Frequency of injuries and orthopaedic conditions sustained by flyball dogs.

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Abstract

The risk of injury to canine flyball competitors has been noted as similar to that reported for canine agility, affecting approximately one third of competitors throughout their careers. To date, no studies have examined whether elements such as consistently turning in one direction during the box turn are associated with specific types of injuries. The aims of this study were to describe the frequency and types of injuries experienced by flyball dogs and to evaluate variables that may affect injury occurrence at specific anatomical sites which may give insight into potential ways of reducing injury risk.

An online questionnaire, sent to owners, was used to obtain data on 75 dogs that had sustained an injury whilst training or competing in flyball in the last five years.

Among the 75 dogs, the most common location was the shoulder region (n=17;16.8% of injured dogs), followed by the back and trunk (n=16; 15.8%). Back injuries had the highest recorded number of repeat injuries n=66 (24.63%), and when all individual injuries were considered, 44.40% (n=119) of them occurred on the forelimbs. The most common type of injury was *inflammation* to soft tissue.

There was a statistically significant association between the direction the dog turns at the box and the side of occurrence of injuries at the shoulder ($X^2(2)= 13.71$, $p=0.0242$), with injuries most likely to occur to the limb on the inside of the turn (left turn = left shoulder). For hip injuries, there was also an association with the most affected side and the side of the box turn ($X^2(2)= 6.702$, $p=0.035$), with injuries most likely to occur on the limb at the outside of the turn (left turn = right hip). These findings identify new risk factors for injury within flyball which can be used to improve welfare and safety for competitors.

Keywords: canine injury; flyball; canine sports medicine; questionnaire; injury risk

Introduction

Research into injury amongst flyball competitors has so far, ascertained that the time taken to complete a flyball run and age of competitor are associated with increased injury risk, whilst bandaging of the carpus has also been associated with higher injury frequency, although causality has not been established (Montalbano *et al*., 2019; Pinto *et al*., 2021 Blake *et al*., 2023). Due to the lack of research in flyball, translating kinetics data from agility is currently the only evidence we have for understanding injury in flyball. Rates of injury between the two sports are comparable (Pinto *et al*., 2021; Blake *et al*., 2023), and in agility, jumping is regarded as one of the key contributors to injury (Levy *et al*., 2009; Sellon and Marcellin-Little, 2022). Turning on a flyball box does bear some similarity to an agility wrap jump, which requires an immediate turn just prior, or just after an obstacle. In agility studies, investigations using a pressure mat have found higher contact durations in the left forelimb in comparison to the right when turning left immediately upon landing and peak vertical forces (PVF) have been shown to be higher in the right forelimb than the left, again when turning to the left (Söhnel *et al.*, 2017). Paw preference is still poorly understood in canines (Siniscalchi *et al*., 2014) but flyball research to date shows that dogs will have a turn preference, which rarely changes throughout their career (Pinto *et al*., 2021; Blake *et al*., 2023). The combination of turning, push-off and landing from the flyball box will therefore involve repeated, asymmetrical loading of the musculoskeletal system, which could have implications for the health and wellbeing of competitors. As such, research is needed to understand whether consistently turning in the same direction can lead to specific injuries, which may give further insight into how welfare may be improved for competitors. A confounding factor is that the angle of impact of a flyball box is not standardised across flyball teams, meaning that levels of asymmetry will be dependent on the angulation used, which may affect both injury type and anatomical location. Whilst there is currently little consensus across agility surveys regarding the most important contributory factors for injuries in the sport (Levy *et al*., 2009; Cullen *et al*., 2031; Kerr *et al*., 2014), the data does agree that agility injuries are consistent with those seen in flyball, with approximately 20% of all injuries occurring to the soft tissues of the shoulder, and a slightly smaller percentage affecting both the iliopsoas muscle or the spine, once contact injuries to the carpus are discounted (Pechette-Markley *et al*., 2021; Pinto *et al*; 2021). The aims of this study were to describe the frequency and types of injuries experienced by dogs involved in flyball, as well as to investigate if repeatedly turning to one side might predispose dogs to more injuries on one side of the body. In addition, we wanted to evaluate additional variables in canine flyball that may affect the occurrence of injuries in any specific site, and, hypothesized that a greater number of injuries to the thoracic limb would be ipsilateral to the turn direction, whilst injuries to the pelvic limbs would be greater on the contralateral side of the turn direction.

