Reduction of the A-Frame Angle of Incline does not Change the Maximum Carpal Joint Extension Angle in Agility Dogs Entering the A-Frame

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Vet Comp Orthop Traumatol 2018;31:77–82.

Abstract

Objective  This article aims to investigate the effect of a decrease in the A-frame angle of incline on the highest carpal extension angle in agility dogs.

Methods  Kinematic gait analysis (two-dimensional) measuring carpal extension was performed on 40 dogs entering the A-frame at 3 angles of incline: 40° (standard), 35° and 30°. The highest carpal extension angle from three trials at each incline was examined for a significant effect of A-frame angle with height, body weight and velocity included as covariates.

Results  There was no significant effect of A-frame angle on the highest carpal joint extension angle for the first or second limb. The adjusted mean carpal extension angle for the first limb at 40° was 64° [95% confidence interval (CI), 60–68], at 35° was 61° (95% CI, 57–65) and at 30° was 62° (95% CI, 59–65). The raw mean carpal extension angle for all dogs across all A-frame angles for the first limb was 62° (95% CI, 60–64) and the second limb was 61° (95% CI, 59–63).

Clinical Significance  Decreasing the A-frame angle of incline from 40° to 30° did not result in reduced carpal extension angles. The failure to find a difference and the narrow CI of the carpal angles may indicate that the physiologic limits of carpal extension were reached at all A-frame angles.

Introduction

Agility is a popular sport where handlers navigate dogs around a set configuration of obstacles including jumps, weaving poles, tunnels and an A-frame. Most obstacles are adjusted to the dogs’ size based on their height at the withers, but other obstacles such as the A-frame, are set at a standard angle of incline for all dogs.

Two previous studies using owner questionnaires have reported on injuries sustained during agility training and competition.1,2 These studies evaluated 1,627 and 3,801 dogs, respectively. Owners indicated injury to a third of the study population and implicated the A-frame as a cause for 29% of these injuries.3 Agility-related sporting injuries in dogs requires further investigation. Members of the Australian National Kennel Council (ANKC) have previously proposed a reduction in the angle of incline of the A-frame to reduce the alleged injuries associated with this contact obstacle, but this proposal was rejected (Proposed change 6.7 presented to Western Australian ANKC: Kriszty Kelly, 27/03/2014).

Subjective observations of agility dogs entering and exiting the A-frame show extreme extension of the carpus (► Fig. 1). The consequence of repetitive loading of this activity is unknown.

Based on observation, it is suspected there is extreme extension of the carpal joint during A-frame agility exercises
Materials and Methods

Study Design
A factorial study design was applied to a cohort of agility dogs to compare the highest carpal extension angle at three angles of incline (40°, 35°, and 30°) of the A-frame in a controlled study environment. To test the hypothesis that reducing the angle of A-frame incline would result in smaller carpal extension angles, estimation of an effect size (mean difference/standard deviation) of 0.5 to 0.4 at 80% power with \( \alpha = 0.05 \) would require a sample size of 31 to 49 dogs, using a factorial design.

Ethical consent was obtained from Murdoch University (R2760/15) prior to study enrolment. The cohort consisted of 40 registered agility dogs (ANKC) that were currently training and competing and all were voluntarily enrolled by their owners with informed consent. All dogs were weighed and their height at the withers was recorded (S.W.). All owners with concern that repetition of this activity could induce injury. Objective measurement of carpal extension angles of dogs entering the A-frame will characterize this activity and allow investigation of whether decreasing the A-frame angle reduces carpal extension.

The aim of this study was to document the highest extension angle of the carpus in a cohort of agility dogs entering the A-frame, and determine if reducing the angle of incline would incrementally reduce carpal extension. We hypothesized that a reduction in the angle of incline of the A-frame from the ANKC standard of 40° to 35° and then to 30° would result in incrementally smaller carpal extension angles.

