The Effects of Y-shaped and Chest Harnesses on Canine Glenohumeral Joint Maximal Extension

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Declaration

I hereby certify that the whole of the work being submitted by me in partial fulfilment of the degree of BSc (Hons) Veterinary Physiotherapy complies with the Academic Regulations of Warwickshire College and is the result of my own investigation and study.

Signed: RNB Rachel Bentley

Date: 1st April 2022

Abstract

It has been suggested that harnesses cause biomechanical abnormalities in dogs, such as restriction of glenohumeral joint extension. There are two main styles of harness, chest harnesses (which have been dubbed "restrictive" of glenohumeral joint extension) and Y-shaped harnesses (dubbed "non-restrictive"). This study aimed to compare the effects of Y-shaped and chest harnesses on the maximal glenohumeral joint extension of dogs in walk and trot overground, using 2D video analysis. 27 dogs of varying breeds were filmed walking and trotting on a loose lead, first wearing a collar (C), then a chest harness (H1), and finally a Y-shaped harness (H2). Dogs had markers placed on the lateral epicondyle of the humerus, greater tubercle of the humerus, and proximal aspect of the scapula spine to enable analysis of the glenohumeral joint using Kinovea video analysis software. No significant difference was found between the three conditions in walk (P value = 0.112) and trot (P value = 0.49). The mean values indicate that harnesses did not cause restriction in glenohumeral joint extension angles in walk (C 128.23 ± 11.58 degrees; H1 133.77 ± 10.75 degrees; H2 134.49 ± 9.63 degrees), or in trot (C 134.39 ± 10.19 degrees; H1 136.74 ± 9.99 degrees; 137.60 ± 10.38 degrees). These findings suggest that harnesses do not cause restriction of glenohumeral joint extension when walking or trotting overground, and they instead stimulate increased extension angles. Consequently, this study suggests that harnesses can be recommended for dogs with musculoskeletal disorders that require extra support, as no locomotive changes are induced in regards to glenohumeral joint extension. The findings also suggest that working and assistance dogs can use either form of harness without concern of immobilising the glenohumeral joint, which may lead to locomotive changes and the development of musculoskeletal conditions.

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1.0 Introduction

There are approximately 12.5 million dogs in the UK (Statista, 2022). All dogs must be suitably restrained in public (Control of Dogs Order, 1992); these restraints take various forms. Collars are the only restraint type mentioned in UK legislation (Control of Dogs Order, 1992), but many dog owners opt to use other forms such as head-collars, or harnesses. However, there is limited research on their effects. The research that has been conducted focuses on behaviour, pressure points, and biomechanical influences (Grainger *et al.*, 2016; Peham *et al.*, 2013, and Lafuente *et al.*, 2019). It is vital to understand how restraints impact biomechanics, as abnormal biomechanics can initiate lameness, pain, and joint dysfunction (Cook, 2010). Instability and muscle weakness can lead to inflammation and tissue degeneration (Cook, 2010). As such, it is vital to ensure that restraints do not cause abnormal biomechanics.

It has been suggested that harnesses cause biomechanical abnormalities in dogs, such as restriction of glenohumeral joint extension (Zink, 2019; Lafuente *et al*., 2019). There are two main styles of harness, chest ("restrictive") and Y-shaped ("non-restrictive"). Within the literature, the idea of restrictive and non-restrictive harnesses are commonly discussed (Zink, 2019). Chest harnesses are considered to restrict glenohumeral joint extension as a strap covers the joint. On the other hand, Y-shaped harnesses are considered non-restrictive as the strap sits further from the glenohumeral joint, in theory, making these harnesses less likely to interfere with joint extension. Despite these terms being frequently used, there is no evidence that chest harnesses are more restrictive than Y-shaped harnesses. In fact, the limited research that has been undertaken suggests that Y-shaped harnesses are actually more restrictive of glenohumeral joint extension than chest harnesses (Lafuente *et al*., 2019). As there has been such little research, especially on the movement of dogs overground, the extent to which these restraints cause restriction needs to be investigated further. As such, this study was created to directly compare the effects of Y-shaped and chest harnesses on maximal glenohumeral joint extension, aiming to determine if one harness is more restrictive than the other. This research could provide further insights into the use of harnesses as restraints in dogs, as well as their impact on forelimb biomechanics.

1.1 Project Aim and Objectives

To determine which form of canine harness ("restrictive" or "non-restrictive") restricts maximal glenohumeral joint extension the least in walk and trot.

1. Develop a literature review by researching studies on kinematic analysis methods, canine restraints, and the effect of harnesses on locomotion.
2. Secure a sample of at least 25 participants that are able to walk on a loose lead for all conditions.
3. Collect data by placing skin markers on the anatomical landmarks of the right forelimb, and recording each participant walking and trotting in 3 conditions: flat collar, Y-shaped harness, and chest harnesses.
4. Evaluate footage using Kinovea video analysis software to determine maximal glenohumeral joint extension in all 3 conditions.
5. Analyse the data for statistical significance using ANOVA and determine which hypothesis is accepted.

1.2 Hypotheses

Null hypothesis (H_0): There will be no significant difference in maximal glenohumeral joint extension between restraint type in walk or trot.

Alternative Hypotheses:

H_1: Flat collars will have a significantly increased maximal glenohumeral joint extension angle compared with Y-shaped harnesses in walk or trot.

H_2: Flat collars have a significantly increased maximal glenohumeral joint extension angle compared with chest harnesses in walk or trot.

H_3: Y-shaped harnesses have a significantly reduced maximal glenohumeral joint extension angle compared with chest harnesses in walk or trot.

H_4: Chest harnesses will have a significantly reduced maximal glenohumeral joint extension angle compared with Y-shaped harnesses in walk or trot

H_5: Flat collars will have a significantly reduced maximal glenohumeral joint extension angle compared with Y-shaped harnesses in walk or trot.

H_6: Flat collars will have a significantly reduced maximal glenohumeral joint extension angle compared with chest harnesses in walk or trot.

2.0 Literature Review

2.1 Available restraints

There are many popular restraint types, with these generally fitting into the categories of neck collars, head-collars, and harnesses. The Control of Dogs Order (1992) specifically states that dogs must be restrained using a collar and a lead, however, this legislation does not take into account other restraint types that have since become popular, such as back-connection harnesses. Given that harnesses are not yet recognised in law, it is perhaps unsurprising that studies on them are limited. Although there are many styles of harness, they are generally classified as either non-restrictive, with a Y-shaped chest piece, or restrictive, with a strap across the chest (Zink, 2019). Yet, not enough investigation has been conducted into the effects of harnesses to enable the classification of restrictive or non-restrictive (Grainger *et al.*, 2016). There is also little consensus on the biomechanical impact of harness use; Lafuente *et al.* (2019) argue that both Y-shaped and chest harnesses restrict glenohumeral joint extension, whilst Nagymáté *et al.* (2018) reported that canine kinematics were unaffected by chest harnesses.

2.2 Rationale behind restraint choices

Harnesses are, perhaps, the most common restraint type used on working and assistance dogs. Peham *et al*. (2013) explain that guide dogs cannot work without a harness, as this is how communication between the guide dog and the owner is facilitated. Working dogs, such as police dogs, also wear harnesses. It may not be coincidental that both assistance dogs and working dogs have increased prevalence of osteoarthritis compared to companion dogs (Alves *et al*., 2020). In fact, approximately 16% of guide dogs are retired early due to health conditions, with 28% of these being due to musculoskeletal diseases, such as osteoarthritis (Caron-Lormier *et al*., 2016). Given that both of these working dogs commonly wear harnesses, there may be a correlation between harness use and musculoskeletal disorder development. It has been found that any degree of immobilisation can impact function, resulting in joint inflammation, and cartilage degradation over time, which can lead to osteoarthritis (Andriacchi *et al.*, 2009; Cook, 2010; Millis and Ciuperca, 2015). However, the development of osteoarthritis in police dogs could be due to increased workload and forces through the joints, leading to early degradation of articular cartilage (Akkiraju and Nohe, 2015). Police dogs included in the Alves *et al*. (2020) study are also breeds with a higher prevalence of osteoarthritis than other breeds (Runge *et al*., 2010), which may also explain the increased prevalence in police dogs. Yet, it may still be suggested that harnesses have the potential to worsen musculoskeletal diseases through a reduction in mobilisation, thus inducing early retirement in working dogs. As such, it is important to determine the least restrictive harness design to extend assistance and working dogs' careers and prevent injury.

Unlike the handlers of working dogs, pet dog owners must choose whether to use collars or harnesses. Given that there are different problems associated with each type of restraint, especially when it comes to their behavioural effects, deciding which form to use can be challenging. Harnesses may be selected by the owners of brachycephalic breeds, such as pugs or French bulldogs, so as to avoid pressure to the upper airway since their breathing is already impeded (Packer and Tivers, 2015). Harnesses may also be selected as a safer, or more comfortable, alternative for dogs of any breed that are prone to pulling on the lead; since harnesses distribute force over a wider area than collars (Shih *et al*., 2021), they may be more comfortable. Given that Hunter *et al*. (2019) suggest that dogs naturally pull, regardless of whether they are wearing a collar or harness, the latter may be selected by owners who are conscious of their dog's safety and comfort.