Materials and Methods

Study design.

A descriptive, cross-sectional, anonymous online questionnaire was created to enable interactions with a geographically diverse respondent group whilst obtaining a sufficient sample size (Evanz and Mathur, 2006). The survey contained 47, mainly closed-ended, multiple choice questions which gathered data on dogs that had been injured whilst participating in flyball in the last five years. Agreement was obtained from the British Flyball Association (BFA), to allow the questionnaire to be distributed to its 3000+ members via social media and was subsequently made available to them for a period of 4 weeks. Potential respondents were asked to confirm that they were over 18 years of age, registered with the British Flyball Association, and had actively participated in flyball in the last 5 years. Participants were also given information pertaining to their data protection rights, risks and benefits of the study, and withdrawal procedures before being asked for consent. Responses were restricted to a single response per internet protocol address, although participants were able to exit and resume at will. Respondents could also enter responses for up to 10 different dogs, and up to 10 different injuries per individual dog. Questions were influenced by the existing literature and broken down into three categories (biological, performance and injury) (Table 1).

Table 1. Categories of areas of significance which led to creation of questions within flyball injury survey.

Biological	**Performance**	**Injury**
Breed	Normal time to complete course (seconds)	Anatomical location
Age (years)	Turn direction at box (left/right/both)	Type (fracture/sprain/other)
Weight (kg)	Typical box angle used for competing (°)	1st or subsequent injury

Height at withers (inches)	Use of carpal bandaging (yes/no)	Experience when injured (years)
Sex (male/female)	Number of years competing (dog)	Age when injury occurred (yrs)
Dew claws removed (yes/no)	Number of years competing (handler)	Diagnosed with osteoarthritis

Statistical Analysis

After a preliminary power analysis, which concluded a minimum sample size of 65 injured dogs was required, answers to the questions on owner experience, age dog started training and dog age were grouped in categories to facilitate analysis.

Descriptive statistics were calculated for the frequency and types of injuries and then tabulated. Associations between direction of turn at the flyball box (left or right) and most injured side on the limbs (neck, head, back and tail injuries have been excluded) were assessed with the Pearson Chi-square test. Values of $P < 0.05$ were considered significant.

Results

Data for 75 dogs were suitable for analysis once incomplete answers were removed. A total of 268 injuries were reported as a result of dogs having injuries in more than one anatomical location, or repeated injuries in the same location.

When age was categorised, the majority of dogs (n=39, 52%) were between 6 and 9 years old, and the most represented height was 21 inches (n=6, 15.4%). Mean weight was 7.83±0.91 kg, with the most represented weights being 8 kg (n=41, 54.7%) and 7 kg (n=18, 24%). Border Collie types were the most commonly reported breed, accounting for 46% of participating dogs (n=36), whilst Lurchers were the second most common at 9% (n=7) (Table 2). Dogs started flyball at a mean age of 1.92±1.22 years, whilst mean age of dogs at the time of their first injury was 4.4 ± 1.88 years (Fig. 1).

Table 2. Distribution of breed and type for dogs (n =75) whose owners responded to the survey concerning the frequency and types of injuries experienced by dogs competing and training in flyball.

Breed or type	Number of dogs with at least 1 injury	% of breed representation amongst injured dogs*
Border Collie	36	48%
Lurcher	7	9.3%
Labrador	6	8.0%
Whippet	5	6.7%
Spaniel	5	6.7%
Mixed breed	5	6.7%
Jack Russell	3	4.0%
Staffordshire Bull Terrier	1	1.3%
Other	7	9.3%

*Calculated as percentage of dogs in the overall sample.

