Placing the markers before the warm up allowed to dogs to familiarise to the markers to prevent any adverse impact upon subsequent data collection (Birch and Lesniak, 2013). Once all dogs had completed the warm up, each dog was allowed a familiarisation run over the A-frame. Then owners were requested to send their dog over the A-Frame 3 times. A successful run over the A- Frame was defined as the dog passing through the starting marker placed 2 metres prior to the incline, to proceed up and over the A- Frame and passing through the finishing marker 1 metre after the decline (Figure 1). A false run was recorded if the dog ran past the A-Frame, prematurely dismounted or did not pass the entry and exit markers. These were discarded from analysis. Dogs were videoed during runs using a Panasonic HDC-SD-10 video camera mounted on a tripod at 24 frames per second (Figure 2). Video footage was transferred to Dartfish™ 7 to enable FL joint angles to be calculated (Gillette and Angle, 2008) for the approach (last stride), incline (FL contact: mid-ramp), apex (FL over), decline (divided into 2 distinct phases: FL touchdown after the apex and FL departure mid-ramp). The range of movement (ROM) for spinal markers was also measured. Mean and standard deviation for each joint angle and spinal flexion and extension were calculated for individual dogs, and for the ED and ID groups. Wilcoxon signed rank analyses, with Bonferroni correction applied (revised significance: $P<0.02$), identified if Ca, RH, SH, atlas, C3 and L3 kinematics differed for ED and ID between the phases.

Results

Limited non-significant differences in kinematics were observed between the ED and ID ($P>0.02$; Figure 3). Atlas (C1) ROM demonstrated the most variation; ID appeared to move their head more and through a greater ROM when they were completing the A-frame than ED. Both groups of dogs presented with similar atlas ROM during the approach with their heads extended (ED: 143.2 ±5.2^0; ID: 143.8 ±16.3^0). ED then demonstrated atlas flexion for the incline, which continued to the apex (132.2±4.3^0) and then ROM gradually increased from the apex to the decline (146.8±9.0^0). ID recorded different patterns: atlas was in extension from the approach to the incline (151.8±12.4^0), in flexion from the incline to the apex (144.6±10.2^0) and in extension from the apex to the decline (155.2±17.4^0) (Figure 4).

A consistent pattern for C3 ROM was observed for both groups throughout all phases of A-frame completion (Figure 3). ROM in L3 also followed a similar pattern, however IDs display increased flexion from the approach (159.5±9.1^0) to the incline (147.1±8.8^0) but achieve the same ROM at the apex (0.1^0 variance). This was followed by extension from the apex and throughout the decline phase (Figure 4).

However no significant differences in FL joint angles or spinal marker ROM (Table 1) were found between the two groups of dogs (ED vs. ID: P>0.02). In contrast, significant differences in ROM were found between incline and apex (75% of IDs; n=3), apex and touchdown (50% of IDs; n=2) and incline and decline (25% of IDs; n=1) of A-frame for individual IDs but not for EDs (P<0.02) (Table 2). Only one ED recorded a significant difference in head and neck ROM between the touchdown and decline phases of the A-frame (Table 2).

Table 1: Mean± standard deviation values for overall joint range of movement across A-Frame phases for all dogs

A-Frame Phases					
Joint	**Approach**	**Incline**	**Apex**	**Touchdown**	**Decline**
Carpus	208.0°± 7.2	206.7°±9.9	124.6°±18.6	210.6°±11.4	214.6°±13.9
Elbow	126.2°±16.6	125.9°±13.1	27.7°± 19.7	125.8°±18.0	131.2°±16.5
Shoulder	129.4°±17.2	139.9°±11.4	125.1°±11.5	137.4°±13.3	138.2°±16.5
Atlas (C1)	143.6° ±12.6	147.0°±12.0	140.0°±14.7	147.1°± 18.7	152.0°±14.8
C3	220.5°±14.3	210.8°± 17.7	192.6°±14.5	196.5°±26.4	204.7°±17.4
T6	161.2°±9.8	162.4°±16.3	166.2°±3.9	166.6°± 3.6	165.6°±5.3
T13	159.7°±8.3	174.3°±3.7	169.0°±4.6	173.4°±7.5	175.0°±8.4
L3	151.3°±10.0	157.8°±9.8	147.0°±7.9	150.0°±4.9	157.0°±9.4