Dog Preparation
Adhesive reflective markers (medium traditional reflective markers, 3M – Belmont, WA) were attached to anatomic landmarks without clipping the hair over the elbow joint (lateral humeral epicondyle), carpal joint (ulnar styloid process) and metacarpophalangeal joint (head of the fifth metacarpal bone) to allow repeatable measurement of the carpal joint angle. A marker was also placed over the 11th rib at the costochondral junction as an estimate of the location of the centre of mass. The markers were placed by the same investigator (C.A.). Dogs were allowed to explore the room for 10 minutes with the markers in place to adapt to their surroundings and the reflective markers.

A-Frame Set Up
The data were collected in an indoor gait analysis laboratory with a nonslip acrylic sports surface (Plexipave, Sport Surfaces, Perth, Australia) (Fig. 2). A custom-built A-frame built to competition standards that could be adjusted to reduce the angle of incline from 40° to 35° and 30° was positioned in the middle of a 25-m long runway. The change in angle of incline equated to change in peak height of the A-frame from 1,542 mm at 40° angle of incline to 1,376 mm height at 35° angle of incline and to 1,200 mm at a 30° angle of incline. A jump was positioned 3 m from the edge of the A-frame, intended to control the velocity of the dogs entering the A-frame. The dogs were categorized by height at the withers according to ANKC guidelines which determined the jump height. Dogs <270 mm jumped 200 mm, dogs 271 to 365 mm jumped 300 mm, dogs 366 to 455 mm jumped 400 mm, dogs 456 to 545 mm jumped 500 mm and dogs >545 mm jumped 600 mm. Two high-speed cameras (Oqus 3+, Qualisys, Gothenburg, Sweden) capturing at 200 Hz were placed perpendicular to the A-frame to capture the left and right sides of the dog. All video data were collected and synchronized using the Qualisys Track manager software (Qualisys, Gothenburg, Sweden).

Trials
Each dog performed three trials over the A-frame at each angle of incline (40°, 35°, and 30°), off leash but guided by their owners, for a total of nine trials. The dogs were grouped in pairs (based on their arrival time) and the sequence of the A-frame angle of incline was determined by block randomization for each sequential pair. Three trials were completed at each angle of incline and the dog was allowed to rest before the A-frame was repositioned to the next angle of incline.

Data Processing
The videos were assessed by the same investigator using the Kinovea software (http://www.kinovea.org/). The centre of mass marker allowed calculation of the speed of approach (using numerical differentiation of displacement data) using vertical and horizontal velocity components before impact. Vertical (vz) and horizontal (vy) velocity was calculated from displacement and time (velocity = displacement/time) using vertical and horizontal displacement values from three video frames before impact to the moment of impact. Speed was defined as the length of the resultant velocity vector. The cameras were 3.5 m away from the A-frame and length calibration was performed using a known 1-m length.

All carpal angles from initial contact with the A-frame of the forelimb, until the forelimb was no longer in contact with the A-frame, were measured and the highest carpal extension angle recorded. Angles were obtained for the first
forelimb that contacted the A-frame and the second forelimb that contacted the A-frame from the perpendicularly placed left and right cameras. The angles were taken from the first forelimb and the second forelimb that contacted the A-frame, regardless of whether it was the left or right forelimb. The software measured the angle located between the radius/ulna and metacarpal bones (Fig. 3). Carpal joint angles were calculated as 0° depicting all the forelimb joints in alignment, positive degrees represents extension and negative degrees represent flexion. The carpal extension angle was calculated as 180° minus the measured angle.