It is worth noting, however, that there is little consensus about whether harnesses exacerbate behavioural issues, such as pulling. Shih *et al*. (2021), for example, found that harnesses are associated with increased pulling, although causation cannot be determined due to the various limitations within this study. For example, reduced pulling in the second trial could be due to the trial design, as dogs were positively rewarded after they had stopped pulling. This could have influenced the second trial, as the dogs would be more likely to repeat the non-pulling behaviour in order to receive a reward (Kang, 2020). This could explain why the dogs pulled to a greater extent in the first food-based trial, and not the second toy-based trial. The sample also consisted solely of shelter dogs whose history is unknown. This may have impacted the study as the dogs pulled "harder and steadier" to reach food but not toys (Shih *et al*., 2021). Given that the dogs' history is unknown, some participants may have been neglected or starved, making them more inclined to reach food (Ziv, 2017). As the dogs' history of restraint use is also unknown, it is unclear whether they had negative associations with a particular restraint type, which may have affected their behaviour, for example, pulling less due to fear of punishment (Ziv, 2017). This lowers the external validity of the study, and must be taken into consideration when applying the results to the general population of dogs in the UK.

Owners may choose to restrain their dog with a collar rather than a harness for various reasons. Perhaps the most obvious reason being that owners are specifically instructed in the Control of Dogs Order (1992) to use a collar and lead. However, in practice, it is unclear how much this impacts which restraints owners choose. Owners may be more likely to consider the behavioural implications of various restraints, especially when it comes to pulling. Being pulled over by dogs is the most common cause of dog-related injuries to people in the UK (Willmott *et al*., 2012), meaning that some owners may use neck collars to reduce their dog's pulling ability. Many owners seemingly opt for increased physical restraint over training, shown in the growing market for devices such as "choke collars" (Herron *et al*., 2009), or self proclaimed "no-pull" harnesses (O'Heare, 2017). As well as the behavioural effects of collar use, there are also emotional effects. Grainger *et al*. (2017), for instance, found that dogs with a history of walking on a neck collar had a lower ear position, suggesting that these dogs were more stressed than those walking in harnesses (Gähwiler *et al*., 2020). Dogs wearing head-collars may have also experienced increased emotional or physical stress, as Ogburn *et al*. (1998) reported that dogs in this restraint type "fought the leash" and pawed at their noses, signifying discomfort.

Behavioural and emotional issues are not the only effects associated with canine restraints; injuries are also discussed in the literature. Injuries caused by the use of neck collars are much more widely explored than harness-related injuries; only one case study exists, detailing how a seatbelt harness caused catastrophic injuries to a puppy in a car accident (Zeleny and Grusova, 2015). On the other hand, injuries caused by neck collars are more widely explored. One such study was conducted by Carter *et al*. (2020) who found that when used as a restraint, all tested neck collar types can cause injury to neck structures. There are many fragile structures in the neck (see Figure 1), such as the oesophagus, larynx, thyroid, and trachea. Neck collars are capable of mechanical or ischaemic damage to all of these structures and the brain, also causing increased intraocular pressure (Grohmann *et al.*, 2013; Pauli *et al.*, 2006). Collars can exert a pressure of between 83 kPa and 832 kPa on the canine neck (Carter *et al*., 2020), whilst harnesses exert a maximum pressure of 26.2kPa (Peham *et al.*, 2013) at the sternum, a far less delicate structure (Hunter *et al.*, 2019). For these reasons, harnesses are often proposed as a safer alternative to collars (Shih *et al.*, 2021), and should be appraised in line with other behavioural and emotional considerations.

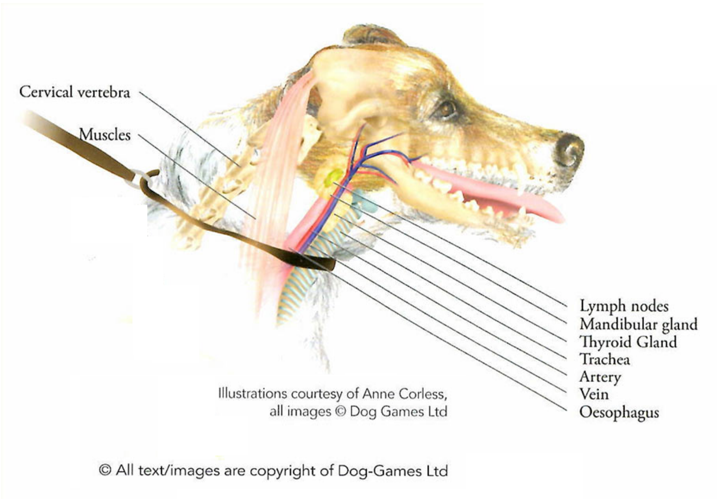

Figure 1: Labelled dog neck anatomy (Corless, 2022)

When it comes to rehabilitation, the use of harnesses is widely encouraged. For example, support harnesses are often recommended post-surgery for stabilisation (Dorn, 2017). Rehabilitative harnesses, such as the "Help’Em up" harness, are available to support mobility until patients are independently ambulatory (Sims *et al*., 2014). These harnesses, and the pelvic support they provide, are particularly beneficial for neurologically impaired patients, typically affected in the hindlimbs (Sims *et al*., 2014). Harnesses can also be used for support where hydrotherapy is required (Preston and Wills, 2018). The National Association of Registered Canine Hydrotherapists (NARCH) state that all dogs receiving hydrotherapy must be fitted with a life jacket or harness to offer maximum support in a neutral spinal position (National Association of Registered Canine Hydrotherapists, 2019). Harnesses are also used in rehabilitative plans for exercises like slow, controlled lead walking (Dycus *et al.*, 2017). Dorn (2019) also details the importance of harnesses for dogs with intervertebral disc herniation as this offers the "safest restraint" when carrying out therapeutic exercises. Dorn (2017) and Dycus *et al*. (2017) do not specify which style of harness should be used for rehabilitation, however, a Y-shaped harness could potentially offer greater support than a chest harness due to their extra chest piece. Chest harnesses are also recommended, with Marcellin-Little *et al.* (2007) endorsing their use after surgical release of the bicipital tendon. Although the authors do not explain why chest harnesses would be most appropriate here, it may be because animals with damaged bicipital tendons guard against glenohumeral flexion and extension (Wernham *et al.*, 2008). Whilst it is not explicitly stated, Marcellin-Little *et al.* (2007) may be suggesting that chest harnesses reduce the glenohumeral joint's range of motion (ROM), thus reducing pain. Any immobilisation of joints and soft tissues can worsen musculoskeletal diseases, so it is important to consider the implications of harness design. Further research is required to improve clinical understanding of the use of harnesses and their biomechanical impacts, to prevent any unintended locomotive changes.

2.3 Harnesses and movement within the literature

2.31 Studying biomechanics through objective gait analysis

The study of biomechanics in dogs can be difficult without the use of objective measures, such as gait analysis (Kostuj *et al*., 2018). Objective gait analysis can assist researchers by allowing a quantitative measure of normal and abnormal gaits (Sandberg *et al*., 2020). Gait analysis is broken into kinematic and kinetic gait analysis. Kinematic analysis involves the study of motion without forces, allowing joint-specific data to be collected (Sandberg *et al*., 2020). On the other hand, kinetic analysis involves the collection of ground reaction forces as they are transmitted through the limb (Hogy *et al*., 2013).

3D kinematic systems are considered the gold standard for advanced kinematic gait analysis (Sandberg *et al*., 2020) as it can detect movements outside of the sagittal plane (Miró *et al.*, 2009). However, 3D analysis imposes significant financial and temporal costs (Maykut *et al*., 2015). As such, kinematic studies often favour the 2D method as it is less expensive, simpler, and does not require very complex equipment (Miró *et al.*, 2009). Kinovea video analysis software uses 2D analysis and has been shown to have high validity, interrater reliability, and intrarater reliability for the analysis of joint angles (Elwardany *et al*., 2015; Abd El-Raheem *et al*., 2015; Elrahim *et al*., 2016). As long as the subject does not stray from the calibration plane, the results of 2D analysis are considered to be fairly accurate. However, as it is not always possible to control animal movement precisely, this can limit its utility in the veterinary field (Maykut *et al.*, 2015).

It is suggested that when kinematic analysis is combined with kinetic analysis, it can provide a more complete depiction of limb function (Sandberg *et al*., 2020). Force plate analysis is the most commonly used method for kinetic gait analysis, in which floor-mounted metal plates measure ground reaction forces (Carr and Dycus, 2016). Force plate measurements have been the most widely used and validated quantitative gait application in veterinary medicine to date. However, force plate analysis has its disadvantages: it cannot measure stride length or joint angles, the software and data analysis are complex, and it is costly and impractical for clinical practice (Carr and Dycus, 2016). An alternative data source for studying motion can be surface electromyography (sEMG), a non-invasive method for recording the electrical activity of muscles using surface electrodes (Negrão *et al.*, 2022). sEMG can provide data to determine muscle, ligament, skeletal or neurological changes that affect locomotion (Araújo *et al.*, 2016). The sEMG signal identifies the initiation of muscle activation, however, only superficial muscles can be detected (Negrão *et al.*, 2022). It would be beneficial for future research to use sEMG, force plate, and kinematic analysis together in the field of biomechanics. Using these techniques in combination would enable the determination of visible biomechanical changes, alongside more imperceptible changes to the superficial tissues, allowing for a more complete picture of how the animal moves.