Table 2: Significant differences in mean range of head and neck (C1-C3-T6) movement for individual dogs between phases of the A- Frame; bold values denote statistical significance (P<0.02)

Phases	**Dog 1 ID**	**Dog 2 ID**	**Dog 3 ED**	**Dog 4 ID**	**Dog 5 ED**	**Dog 6 ED**	**Dog 7 ID**	**Dog 8 ED**
Approach vs. incline	0.779	0.208	0.674	0.123	0.779	0.779	0.327	0.208
Incline vs. Apex	0.93	**0.012**	0.050	**0.012**	0.025	0.263	**0.012**	0.069
Apex vs. Touchdown	**0.017**	**0.012**	0.123	0.050	0.161	0.263	0.575	0.036
Touchdown vs. Decline	0.069	0.326	0.69	0.123	0.889	**0.012**	0.327	0.779
Incline vs. Decline	0.123	0.123	0.779	**0.017**	0.263	0.401	0.161	0.208

Discussion

Fundamentally, dogs complete the A-frame in the same way. Inexperienced and experienced dogs within the study displayed minor difference in the locomotion patterns used to negotiate the A-Frame, although these were found to be non-significant. IDs were less consistent in their movement patterns than EDs, which could reflect their inexperience and that they are still refining the motor skills required to complete the A-frame or that they are still focusing on their handler, which is influencing their kinematics. As expected, EDs completed the A-frame faster than IDs and with more consistent head, neck and spinal positioning creating a more fluent and efficient movement pattern through the equipment (Plate 1); this can be attributed to their increased training and experience.

IDs were observed to complete the A-frame more slowly than their experienced peers and were not as consistent in the kinematic patterns. Significant differences were found in mean range of movement particularly between the incline and apex, and apex to touchdown phases ($P<0.02$). The IDs examined either displayed a fast sprint up the incline followed by a rapid decline in speed at the apex before momentarily hesitating at the highest point of the incline, and seeking guidance from the handler, prior to the point of suspension as they negotiate the apex, followed by a rapid decline (Plate 2). Alternatively, the ID negotiated the obstacle using a more consistent, slower and measured approach using more strides to cautiously complete the A-frame, again seeking reassurance from the handler during this process. Whilst ID movement is very similar to EDs, the exaggerated flexion recorded in atlas (C1) and L3 during kinematic evaluation corresponds to IDs moving their head more and looking over the apex before completing it, which could be a manifestation of their unrefined technique, a lack of refined motor skills, apprehension, excitement or distraction (seeking handler) due to their inexperience. Birch et al. (2015) also found IDs exhibited different kinematic profiles compared to EDs when jumping a hurdle. The impact of training on kinematic parameters has been explored in showjumping horses. Certain temporal and linear parameters of free jumping (vertical acceleration generated in the hind limb, vertical velocity at take-off, duration of the airborne phase, and vertical displacement of the centre of gravity during the airborne phase) were found to exhibit consistent patterns from 6 months of age to 4 years (Santamaría et al., 2004). Therefore, differences exhibited in this study may be attributable to talent or inherent skill of the dogs, and not related to experience or the cumulative effect of training. However training has been shown to result in more consistent performance in showjumpers; Lewczuk et al. (2006) reported superior jump performance, defined by kinematic evaluation, in horses with a rider after a training period, compared to the same horses free-jumping loose (with no rider). The ridden condition in Lewczuk's et al.'s (2006) work could be considered the equivalent of having a handler instructing an agility dog and represents the collective impact of previous training, suggesting experience could be an influential factor in performance. Learning a new skill such as negotiating the A-frame requires high cognitive demands and could easily lead to distraction (Helton and Williams, 2007) and can be exciting for dogs altering their motor patterns resulting in abnormal loading (Cullen et al., 2013, Plate 3). Skill acquisition is a key component of equine training regimens (Williams, 2015) and could be responsible for the more refined and consistent motor patterns observed in the EDs found here rather than talent as the EDs were not competing in elite level competition. Further research is warranted to fully understand the impact of training on canine performance and kinematic parameters.

