The Influence of Harness Design on Shoulder and Elbow Biomechanics in Pet Dogs

Lauren Dowdeswell

Abstract

Dog harnesses are a popular walking aid used on pet dogs. Research has focused on the biomechanical impact of assistance dog harnesses, however, is lacking in the pet dog harness industry. Current literature disregards the style diversity available, focusing on straight-front or y-front harnesses exclusively. This study aimed to explore the impact of six different harness types on canine biomechanics compared to a standard (base) collar, specifically shoulder extension, shoulder flexion, elbow extension and elbow flexion. A high-speed recording device recorded a total of twenty-one videos per dog (n=30), and analysis demonstrated that the straight-front harness allowed for the most elbow and shoulder extension and flexion, whereas the front-clip allowed for the least, therefore causing the largest reduction of biomechanics. By directly comparing the six harnesses, three of which are new to research inclusion, the evidence drawn demonstrates which harnesses should be utilised more, and which should potentially be avoided. These results provide the starting point for future study, and recommendations have been outlined, specifically considering breed difference, morphological impacts, and long-term effects of harness design on canine gait. With advancements in the canine industry, this research is indispensable to maximise safety and potentially prevent or delay various musculoskeletal disorders.

Keywords - Harnesses, Biomechanics, Flexion and Extension, Quintic.

Literature Review & Introduction

The use of harnesses in the United Kingdom is increasing in popularity (Grainger et al., 2016; Shih et al., 2021); pet dogs, working dogs and sports dogs all utilise different harness styles (Cobb et al., 2015). Studies have investigated harness use on guide dogs (Peham et al., 2013), and harness behavioural impacts (Grainger et al., 2016; Kumpulainen et al., 2021), but research lacks the consideration of pet dogs. Harness brands' Ruffwear (2020) and Julius K9 (2020b) have conducted research to demonstrate the benefits of their own harness, however there are no comparisons between brands. There is a risk that research conducted by parties with financial investment may withhold data to maintain a positive public image (Fabbri et al., 2018), which therefore lowers the reliability of their findings.

Canine Biomechanics

Nagymáté et al. (2018) investigated the biomechanics of three Julius K9 harnesses using 3D motion capture of dogs at walk. The results showed no significant differences between the three harnesses when compared to unleashed movements. This directly challenges Julius K9's poor reputation for causing shoulder injuries and limiting movement (Thompson, 2020). Julius K9 (2020a) state that this opinion is caused by a lack of research and misinformation spread on social media, and have given scientific, biomechanical proof of their harness's safety.

Pálya et al. (2022) completed a follow-up study investigating two 'restrictive' harnesses and two 'non-restrictive harnesses', three of which were Julius k9-branded. They could not overall recommend one particular harness, as it depended on the breed and use of the harness (Edmunds et al., 2021). This further shows that harness impact depends mainly on the build of the individual dog, so opinions on certain brands should not be generalised.

Zink (2019) compared a straight-front and y-front harness, hypothesizing that the straight-front harness would restrict movement. Assessments of dogs on a treadmill at walk and trot showed that the y-front allowed for less shoulder extension than the straight-front, opposing their hypothesis. They assumed this to be caused by incorrect harness fitting and is therefore a limitation of the study as other research has shown that ill-fitting harnesses can impact gait (McMillan and Spaulding, 2022). Internal validity of this study is weakened, as incorrectly fitting harnesses were not controlled or measured, making it an extraneous variable and influencing results (Flannelly et al., 2018).

Furthermore, their small sample size of nine dogs increases the risk of Type II errors, which occurs when data fails to show the differences in statistical tests due to a small sample (Sedgwick, 2014). This decreases the accuracy of results (Alobeng, 2016). This sample size was restricted further by the inclusion of Border Collies only. The results may represent the breed, but cannot be generalised to their target population of all dog breeds (Omair, 2014; Winter, 2013).

Lafuente et al. (2018) completed a similar study utilising a treadmill but implemented markers on the dogs for angle analysis. They also found y-shaped harnesses reduced shoulder extension more than the straight-front. While markers can increase accuracy (Moro et al., 2022), some studies have shown that markers can influence the dogs' natural motion due to the treadmill pressure generating increased skin movement (Schwencke et al., 2012). This means that markers may lead to inaccurate results due to the causation of extraneous variables.

Söhnel et al. (2022) recommend the use of treadmills for gait analysis due to the speed gait analyses can occur, and less variability in movement compared to overground locomotion. However, Piccione et al. (2012) expressed that minimal prior experience on treadmills may impact a dogs' behaviour, therefore influencing their gait Dogs have three planes of motion, but treadmills only allow for one (Torres et al., 2013), potentially altering their gait (McIntyre, 2019). This may misrepresent the impact of harnesses on typical pet usage.

Musculoskeletal Disorders

O'Neill et al. (2017) looked into disease predisposition in German Shepherd Dogs, finding that musculoskeletal disorders, such as osteoarthritis, were the leading cause of death. Mocchi et al. (2020) found extensive reports of osteoarthritis in veterinary practices. Osteoarthritis is the irreversible, progressive degeneration of bone and cartilage (Zeira et al., 2018). Belshaw et al. (2020) looking into gait changes caused by osteoarthritis, finding that exercise was severely impacted. Considering the influence of a harness on the musculoskeletal system, it is likely that dogs will adapt their gait to accommodate a harness during exercise, and this adaptation may be more severe if the harness is ill-fitting (Anderson, 2020).

In humans, osteoarthritis cannot be cured, but progression can be prevented by maintaining a healthy weight and adequate exercise (Charlesworth et al., 2019). Presumably, these will also help to manage canine osteoarthritis. Both the AKC (American Kennel Club) (2022) and Pettitt and German (2016) state that a controlled diet, exercise and joint supplements will prevent joint and tissue degeneration. Research has proven that harnesses can impact the skeletal system (Fleyshman et al., 2021), so harness style and fitting may also aid in management of osteoarthritis.

Harnesses can alter posture, impacting the asymmetries between specific joints (Packer and Tivers, 2015). This can significantly impact breeds with conformation disorders, such as English Bulldogs (Escobar et al., 2017). Conformational disorders occur in breeds with exaggerated body structures which causes negative impacts to their health and welfare (Packer et al., 2023). These body structures have been shown to influence biomechanics, due to the predisposition of orthopaedic diseases and the interference with locomotion causing changes in asymmetry and peak vertical force (Escobar et al., 2017; Humphries et al., 2020a; Humphries et al., 2020b; Jeandel and Garosi, 2018).

Injury can lead to gait abnormalities due to the compensating to reduce weight-bearing on the affected limb(s) (Carapeba et al., 2016; Goldner et al., 2018). Żuk and Księżopolska-Orłowska (2015) investigated arthritis in children, finding a reduced range of motion in the affected limb, and microtrauma in the unaffected limb. Although this research investigated children, Meeson et al. (2019) recently discovered that both dogs and humans share commonalities in osteoarthritis, such as areas of development, and causes of development. Due to this, it is likely that dogs would show similar gait abnormalities caused by the compensation.

Additionally, equine research has established that lameness causes compensatory weight redistribution onto the non-affected limbs, resulting in gait abnormalities due to the transfer of vertical force (Bragança et al., 2020; Clayton, 2016; Maliye and Marshall, 2016). Dogs and horses have musculoskeletal similarities, so for this reason, similar compensatory redistribution is expected in dogs (Ahmed et al., 2019).