Forty-one (54.7%) dogs turned right at the flyball box, and the remaining turned left (n=34; 45.3%). No dogs turned in both directions. Forty-seven dogs (62.7%) could complete a standard flyball run between 4.1 and 5.0 seconds, whilst 22.7% could complete a course in under 4.0 seconds (n=17). The remainder took over six seconds. Box angulations between 45-55°, were used by 28.0% of respondents, whilst 29.3 % (n=22) stated 56-65°, 13.3% (n=10) used 66-75°, 6.7% (n=5) used 76-85°, and 1.3% (n=1) used 86-95° boxes. Only 26.7% (n=20) of owners used carpal bandaging for training and competition. Regarding owner experience, the majority of owners (n=39; 52.0%) reported having more than 10 years of experience, whilst the mean numbers of years' experience before dogs suffered their first injury was 3.28±2.03 years.

The most common injury location was the shoulder (n=17;16.8% injured dogs), followed by back and trunk (n=16; 15.8%); stifle (n=15;14.9%), hip (n=11; 10.9%); forelimb paw (n=11; 10.9%); and carpus (n=9; 8.9%). Owners reported that, 54 dogs (72%) had experienced injuries in a single anatomical site, whilst 12 dogs (16%) had experienced injuries in two. Six dogs (8%) had suffered injuries in three different locations, four injured anatomical locations were reported in three dogs (4%), with only one dog (0.4%) suffering injuries in five different anatomical locations (Table 3).

When considered as individual, but repeated injuries, back injuries had the highest incidence (n=66; 24.63%), followed by forelimb paw, carpus and shoulder (n=40; 14.93%; n=39;14.55% and n=37; 13.8%, respectively). Stifle injury was noted as (n=30; 11.2%) and hip injury (n=22;8.5%) (Table 4). All other anatomical locations had less than 10 injuries. When individual injuries were combined per anatomical region, 44.4% (n=119) occurred on the forelimbs; 31.1% (n=83) on the main body (head, neck, back and groin); whilst hindlimb injuries accounted for 24.63% (n=66) of all injuries.

Within shoulder injuries, the most common injury was *bruising/inflammation* (n = 18), followed by tendon or ligament injuries (n=6), and muscle strain/tear (n=4). Amongst the 66 back/trunk injuries (including iliopsoas muscle), the most common injury was muscle strain/tear (n = 31), followed by bruising /inflammation (n=13) and intervertebral disc disease (n=8). Regarding forelimb paw injuries, the most common were lacerations/abrasions (n = 23), inflammation (n=14), and digit luxation (n=2). The most common injuries at the carpus were inflammation (n = 21), dew claw avulsion/fracture (n=11), and laceration/abrasion (n=4) (Table 5).

There was no association between dogs' direction of box turn (left, right or both) and most affected side of limbs injuries (left or right) ($X^2(2)= 1.933$, p=0.380). Similarly, when separated into injuries to forelimb versus hindlimb, there was no statistically significant association between the most injured side on forelimbs and the side that the dog performs the turn at the box ($X^2(2)= 5.251$, p=0.072). However, when injuries were considered in separate anatomical sites, there was a statistically significant association between the side the dog turns at the box and an increase in injuries to the shoulder that is located on the inside of the turn (left turn = left shoulder) ($X^2(2)= 13.71$, p=0.0242). For hip injuries, there was also an association with the most affected side and the side of the box turn ($X^2(2)= 6.702$, p=0.035). Unlike the shoulder, the hip was more likely to be injured if it was on the outside of the turn (left turn = right hip). No other variables were associated with either the type or location of injury.

1. Table 3. Percentages of British Flyball Association dogs with an injury in various anatomic regions, by breed or type of dog.