No significant differences were found between forelimb joint angles ($P>0.05$); therefore, we postulate that forelimb functionality is consistent regardless of the dogs' experience level. Loading of the forelimbs occurs during the take-off from the incline and on landing after the suspension phase of the apex (Pfau, 2011). The variation observed in the forelimb joint angles recorded, mirrors the role of the forelimb during the five phases of the A-Frame. Individual differences occur between dogs and are attributed to different methods of approach including speed, different take off locations and the length of time the dog spends in suspension over the apex (Birch et al., 2015; Pfau et al, 2011).

The kinematic patterns observed in both groups of dogs provide evidence to support the loading patterns theorised for agility dogs when completing the A-frame. Dogs jump on and off the contact points when completing the incline and decline phases accompanied by extending their leading forelimb from the shoulder. They also jump over the apex and have been demonstrated to land with an extended leading forelimb which will be exposed to braking forces on landing. Pfau et al. (2011) reported increased peak forces (>45 Newtons) for the take-off and landing phases when agility dogs jump over hurdles compared to running on a level surface (>25 Newtons). Therefore, jumping on and off the A-frame, and over the apex represent opportunities for dogs to acquire shoulder, carpal and digit injuries as reported by owners (Cullen et al., 2013; Levy et al., 2009). Differences were also found between ROM for L3 across the phases of the A-frame. These differences represent how dogs utilise the spine to negotiate the A-frame, with dogs moving from lumbar flexion on the incline to the apex and through the suspension phase, to lumbar extension in the touchdown and decline phases. The rapid changes in spinal kinematics combined with the speed in which agility dogs complete the A-frame present opportunities for injuries to occur, offering an explanation for the high rates of spinal injury reported on this piece of equipment (Cullen et al., 2013; Levy et al., 2009). The exaggerated kinematic patterns observed in IDs compared to EDs, also suggest that IDs have not refined their technique for successfully completing the A-frame and this variability could also expose them to injury, which could explain the higher injury rates recorded in agility dogs with less than 4 years' experience (Cullen et al., 2013). Rounding the A-frame during training and progressively increasing the angle once a consistent and fluent technique has been established, could help prevent injury and promote skill acquisition in IDs. It should also be noted that both IDs and EDs are at risk of repetitive strain, chronic overload and traumatic overload injuries when they train or compete over an A-frame, however these risks should be minimised by effective training and management.

Limitations and future research

Our results represent a preliminary investigation of how agility dog kinematics adapt when completing the A-frame. However the sample size is small, all dogs come from one club, which could translate to training practices preferred by this club, therefore repetition using more dogs, and more clubs is required to confirm the patterns observed here. We chose to divide dogs by experience defined by years of training, however skill level may be a more effective measure to ascertain if movement patterns over the A-frame are related to increased injury acquisition. Future research using skilled or talented agility dogs competing at national level is warranted to analyse if differences in A-frame kinematics exist to this sample. Further investigation of how dog's complete the A-frame as a novel piece of equipment would also be of interest.

Conclusion

Inexperienced and experienced agility dogs display non-significant kinematic differences when completing the A-frame. EDs demonstrate a consistent movement pattern; ID vary their head and neck position more, and exaggerate their apex jump. The kinematic profiles observed in agility dogs when they negotiate the A-frame could explain why this piece of equipment records a high frequency of injuries. Rounding the A-frame apex could encourage a more consistent technique in ID. Agility dog owners and trainers are therefore encouraged to train their dogs to promote a consistent kinematic profile that prevents abnormal loading and exaggerated movements with the aim to reduce canine injury.

Conflict of Interest

No conflicts of interest apply to this work.

Acknowledgements

We would like to thank the Agility club and our participating dogs and owners for their enthusiastic support of our study.

Figure legends

Figure 1: Points of joint angle analysis; red dots symbolise points of analysis

Figure 2: Experimental set up

Figure 3: Range of movement (ROM; degrees) patterns for all dogs during completion of the phases of the A-frame. Touchdown is an intermediate phase that occurs after the dog crosses the apex at the start of the declining ramp. Anatpos: anatomical position of marker, C3: carpus (Ca), radiohumeral (RH), scapulohumeral (SH) joints, atlas (C1), cervical vertebra 3 (C3) and lumbar vertebra 3 (L3).