Alternatives to Harnesses

Many trainers and behaviourists recommend the use of collars over harnesses due to the misconception that harnesses actively cause a dog to pull (Landsberg et al., 2023). This is incorrect; harnesses were designed to enable sled dogs to pull (Ramey et al., 2022), but they are not the primary causation of pulling (Shih et al., 2020).

Townsend et al. (2020) stated that collars can cause tracheal and oesophageal issues, especially in brachycephalic breeds. Harnesses can prevent this by redistributing pressure across the body (Carter et al., 2020; Hunter et al., 2019). However, Shih et al. (2021) found this enabled significantly more pulling, so headcollars may be more suitable for these dogs (Grainger et al., 2016). The AKC (2021) express that harnesses help to avoid injury and discourage pulling but have a greater escape risk. Both Takáčová et al. (2021) and Ward (2021) state that this is usually due to user fitting error, rather than harness design, so still recommends their use.

Gaps in the Research

There is a vast array of harness designs available, but research is severely lacking, especially research directly comparing different styles. Blake et al. (2019) states that biomechanical research is sparse, and future research must include comparisons between multiple harness designs, specifically in relation to gait. Improved understanding of the biomechanical impacts of harnesses may aid in harness production, ensuring brands offer safe and secure harnesses. Furthermore, statistical information on a wider variety of harnesses is needed so owners can make informed decisions, by providing results on the impact each style/design can have on biomechanics.

This study will close this gap by investigating the influence of harness design on shoulder and elbow biomechanics, specifically flexion and extension, in pet dogs. It will include the following harnesses: Halti Comfort Collar (base collar), Julius K9 IDC® Powerharness (straight-front), Ruffwear Front Range® Dog Harness (front-clip), EzyDog Chest Plate Harness (chest-plate), Halti No Pull Harness and Walking Harness (no-pull and y-front), and 3 Peaks Step In Harness (step-in) (see Appendix One).

These have been chosen due to being readily available to the public in high-street pet shops, ensuring that the harnesses are accessible to owners. This new approach may facilitate the further study of the long-term effects of harnesses. This research will provide the vital information needed for owners to choose harnesses and to bring awareness to the variety of styles available.

Canines have various morphologies depending on their breed (Bannasch et al., 2021). Improving owner-awareness of the variety of harnesses available means they are more adept to finding a well-fitting, suitable harness. This can therefore prevent the risk of harnesses having a negative impact on the dogs' biomechanics (Preston et al., 2012).

Research Information

Research Question

How do different harnesses available to the public in high-street pet shops affect the biomechanics of pet dogs?

Research Aims

This research will investigate how different harnesses can affect a dog's gait, focusing on shoulder extension (SE), shoulder flexion (SF), elbow extension (EE) and elbow flexion (EF).

This will include the following styles and brands: Halti Comfort Collar (base collar), Julius K9 IDC® Powerharness (straight-front), Ruffwear Front Range® Dog Harness (front-clip), EzyDog Chest Plate Harness (chest-plate), Halti No Pull Harness and Walking Harness (no-pull and y-front), and 3 Peaks Step In Harness (step-in) (see Appendix One).

These have been chosen due to their popularity, as well as being available to the public in most high-street pet shops. This will ensure that the harnesses are easily accessible, so owners can utilise the information provided to find a suitable harness.

The changes in biomechanical measurements will demonstrate the impact of each harness on canine gait by allowing for normal gait, or by reducing extension or flexion. Comparisons between results will hopefully conclude if general harness use has a larger impact on gait compared to a collar, and if the type of harness influences the extension or flexion allowed.

Research Objectives

The main objective is to determine if the choice of harness affects the dogs' biomechanics. Specifically, to determine how harnesses can affect shoulder extension and flexion, and elbow extension and flexion (see Appendix Two).

There are two secondary objectives. Firstly, to provide a foundation for further research to advance this field's knowledge and statistical information. Secondly, to create accessible and clear statistical information for both pet owners and harness creators to influence their future decisions.

Hypotheses

(H_1) - there will be a significant difference in biomechanics depending on the type of harness worn.

(H_1) - there will be a significant difference in shoulder extension, between the y-front harness and the front-clip harness.

(H_1) - a straight-front harness will significantly reduce a dog's elbow extension more than the other harness designs.

(H_1) - a step-in harness will have a lesser significant impact on biomechanics compared to a straight-front harness.

Methodology

Study Subjects

The study was open to all dogs, excluding the four banned breeds (The Dangerous Dogs Act, 1991). Due to accepting all breeds, one harness of each size, per harness type, was required (see Appendix Three). Dogs had to be over the age of 18 months to prevent the open growth plates of puppies causing abnormal results (Virag et al., 2022). They also had to be fit and well, with no existing musculoskeletal disorders, due to these impacting biomechanics (Adrian et al., 2019), or causing harm/ discomfort (Shih et al., 2021).

The total sample size was thirty dogs (n=30). This surpasses similar research and will provide sufficient data for accurate conclusions within the time constraints (Morse, 2015). Ker & Ramalingam (2013) state that a sample size of around thirty participants represents the target population whilst managing time and resources.

Sample

Participants were enlisted through social media advertisement explaining the study and inviting participation. Staff who enrolled their dogs in the University kennels were also approached regarding the inclusion of their dogs. These were included due to the convenient access to the dogs during the working day.

Potential participants were required to complete a pre-trial questionnaire per dog before their trial could begin (see Appendix Four). Three screening questions were included to ensure three main requirements. The first being that the owner was at least 18 years old (UK General Data Protection Regulation, 2021). Secondly, that the dog was over 18 months old. Finally, ensuring the dog had no known musculoskeletal disorders.

The remainder of the questionnaire gathered information pertaining to each participant, such as breed and age. All owners were asked if their dog was likely to become distressed during harness fitting. If yes, the participant was excluded to ensure researcher safety (Thompkins et al., 2016).

Data Collection

The video data was collected using a high-speed 60fps (frames per second) camera; an iPhone 11, due to its simplicity and availability. The room was laid out as shown in Appendix Five. At the beginning of the trial, each dog was fitted with a collar as a control measure (Simmons et al., 2015), and each harness was fitted by, or under the guidance of, the author. This was to ensure they were correctly fitted and sized, to avoid either factor becoming an extraneous variable and influencing results (Bremhorst et al., 2018).

Each dog was walked down a 4m walkway on a 4ft lead, marked using a 5m lead, with a camera situated 3-6ft away on a stand. This distance was altered depending on the height of the dog. Three repetitions per harness/collar were required; any unsuccessful videos were re-recorded. Once recorded, these videos were transferred onto the study laptop via Telegram and saved in a password-protected Microsoft Vault.

The independent (explanatory) variable was the different harness styles included, and the dependent (response) variable was the elbow extension, elbow flexion, shoulder extension or shoulder flexion. This study included a third variable, a (random) data variable, which was the dogs involved. To ensure control, each dog was walked on a standard (base) collar and lead to gather an approximate base-gait measurement before the addition of the harnesses. Owners picked the direction of walking, and this will remain constant for each video to ensure directional changes has no impact.

Once collected, each video was analysed using Quintic Software, before being exported onto Excel; R-Studio was used to fully analyse the data. Primary data was collected; although this can be more expensive and time-consuming to complete, data is gathered first-hand, therefore increasing the reliability and validity of the results (Vetter, 2017).