2.32 Existing literature on the biomechanical effects of harnesses

There has been limited research into the effects of restraints on canine biomechanics. However, there has been some investigation into harnesses and their effects on forelimb biomechanics and stride length. Lafuente *et al.* (2019) studied the effects of Y-shaped and chest harnesses on maximal glenohumeral joint extension and found that both Y-shaped and chest harnesses restrict glenohumeral joint extension, with Y-shaped harnesses restricting extension to a greater degree. Lafuente *et al.* (2019) state that "this result was unexpected", as Y-shaped harnesses were previously dubbed non-restrictive and chest harnesses restrictive.

Although Lafuente *et al.* (2019) are the only authors to have directly compared Y-shaped and chest harnesses, their research is somewhat limited. For example, the authors deviated from the standard positions for skin markers for analysing canine glenohumeral joint kinematics: proximal spine of the scapula; greater tubercle of the humerus; and lateral epicondyle of the humerus (Kopec *et al.*, 2018; Knights and Williams, 2021; Humphries *et al.*, 2020). Lafuente *et al.* opted to use the acromion rather than the greater tubercle of the humerus without explanation. This potentially biases their results as they may have, inadvertently, chosen a location that provides more desirable results. This placement also means that Lafuente *et al.* (2019) studied caudally and dorsally to the glenohumeral joint, rather than the joint itself, reducing the ability to calculate maximal joint extension angles. The authors also neglect to specify the size of the markers used, thus reducing the study's repeatability and reproducibility.

This is not to say, however, that the Lafuente *et al.* (2019) study is not without merit. In particular, the use of a treadmill allowed greater control of conditions, such as the incline, surface type, and consistent walking and trotting speeds for each dog. Although this increased the study's reliability, the use of the treadmill also limits the application of the results to natural canine locomotion. Whilst Lee and Hidler (2008) explain that temporal gait parameters and kinematic patterns are similar between treadmills and overground walking, muscle activation patterns and joint moments are often different, reducing the external validity of the Lafuente *et al.* (2019) study. Lafuente *et al.* (2019) attempted to control the difference in locomotion by acclimating the dogs to the treadmill for "at least one hour". Although this was done in short sessions (3-5 minutes), exercising the dogs for this length of time may have caused fatigue, affecting normal locomotion (Takahashi *et al.,* 2021). Moreover, Gustås *et al.* (2016) found that full treadmill habituation takes at least 80 minutes across two consecutive days, meaning that Lafuente *et al.* (2019) may not have allowed full habituation. This is apparent as Lafuente *et al*. write that the initial sample consisted of 30 dogs, however, 21 dogs could not complete their trials and were excluded due to "suspected subject discomfort and fear of the treadmill". A further limitation is that despite sampling just 9 dogs, the population consisted of unusual breeds, such as a Nova Scotia duck tolling retriever. This reduces the external validity of the study as the sample is not representative of the UK dog population, thus caution must be taken when generalising the results.

Little research has been conducted on chest harnesses and canine locomotion, and the research that does exist has major limitations. Whilst Nagymáté *et al.* (2018) found that chest harnesses do not restrict glenohumeral joint extension, this study has not been peer-reviewed, limiting its credibility. A further study on chest harnesses has been performed by the Hungarian Greyhound Race Society (Julius-K9, 2020) on behalf of Julius-K9, a chest harness manufacturer. This indicates potential bias. It is also important to note that the article is only accessible via the Julius-K9 website as promotional material.

The Julius-K9 (2020) study also has methodological limitations. The method of determining "no restriction on the animal’s movement" was by recording race time, when only kinematic analysis can accurately determine this (Lorke *et al.*, 2017; Lafuente *et al.*, 2019; Bennett *et al.*, 1996; Allen *et al.*, 1994; Schwencke *et al.*, 2012). Julius-K9 (2020) reduced the inter and intra rater reliability of their study by neglecting to use 2D motion analysis software (Damsted *et al.*, 2015). It is stated that all participants' running times were measured to "millisecond accuracy", however, it does not state if these times were recorded using specific measures to avoid human error. Furthermore, the lack of methodological detail provided means that this study is neither repeatable nor reproducible.

2.4 Summary of the literature and scope for further research

Through this brief overview of the existing literature, it is clear that there is little consensus on what restraint type is the most beneficial for both dogs and owners. Although harnesses are beneficial in terms of reducing the risk of neck injuries, and as a tool for rehabilitation, there is still limited understanding of the biomechanical impact of their use (Blake *et al.*, 2019). There has also been little exploration into which form of harness least impacts natural canine locomotion. The only study attempting to compare Y-shaped and chest harnesses is that of Lafuente *et al.* (2019). However, the results of the Lafuente *et al*. (2019) study are limited through their use of a treadmill, as well as their deviation from standard anatomical marker placements to analyse the glenohumeral joint. As such, this study has built upon the work of Lafuente *et al.* to explore the effects of Y-shaped and chest harnesses on maximal glenohumeral joint extension. This study was performed overground using standard anatomical marker positioning, allowing for greater illumination into the effects of harnesses on forelimb biomechanics.

3.0 Methods and Materials

In order to test the difference that harness-type has on shoulder extension in dogs, videos of each participating dog needed to be collected to analyse the extension angle. A pilot study was performed to determine if the trial design was appropriate, and to ensure that any sized participant would be in view of the camera. Once the pilot study was completed and the trial design altered, data collection was able to take place. The study took place over 5 weeks, with a sample of 27 dogs of varying breeds. The study population were acclimated to skin markers placed on bony landmarks of their right shoulder and were then acclimated to walking on a flat neck collar. Next, the dogs were recorded walking and trotting along a 2-metre track at least 4 times in the collar. This procedure was then repeated for the chest harness and then the Y-shaped harness. The videos were then analysed using Kinovea video analysis software and angles were determined for statistical analysis.

3.1 Pilot study

A pilot study was carried out using 2 dogs, one Caucasian Shepherd mix and one German Shepherd. This pilot study ensured the camera quality and track design was appropriate to analyse the right glenohumeral joint. Both dogs were anatomically marked (Figure 1), and videoed using a Sony A6300 camera (60 frames per second) in a flat collar, chest harness, and Y-shaped harness. The pilot study resulted in a few minor changes to track design, such as altering the camera height from 77cm to 56cm, and the distance of the camera to the track from 1m to 1.52m. These changes allowed the full length and width of the track to be in view, enabling any breed to be visible when crossing the track. A further change was that the researcher had to exclude any long-haired breeds as the markers would not stick to the fur of the long-haired German Shepherd used in the study.

Figure 2: Location of anatomical markers, proximal aspect of scapula spine (top), greater tubercle of the humerus (middle), and lateral epicondyle of the humerus (lower) (Author's Own, 2022).

3.2 Study population

The study population consisted of 27 dogs (18 female, 9 male) of varying breeds (please see Table 1), with a mean age of 4.6 years +/- 2.7. Body height, body mass and neutering status were not recorded. This sample size was selected to provide a sample large enough to identify any outliers within the results but was a manageable number to allow data analysis, with 162 videos to analyse. Although there were conformational differences between breeds, potentially influencing the results of the study (Voss *et al.*, 2011), using a mix of breeds is more reflective of the UK's dog population (Statista, 2020), thus increasing the study's external validity. The participants were selected via a survey distributed through social media platforms Facebook and WhatsApp (Appendix A). This surveyed dog owners in the researcher's surrounding area interested in taking part in the study. The survey required owners to fill in their dog's basic information and their contact details to organise data collection. This survey screened all candidates and from this, the researcher excluded any dogs with orthopaedic or neurological conditions, long-haired dogs, dogs under 12 months old, and any dog owners living outside of a 10-mile radius of the researcher's home. 30 dogs were available for data collection, however, 2 had to be excluded due to inability to walk on the lead, and 1 due to hindlimb lameness being present. Originally, the proposed population would have consisted of 25 dogs from rescue centres in Derbyshire, however, the researcher would not have been able to apply the skin markers, fit harnesses and collars, or handle the dogs in any way due to shelter policy. This would have increased the variability between the dogs in different centres as different handling styles could have influenced the dogs' movement (Keebaugh *et al*., 2015). The harnesses or skin markers may have also been fitted/applied differently. When using dogs from a shelter, the history of restraint usage may also be unknown; a dog may have negative associations with one particular condition and thus act unusually (Ziv, 2017). Thus, it was determined that volunteers that would be happy for the researcher to handle their dogs should be sought to limit these variables.