**Statistical Analysis**

Only data for dogs that had at least one successful run over each of the three A-frame angles were included. The mean highest carpal extension angle for the successful runs (maximum three runs) was calculated for each A-frame angle and was the response of interest. The carpal extension angles were considered continuous and found to be normally distributed based on failure to reject the null hypothesis of normality using the Shapiro–Wilk statistic. Mean and 95% confidence interval (CI) of highest carpal angles were calculated overall, and for various groupings, and reported. The intra-dog coefficient of variation (CV = SD/mean × 100%) was calculated for dogs that had multiple successful trials at each angle of incline and the mean intra-dog CV for each A-frame angle is reported. The mean (CI) velocity for the successful runs (maximum 3 runs) was calculated for each A-frame angle and reported. Velocity was compared between A-frame angles using a one-way analysis of variance for repeated measures followed by post hoc comparisons of means against a Tukey-adjusted \( p < 0.05 \) if the \( F \)-test was significant at \( p < 0.05 \).

The highest carpal extension angles were evaluated using a mixed linear model, including the fixed effect of A-frame angle, the random variance of dog and the covariates dog.
height, body weight and velocity. Where there was a significant effect of A-frame angle, multiple pairwise comparisons were made between A-frame angles using least square means against a Tukey adjusted p-value. Significance was determined at p< 0.05. The least squares mean and 95% CI, and inter-dog CV, adjusted for the covariates, are reported for each A-frame angle. All statistical analysis was performed using SAS v9.4 (SAS Institute, Cary, NC).

Results

The cohort consisted of 14 Border Collies, 4 Jack Russells, 3 Labrador Retrievers, 3 Papillons, 3 Belgian Tervuerens, 2 Irish Terriers, 2 Kelpies, 2 Pugs, 2 West Highland White Terriers, and 1 each of Cavalier King Charles Spaniel, German Short Haired Pointer, Poodle, Samoyed and Springer Spaniel. There were 19 female and 21 male dogs with a mean (SD) age of 5.8 (2.8) years and body weight of 15.9 (6.8) kg. Ten dogs were classified as novice according to ANKC guidelines, 7 as excellent and 23 as masters. Five dogs were in 200 mm jump category, 8 in 300 mm, 2 in 400 mm, 23 in 500 mm and 2 in 600 mm.

Data from 40 dogs were included. Dogs consistently landed with one forelimb touching the A-frame followed by the second forelimb touching the A-frame; that is, no dogs landed with both forelimbs at the same time. Most dogs landed consistently with the same sided (left or right) first forelimb contacting the A-frame.

For some dogs, the carpal extension angles were not available for both forelimbs because the handler obstructed the field of vision of one of the cameras. There were a total of 327 successful trials for the first forelimb and 324 for the second forelimb.

For the 40° angle of incline, there were a total of 113 carpal extension angles recorded for the first forelimb. Only one run could be used to calculate the mean highest carpal extension angle for the first forelimb in one dog, two runs in five dogs and three runs in 34 dogs. There were a total of 110 carpal extension angles recorded for the second forelimb. Only one run could be used to calculate the mean highest carpal extension angle for the second forelimb in one dog, two runs in eight dogs and three runs in 31 dogs.

For the 35° angle of incline, there were a total of 106 carpal extension angles recorded for the first forelimb. Only one run could be used to calculate the mean highest carpal extension angle for the first forelimb in four dogs, two runs in six dogs and three runs in 30 dogs. There were a total of 108 carpal extension angles recorded for the second forelimb. Only one run could be used to calculate the mean highest carpal extension angle for the second forelimb in four dogs, two runs in six dogs and three runs in 30 dogs.

The mean intra-dog CV for the first forelimb touching the A-frame at the 40° angle of incline was 9%, for the 35° angle of incline was 10% and for the 30° angle of incline was 11%. The mean intra-dog CV for the second forelimb touching the A-frame at the 40° angle of incline was 11%, for the 35° angle of incline was 11% and for the 30° angle of incline was 10%.

The overall mean (95% CI) velocity for all included trials was 6.7 m/s (4.8–8.5). The velocity for 40° angle of incline was 6.34 m/s (3.6–9.07), for 35° angle of incline was 5.36 m/s (4.85–5.87) and for 30° angle of incline it was 6.76 m/s (3.37–10.16). The velocity was not significantly different between angles (p = 0.719).