Data Analysis

A Generalised Linear Mixed Model (GLMM) was used for data analysis, due to being appropriate for large amounts of clustered data (Rabe-Hesketh and Skrondal, 2010); this study collected approximately 2,500 individual results. Due to the third, random variable, the GLMM can account for this by basing itself on the entire sample population instead of each individual subject, which allows for sparse sampling (Huang and Li, 2007). A post-hoc test is not required for a GLMM, because the data is being tested to compare a collar to each harness, but comparisons between each harness is not required.

A normality test is also not required for a GLMM as there is no alternative test depending on the normality of the data. However, one was still performed to justify the correct descriptive statistics. The data was not normally distributed ($p<0.05$), so the median and interquartile range was used.

Ethical Principles

Informed consent will be obtained at the start of the pre-trial questionnaire (Nijhawan et al., 2013). This must be obtained before the collection and storage of any data. Owners can opt out of the study verbally or in writing, to a provided email address, at any time throughout or after the trial, protecting their right to withdraw (Greaney et al., 2013). This study will ensure data is stored securely to maintain integrity and confidentiality (Petrova et al., 2014). Participant protection will be guaranteed by ensuring both dog and owner leave in the same condition of health as they arrived (Geneviève et al., 2019). All owners will be debriefed after their dogs' trial (McShane et al., 2015).

Results

A Generalised Linear Mixed Model (GLMM) was performed to compare the influence of each harness on elbow and shoulder extension and flexion. Table 1 shows the median and interquartile range as the primary descriptive statistics; harness results display these statistics compared to the base collar.

Results are recorded as (median (IQR: 25th percentile - 75th percentile)).

Table 1

Median and Interquartile Range of Each Harness Design and Base Collar

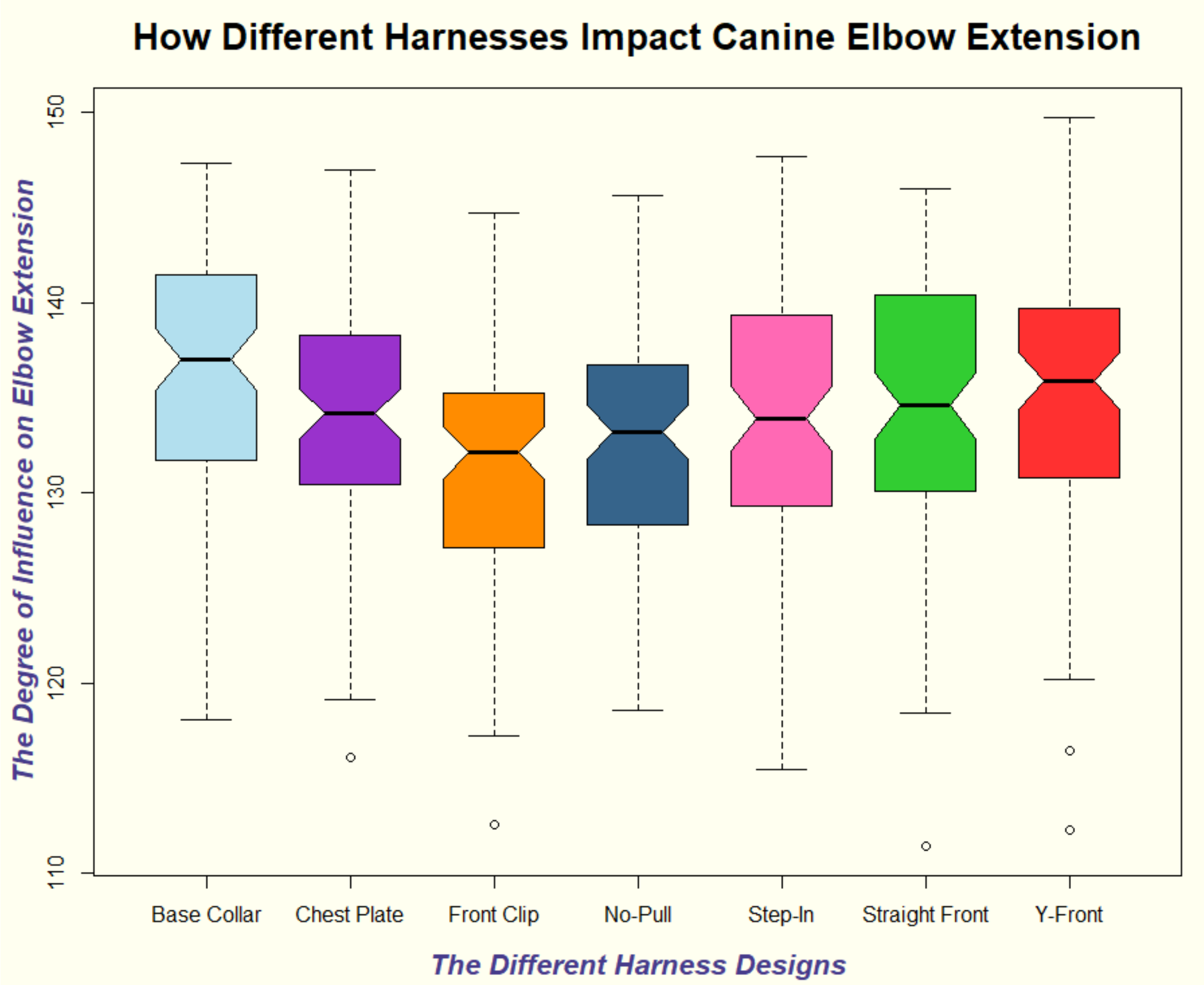
Joint	Angle	Base Collar		Chest Plate		Front Clip		No-Pull		Step-In		Straight Front		Y-Front	
		Med	*IQR*	*Med*	*IQR*	*Med*	*IQR*	*Med*	*IQR*	*Med*	*IQR*	*Med*	*IQR*	*Med*	*IQR*
Shoulder	Extension	97.4°	88.5° - 102.5°	88.5°	80.9° - 97.6°	84.7°	79.6° - 95.2°	88.2°	76.8° - 95.2°	86.3°	80.9° - 96.2°	93.8°	86.0° - 99.6°	93.5°	84.3° - 99.3°
	Flexion	91.3°	85.9° - 97.6°	88.4°	82.5° - 94.5°	84.1°	78.2° - 90.7°	85.7°	79.7° - 91.2°	87.6°	82.8° - 93.8°	89.6°	85.4° - 94.9°	88.9°	84.4° - 93.8°
Elbow	Extension	137.0°	131.8° - 141.4°	134.2°	130.5° - 138.3°	132.1°	127.1° - 135.2°	133.2°	128.3° - 136.7°	133.9°	129.4° - 139.3°	134.6°	130.1° - 140.4°	135.9°	130.8° - 139.7°
	Flexion	80.9°	73.7° - 86.9°	81.4°	74.0° - 84.2 °	76.4°	69.6° - 81.0°	78.0°	74.0° - 83.1°	75.7°	71.0° - 80.5°	79.7°	75.9° - 84.3°	79.5°	75.2° - 85.0°

Note. The influence of each harness design on shoulder and elbow extension and flexion, compared to the base collar is displayed. The descriptive statistics are recorded as (median (IQR 25^{th} percentile - 75% percentile)).