Table 1: Study population listed by breed and age.

Dog	Breed	Age (Years)
1	Beagle	8
2	Boxer	1.83
3	Cocker Spaniel	3
4	Cocker Spaniel	1.83
5	Cockerpoo	4
6	Cockerpoo	2.5
7	Cockerpoo	4
8	Collie x Whippet	10
9	Dalmatian	7
10	Labrador Retriever	10
11	Labrador Retriever	1.92
12	Labrador Retriever	3
13	Labrador Retriever	2
14	Labrador Retriever	3.5
15	Lurcher mix	6
16	Maltese x Poodle	4
17	Miniature Poodle	6
18	Miniature Poodle	4
19	Miniature Poodle	2
20	Miniature Poodle	2
21	Pug	2
22	Saluki x Doberman	6
23	Staffordshire Bull Terrier	2
24	Standard Poodle	9
25	Whippet	8
26	Whippet	8
27	Whippet x Italian Greyhound	3

The owners of all 27 dogs reported no gait-altering medical conditions, and the researcher looked for any obvious lameness in walk and trot prior to the study's commencement. The study was approved by the Warwickshire College Ethics Committee to ensure that dogs' welfare would not be compromised. GDPR regulations were also followed with regards to taking owner details in the survey and in consent forms. A risk assessment was completed prior to the study taking place (Appendix B). Prior to participation, all owners received a briefing about the study and what would be involved, and a consent form was signed by each owner for their dog(s) (Appendix C).

3.3 Experimental trial design

Skin markers 10mm in diameter (Goldner *et al*., 2015) were placed on the right side of the body on the following anatomical landmarks: proximal spine of the scapula, greater tubercle of the humerus, lateral epicondyle of the humerus (Kopec *et al*., 2018; Knights and Williams, 2021; Nagymáté *et al*., 2018; Humphries *et al*., 2020). These landmarks were determined via palpation and visual identification. Yellow stickers 10mm in diameter were placed on white sticky tape, similar to the Lafuente *et al*. (2019) study, to ensure they stuck to the fur and were visible. The researcher identified the anatomical landmarks and placed the skin markers for all dogs to reduce any differences in placement. The researcher has been trained and signed off by a qualified and registered veterinary physiotherapist to correctly identify these landmarks. The application of markers was necessary for video analysis of canine gait (Lafuente *et al*., 2018), and the dogs were recorded walking and trotting along a track to determine the maximal glenohumeral joint angle for each condition using Kinovea video analysis software. It has been found that studying both sides of an animal is unnecessary for accurate kinematic analysis, as the differences between the two sides are negligible (Agostinho *et al*., 2011). As such, only the right side was considered. The dogs were each allowed a period of 3–10 minutes to acclimatise to the skin markers prior to any harness or collar being fitted (Ladha *et al*., 2017), reducing the influence of markers on locomotion, and thus the effect on the results. During this period of acclimatisation, the dogs were encouraged to walk and trot with the handler across the track to accelerate their habituation (Ladha *et al*., 2017). The same handler was used for all dogs to ensure continuity (Keebaugh *et al*., 2015).

A rubber mat track 100cm in width and 200cm in length was placed for the dogs to walk and trot on in front of the camera, allowing at least one full forelimb gait cycle to be recorded. The camera was positioned at 56cm height and was 152cm away from the track, allowing the dog to be in full view in the recordings as they moved down the length of the track (see Figure 3 for the track design). This study was performed overground rather than using a treadmill as Lee and Hidler (2008) have shown that muscle activation patterns and joint moments differ in these conditions. Performing the study overground increases the external validity as this is the usual scenario for a dog walking on a lead.

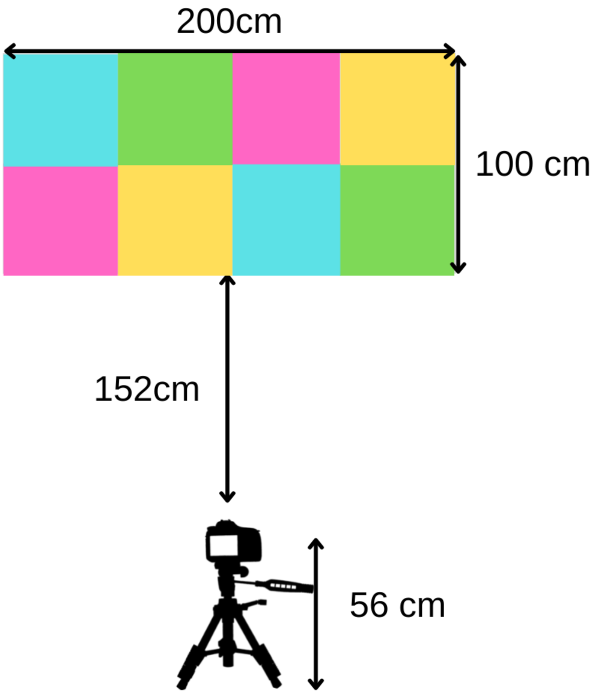

Figure 3: Track design (Author's Own, 2022)

The control condition for this study was using a flat collar, the Halti walking collar made from nylon webbing with a neoprene lining and a clip lock, purchased in a size small, medium and large. The Y-shaped harness was the Front Range Harness from Ruffwear, provided by the company for the study in a size small, medium, and large. The Y-shaped harnesses have a 300 denier polyester ripstop shell, closed-cell foam padding, polyester knit mesh lining, polyester webbing, and the lead was clipped to the back attachment V-ring made from anodized 6061-T6 aluminium. The chest harness was the IDC Powerharness from Julius-K9 with an OEKO-TEX lining and stainless steel back attachment ring, purchased in sizes mini, size 1, and size 3 as these were closest in measurement to the Ruffwear small, medium, and large equivalents. The dogs' neck and girth circumference measurements were sent from the owner to the researcher to ensure they could use the available sizes as per the manufacturer's recommendations. All restraints were fitted as per the manufacturer's fitting instructions.

After the skin marker acclimatisation period, the dogs were fitted with a flat collar and had another 3-10 minute period of acclimatisation prior to data collection (Ladha *et al.*, 2017). The dogs were recorded walking on the flat collar with a loose lead. The right side of their body was in view of the camera, placed perpendicular to the track. They were then turned and walked back down the track but this was not analysed; no useful data could be extrapolated due to the absence of skin markers. This was repeated so there were at least 4 good quality repeats of each dog walking with the right side of their body in view of the camera with a loose lead for each condition. The dogs were then recorded trotting on the flat collar with a loose lead. The 4 repetitions ensured that the researcher would be able to take an average of the 4 measurements for each trial. This ensured that the presence of any anomalous data on 1 of the trials would be identified and would not affect the results.

The dogs were then fitted with the chest harness and the flat collar was removed. They were allowed another 3-10 minute acclimatisation period prior to data collection (Ladha *et al.*, 2017). The dogs were then recorded walking with the lead clipped to the D-ring on the back of the chest harness, repeating the steps taken with the flat collar so that there were 4 good-quality trials of each dog walking with a loose lead. The dogs were then recorded trotting with the chest harness on a loose lead, with the recordings taking place as before. The chest harness was removed and then the same procedure was performed with the Y-shaped harness (3-10 minute acclimatisation period followed by data collection).

3.4 Data analysis

Once all recordings were collected, the videos were uploaded and analysed using Kinovea video analysis software; 2D video analysis software has been found to increase inter and intra rater reliability when analysing gait (Damsted et al., 2015). The maximal glenohumeral joint extension angle was measured using this software through an electronic goniometer for each individual in all three conditions in walk and trot, see Figure 4. For each dog, 4 measurements of the maximal extension angle were taken in each condition, these measurements were then averaged and the mean measurement for each condition were tabulated in Google Sheets. This data was then tested for significant differences of the maximal glenohumeral extension angle, using XLMiner Analysis Toolpak and a single factor ANOVA test, between the three groups: Y-shaped harness, chest harness, and the control condition—flat collar—for walk and trot.

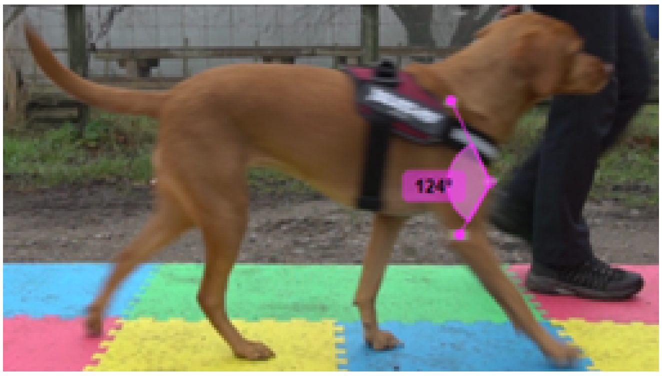

Figure 4: A snapshot of Kinovea's electric goniometer showing the maximal extension angle of the glenohumeral joint in one of the participants (Author's Own, 2022).