Anatomic region	**Border Collie**	**Lurcher**	**Labrador**	**Whippet**	**German Shepherd**	**Spaniel**	**Mixed breed**	**Jack Russell**	**Kelpie**	**S' Bull Terrier**	**Other**	**Total**
Shoulder	58.8%	17.6%	17.6%	0%	0%	0%	0%	0%	5.9%	0%	0%	100%
Back/trunk	25.0%	25.0%	12.5%	12.5%	0%	12.5%	6.3%	0%	0%	0%	6.3%	100%
Stifle	46.7%	6.7%	13.3%	13.3%	6.7%	0%	13.3%	0%	0%	0%	0%	100%
Hip	45.5%	18.2%	9.1%	9.1%	0%	0%	0%	18.2%	0%	0%	0%	100%
Forelimb Paw	45.5%	18.2%	9.1%	0%	0%	0%	9.1%	9.1%	0%	9.1%	0%	100%
Carpus	66.7%	0%	11.1%	11.1%	0%	0%	0%	0%	0%	0%	11.1%	100%
Groin	16.7%	0%	0%	0%	33.3%	0%	16.7%	0%	0%	0%	33.3%	100%
Neck	40.0%	0%	20.0%	20%	0%	0%	0%	0%	0%	0%	20.0%	100%
Head	0%	25.0%	0%	0%	0%	0%	25.0%	0%	0%	0%	50.0%	100%
Hock	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Elbow	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
Hindlimb Paw	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100.0%	100%

Data represent percentage of dogs of each breed or type reported to have an injury in that anatomic region. Some dogs experienced > 1 injury

Table 4. Distribution of injuries within British Flyball Asscoiation dogs, when considered as anatomical site and when considered as individual injuries (n=268)

Anatomic region	**Number (%) of individual/repeated injuries**	**Number dogs (%) with injuries in specified anatomic region ***	**Ratio of single injuries in anatomical location versus total number of injuries in same location (repeat injuries)**
Shoulder	37 (13.8%)	17 (16.8%)	2.17:1
Back and trunk	66 (24.6%)	16 (15.8%)	4.12:1
Stifle	30 (11.2%)	15 (14.9%)	2:1
Hip	22 (8.50%)	11 (10.9%)	2:1
Forelimb Paw	40 (14.3%)	11 (10.9%)	3.63:1
Carpus	39 (14.5%)	9 (8.9%)	4.33:1
Groin	6 (2.20%)	6 (5.9%)	1:1
Neck	6 (2.20%)	5 (5.0%)	1.2:1
Head	5 (1.90%)	4 (4.0%)	1.25:1
Hock	8 (2.9%)	4 (4.0%)	2:1
Elbow	3 (1.1%)	2 (2.0%)	1.5:1
Hindlimb paw	6 (2.20%)	1 (1.0%)	6:1
Total	268 (100%)	101 (100%)	2.65:1

*In this column, if the dog had more than one injury on the same anatomic region, it was registered as 1.

196 Table 5. Most commonly reported injuries and orthopaedic conditions, by anatomic region, for British Flyball Association injured dogs (n=268)

Anatomic region	**Injury or condition (Number of dogs)**		
	Most common	**Second most common**	**Third most common**
Shoulder	Bruising/inflammation (18)	Ligament or tendon injury (including MSS and BT (6)	Muscle strain/tear (4)
Back and Trunk	Muscle Strain/tear including iliopsoas (31)	Bruising/Inflammation (13)	Disk injury (8)
Stifle	Cranial cruciate ligament rupture or tear (8)	Bruising/Inflammation (7)	Medial patella luxation and generic lameness (tie: 4 each)
Hip	Bruising/inflammation (12)	Muscle strain/tear (7)	Nerve impingement (2)
Forelimb paw	Laceration/abrasion (23)	Bruising/Inflammation (14)	Digit luxation (2)
Carpus	Bruising/inflammation (21)	Dew claw avulsion/fracture (11)	Laceration/abrasion (4)
Groin	Muscle strain/tear (4)	Laceration (2)	
Neck	Bruising/Inflammation and disk injury (tie: 2 of each)	Nerve impingement and muscle strain/tear (tie: 1 of each)	
Head	Bruising/inflammation (2)	Laceration; eye injury and tooth loss (tie: 1 of each)	