As indicated below in Figure 1, the front-clip (132.1° (IQR: 127.1° - 135.2°)) and no-pull (133.2° (IQR: 128.3° - 136.7°)) had the most significant impact on elbow extension compared to the base collar (137.0° (IQR: 131.8° - 141.4°)). The chest-plate (134.2° (IQR: 130.5° - 138.3°)) and step-in (133.9° (IQR: 129.4° - 139.3°)) both had a significant impact, but less so than the aforementioned harnesses. However, neither the straight-front (134.6° (IQR: 130.1° - 140.4°)) or y-front (135.9° (IQR: 130.8° - 139.7°)) had a significant impact on elbow extension.

Figure 1

Box-and-Whisker Plot showing Elbow Extension for each Harness Design



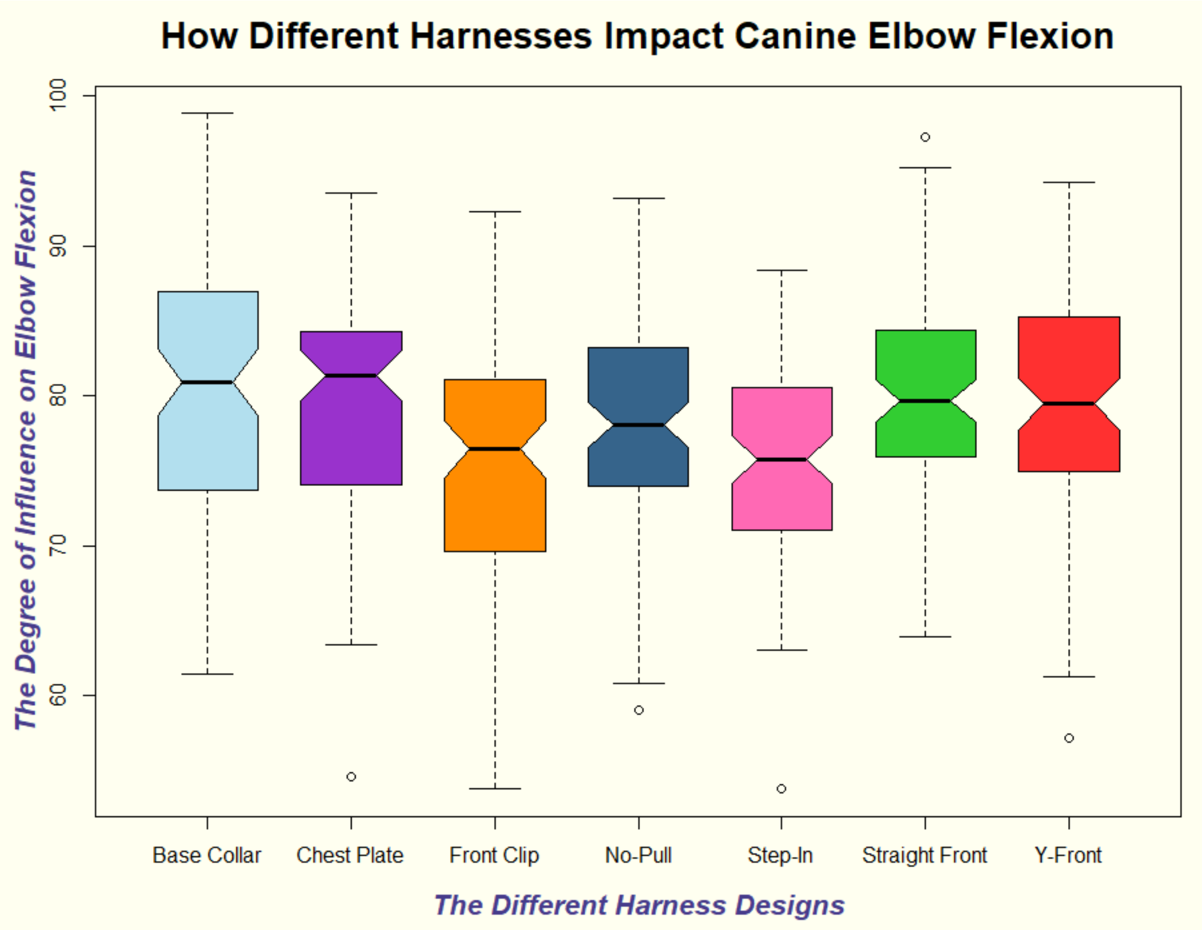
Note. The degree of canine elbow extension for each harness design and base collar is displayed (n=60). This is displayed as a box-and-whisker plot with outliers.

(GLMM: chest-plate $t = -0.942$, $p=0.034$; front-clip $t = -2.123$, $p<0.001$; no-pull $t = -5.642$, $p<0.001$; step-in $t = -4.057$, $p=0.027$; straight-front $t = -2.210$, $p=0.078$; y-front $t = -1.765$, $p=0.346$).

Conveyed in Figure 2, the front-clip (76.4° (IQR: 69.6° - 81.0°)) and step-in (75.7° (IQR: 71.0° - 80.5°)) had the most significant impact on elbow flexion compared to the base collar (80.9° (IQR: 73.7° - 86.9°)). The no-pull (78.0° (IQR: 74.0° - 83.1°)) also had a significant impact, but not to a considerable degree. The straight-front (79.7° (IQR: 75.9° - 84.3°)), y-front (79.5° (IQR: 75.2° - 85.0°)) and chest-plate (81.4° (IQR: 74.0° -84.2 °)) did not have a significant impact on elbow flexion.

Figure 2

Box-and-Whisker Plot showing Elbow Flexion for each Harness Design



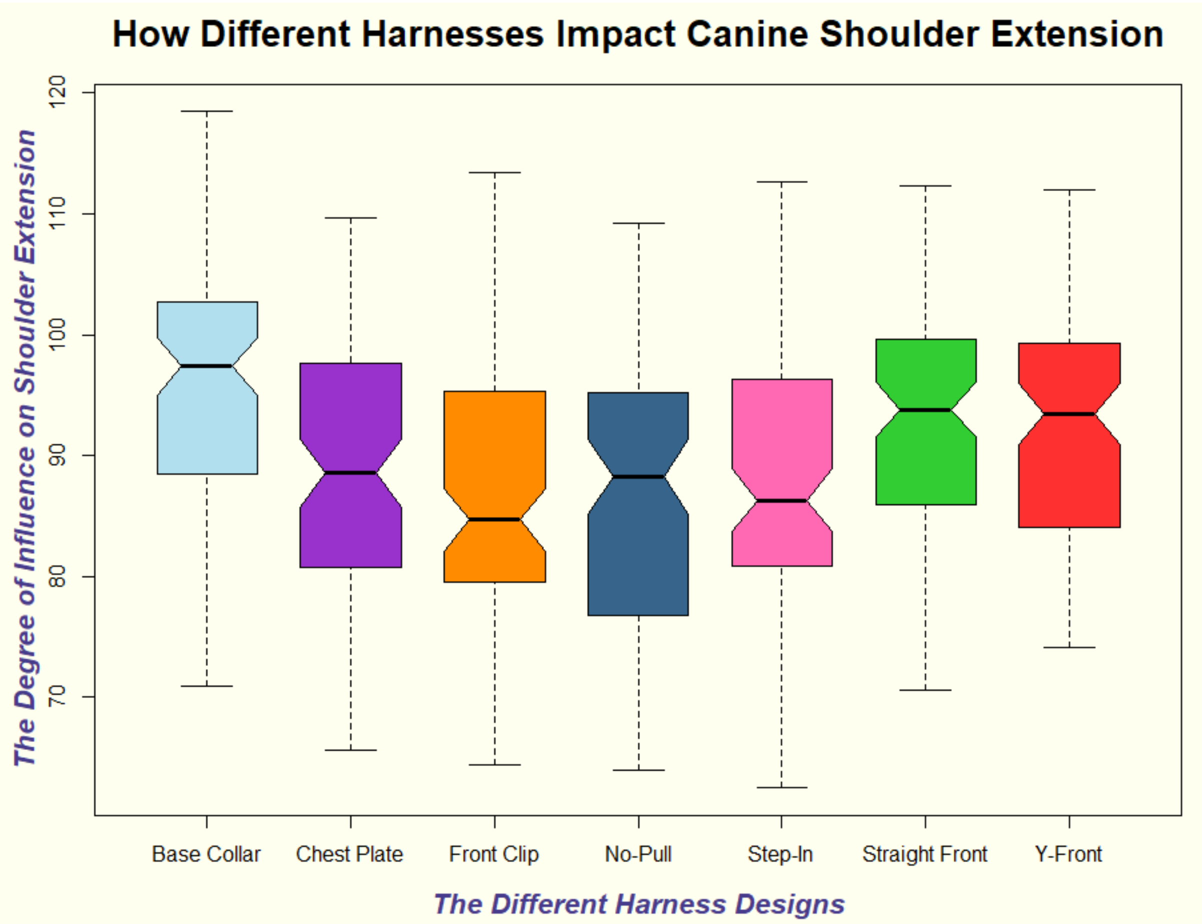
Note. The degree of canine elbow flexion for each harness design and base collar is displayed (n=60). This is displayed as a box-and-whisker plot with outliers.