The unadjusted mean (95% CI) overall highest carpal joint extension angle for the first forelimb touching the A-frame was 62.3° (60.2–64.4) and the second forelimb touching the A-frame was 61.4° (59.3–63.5). The adjusted mean (95% CI) highest carpal angle for the first forelimb at 40° angle of incline was 63.9° (60.2–67.6), at 35° was 61.1° (57.4–64.8) and at 30° was 61.8° (58.1–65.5). The adjusted mean (95% CI) highest carpal angle for the second forelimb at 40° angle of incline was 63.1° (59.4–66.8), at 35° was 60.1° (56.4–63.8) and at 30° was 61.1° (57.4–64.8). There was no significant effect of A-frame angle on the highest carpal joint extension angle for the first forelimb (p = 0.288) or the second forelimb (p = 0.182). The adjusted inter-dog CV for each angle of incline, and each forelimb, was 3%, respectively.

Discussion

We failed to demonstrate that a reduction in the A-frame angle of incline from 40° to 35° and 30° would result in incrementally smaller carpal extension angles. Observation of the results shows that the mean highest carpal extension angles in vivo for any forelimb (first or second) for any angle of incline was ~60° with narrow CIs for the estimates. Thus, we consider the failure to find a difference in the carpal extension angles for the different angles of incline of the A-frame is not type II error but indicates no true difference. The carpal extension angles recorded probably reflect normal variation around what may be the maximum physiologic carpal extension possible with A-frame contact.

Agility dog owners have expressed some concern over the effect of carpal extension on the canine carpus and this motivated a proposal by owners to reduce the A-frame angle of incline (Proposed change 6.7 presented to Western Australian ANKC: Kriszty Kelly, 27/03/2014). Repetitive carpal extension to the boundaries of the physiological limit of extension could predispose to carpal sprain injuries. Sprain injuries could be a consequence if agility dogs entering the A-frame experience repetitive maximum carpal extension. The carpus is a unique joint with an extensive range of motion which is further demonstrated by the results of this study. The carpus consists of the antebrachiocarpal, middle carpal and carpometacarpal joints. The antebrachiocarpal joint accounts for ~70% of the carpal range of motion and carpal stability is provided exclusively by soft tissue structures that enables the
The carpus is the extensive range of motion in the sagittal plane. Repetitive loading at the end range of extension could damage these soft tissue structures which most likely involve grade I sprain injuries. Ligaments are dense bands of fibrous tissue with little elasticity. They can be stretched only to a limited degree before fibrous tissue bands (fibrils) will tear.

Based on our results, reducing the A-frame angle in competition from 40° to 30° will not reduce the carpal extension angle on contact. Agility owners and owner questionnaires have implicated the A-frame in causing injury but it appears unlikely that a reduction in the A-frame angle of incline to 30° will address this concern. It has been proposed that agility sporting dogs may benefit from specialized carpal support wraps and orthoses. These devices may reduce the joint range of motion. However, when range of motion is altered in any load-bearing limb, compensatory adjustments are made in other load-bearing limbs as well as in the axial skeleton. The recommendation for supports and wraps should be approached with caution and requires further evaluation. Unilateral soft bandage restriction of carpal range of motion has been evaluated although it did not evaluate custom-made orthoses. The most significant effect was restriction of carpal flexion rather than extension. Increased flexion and extension in the ipsilateral shoulder, and increased extension and decreased flexion within the contralateral stifle, was also reported.