Anatomic region	Injury or condition (Number of dogs)		
	Most common	**Second most common**	**Third most common**
Hock	Bruising/Inflammation (5)	Over extension (2)	N/A
Elbow	Bruising/Inflammation (3)	N/A	N/A
Hindlimb Paw	Laceration/abrasion (6)	N/A	N/A

BT= bicipital tenosynovitis; MSS= medial shoulder syndrome;

Discussion

Our results have shown an association between the direction that a dog turns during a flyball box turn, and anatomical location of injury. The greatest number of shoulder injuries were associated with being on the inside of the box turn, which may be as a result of forces incurred upon both impact and pushing away from the box, so it is assumed that these would mostly occur in the forelimb that first contacts the box. Likewise, if the dog is completing the turn during initial impact, the same limb would be subject to torque as the body rotates, as well as both centripetal and ground reaction forces (Hayati *et al.*, 2019). A similar theory may explain the site of hip injuries, where the majority occurred on the outside of the box-turn. The outer hindlimb would be expected to be the last to leave the box and would also be subject to torque forces as the dog is turning to reverse its direction, whilst the associated musculature is activated to enable push off from the box surface. A similar phenomenon is found in racing greyhounds who incur a higher number of injuries to the left forelimb and right hindlimb, as a result of always running anti-clockwise on an oval track (Mahdavi *et al*., 2019), which mirrors the association we have identified between injuries at the hip and turn direction. If a dog executes a so-called swimmers turn at the flyball box, where it angles its body at take-off in the direction of the turn, so that it does not land head on to the box, it is expected that the hindlimbs would drive off of the box as it turns, creating asymmetrical loading. However, it is unknown which hindlimb may be responsible for the largest amount of force generation, and which direction forces are being applied ie; longitudinal, perpendicular or lateral. By the same measure, the rapid acceleration that is required once a flyball dog completes its turn will require large increases in joint work at both the hip and hock joints, as well as power production via the hip extensor muscles to generate the amount of torque required (Carrier *et al*., 1998), both of which have been shown to be highest in the lead limb in accelerating dogs (Williams *et al*., 2008). No conclusions can be drawn from the data at this stage however, simply because there is no kinetic or kinematic data on this type of canine sporting activity.

Bruising and inflammation were the most common injuries reported in the shoulder, followed by tenosynovitis and tendon related issues. Similar conditions, such as medial shoulder syndrome (MSS) and tendinopathies of the *m. supraspinatus*, *m. infraspinatus*, and *m. bicep* are also associated with both the jump and weave obstacles in agility (Canapp, 2013; Cullen *et al*., 2016). The biceps tendon passively stabilises the shoulder joint, whilst the *m.teres* *minor.*, *m.supra/infraspinatus* and *m.subscapularis.* are active stabilisers (Carrier *et al*., 2008), which would suggest that the box turn may place the shoulder joint at the extremes of its range of motion (Gray, 2005). Loading through the hip joint has been shown to correspond to a dog's bodyweight during jumping or whilst negotiating an obstacle (Fischer *et al*., 2019), but our results, as well as previous flyball studies, have not found a statistically significant association between body mass and injury frequency or risk. This may be because of a general lack of variation of body mass in flyball dogs, but further investigation would be required. We did not find an association between direction of box turn and the most injured side of the body overall, suggesting that the stresses acting on the forelimbs are different from those at the hindlimbs, although previous work by Pinto *et al* (2021) reported a greater degree of injuries in the right side compared to left, but no association with turn direction. With the direction of turn in mind, a fundamental risk to competitors may be laterality, which has been shown to exist in both dogs and horses (Siniscalchi *et al*., 2014; Byström *et al*., 2019). In early training, handlers will ascertain which direction a dog naturally turns, which is then maintained throughout its career. If dogs continually turn to the same side, and approach the box in a similar manner during every run, specific joints will be subject to repetitive, increased loading, which has been shown to be predictive of both acute injury and chronic musculoskeletal conditions (Marcellin- Little *et al*., 2007).Clearly, further research is needed to ascertain the biomechanical demands placed on a dog at the box turn, which would need to include an understanding of the angle of impact with the box, as well as the forces present at contact, push off and landing.