(GLMM: chest-plate t = -0.755, p=0.511; front-clip t = -0.658, p<0.001; no-pull t = -5.769, p=0.003; step-in t = -3.006, p<0.001; straight-front t = -5.471, p=0.501; y-front t = -0.673, p=0.451).

Exhibited in Figure 3, the chest-plate (88.5° (IQR: 80.9° - 97.6°)), front-clip (84.7° (IQR: 79.6° - 95.2°)), no-pull (88.2° (IQR: 76.8° - 95.2°)), step-in (86.3° (IQR: 80.9° - 96.2°)), straight-front (93.8° (IQR: 86.0° - 99.6°)) and y-front (93.5° (IQR: 84.3° - 99.3°)) all had a significant impact on shoulder extension compared to the base collar (97.4° (IQR: 88.5° - 102.5°)).

Figure 3

Box-and-Whisker Plot showing Shoulder Extension for each Harness Design



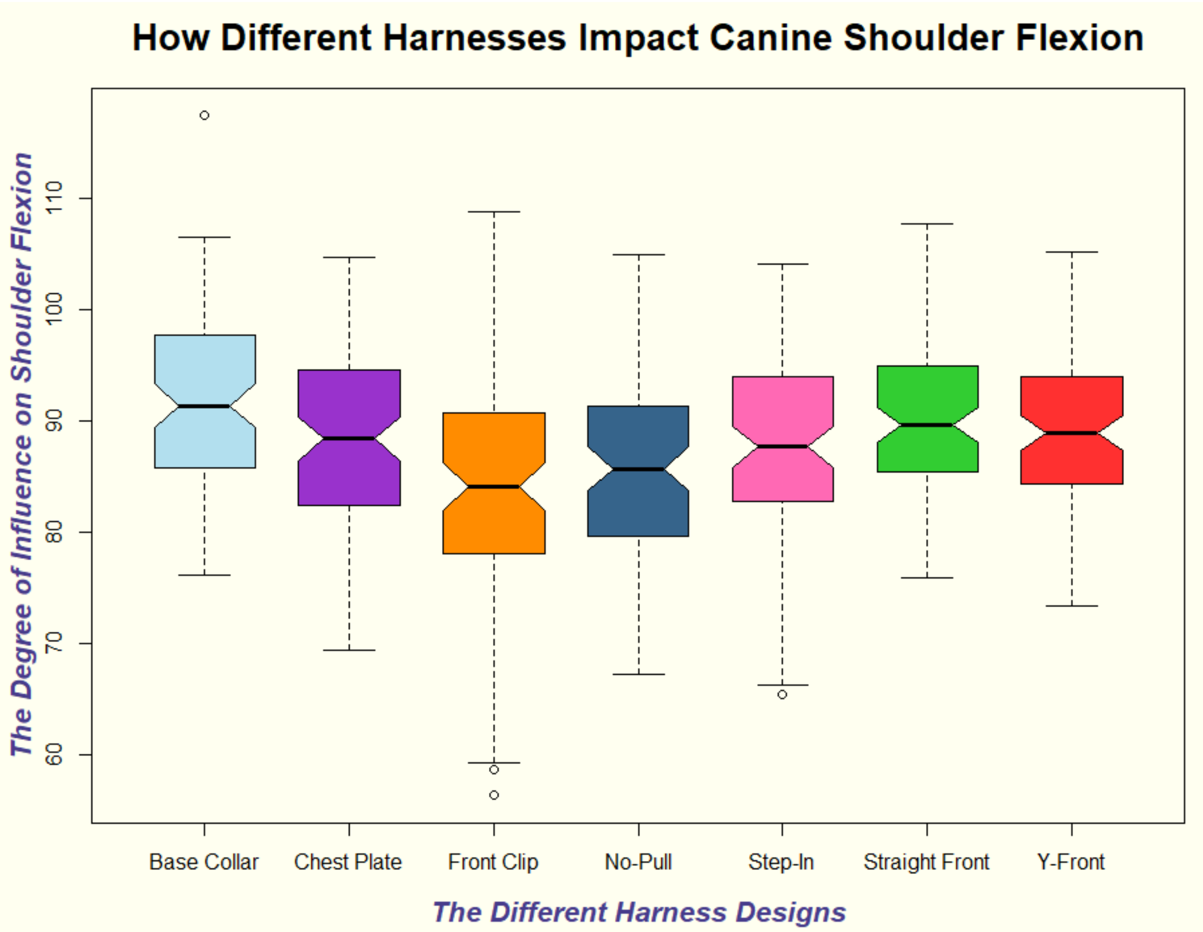
Note. The degree of canine shoulder extension for each harness design and base collar is displayed (n=60). This is displayed as a box-and-whisker plot with outliers.

(GLMM: chest-plate t = -3.863, p<0.001; front-clip t = -7.403, p<0.001; no-pull t = -9.514, p<0.001; step-in t = -10.030, p<0.001; straight-front t = -8.340, p<0.001; y-front t = -3.547, p<0.001).

Displayed in Figure 4, the chest-plate (88.4° (IQR: 82.5° - 94.5°)), front-clip (84.1° (IQR: 78.2° - 90.7°)), no-pull (85.7° (IQR: 79.7° - 91.2°)), step-in (87.6° (IQR: 82.8° - 93.8°)) and y-front (88.9° (IQR: 84.4° - 93.8°)) all had a significant impact compared to the base collar (91.3° (IQR: 85.9°- 97.6°)). The only harness to not significantly impact shoulder flexion was the straight-front (89.6° (IQR: 85.4° - 94.9°)).

Figure 4

Box-and-Whisker Plot showing Shoulder Flexion for each Harness Design



Note. The degree of canine shoulder flexion for each harness design and base collar is displayed (n=60). This is displayed as a box-and-whisker plot with outliers.