4.0 Results

Descriptive statistics determined that the walking control condition produced a mean maximal glenohumeral joint extension angle of 128.23 degrees (+/- 11.58), the Y-shaped harness 134.49 degrees (+/- 9.63), and the chest harness 133.77 degrees (+/- 10.75). See figure 5 for a box plot of the data. When ANOVA was applied to the data, no significant difference was found for the maximal glenohumeral joint extension angle between the 3 conditions (P value = 0.112, degrees of freedom = 80, f value = 2.25).

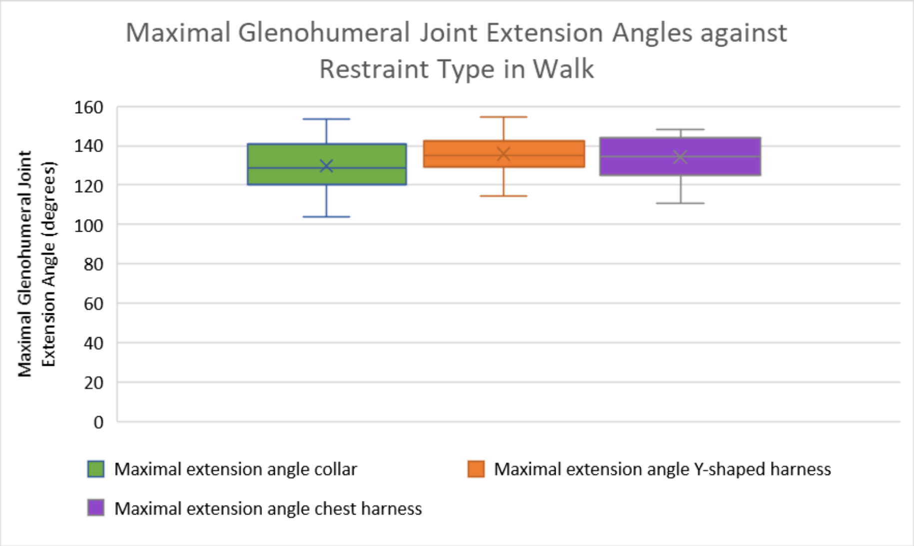

Figure 5: A box plot chart showing the median line, mean value (the X point), and the range of data as the whisker points for the walking maximal extension angle of the glenohumeral joint of the collar control condition in green, Y-shaped harness in orange, and the chest harness in purple.

Descriptive statistics determined that the trotting control condition produced a mean maximal glenohumeral joint extension angle of 134.39 degrees (+/- 10.19), the Y-shaped harness 137.60 degrees (+/- 10.38), and the chest harness 136.74 degrees (+/- 9.99). See figure 6 for a box plot of the data. When ANOVA was applied to the data, no significant difference was found for the maximal glenohumeral joint extension angle between groups (P value = 0.49, degrees of freedom = 80, f value = 0.719).

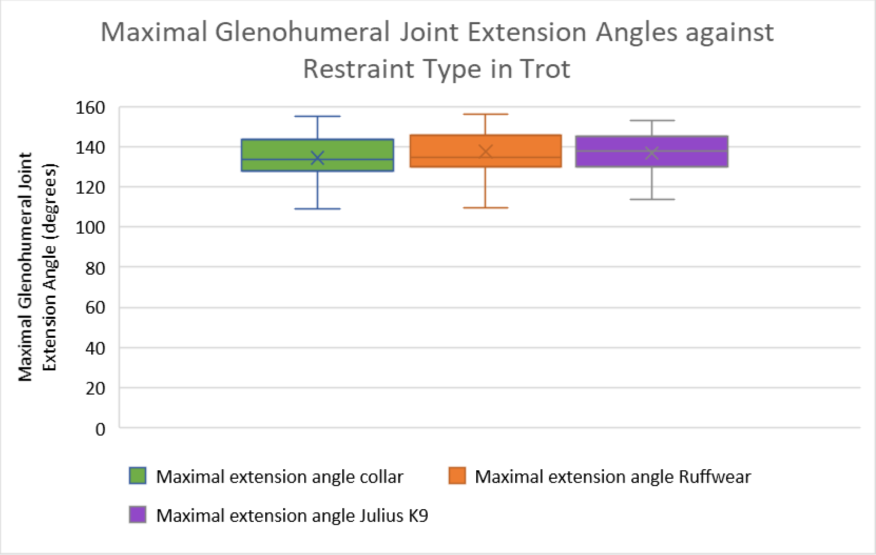

Figure 6: A box plot chart showing the median line, mean value (the X point), and the range of data as the whisker points for the trotting maximal extension angle of the glenohumeral joint of the collar control condition in green, Y-shaped harness in orange, and the chest harness in purple.

There was no significant difference found between Y-shaped harnesses, chest harnesses, and collars, however, the mean maximal extension angles show that the collar control condition produced a lower mean angle than both forms of harness. Extension of the glenohumeral joint increased compared to the collar condition in 92.6% (n=25) of participants walking in the Y-shaped harness, and 63% (n=17) of participants walking in the chest harness. When trotting in the Y-shaped harness, the percentage of participants with increased glenohumeral joint extension is reduced to 81.5% (n=22). Whereas, the percentage of participants with increased maximal glenohumeral joint extension remains at 63% (n=17) when trotting in the chest harness. This shows that the majority of participants had an increased maximal glenohumeral joint extension angle in the harness conditions compared to the collar condition.

5.0 Discussion

This study aimed to determine which form of canine harness least restricts maximal glenohumeral joint extension. In line with previous research by Lafuente *et al*. (2019), it was hypothesised that Y-shaped harnesses would significantly reduce the maximal glenohumeral joint extension angle compared to chest harnesses in walk and trot. However, the findings from this study suggest that there is no significant difference (P>0.05) in maximal glenohumeral joint extension between the two forms of harnesses. The findings also suggest that there is no significant difference in maximal glenohumeral joint extension angles between either form of harness or, surprisingly, the neck collar control condition. As such, the null hypothesis (there will be no significant difference in maximal glenohumeral joint extension between restraint type in walk or trot) is accepted.

5.1 Differences between harnesses

No significant difference was found between chest and Y-shaped harnesses in their restriction of glenohumeral joint extension in walk and trot, which is unexpected for a number of reasons. Firstly, previous research found that Y-shaped harnesses restricted glenohumeral joint extension more than chest harnesses (Lafuente *et al*., 2019). Secondly, because the designs of the harnesses differ, it would be expected that their effects on glenohumeral joint extension would also differ. The findings of this study conflict with those of Lafuente *et al.* (2019), and although the studies are fairly similar, there are still methodological differences that could account for the altered findings. Primarily, the Lafuente *et al*. (2019) study used a treadmill rather than studying locomotion overground, potentially affecting the dogs' movement (Lee and Hidler, 2008). The Lafuente *et al*. (2019) study also used different anatomical marker locations than the current study, possibly explaining the difference in extension angles. As Lafuente *et al*. (2019) studied only medium and large breed dogs, it could be argued that smaller breed dogs, may produce different results.

There are several possible explanations as to why no difference was found between harnesses. For example, although Y-shaped harnesses do not have a strap across the chest, they are designed with a strap that sits caudally of the scapula. This strap could restrict scapular motion, as the scapula is potentially less able to tilt caudally, as occurs in glenohumeral joint extension (Stark *et al*., 2021). As glenohumeral joint restriction is possible in both harnesses, this may explain the insignificant difference in extension angles. Another possible explanation for the insignificant difference between harnesses is that, all harnesses in this study were fitted according to the manufacturers' specifications, something that was not discussed in previous research (Nagymáté *et al*., 2018; Lafuente *et al*., 2019). In fact, one of the limitations that Lafuente *et al*. (2019) discuss is that the chest harness was modified to allow the application of weights. This modification of the harness may have altered the strap position, affecting the results. Whilst the Nagymáté *et al*. (2018) study does not mention harness fitting, they include two figures (see Figures 7 and 8 below) of their participants wearing harnesses. The harnesses are seemingly fitted differently on the two dogs; the chest strap in Figure 7 is positioned at the base of the neck, whereas, in Figure 8 the chest strap appears looser, with the strap covering a lower area. It is possible that no significant difference was found between harnesses in the current study as they were fitted correctly.

Figure 7: One of the participant dogs in the Nagymáté *et al*. (2018) study wearing a chest harness, fitted so that the chest strap sits at the base of the neck. (Source: Nagymáté *et al*., 2018).

Figure 8: A further participant dog in the Nagymáté *et al*. (2018) study wearing a chest harness, fitted so that the chest strap sits lower than the base of the neck. (Source: Nagymáté *et al*., 2018).

Despite different designs of harness being used in the current study, it could be suggested that because both harnesses were tested using the back connection D-ring, they produced similar effects. However, the Y-shaped harness used in this study had both a front connection D-ring located in the middle of the chest piece, and a back connection D-ring. As such, the harness may have produced different effects if the front connection was used in the Y-shaped harness, and the chest harness used the back connection.