Figure 4: Comparison of range of movement (ROM; degrees) between inexperienced and experienced dogs across all phases of A-frame completion.

Plate 1: The A-frame (Kennel Club, 2014b)

Plate 2a: Experienced dog completing the A-frame; A: incline, B: apex, C: decline

Plate 2b: Inexperienced dog completing the A-frame; A: incline, B: apex, C: decline

Plate 3: Visual representation of abnormal kinematic patterns associated with excitement in an inexperienced agility dog

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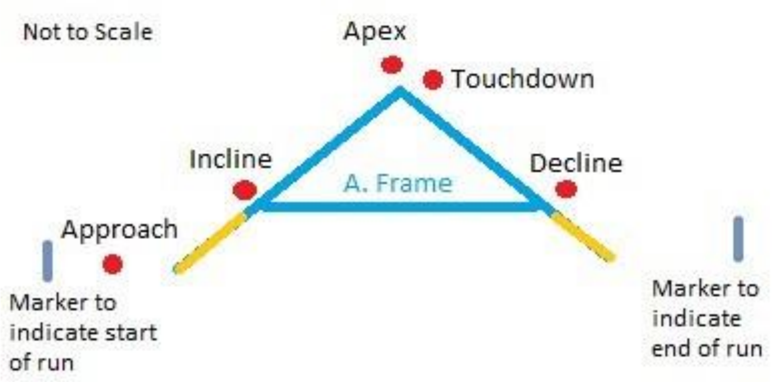
Plate 2b: Inexperienced dog completing the A-frame; A: incline, B: apex, C: decline

Plate 3: Visual representation of abnormal kinematic patterns associated with excitement in an inexperienced agility dog



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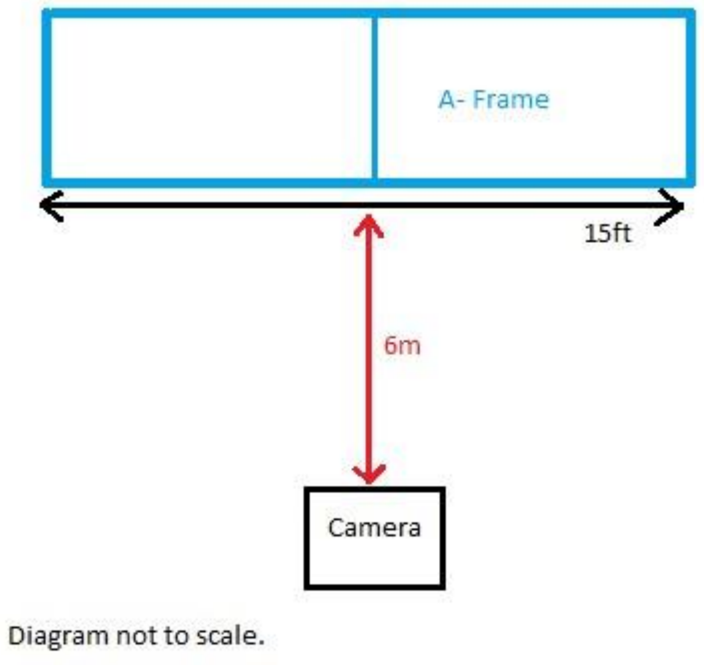