(GLMM: chest-plate t = -3.557, p<0.001; front-clip t = -4.736, p<0.001; no-pull t = -9.184, p<0.001; step-in t = -7.824, p<0.001; straight-front t = -5.079, p=0.02; y-front t = -2.330, p<0.001).

Across all four statistical analyses, the front-clip is the only harness that significantly reduced all four angles measured.

Opposingly, the straight-front harness is the only harness to not significantly reduce three of the angles measured. The only significant reduction was of shoulder extension; however every harness significantly impacted this angle compared to the collar.

The y-front did not significantly reduce elbow extension or flexion but did significantly reduce shoulder extension and flexion.

The chest-plate did not reduce elbow flexion, but significantly reduced both shoulder extension and flexion. It also reduced elbow extension, but to a lower statistical degree.

Finally, the no-pull and step-in both reduced every angle, with both significantly reducing shoulder extension and flexion. Both harnesses reduced elbow flexion, but the impact was more significant in the step-in. Similarly, both also reduced elbow extension, but the impact was more significant in the no-pull.

Alongside reporting the median and interquartile range, the mean and standard deviation (mean +/- standard deviation) were noted, as presented in Table 2 below. This table displays the influence of each harness design on shoulder and elbow extension and flexion. The coloured shadings are explained in Figure 5.

Table 2

Mean and Standard Deviation of Each Harness Design and Base Collar

Joint	Angle	Lorke et al., 2017 Maximum Angles	Base Collar	Chest Plate	Front Clip	No-Pull	Step-In	Straight Front	Y-Front
Shoulder	Extension	138.3° +/- 7.2°	95.7° +/- 9.7°	89.0° +/- 10.7°	87.1° +/- 11.3°	86.6° +/- 11.2°	88.1° +/- 10.1°	92.3° +/- 8.9°	92.1° +/- 10.1°
	Flexion	104.5° +/- 6.1°	91.9° +/- 7.6°	87.9° +/- 8.0°	84.3° +/- 10.3°	85.3° +/- 8.0°	87.6° +/- 8.0°	89.8° +/- 7.0°	88.8° +/- 7.7°
Elbow	Extension	152.0° +/- 10.5°	135.8° +/- 7.2°	134.1° +/- 5.8°	131.2° +/- 6.7°	132.5° +/- 6.0°	134.0° +/- 6.4°	134.4° +/- 7.1°	135.0° +/- 6.7°
	Flexion	83.2° +/- 11.1°	80.4° +/- 8.9°	79.8° +/- 7.4°	75.4° +/- 6.7°	77.7° +/- 7.0°	75.6° +/- 6.1°	79.7° +/- 6.5°	79.7° +/- 6.9°

Note. The influence of each harness design on shoulder and elbow extension and flexion, compared to the base collar is displayed. The descriptive statistics are recorded as (mean +/- standard deviation).

Figure 5

The Highlighting Key for Table 3

Highlighting Key

Least Impact on Gait

- harness which allows the most extension/flexion
- harness which allows the second most extension/flexion
- harness which allows the third most extension/flexion
- harness which allows the third least extension/flexion
- harness which allows the second least extension/flexion
- harness which allows the least extension/flexion

Most Impact on Gait

Note. This key displays the harnesses in order of most extension/flexion measured. The base collar is not included.

In Table 2, the base collar was not included in the highlighted order of flexion/extension allowed, as this is expected to be higher due to the absence of contact with the shoulder/elbow. Table 2 also includes the maximum flexion and extension of the shoulder and elbow from Lorke et al's. (2017) study on Beagle dogs for comparison and accuracy assurance.

Discussion

Reviewing the results, all six harnesses all significantly reduced shoulder extension compared to the base collar. This finding disproves the hypothesis that there would be a significant difference in shoulder extension between the y-front and front-clip harness. However, because every harness impacted this angle, future research could remove the base collar to determine which harness has the least impact, as a collar may not always be an option for an owner (Bailey, 2022; Bolton et al., 2021), and many force-free trainers and owners may not use other alternatives such as head harnesses or slip leads (Reid and Rehner-Fleurant, 2022).

Exploring the front-clip harness, previously considered 'non-restrictive,' (Zink, 2019) this harness significantly reduced all four angles measured (EE (4.9°), EF (4.5°), SE (12.7°), SF (7.2°)). The y-front harness also significantly reduced shoulder extension (3.9°) and flexion (2.4°) but had minimal impact on elbow extension (1.1°) or flexion (1.4°). Blake et al., (2019) deem this impact to be caused by the y-front restricting the scapula angulation (Aspinall and Cappello, 2019), thus reducing movement.

Both the front-clip and y-front harnesses are manufactured with the strap running from the sternum to the dorsal neck, which could potentially influence biomechanics due to the loading on the sternum (Peham et al., 2013). More research would be required to compare strap positioning and sternum impact. This harness design is thought of as being 'non-restrictive' due to the strap not crossing the chest, however future research would be necessary to definitively prove which strap positioning has the least impact on biomechanics.

When comparing the elbow extension and flexion of the y-front and front-clip, it is interesting that only one resulted in significant impact, as this potentially shows that the strap positioning is not the key factor in what influences biomechanics. Due to the similar style, the other variables of lead position and strap width must be considered. More research is needed into chest strap width and its interference with elbow movement, as this may be the factor causing the difference in impact. The largest front-clip harness width is 4 inches at the widest part, compared to the largest y-front harness width being 1.5 inches at the widest part. Due to this large difference, it is possible that this factor would have an impact, but more research is needed to prove/disprove this.

The straight front allowed for the largest shoulder extension (93.8°) and flexion (89.6°), and the second-most elbow extension (134.6°), only significantly impacting shoulder extension (79.7°). Many studies have hypothesised that the 'non-restrictive' y-front harness would have less of an impact than the 'restrictive' straight-front harness (Pálya et al., 2022; Sandberg, 2022), yet their results showed the opposite, that y-fronts are more restrictive.

Zink's (2019) study also found that the non-restrictive y-front significantly restricted shoulder extension when walking. Conclusions can be drawn that the straight front had the least impact on canine biomechanics, which is a key finding for the pet dog community as this may lessen the negative associations with this style (Julius K9, 2020b).

Furthering the comparison between straight-fronts and y-fronts, Pálya et al's. (2022) study compared the Julius K9 straight-front to the new Julius K9 y-front. They found that both harnesses limited gait compared to a standard collar, but there was no significant difference between the two harness designs, thus showing a straight-front is not 'restrictive' compared to a y-front. They concluded that movement restriction depends on the individual dog, and the fit of the harness, however expressed that future research would be needed to support this.

Clayton et al. (2017) completed equine research into saddle fitting, and discussed how saddles impact stride, velocity and acceleration. They stated that a poor-fitted saddle impairs the mobility of the horse's back, and inhibits a consistent gait, which can cause lameness and musculoskeletal issues in the long term. Linking this to pet dogs, if an owner struggles to fit a harness, it can impact their gait, which can cause issues over time. Future studies could see the ability of owners to fit different harnesses, and this could encourage brands to increase the harness-fit education they provide.

This research may aid in the safe production and scientifically-informed harness advertisement and information to the public. It may also help dispel the incorrect beliefs around harness restriction. As discussed, the y-front harness is commonly sold as 'non-restrictive,' but this study has proven that it restricts flexion and extension of both the elbow and shoulder, which is a misrepresentation to the buyers. Alternatively, the Julius K9, which is often labelled as 'restrictive' and is regularly disfavoured by animal professionals and the public, has been proven to have little impact on canine biomechanics. This also supports Julius K9's (2020a) statement regarding the safety and impact of their harness.