5.11 Implications: inter-harness comparison

There are several industry implications for finding no significant difference in glenohumeral joint extension between harnesses. Firstly, there are implications for working and assistance dogs that, as discussed earlier, are often required to wear harnesses to allow them to perform in their roles. Determining that there is no difference between harness styles enables research to be directed at other factors that may affect biomechanics, such as the location of handles on harnesses for guide dogs. The lack of biomechanical difference between the harnesses also means that working dogs, like police dogs, can use the most appropriate design for their role without concern over biomechanical abnormalities being induced by one particular design. It can also be determined that harness use does not cause immobilisation or restriction of glenohumeral joint extension, and as such, we can be more confident that harnesses are not the cause of increased musculoskeletal disorder prevalence in working dogs. The increased prevalence of osteoarthritis, for example, in working dogs can now be investigated further, eliminating harnesses as a potential source of biomechanical abnormalities. However, as this study did not investigate dogs in working conditions, this reduces our ability to generalise the results to working dogs. As such, it would be beneficial for future research to study working dogs in their roles, for instance, climbing stairs or jumping fences, whilst wearing different harness designs.

Handlers of working dogs are not the only group that may be affected by the findings of the study, implications also exist for pet owners. Owners of dogs that wear harnesses for medical reasons, as well as owners of brachycephalic breeds (Packer and Tivers, 2015), can be reassured that they can use either form of harness without inducing restriction of the glenohumeral joint. As such, pet owners have increased choice in their selection of harness, enabling them to choose the style that best suits their dog in terms of comfort, ease, and budget. This study only used 2 brachycephalic breed participants, thus, care should be taken when applying the results to brachycephalic breeds. It would be beneficial for further research to be undertaken looking specifically at these breeds to determine if harness use may affect their biomechanics differently.

The current study can also be applied to harness use in a physiotherapeutic setting as harnesses are often recommended for rehabilitative use (Dorn, 2017). The findings mean that harnesses can be used freely in dogs with musculoskeletal disorders, without the potential for reduction in glenohumeral joint extension. Rehabilitative and hydrotherapy harnesses can also be endorsed, with the study showing there was no significant biomechanical change in the extension of the glenohumeral joint between harnesses. As such, we can be confident in the use of support and hydrotherapy harnesses, regardless of design, as no unintended locomotive changes are induced in regard to glenohumeral joint extension (Jarvis *et al.*, 2013). However, only healthy dogs, those with no diagnosed orthopaedic or neurological conditions, were considered in this study. As such, this caveat must be taken into account when applying results to dogs with these conditions. Moreover, it would be beneficial for future research to study dogs with diagnosed musculoskeletal conditions.

5.2 Differences between harnesses and collars

Another unexpected finding resulting from this study was that there was no significant difference between harnesses and flat collars in their restriction of glenohumeral joint extension in walk and trot. The mean for each condition in fact suggests that harnesses produce greater extension of the glenohumeral joint than collars, which is perhaps the most unexpected result of the study. This is particularly surprising as the collar was used as the control condition; it was expected to provide the freest movement of the glenohumeral joint as it is positioned away from the glenohumeral joint anatomy (Budras *et al*., 2007), whereas harnesses sit over, or around, the joint (Zink, 2019).

A small-scale study by Nagymáté *et al*. (2018) also found that harnesses did not restrict movement overground in comparison to a no harness condition. However, this research did not specifically look at maximal glenohumeral joint extension. Nevertheless, Nagymáté *et al*. (2018) studied three different forms of chest harness against a no harness condition (the restraint in this condition is unknown) and found that, when studied overground, the harnesses did not significantly affect the movement of the thoracic and pelvic limbs. Nagymáté *et al*.'s (2018) study of three chest harnesses corroborates the results of the current study despite only one chest harness being considered. This similarity in results means that it is more possible to generalise the findings of the current study to all chest harnesses. Whilst there were no significant differences found walking overground, Nagymáté *et al*. (2018) did find significant differences in gait walking on the treadmill in comparison to walking overground. The difference in results provides further confidence in the results of the current study, as it shows that Lafuente *et al*. may not have found significant differences had they investigated overground rather than using a treadmill.

The increased mean glenohumeral joint extension angles in harnesses compared to collars could be explained by increased proprioceptive input, encouraging the dog to extend further (Hindle *et al*., 2012). An example of stimulating proprioception is using kinesiology tape, this stimulates cutaneous sensory receptors and facilitates muscle contraction (Paulekas and Haussler, 2009). Hydrotherapy using an underwater treadmill is also an excellent example of how proprioceptive input can increase stride length and ROM in the forelimbs of dogs (Preston and Wills, 2018). When walking on an underwater treadmill, dogs have to push through the water to take a step. Similarly, it could be suggested that when dogs are wearing harnesses, they may have a sense of having to push through the material to take a step. However, this theory cannot be quantified as there is no gold-standard method for measuring proprioception (Laboute *et al*, 2019). As such, further research should be undertaken to determine if increased proprioception can increase glenohumeral joint maximal extension in dogs; kinesiology tape could be used, as this is understood to increase proprioception (Paulekas and Haussler, 2009).

There are other, less biological explanations as to why harnesses increased mean glenohumeral joint extension more than collars. It may be that dogs have increased physical and emotional comfort when walking on harnesses compared to walking on a collar (Shih *et al.*, 2021). Increased comfort could potentially result in freer movement of the joints, with dogs in collars being more stressed than those in harnesses (Grainger *et al*., 2017). It would not be illogical to assume that a stressed dog may move with reduced ROM of the joints, fearful of taking full strides due to the increase in physical discomfort that arises from pulling on a collar (Shih *et al.*, 2021). As dogs have increased emotional comfort when walking on harnesses (Grainger *et al*., 2017), they may not have the same concern surrounding taking full strides and, as such, produce increased glenohumeral joint extension. In the Lafuente *et al*. (2019) study, it is not stated how dogs were restrained when studied in the "no harness" condition but the researcher assumed that a neck collar of some description must have been fitted. If the dogs in the Lafuente *et al*. (2019) study had no restraints applied in the control condition, this could explain the reduction in glenohumeral joint extension in the flat collar control condition in the current study. However, this explanation is speculative and must be investigated with further research.

5.21 Implications: collar-harness comparison

Many implications arise from finding no significant difference in glenohumeral joint extension across the three restraints. One such implication is that dog owners have increased choice when selecting restraints. As any alteration to normal limb kinematics can potentially lead to the development of musculoskeletal conditions (Jarvis *et al.*, 2013), reports that harnesses restrict movement may have concerned some owners and prevented them from choosing harnesses. As this study has determined that harnesses do not cause glenohumeral joint extension restriction, owners may have new confidence that harnesses would not cause musculoskeletal diseases.

The fact that there is no significant difference between these three restraint types also holds implications for dogs' physical and emotional wellbeing, especially when it comes to harness use. Shih *et al*. (2021) determined that harnessed dogs are more physically comfortable than collared dogs, and Carter *et al*. (2020) found that all collar types can cause injury. As such, this study determining that there is little difference between harnesses and collars in terms of glenohumeral joint extension, adds to the consensus that collars may not be the best choice for the physical comfort of dogs. Grainger *et al*.'s (2017) findings that harnessed dogs are less stressed than collared dogs also suggests that harnesses are more comfortable for dogs, albeit in an emotional sense. This may also have implications for owners' choice of restraint, owing to a more comprehensive understanding of collars and harnesses on physical and emotional welfare.

5.3 Limitations and scope for future research

The study was designed based on the limited research that has been carried out previously, particularly drawing from the Lafuente *et al*. (2019) study whilst altering the methods to thoroughly test the hypotheses of the study overground. There were some limitations of this research, those associated with study design, and those associated with analysis techniques. As the study population consisted of 16 different breeds of dog, there is a risk that each form of restraint may affect movement of the glenohumeral joint differently in individual dogs. Body conformation can have an impact on locomotion and biomechanics (Gillette and Angle, 2014), and Voss *et al*. (2011) explain that kinematic data cannot be compared between different breeds due to the variability of gait and conformation. However, the variety of breeds can also be beneficial as it allows the data to be more representative of the population of dogs in the UK, increasing the external validity of the study. It would be beneficial for future research to use only one breed, and repeat the study with a different breed each time. As well as still being representative of the UK dog population, this would also help to eliminate conformation bias.

A further consideration of this study is the influence of external variables, such as surface, inclines, and weather. Some participants performed the trial with the track placed on concrete, and some on grass. As different surfaces produce differences in locomotion (Chateau *et al*., 2010; Symons *et al*., 2013), this could have influenced the results of the study. However, this variable was minimised through the use of a rubber mat placed over the surfaces. Due to the study being performed outside, on the advice of the Government due to the COVID-19 pandemic, weather also became a variable. The study took place over a period of 5 weeks from December-January. As such, the temperature varied between dogs, which could potentially influence the ROM of the joints (Bleakley and Costello, 2013). However, due to the study's design, where all three conditions were recorded on the same day, it is unlikely that systematic bias is present. Lafuente *et al*. (2019) and Nagymáté *et al*. (2018) controlled variables in their study through the use of a treadmill inside, however, this lowers the external validity. It could be argued that conditions in this study were more naturalistic than in the Lafuente *et al*. (2019) and Nagymáté *et al*. (2018) studies, and thus represent a dog's natural walking conditions. Therefore, despite the increased presence of variables, external validity in this study is high.