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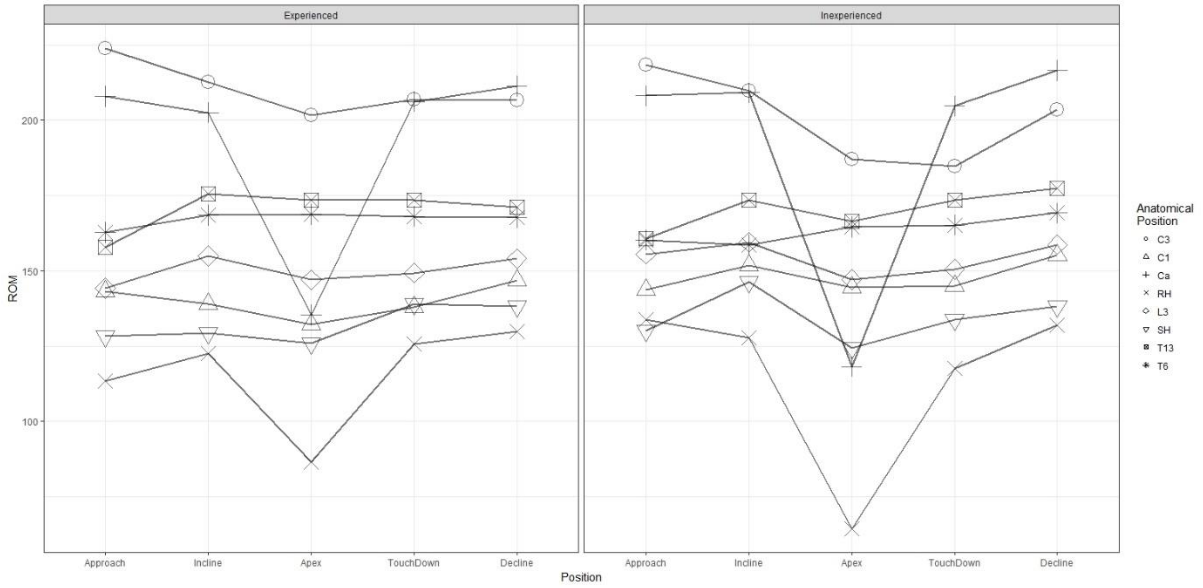

Figure 3

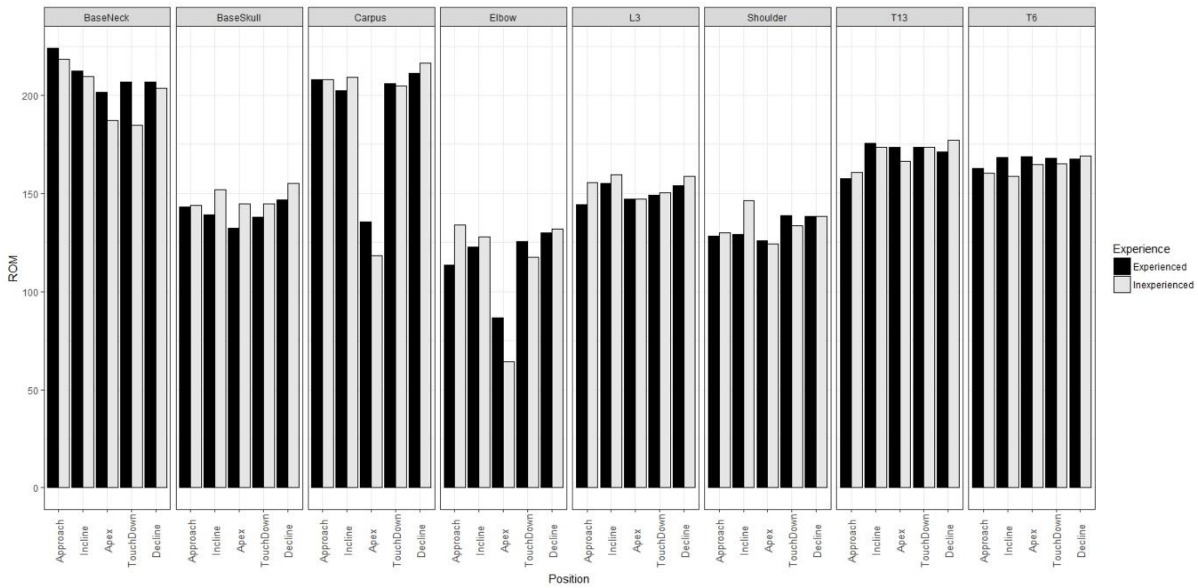

Figure 4

Plate 1

Plate 2a

Plate 2b

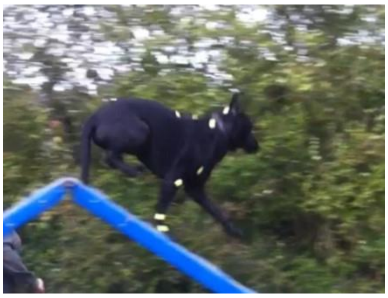

Plate 3