Results of this study found that the chest-plate and step-in also significantly reduced shoulder extension (chest-plate (88.5°), step-in (86.3°)) and flexion (chest-plate (88.4°), step-in (87.6°)). However, both also had a significant impact on elbow extension (chest-plate (134.2°), step-in (133.9°)), but to a lesser degree. The step-in harness did significantly impact elbow flexion (75.7°), whereas the chest-plate had no impact on this angle (81.4°).

Focusing on the step-in harness, this harness has a similar design to the straight-front, with the chest strap crossing the chest and shoulders. The Julius K9 straight-front has a thicker chest strap that could have impacted gait less, due to the larger distribution of pressure, whereas the step-in chest strap is thinner, so pressure is distributed to a much smaller area. This could explain why the straight-front had a much less impact on all measurements compared to the step-in. This refutes the hypothesis that predicted the step-in would have less impact than the straight-front, and clearly demonstrates the need for future research to consider chest strap width and its impact on biomechanics.

Peham et al. (2013) measured the pressure distribution of three straight-front guide dog harnesses with different chest-strap widths. They found that when the forelimb extended, the pressure force on the chest increased, but remained low when the forelimb was in flexion. They also found that the pressure force was lowest in the harness with the widest chest strap. Future research could involve similar research but using pet dogs, to examine what width chest strap is optimum for low pressure force but still allows for standard flexion and extension.

Moving onto the no-pull harness, this is highly recommended for dogs that pull due to the tightening mechanism under the axilla (armpit), causing slight discomfort to the dog (Company of Animals, 2022). This harness has never been included in research, based on the authors' knowledge. The no-pull reduced all four angles measured: it significantly reduced shoulder extension (9.2°) and flexion (5.6°), and elbow extension (3.8°) and flexion (2.9°), but it reduced elbow extension to a lesser significant degree.

Coincidentally, both the y-front and the no-pull are produced by the brand Halti (VioVet, 2023), which is interesting that their no-pull had such a significant impact on biomechanics, whereas the y-front had very little impact. This demonstrates the requirement for future research to explore the different Halti-branded harnesses and compare how each influences canine gait, potentially supporting their future harness production.

Exploring all six harnesses, the hypothesis that a significant difference in biomechanics would be witnessed depending on the harness worn has been confirmed. However, based on the statistical data, the straight-front had the least impact on canine gait, therefore is the authors' top recommendation.

As highlighted previously, there is a need for future research to focus on canine gait and harness impact (Blake et al., 2019). Lafuente et al. (2018) discussed the necessity for future research to include multiple harness styles and brands. They also discussed the requirement of studies to include a researcher with experience surrounding dogs and physiology to improve the reliability of the results (Wang et al., 2022). This study has confidently met both future research recommendations, by including six harness designs, and being controlled by an author with canine experience.

Moreover, this study has overcome the limitations of previous studies by ensuring a larger sample size (Zink, 2019), a variety of breeds (Winter, 2013), and controlled extraneous variables, such as the influence of weather or treadmills (Lafuente et al., 2018; Söhnel et al., 2022).

The results of this study have been consistent with the results found by Lorke et al. (2017). Their data was included in Table 2 to demonstrate the maximum elbow and shoulder extension and flexion achieved by healthy Beagle dogs during free movement. As results remained under the threshold identified by Lorke et al. (2017), and there is consistency within the ranges, this demonstrates a lack of anomalous data and suggests a high accuracy of the manual angles drawn in this study. Moreover, this suggests high concurrent validity due to the agreement between this study and Lorke et al. (2017).

Alongside this, internal consistency reliability has been assured, as results from each harness style have remained consistent (Salonen et al., 2021). Both construct and content validity have also been upheld by ensuring the software used for analysis was specifically for biomechanics (Topál et al., 2019), and that all angles were measured in the same way (Rocznik et al., 2014).

Health and Safety and Ethics

The health and safety and ethics for this study were upheld, meaning this research was ethically produced, and demonstrates to future researchers how to ethically conduct dog-related studies (Woodin, 2015). Particularly, one dog was excluded from the trial due to their negative reaction to the study location, so removing him from the study was the most ethical decision (Tasker et al., 2018).

Alongside this, participants never came into contact with other dogs outside of their household (King and Zohny, 2022). Time-slots were given to each participant, allowing sufficient time for them to leave before the next participants' trial. This ensured dogs did not come into contact with each other; to give us time to finish each harness; and to ensure the dog had time to acclimatise to the room before beginning the trial.

Any dogs with nervousness or disfavour of having their paws touched were handled by the owner to protect researchers from any reactions (Health and Safety at Work Act 1974), but to also keep anxiety levels of the dogs as low as possible (Animal Welfare Act 2006). Although changing the walker for some dogs may be an extraneous variable, the author prioritised the ethics and safety of each participant as paramount (National Dog Warden Association, 2012).

Limitations and Future Research

The results and conclusions drawn from this study will provide invaluable information for not only pet dog owners, but for future researchers who wish to build on these findings. However, the author acknowledges the presence of some limitations within this study in order for others to build on these and provide essential future research.

Due to the time restraints within this study, only thirty dogs were included. Whilst Ker and Ramalingam (2013) deemed this sufficient as the sample is significantly larger than other studies (Laverack et al., 2021; Wiener and Haskell, 2016), the author identifies that a larger sample size would allow for investigation into the morphological differences between breeds (Carlisle et al., 2019; Hecht et al., 2019). This would allow for more specific harness recommendations for owners based on individual breed conformation (Voss et al., 2011).

Due to the nature of a university setting, flexibility in study site was required. The author does not feel this affected the results; however future studies should ensure site consistency (Desai, 2020). Whilst all participants were trialled in the same harnesses, the order of these was randomised. This may have negated the impacts of habituation to harness wear or trial behaviour expectations (Suresh, 2011). This is especially relevant for dogs who do not normally wear harnesses. Future research should consider the benefits of randomised studies and/or training prior to the trial.

Although this study considered harness fitting and possible reactions to the researcher in the pre-trial questionnaire, it did not pre-asses the dogs' comfort level or experience of being walked on lead by a stranger. To ensure ethicality, some dogs were walked by their owners to alleviate anxiety. This change in handler may question the inter-rater reliability of the study due to the different handling techniques or the speed of the walk (Posluns et al., 2017). Future studies should ensure participants will be comfortable with being handled by a stranger as part of the screening questions.

To help ensure reliability of results, the same researcher completed every manual angle measurement. However, as the angle data was produced manually, there may be a level of unconscious or observer bias. Tanneberger and Ciupitu-Plath (2017) conclude that existing beliefs can impact the results drawn, as has been discussed above with Zink's (2019) study.

Future studies could implement blind trials or multiple researchers to avoid this possibility, or could attach markers onto each dog so Quintic measures the angles automatically, which may increase reliability (Engelsman et al., 2022). If markers were used, limitations with this technique, such as lacking visibility on thick-furred dogs or movement alterations caused by the markers, must be accounted for (Torres et al., 2013).

The inclusion of other biometrics, such as stride length, would strengthen these findings further (Torres et al., 2017). Size difference and breed conformation impacts stride length, which could influence extension and flexion, so inclusion would add further clarity (Bliss et al., 2022).