This study used kinematic gait analysis for objective assessment of the movement of dogs entering the A-frame, including measurement of carpal joint angles and velocity. The low mean intra-dog CV supports the repeatability of the study design. Several kinematic gait analysis studies have investigated the movement of the distal forelimb. Comparisons between studies is compromised by dissimilarity in joint angle measurement and failure to specify how measurements were obtained, as well as dissimilar velocity ranges and restricted study populations. Furthermore, kinematic gait analysis can be performed by three-dimensional or two-dimensional gait analysis and it is unknown how the different measurement methods will affect joint angle calculation. The mean (SD) angle of extension of the carpus in a standing dog assessed radiographically is reported as 13.7° (5.7°). The carpal joint angle at a walk (0.8–1.2 m/s) is ~18° throughout most of the stance phase and it reaches a maximum mean (SD) extension at 75% of the gait cycle of 26° (20°). The carpus range of motion has also been evaluated over a slight inclined (6.3°) and declined slope, and over a low obstacle at a walk (0.8–1.2 m/s). There was no difference between the carpal mean (SD) extension angles at a slight incline [25.4° (5°)] and walking on a flat surface [24.8° (4.8°)] but the low obstacle caused a significant increase in the mean (SD) carpal extension to 28.7° (4.4°). Carpal joint angles in agility dogs traversing jumps revealed a mean (SD) maximum extension angle of 44.1° (13.5°) but the velocity was not reported. The carpal extension angle reported in our study is the highest reported carpal extension angle thus far, and the higher angle of incline evaluated combined with the higher velocity probably contributes toward this finding.

This study examined a large heterogeneous cohort. Movement of dogs with different morphology, both size and body type, is variable and was the reason for inclusion of body weight and height at withers. Velocity is affected by limb length and dog body type, and is also known to affect joint range of motion. While the jump in front of the A-frame controlled velocity, velocity was also included as a covariate to further control dog-to-dog variation. Inclusion of these covariates resulted in acceptable and low inter-dog CV. Studies designed to compare breeds for kinetics and kinematics have used various morphometric measurements such as the functional limb length to explain how conformational features affects musculoskeletal function. The factorial study design allowed for controlled comparison within dogs and the intradog variation for trials was 10% or less, indicating good repeatability across trials.

Placement of the skin markers over the presumed joint centres without clipping the hair can induce error and is a limitation. The inability to clip the hair may have induced further error and every attempt was made to part the hair and attach the markers to the skin to limit marker movement. Markers were placed by the same investigator to avoid variation in placement. Mathematical models are used in equine kinematic gait analysis to correct for the biological error that is caused by sliding of the skin over the underlying bone landmarks. Errors in placement could decrease the accuracy of kinematic data and, in turn, would affect the calculated carpal joint extension angles. Furthermore, only one investigator measured the carpal joint extension angles which may introduce bias but obviates interobserver variability. Measurements were categorized according to the first or second forelimb that contacted the A-frame, regardless of whether it was the left or right forelimb. The sequence of the forelimb contact (first versus second) was considered the most likely discriminating feature affecting the carpal angle when landing on the A-frame rather than side (left or right), regardless of sequence. Interestingly, almost every dog landed with the same-sided forelimb first.

In conclusion, the angle of incline of the A-frame between 30° and 40° did not significantly affect the highest carpal extension angle. There was consistency in the maximum carpal extension angles measured across all A-frame angles, and this may represent the limit of carpal extension for the A-frame at an angle between 30° and 40°. Further research is required to assess the effect of repetitive maximum carpal extension on injuries in the carpus and whether any further reduction in the A-frame angle of incline will benefit agility dogs.

Note
Results of this study were presented in part in the Resident Research Competition at the 26th Annual meeting of the European College of Veterinary Surgeons, 13–15 July 2017, Edinburgh, Scotland.

Disclosure
The authors declare no conflicts of interest related to this report.
Author Contributions
Conception of study: all authors; Study design: C. Appelgrein, M. R. Glyde, G. Hosgood, A. R. Dempsey; Acquisition of data: all authors; Data analysis and interpretation: C. Appelgrein, M. R. Glyde, G. Hosgood, A. R. Dempsey; Drafting or revising of manuscript: C. Appelgrein, M. R. Glyde, G. Hosgood, A. R. Dempsey; Approval of submitted manuscript: all authors.

Acknowledgment
Funding in part was provided by the Australian National Kennel Council and the College of Veterinary Medicine, Murdoch University.

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