A potential limitation of the study is that the same handler was employed for each dog, lowering external validity. This was done to ensure handling styles were kept consistent across all participant dogs, though it has to be taken into consideration that the dogs would usually be walked by their owners. As such, the study was not a normal walking situation, therefore behaviour and kinematics may have been affected (Beerda *et al*., 2000). As handlers of dogs have been shown to influence canine forelimb kinetics (Keebaugh *et al*., 2015), it could be suggested that kinematics are also likely to be influenced. Therefore, the use of only one handler reduced the impact that different handling styles would have on the dogs' locomotion and thus, the results. It should also be noted that the study had a considerably larger sample size than several previous studies, with sample sizes all between five and thirteen dogs (Lafuente *et al*., 2019; Nagymáté *et al*., 2018; Peham *et al*., 2013; Knights and Williams, 2021). It may be that some dogs were affected by walking with someone other than their owner, however, a larger sample size will have reduced the effects of this; not every dog will have been influenced by the absence of their owner. A larger sample size increases the accuracy of the mean values, as well as giving more reliable results with greater precision and employability (Hedge *et al*., 2017).

The last notable limitation with the trial design is that skin markers were used. Despite skin markers being frequently used in kinematic studies (Lafuente et al., 2019; Nagymáté et al., 2018; Peham et al., 2013; Knights and Williams, 2021), soft tissue artifacts remain a concern for studies using skin markers (Sandberg *et al*., 2020). Soft tissue artifacts are characterised by the displacement of the skin surface relative to the underlying bone (Lin *et al*., 2018), diminishing the accuracy of the measurements. However, by placing the anatomical markers over the selected bony landmarks, any errors are minimised as soft tissue movement is reduced (Sandberg *et al*., 2020). Skin marker movement in long-haired dogs was identified as a significant problem in the pilot study, as such, to reduce the impact of this, long-haired dogs were excluded from participation. To reduce variability in marker positioning between dogs, the researcher placed anatomical skin markers on each participant. The researcher has been trained by a qualified and registered veterinary physiotherapist to correctly identify anatomical landmarks, as such, increasing the accuracy of placement and the results. It is important to note the potential for marker displacement in the study and this should be taken into account when extrapolating the findings (Lu *et al*., 2020).

There were also limitations of the study in terms of data analysis. The study only investigated one aspect of kinematics, glenohumeral joint extension, neglecting to analyse other possible biomechanical changes. However, glenohumeral joint extension is a key aspect of kinematics in the investigation of restraints, as harnesses have specifically been reported to restrict glenohumeral joint extension (Zink, 2019). Also, the two key papers studying biomechanical effects of harnesses, Lafuente *et al*. (2019) and Nagymáté *et al*. (2018), both investigate the influence of restraints on extension of the glenohumeral joint, suggesting this to be the key aspect of kinematics. This is not to say that future research should not take other areas of kinematics into account, it would be beneficial to study spinal kinematics and other joints to gather a more complete picture of how restraints affect canine biomechanics.

One further limitation is that video analysis was used in this study, with the researcher using their own judgement to determine the maximal point of extension for the glenohumeral joint. This could introduce observer bias as the researcher was aware of the hypotheses so could have subconsciously influenced the results to be more in favour of one condition. Future studies could avoid the influence of observer bias through a secondary individual, unaware of the aims and hypotheses, analysing the footage. One other difficulty with using video analysis was ensuring that the dogs remained strictly perpendicular to the camera and moved in a straight line across the track, as turning from the camera showed an increased angle of the glenohumeral joint. This is a limitation of the use of 2D video analysis (Maykut *et al*., 2015), however, the use of this software has been found to increase inter and intra rater reliability when analysing gait (Damsted *et al*., 2015). As such, the decision to use Kinovea did increase the validity and reliability of the study (Elwardany *et al*., 2015). Future research could combine kinetic and kinematic gait analysis to provide a more complete depiction of limb function (Sandberg *et al*., 2020). Force plates could be used to establish if weight-bearing was altered between harness styles, and this data could be combined with the kinematic analysis of other forelimb and hindlimb joints. Lead influence is another factor which has not yet been investigated. All dogs in the current study used the same lead to reduce variability in conditions. As such, studying the effects of retractable leads, or bungee leads would be beneficial for increasing understanding of the full effects of restraint. Studying the effects of lead position could also be useful, especially when comparing leads attached dorsally, laterally, and ventrally of the neck.

All studies have limitations related to either trial design or data analysis. Whilst bearing the above caveats in mind, this study is a useful starting point for future researchers to explore the biomechanical effects of restraint types in further detail.

6.0 Conclusion

The aim of the study was to determine which form of canine harness restricts maximal glenohumeral joint extension the least in both walk and trot. The findings from this study suggest there is no significant difference ($p>0.05$) in maximal glenohumeral joint extension between the Y-shaped and chest harnesses, as well as the control condition of the flat collar. This was an unexpected result as previous research performed on a treadmill suggested that both forms of harness produce reduced glenohumeral joint extension angles, and Y-shaped harnesses produced greater restriction than chest harnesses. Consequently, this study suggests that harnesses can be recommended for dogs with musculoskeletal disorders requiring extra support as no locomotive changes are induced in regards to glenohumeral joint extension. It also suggests that working and assistance dogs can use either form of harness without concern of immobilisation of the glenohumeral joint leading to locomotive changes and the development or worsening of musculoskeletal conditions.

Further research is required to improve the clinical understanding of the use of harnesses and to determine the biomechanical impact of their use more generally in terms of thoracic limb stride length, other joints' ROM, and pelvic limb locomotion. It would also be beneficial for future research to investigate whether the breed and size of dog may influence the impact of harnesses on locomotion. These investigations would allow a more concrete understanding of how different restraints affect locomotion in dogs, also allowing the determination of the most appropriate restraint to use for the health and welfare of dogs.

7.0 References

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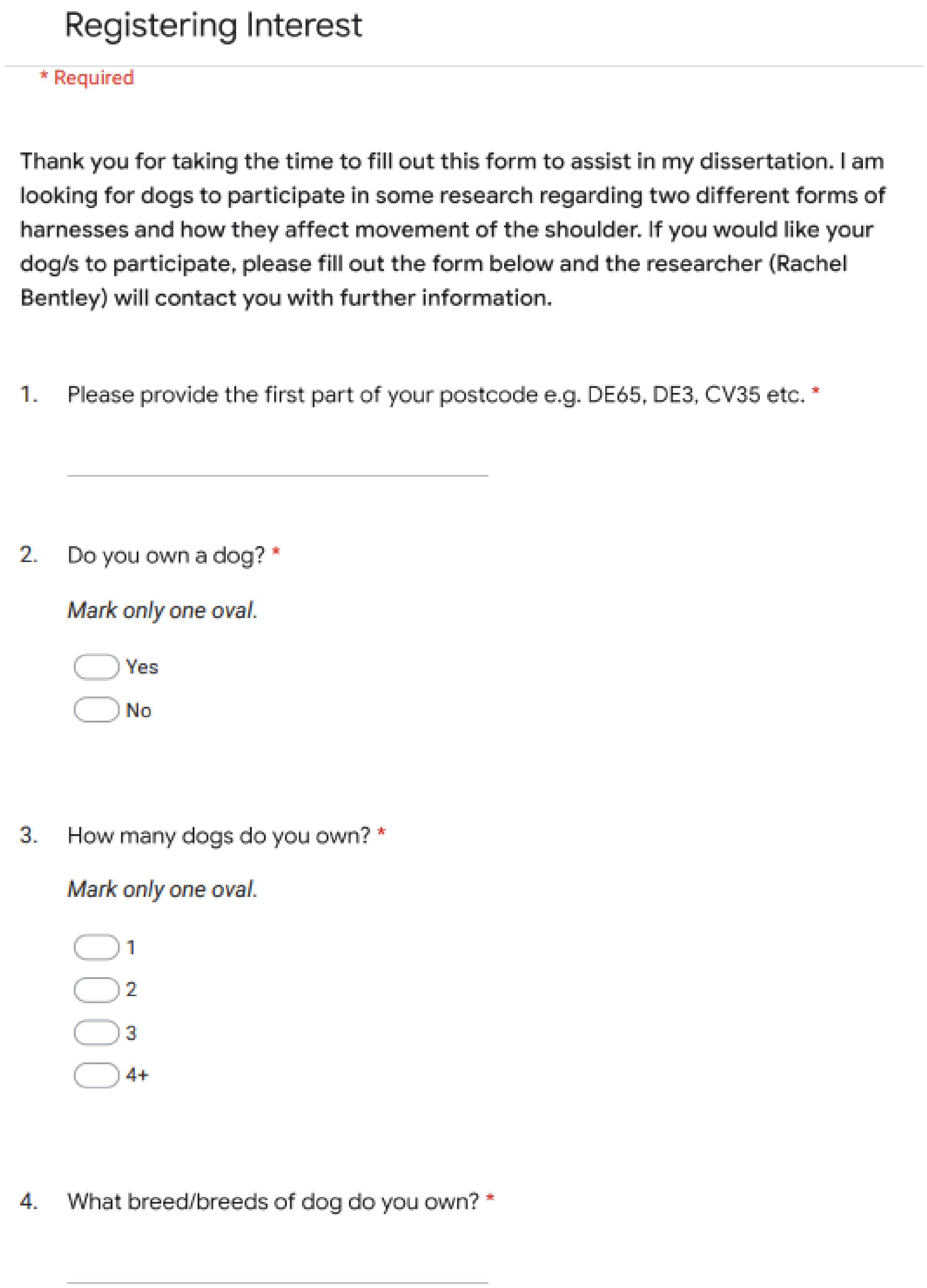
8.0 Appendices

8.1 Appendix A

A survey to register interest



Registering Interest

* Required

Thank you for taking the time to fill out this form to assist in my dissertation. I am looking for dogs to participate in some research regarding two different forms of harnesses and how they affect movement of the shoulder. If you would like your dog/s to participate, please fill out the form below and the researcher (Rachel Bentley) will contact you with further information.