Furthermore, comparisons of different gaits (e.g. hindlimb angles, or dogs at a trot) would provide further results. This would be especially relevant when researching the long-term effects of harnesses, as pet dogs vary their gait during standard walks (Kano et al., 2016).

Longitudinal studies exploring the correlation between harness design and use, and musculoskeletal disorders will help inform harness choices. Ethical considerations must be made here, as this study has shown the potential biomechanical influences of some harness designs (Murray et al., 2021).

A final recommendation for future researchers is the consideration of a larger array of harnesses and brands available to pet owners. Analysis of the different styles within brands (e.g. the Julius K9 straight-front and y-front), different brands within styles (e.g. Ruffwear y-front and Julius K9 y-front) and differing the attachment point (e.g. front-clip and back-clip) would deepen the understanding of harnesses and biomechanics. Focus on brands more/less readily-available may result in shifts in the market, improving the knowledge of owners and widening their harness choices.

Despite the aforementioned limitations and requirements for future research, the results of this study are still extremely valid and beneficial for the canine industry as a whole, and provides the building blocks for students and researchers to study further into this field. Providing an accessible version for owners will impart clarity and enable them to make informed decisions. Hopefully, these results will drive the future of harness production, to ensure for maximum safety and comfort for all dogs.

Conclusion

This study has concisely demonstrated that the choice of pet dog harness impacts biomechanics, closing the research gap into harness impact on canine biomechanics in pet dogs. The results display the impact of each via angulation and have demonstrated how different harness styles impact shoulder and elbow extension and flexion.

Comparing results of all six harnesses, this study can confidently recommend the Julius K9 straight-front harness or the Halti y-front harness as the preferred option for pet owners. Furthermore, the highly-regarded Ruffwear front-clip harness exhibited the largest impact on biomechanics overall, thus illustrating its unsuitability. The author notes that whilst these harnesses were graded on suitability in results, the aim was not to conclude ‘the best’ harness overall; owners must use the information to select the best-suited harness for their individual dog.

Careful analysis of previous studies has allowed this study to accurately improve on previous limitations and draw updated conclusions on their findings. The study has demonstrated a need for further research to assess the impact that width of harness material has on canine biomechanics. Research into breed differences will also help expand this area further.

These findings provide long-term benefits to the pet dog community. The inclusion of commonly-available harnesses means that these conclusions are accessible for the average dog owner, and will help them to make informed decisions on their dogs’ safety and wellbeing. This also provides appropriate alternatives and reassurance for those dogs for whom a collar is unsuitable.

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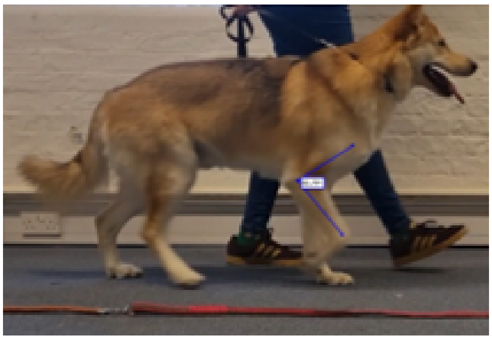
Appendices

Appendix 1: Table displaying harness brands, names, styles and images

Harness Brand	Harness Name	Harness Style	Image of Harness
Julius K9	IDC® Powerharness	Straight-front	
Ruffwear	Front Range® Dog Harness	Front-range	
EzyDog	Chest Plate Harness	Chest-plate	
Halti	Comfort Collar	Base collar	
	No Pull Harness	No-pull	
	Walking Harness	Y-front	
3 Peaks	Step In Harness	Step-in	

Appendix Two - Table displaying the four gaits measured

Elbow Extension	**Elbow Flexion**
	
Shoulder Extension	**Shoulder Flexion**
	

Appendix Three - list of all harness brands/styles and the sizes required

Julius K9 IDC Powerharness

- Baby 1
- Baby 2
- Mini-Mini
- Mini
- Size 0
- Size 1
- Size 2
- Size 3
- Size 4

Ruffwear Front Range Dog Harness

- XXSmall
- XSmall
- Small
- Medium
- Large/XLarge

EzyDog Chest Plate Harness

- XXSmall
- XSmall
- Small
- Medium
- Large
- XLarge
- XXLarge

Halti Y Front Harness

- XSmall
- Small
- Medium
- Large

Halti No Pull Dog Harness

- Small
- Medium
- Large

3 Peaks Step-In Dog Harness

- Small
- Medium
- Large

Appendix Four - pre-trial questionnaire

1. Are you (the handler) over 18 years old?
   - O Yes
   - O No

Unfortunately, this study is for participants over the age of 18 only.

2. Is your dog over the age of 18 months old (as of February 2023)?
   - O Yes
   - O No

Unfortunately, this study is for dogs over the age of 18 months.

3. Does your dog have any form of musculoskeletal disorder?
   (For example, arthritis or hip/elbow dysplasia)
   - O Yes
   - O No

Unfortunately, musculoskeletal disorders can affect canine kinematics.

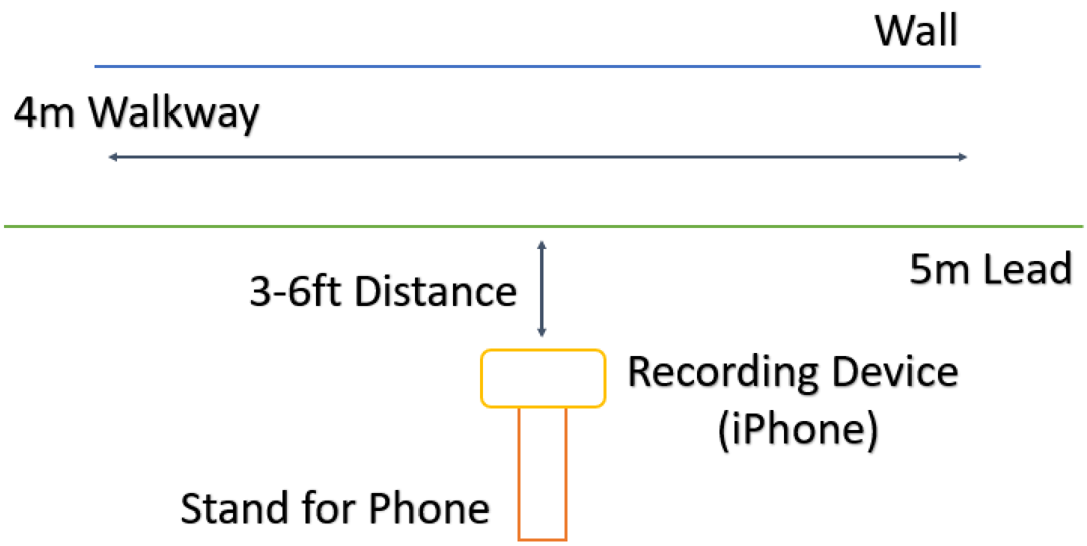
4. What breed(s) is your dog?
   (If your dog is a mixed breed, please try and list the breeds they include)

5. Dog's date of birth
   (Please be as exact as possible, if you don't know, please just put 01/01 and the year you think)

6. Is your dog likely to have a reaction during the harness fitting?
   - O Yes
   - O No

Note - this questionnaire has been made on Microsoft Forms, but the Word version has been attached here. The right to withdraw information has been excluded.

Appendix Five - layout of the room for each trial



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