The most frequent injuries reported were seen at the back and trunk (n=66) followed by the forelimb paw (n=40) and carpus (n=39), which are similar to frequencies seen in existing studies relating to both agility and flyball (Pinto *et al*., 2021; Inkilä *et al*., 2022). The back and carpus are noteworthy in that they had a high degree of repeat injuries, which could indicate inadequate recovery times or excessive training and competition workload (Evans, 2007), or a result of chronic conditions developing, which is worthy of further investigation relating to earlier identification of injury. These data could also support the making of recommendations regarding training and equipment to improve competitor welfare. Training or encouraging dogs to turn in either direction at will or on command may lead to a reduction in performance until the dog becomes habituated but could be advantageous in the longer-term regarding decreased time away from the sport due to injury, as well as an improvement in the dog's wellbeing. At present a ball is placed in one of two holes on the flyball box depending on which way the dog turns, and the potential improvements in performance that may be obtained from the mental plasticity required to be able to use either hole, or any tactical advantage that might be gained by having ambidextrous dogs are outside of the scope of this work but warrant further investigation.

Border Collies were the most injured breed, albeit they make up the largest percentage of flyball competitors, which leads us to conclude that the distribution of breeds amongst injured dogs, simply follows the distribution of breeds within the sport. Similar to existing studies (Sellon *et al*., 2018: Pechette Markley *et al*., 2021), there was a relatively low number of dogs who had sustained an injury in more than one anatomical location, however these data may be because owners have stopped competing in flyball if their dogs had been injured multiple times. Similarly, eligibility for our survey was on the basis that respondents were active BFA members, so may not account for owners of dogs injured in previous years that are no longer participating in the sport. Reported injury numbers overall were lower than those seen in previous studies, but our questionnaire accounted for injuries over the last five years, which encompasses the COVID-19 pandemic, where training and competition would not have taken place for a proportion of that time.

There were some limitations to our study, with perhaps the most relevant being that responses were based on owners' perception that injury was as a direct result of taking part in flyball, which may not be the case, but would be very difficult to confirm without access to veterinary records. Also in this regard, because injuries declared were based on owner understanding, specificity in certain cases may have differed if veterinary intervention was sought. An injury that occurred whilst not participating in flyball may only become evident during training or competition, but similarly, an injury that occurs whilst taking part in flyball may take some time to manifest. As such, any survey of this nature has to be viewed in the context of somewhat opaque data. TEXT DELETED

Conclusion

This is the first time that an association has been identified between the direction of box turn and anatomical location of injury in flyball. Currently there is insufficient evidence to state causation, so further research to understand both the kinematics and kinetics of turning at the flyball box is required. Similarly, due to the limitation of owner declared injury, a retrospective study utilising veterinary records would provide more conclusive insight into the potential injury risks to sporting dogs in general. Frequency of training and competition may be a factor regarding rates of injury, with inadequate time given between sessions for recovery, but further research is needed regards optimum practices before any recommendations could be made. Similarly future research into flyball specific, progressive conditioning programmes may be of benefit in reducing rates of injury, as well as exploring whether or not dogs would be capable of turning in either direction during a box turn, which may impact on current injury rates, by reducing the level of ongoing, one sided asymmetrical movement required to take part in flyball.

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References

Birch, E., Leśniak, K., 2013. Effect of fence height on joint angles of agility dogs. Veterinary Journal 198. https://doi.org/10.1016/j.tvjl.2013.09.041

Byström, A. *et al.* (2020) 'Equestrian and biomechanical perspectives on laterality in the horse', *Comparative Exercise Physiology*, 16(1), pp. 35–45. Available at: https://doi.org/10.3920/CEP190022.

Canapp, S.O., Canapp, D.A., Carr, B.J., Cox, C., Barrett, J.G., 2016. Supraspinatus Tendinopathy in 327 Dogs: A Retrospective Study. VE 1. https://doi.org/10.18849/ve.v1i3.32

Carrier, D.R., Deban, S.M., Fischbein, T., 2008. Locomotor function of forelimb protractor and retractor muscles of dogs:evidence of strut-like behavior at the shoulder. Journal of Experimental Biology 211, 150–162. https://doi.org/10.1242/jeb.010678

Carrier, D.R., Gregersen, C.S., Silverton, N.A., n.d. Dynamic gearing in running dogs 11.

Carter, A., Boyd, J., Williams, E., 2022. Understanding the Impact of Scale Height on the Kinetics and Kinematics of Dogs in Working Trials. Frontiers in Veterinary Science 8.

Cullen, K.L., Dickey, J.P., Bent, L.R., Thomason, J.J., Moëns, N.M.M., 2013. Survey-based analysis of risk factors for injury among dogs participating in agility training and competition events. Journal of the American Veterinary Medical Association 243, 1019–1024. https://doi.org/10.2460/javma.243.7.1019

Evans, D.L., 2007. Welfare of the Racehorse During Exercise Training and Racing, in: Waran, N. (Ed.), The Welfare of Horses, Animal Welfare. Springer Netherlands, Dordrecht, pp. 181–201. https://doi.org/10.1007/978-0-306-48215-1_8

Evans, J.R., Mathur, A., 2005. The value of online surveys. Internet Research 15, 195–219. https://doi.org/10.1108/10662240510590360

Fischer, M.S., Lilje, K.E., Lauströer, J., Andikfar, A., 2014. Dogs in motion, 2nd edition. ed. VDH Service GmbH, Dortmund.

Gray, M.J., Lambrechts, N.E., Maritz, N.G.J., Joubert, K.E., 2005. A biomechanical investigation of the static stabilisers of the glenohumeral joint in the dog. Vet Comp Orthop Traumatol 18, 55–61. https://doi.org/10.1055/s-0038-1632932

Hayati, H., Eager, D., Walker, P., 2019. The effects of surface compliance on greyhound galloping dynamics. Proceedings of the IMechE 233, 1033–1043. https://doi.org/10.1177/1464419319858544

Kerr, Z.Y., Fields, S., Comstock, R.D., 2014. Epidemiology of injury among handlers and dogs competing in the sport of agility. Journal of Physical Activity and Health 11, 1032–1040. https://doi.org/10.1123/jpah.2012-0236

Levy, I., Hall, C., Trentacosta, N., Percival, M., 2009. A preliminary retrospective survey of injuries occurring in dogs participating in canine agility. Veterinary and Comparative Orthopaedics and Traumatology 22, 321–324. https://doi.org/10.3415/VCOT-08-09-0089

Mahdavi, F. *et al.* (2019) 'Track Shape, Resulting Dynamics and Injury Rates of Greyhounds', in. *ASME 2018 International Mechanical Engineering Congress and Exposition*, American Society of Mechanical Engineers Digital Collection. Available at: https://doi.org/10.1115/IMECE2018-87156.Montalbano, C., Gamble, L.J., Walden, K., Rouse, J., Mann, S., Sack, D., Wakshlag, L.G., Shmalberg, J.W., Wakshlag, J.J., 2019. Internet Survey of Participant Demographics and Risk Factors for Injury in Flyball Dogs. Frontiers in Veterinary Science 6, 1–6. https://doi.org/10.3389/fvets.2019.00391

Pechette Markley, A., Shoben, A.B., Kieves, N.R., 2021. Internet-based survey of the frequency and types of orthopedic conditions and injuries experienced by dogs competing in agility.

Journal of the American Veterinary Medical Association 259, 1001–1008. https://doi.org/10.2460/javma.259.9.1001

Pinto, K.R., Chicoine, A.L., Romano, L.S., Otto, S.J.G., n.d. An Internet survey of risk factors for injury in North American dogs competing in flyball 62, 8.

Sellon, D.C., Marcellin-Little, D.J., 2022. Risk factors for cranial cruciate ligament rupture in dogs participating in canine agility. BMC Veterinary Research 18, 39. https://doi.org/10.1186/s12917-022-03146-2

Siniscalchi, M., Bertino, D., Quaranta, A., 2014. Laterality and performance of agility-trained dogs. Laterality 19, 219–234. https://doi.org/10.1080/1357650X.2013.794815

Söhnel, K., Rode, C., de Lussanet, M.H.E., Wagner, H., Fischer, M.S., Andrada, E., 2020. Limb dynamics in agility jumps of beginner and advanced dogs. J Exp Biol 223, jeb202119. https://doi.org/10.1242/jeb.202119

Williams, J.M., Jackson, R., Phillips, C., Wills, A.P., 2017. The effect of the A-frame on forelimb kinematics in experienced and inexperienced agility dogs. Comparative Exercise Physiology 13, 243–249. https://doi.org/10.3920/CEP170014

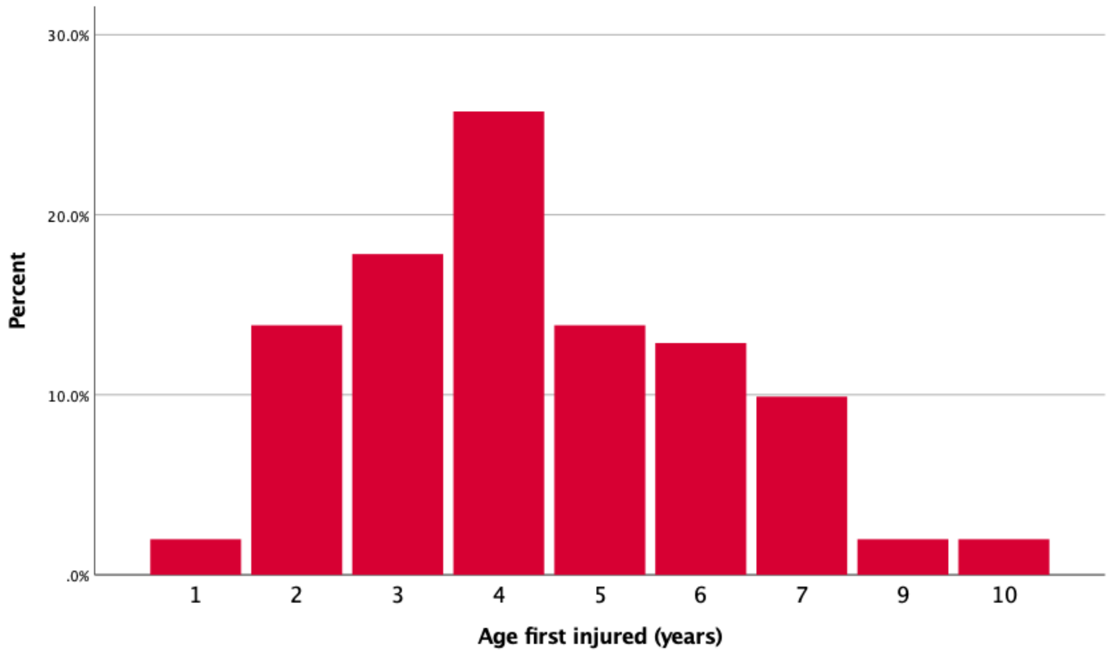

Figure 1. Mean age of injured *British Flyball Association* dogs when first injured.