1. Please provide the first part of your postcode e.g. DE65, DE3, CV35 etc. *

2. Do you own a dog? *

Mark only one oval.

○ Yes
○ No

3. How many dogs do you own? *

Mark only one oval.

○ 1
○ 2
○ 3
○ 4+

4. What breed/breeds of dog do you own? *

5. How old is your dog? *

6. Does your dog have any orthopaedic or neurological conditions that may affect their movement? E.g. osteoarthritis, hip dysplasia, elbow dysplasia, degenerative myelopathy *

Mark only one oval.

○ Yes
○ No
○ Unsure

7. Are you happy for the researcher to contact you to discuss using your dogs in their research? *

Mark only one oval.

○ Yes
○ No

8. If you answered yes to the previous question please provide your name and contact information below. *

8.2 Appendix B

A risk assessment

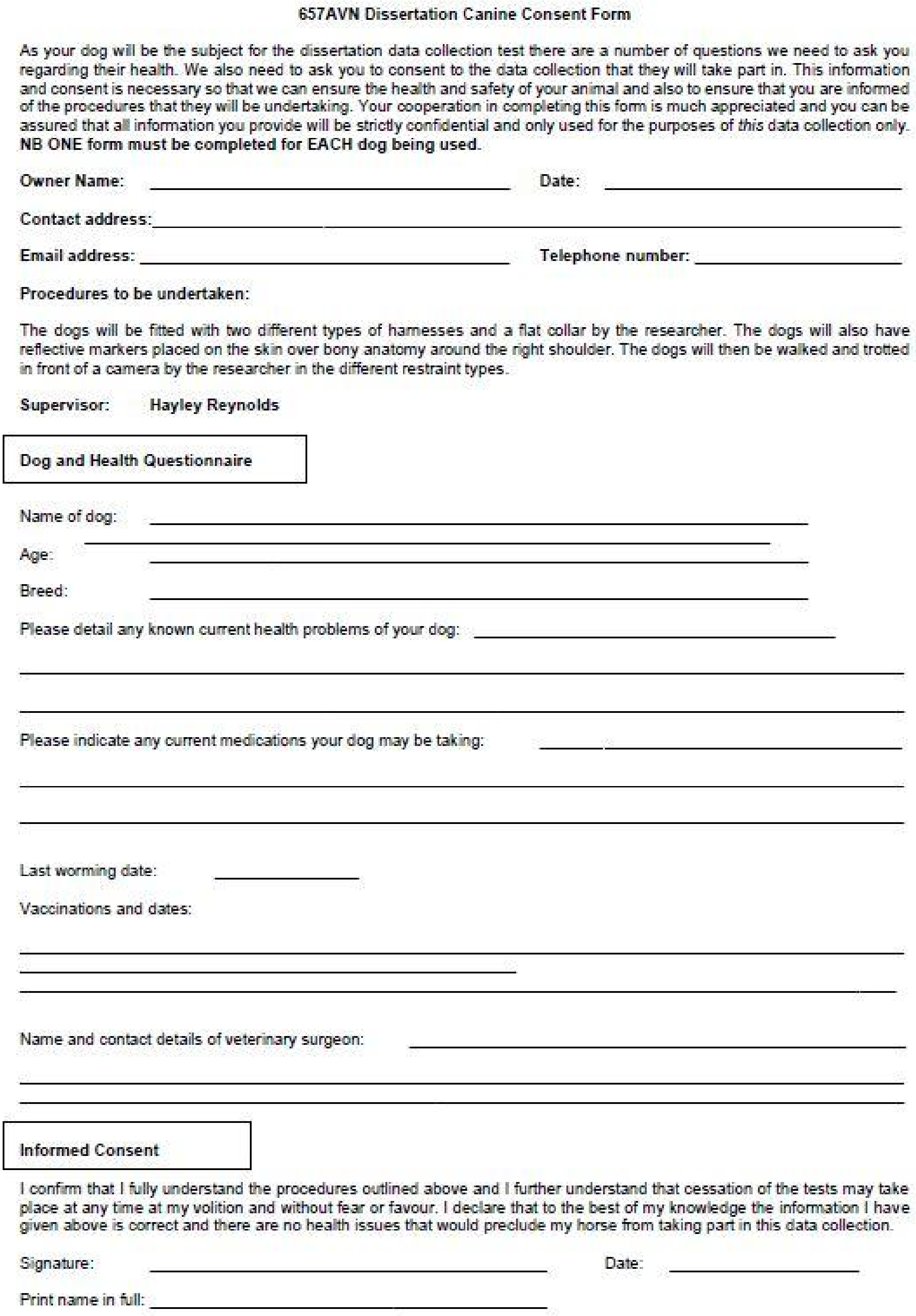
Risk assessment	
Unit/ Department: Animal/Veterinary Nursing	
Logical Assessment Unit:	
Completed by: Rachel Bentley (the researcher)	
Date: 03/11/2021	
Review Date:	
Authorised By:	

PERSONNEL AFFECTED - KEY				**RISK RATING - KEY**			
				Severity	x	Likelihood	
Staff	ST	Contractors	C	Fatality	3	Probable	3
Students	S	Young Persons	Y	Major Injury	2	Possible	2
Public	P		P	Minor Injury	1	Unlikely	1

Activity	Hazards	Who can be harmed	Existing Control Measures	Residual Risk (Severity x Likelihood)	Action Required	By whom	Target Date	Date completed
Handling the dogs - fitting restraints	Dogs biting the handler. Adjusting the harness incorrectly and injuring the dog.	P	The handler is experienced in canine body language and will halt if the dog appears stressed or in any discomfort. The handler will follow fitting instructions via the manufacturer.	(2x1) 2	None	N/A	N/A	
Handling the dogs - walking and trotting	Slips and trips.	P	Non-slip matting will be utilised so the dogs will not slip or trip.	(1x1) 1	The public will be made aware of the presence of the mat and asked to not walk or run on the mat to avoid tripping.	Researcher	Date of data collection	
Walking the dogs	Dogs escaping	P	The dogs will be in an enclosed area with restraints on at all times.	(1x1) 1	Ensure under restraint	N/A	N/A	
Walking the dogs	Temperature - dogs or handlers developing hypothermia	P	If it is deemed unsafe to proceed with the temperature being too low, the study will take place on an alternative day.	(2x1) 2	The handlers will be advised to dress appropriately for the weather.	Researcher	Date of data collection	

8.3 Appendix C

Consent Forms



657AVN Dissertation Canine Consent Form

As your dog will be the subject for the dissertation data collection test there are a number of questions we need to ask you regarding their health. We also need to ask you to consent to the data collection that they will take part in. This information and consent is necessary so that we can ensure the health and safety of your animal and also to ensure that you are informed of the procedures that they will be undertaking. Your cooperation in completing this form is much appreciated and you can be assured that all information you provide will be strictly confidential and only used for the purposes of *this* data collection only. **NB ONE form must be completed for EACH dog being used.**

Owner Name: **Date:**

Contact address:

Email address: **Telephone number:**

Procedures to be undertaken:

The dogs will be fitted with two different types of harnesses and a flat collar by the researcher. The dogs will also have reflective markers placed on the skin over bony anatomy around the right shoulder. The dogs will then be walked and trotted in front of a camera by the researcher in the different restraint types.

Supervisor: **Hayley Reynolds**

Dog and Health Questionnaire

Name of dog:

Age:

Breed:

Please detail any known current health problems of your dog:

Please indicate any current medications your dog may be taking:

Last worming date:

Vaccinations and dates:

Name and contact details of veterinary surgeon:

Informed Consent

I confirm that I fully understand the procedures outlined above and I further understand that cessation of the tests may take place at any time at my volition and without fear or favour. I declare that to the best of my knowledge the information I have given above is correct and there are no health issues that would preclude my horse from taking part in this data collection.

Signature: Date:

Print name in full: