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Are there laterality differences in passive flexion and extension of the proximal limb joints in working Siberian Husky dogs?

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Abstract

Differences between left and right-side joint range of motion may affect canine locomotive ability and movement. Passive range of motion (PROM) joint measurement provides the limits that a particular joint can move in its physiological planes of motion without influence of muscle activity. To compare left and right-side flexion and extension of the glenohumeral, humeroulnar/humeroradial, coxofemoral and femorotibial joints and for laterality PROM differences. Siberian Husky dogs were selected (n = 18), mixed gender, aged (1.4–11.8) years living and working together. Goniometry measured joint PROM, a validated, non-invasive method. Dogs were conscious and placed in standing position. Triplicate measures of joint flexion and extension were taken bilaterally of each dog for afore-mentioned joints. Median values of triplicate measures were computed. Paired t-tests compared laterality of joint PROM, gender, age (< 6 vs. ≥ 6 years) effects. Inferential symmetry indices [SI] were calculated. For all joints, there was no significant difference ($p > 0.05$) between left and right-side flexion and extension measures nor between genders. Age (< 6 vs. ≥ 6 years) had a significant effect on right hip flexion ($p < 0.001$); both left and right-side shoulder flexion ($p < 0.001$); elbow flexion ($p = 0.001$ and $p < 0.001$); hip extension ($p = 0.02$ and $p < 0.001$) respectively. The shoulder joint showed greatest PROM asymmetry (SI = 3.63%). Bilateral PROM measures are important to consider in joint movement and assessment. These results warrant further investigation with larger cohorts of defined age groups.

Keywords: arthrometry; articular; joints; range of motion; dogs; ageing

Introduction

Canis familiaris have the greatest morphology amongst mammals, with their limb morphology more variable than other canid species [1]. Joint range of motion (ROM) refers to the distance a joint can be moved in its physiological planes of motion, either actively or passively. Its relationships to overall locomotive ability and movement are important factors for veterinary professionals. Passive ROM (PROM) is the extent a joint can be moved without self-assistance and so demonstrates the integrity of the joint capsule, ligaments, fascia and articular surfaces of the joint without the influence of muscle activity. Joint restriction or changes in joint motion can identify potential pathological changes; any soft tissue changes around the joint can lead to a laxity and instability. Joint laxity maybe linked to growth rate, and can occur in all the joints, it is primarily noticed within the composite joint of the elbow consisting of the humeroulnar joint, humeroradial joint and the proximal radioulnar joint, and the hip (coxofemoral) joint. Laxity within these joints is a major risk factor contributing to the development of canine elbow dysplasia, hip dysplasia, degenerative joint disease and osteoarthritis [2,3]. These conditions often present with minimal clinical signs but impact on overall performance of working dogs and can be highly debilitating for pet dogs. Measuring the extent of articulation via goniometry in the shoulder, elbow, hip, and stifle joints could provide quantifiable and fundamental data for the evaluation and identification changes in joint pathology.

The term laterality is interchangeable with the term asymmetry when referring to functional differences between the left and right sides, asymmetry is used to describe structural differences. There is little research into musculoskeletal imbalance and differences between the left and right-hand sides (RHS) in *C. familiaris* [4], Most studies investigate biomechanics and ground reaction forces [5–8].

Goniometry measurements are established as reliable and objective method of determining PROM of joints [9]. It is inexpensive, practical and operators can quickly learn good precision and repeatability.

It is widely accepted that the ageing process can cause a loss of joint motion and dogs are no exception [10,11]. Cellular ageing causes physiological changes; research into telomere length within humans has shown it is a good biomarker for cell aging and correlates with age-related diseases [12]. During the ageing process, muscle atrophy may become apparent. Most geriatric dogs will exhibit a decrease in muscle mass and strength which can result in the onset of degenerative joint disease [11,12].

Pain is a major contributor to decreased joint motion [13,14], by decreasing joint motion, the nociceptive activity in the brain will be decreased [2]. Orthopaedic diseases causing pain can lead to disuse of the affected limb and inevitably muscle atrophy [15]. This link between pain and muscle atrophy has been verified in numerous studies [11,12,16,17], suggesting painful joints are a major cause of lameness in dogs.

Assessment of joint motion may be an effective monitor of sub-clinical changes related to movement which may then contribute to laterality traits. Early treatment interventions could reduce effects of degenerative joint disease and its progression.

Regular assessment of joint motion may be an effective monitor of sub-clinical changes related to movement which may then contribute to laterality traits. Reduction in PROM, either unilaterally or bilaterally as an indicator for early treatment intervention(s) could reduce effects of degenerative joint disease and its progression. This could be of particular value in working dogs.

At the time of this current research there were no scientific publications of normal PROM in Working Siberian Husky dogs (WSHDs); this research aims to provide this information and investigate joint PROM in regard to laterality, and in relationship to ageing.

Measuring the extent of articulation in the shoulder, elbow, hip and stifle joints in a sample of Siberian Huskies, this initial study could provide quantifiable and fundamental data for the evaluation and identification of PROM deviation; as a potential an indicator of change in joint pathology and an indicator for further investigation, thus providing the opportunity for early intervention and enhanced welfare in these working dogs.

Do WSHDs show laterality and any disparity in PROM of the glenohumeral (shoulder), humeroradial/humeroulnar (elbow), coxofemoral (hip) and femorotibial (stifle) joints during flexion and extension?

Is there a relationship between age < 6 years and > 6 years and joint PROM measures of the shoulder, elbow, hip and stifle joint in flexion and extension?

It is hypothesized that there will be a relationship between age and joint PROM measures of the shoulder, elbow, hip and stifle in flexion and extension.

Materials and Methods

Ethics statement

The study was approved by the College of Health Research Ethics Committee (CoHREC), November 27th, 2020. Informed client consent for animals participating in the study was obtained prior to data collection.

A total of 22 WSHDs were selected for this cohort study; only Kennel Club registered purebred sled dog breeds are eligible to race under British Siberian Husky Racing Association regulations. This number relates to the statistical power analysis conducted in previous research to meet minimum sample size for statistical comparison between study groups [9].

The study cohort lived in compounds together as packs however entire males lived separately from the females. There is genetic link up within the kennel as it is line bred with the exclusion of some males to keep the breeding coefficient low. Genetic difference is limited by choosing subjects from the same kennel. Controlling and limiting genetic variability is important as there have been various studies showing dysphasic hip joints can be from a genetic factor [2,8].

Dogs eligible for inclusion in this study were: (1) active sled dogs > 6 months and < 12 years old; (2) dogs with no known lameness or recent trauma and orthopaedic conditions; (3) no history of neurological conditions; (4) bitches not in season or

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known to be in pup.

Bitches in season may experience hormonal changes, which may affect behaviour. Consideration to bitches potentially in pup was paramount to the welfare of the animals. These criteria when implemented led to a remaining sample of 18 dogs.

Goniometry measurements were undertaken on a single day by the same operator, previously tested for reliability of measurements using 3 subjects, triplicate measures of flexion and extension PROM of all joints with a single-rating, absolute-agreement, 2-way random-effects model intraclass correlation coefficient of 0.98. Forty-eight measures of PROM for both flexion and extension on both left and right sides were undertaken.

Goniometry measurements were undertaken on a single day by the same operator tested for reliability of measurements. Two plastic goniometers with a 360º scale were used; 15 cm and 30 cm, allowing 1° increments in joint angle measures.

Forelimb and hindlimb bony landmarks as described below, were palpated, identified and marked with 2 cm self-adhesive circular markers on both sides before the start of goniometer measuring. The palpable bony landmarks marked for the forelimb joint measures were the dorsal border of scapular and greater tubercule of the humerus for the shoulder flexion and extension measures, the lateral humeral epicondyle and lateral styloid process of ulnar for elbow flexion and extension measures. The palpable bony landmarks marked for the hindlimb joint measures were the sacral tuberosity of the ilium and the greater trochanter of the femur, for hip flexion and extension measures; the lateral femoral epicondyle and the lateral malleus of the fibula for stifle flexion and extension measures (Fig. 1) [18].

Dogs were conscious and placed in standing position [19]. Shoulder joint flexion and extension were determined by measuring the angle between the longitudinal axis of the humerus and the spine of the scapula. The goniometer's vertex was placed on the greater tubercle of the humerus at the glenoid cavity, the static arm was placed along the spine of the scapula and the mobile arm was placed along the humerus.

Elbow joint flexion and extension were determined by measuring the angles formed between the antebrachial and humeral longitudinal axes. The vertex of the goniometer was placed on the lateral epicondyle of the humerus with the static arm along the major tubercle of the humerus and the dynamic arm along the lateral border of the radius.

Hip joint flexion and extension were determined by measuring the angle between longitudinal axis of the femur and the line that joins the tuber sacrale and the ischiadicum. The vertex of the goniometer was placed over the greater trochanter with the static arm on the iliac spine and mobile arm along the femoral longitudinal axis.

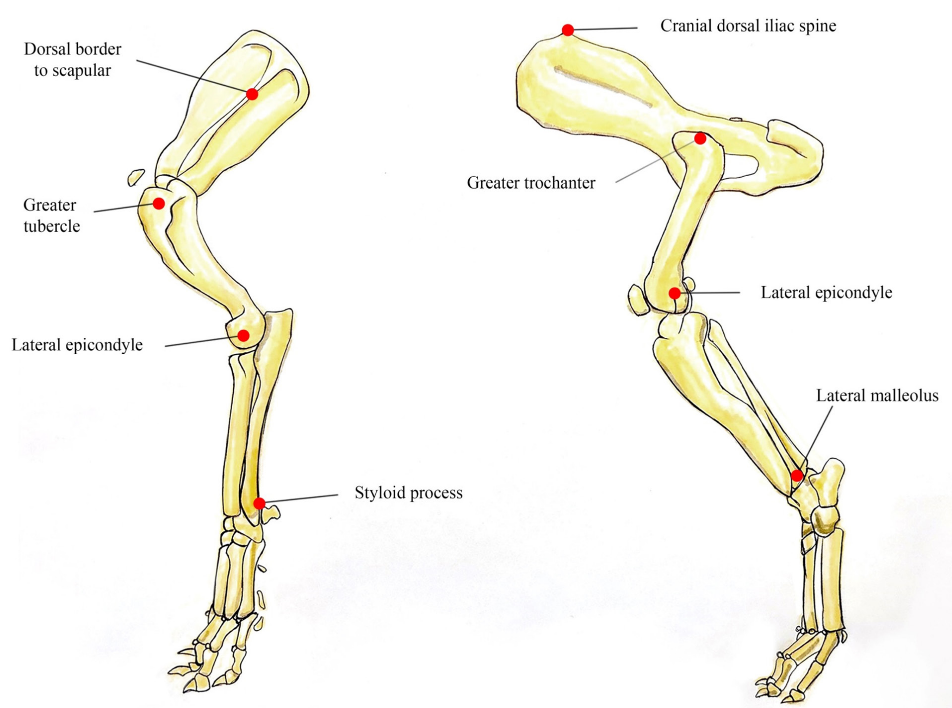

Fig. 1. Bony landmark locations (red dots) in lateral forelimb and hindlimb.

Stifle joint flexion and extension were determined by measuring the angle between the tibial shaft and the longitudinal axis of the femur. The vertex of the goniometer was placed at the lateral epicondyle of the femur, the static arm along the femoral longitudinal axis and the mobile arm was placed at the lateral malleolus (Fig. 2) [19].

Maximum passive flexion and extension were defined as the position where the angle between the bones of a joint were maximally decreased or increased to the end-feel of PROM, when resistance to further motion is felt upon approaching an anatomic or physiological barrier.

To complete goniometric measures the owner/handler moved the dog into a square standing position and triplicate measures of the joint PROM were taken on the RHS in logical order, shoulder, elbow, hip and stifle, each joint was measured in flexion and extension by the examiner. This was followed by the same sequence on the left-hand side (LHS). If the dog took up a sitting position the owner/handler moved the dog to ask for a standing position.

Statistical analyses

Raw data was collated into Excel ver. 2010 program (Microsoft, USA). Descriptive statistics (range, median, interquartile range [IQR] and 95% confidence interval [CI]) were used to analyse each goniometric dataset for the whole group (n = 18) and by gender and age groups (< 6 years old and > 6 years old). Mean values of the triplicate goniometer measures were computed for each dog as suggested by Jaegger et al. [9].

Data was tested for normality with the coefficient skewness at zero (found if mean = median = mode) to show normal distribution. With normal distribution the data sets were analysed using Students paired t-test to investigate relationships between contralateral limbs. Students t-test (2 sample assuming unequal variances) investigated relationships between gender and age groups. Values of $p < 0.05$ were considered significant.

Inferential symmetry indices (SI) were calculated as a quantifiable test for relationship between RHS and LHS PROM measures of the shoulder, elbow, hip and stifle joints. The ROM for each joint, was calculated by subtracting the mean of the flexion angle measures from the mean of the extension angle measurements.

$$X_E - X_F = ROM$$

Symmetry can range from –100% to +100% a value of 0 indicating perfect symmetry (SI = 0) shows there is no difference between X_L and X_R. In effect indicating that perfect symmetry exists between the LHS and RHS, a positive SI value indicates $X_L > X_R$, with a negative value it would indicate $X_R > X_L$ this is in concordance with previous research [20].

$$SI = \frac{X_L - X_R}{0.5 \times (X_L + X_R)} \times 100$$

Results

All data was analysed for the whole sample group (n = 18) for goniometer PROM measures, analysis was also completed with the sample split into gender and age (< 6 years old, > 6 years old).

The group consisted of 55.6% males (n = 10) and 44.4% fe-

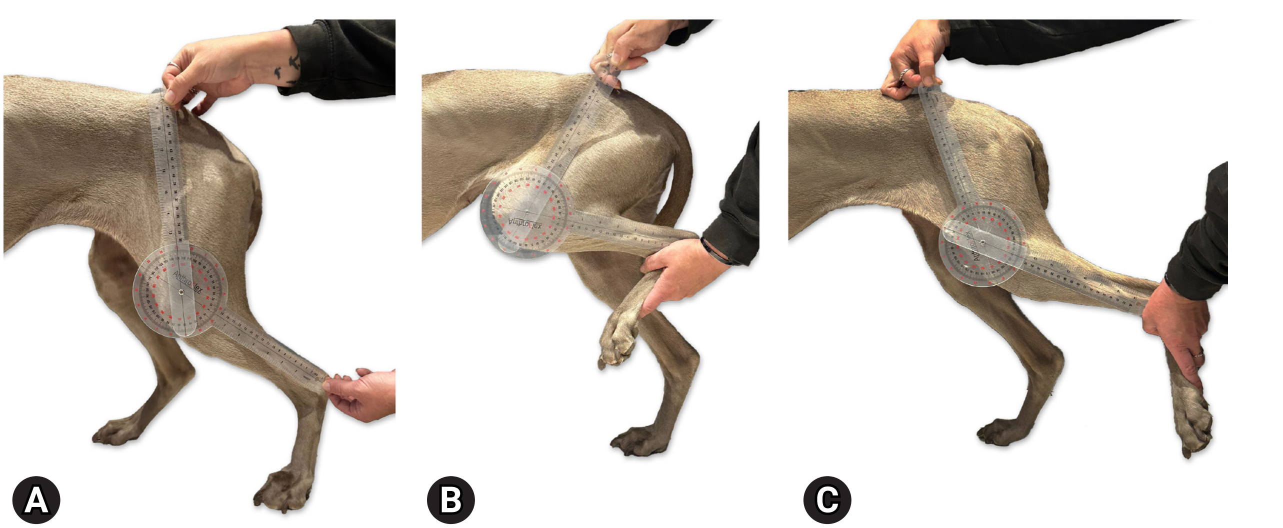

Fig. 2. Shows placement of goniometer for the stifle neutral (A), flexion (B) and extension (C). Photographed by the author.

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males (n = 8). There were 61.1% (n = 11) dogs aged between 1.4 years and 5.1 years of age (<6-year group) and 38.9% (n = 7) dogs aged between 6.1 years and 11.8 years (≥6-year group) (Table 1). In the < 6-year group 63.6% were male (n = 7) with 36.4% female (n =4), in the > 6-year group 42.9% were male (n = 3) and 57.1% were female (n = 4).

The median (IQR) age of all dogs was 5.1 (2.25–7.9) years. The median age of the male dogs was 4.0 (2.4–7.3) years whilst the median age of the female dogs was 6.1 (5.1–8.5) years. P (T ≤ t) 2-tail = 0.5 therefore > 0.05 thus suggesting there is not a significant difference between male and female mean age (Table 1).

The median (IQR) of body weight of all dogs was 20.6 (19.1–23.8) kg. Median body weight for male dogs was 23.3 (1.7) kg (21.3–26.1 kg), whilst the median body weight of the females was 21.3 (18.3–19.5) kg. P (T ≤ t) 2-tail = 0.07 therefore >0.05 thus suggesting there is not a significant difference between male and female mean weight (Table 1).

The median (IQR) (range) of LHS shoulder joint PROM in flexion for all dogs (n = 18) was calculated as 67° (18) (57.5°–75.5°). The median (IQR) (range) of RHS shoulder joint PROM in flexion for all dogs (n = 18) was calculated as 64° (16) (58.2°–74°). P (T ≤ t) 2-tail = 1 therefore > 0.05 thus supporting the null hypothesis that there is no significant difference between LHS and RHS of the shoulder joint PROM in flexion.

There was no significant difference ($p > 0.05$) between left and right-side passive flexion and extension measure for all joints (shoulder, elbow, hip, stifle). Gender had no significant effect ($p > 0.05$) on joint measures for passive flexion or extension of all joints.

Median (IQR) for passive joint flexion and extension of each joint when grouped by age is detailed in Table 2 (< 6 years old) and Table 2 (> 6 years old).

Age (< 6 vs. > 6 years) had a significant effect on right hip

Table 1. Participant data by age and gender

	Total dogs	Male dogs	Female dogs	< 6 y dog	> 6 y dog
Animals	18 (100.0)	10 (55.6)	8 (44.4)	11 (61.1)	7 (38.9)
Age (y)	5.1 (2.25–7.9) (1.4–11.8)	4.0 (2.4–7.35) (2.1–9.1)	6.1 (5.1–8.5) (1.4–11.8)	4.0 (2.1–4.0) (1.4–5.1)	8.1 (7.7–9.5) (6.1–11.8)
Weight (kg)	20.6 (19.1–23.8) (17.5–26.0)	23.3 (22.9–24.6) (21.3–26.1)	21.3 (18.3–19.5) (17.5–26.5)	21.4 (19.3–23.8) (17.8–26.0)	22.9 (19.2–23.9) (18.8–27.7)
Height (cm)	60.0 (58.4–61.7) (55.4–67.0)	63.5 (58.6–62.2) (58.0–67.0)	57.2 (55.8–58.4) (55.0–62.0)	60.0 (58.4–62.9) (55.4–67.0)	58.0 (57.1–60.9) (55.7–63.5)

Values are presented as number (%) or median (interquartile range) (range).

Table 2. Left and right-side median (IQR) goniometer measurements of PROM (degrees) for joint flexion and extension for all dogs and grouped by gender and age

Joint	Side	All dogs (n = 18)	Male (n = 10)	Female (n = 8)	< 6 y dog (n = 11)	≥ 6 y dog (n = 7)
Shoulder Flexion	Left	67.0 (57.5–75.5)	69.0 (56.7–74.2)	64.5 (58.7–72.5)	72.0 (69.0–78.5)*	56 (50.5–58.5)*
	Right	64.0 (58.2–74.0)	64.5 (62.2–75.5)	62.5 (57.0–70.5)	72.0 (64.5–78.0)*	56 (50.5–61.5)*
Shoulder Extension	Left	143.0 (129.2–150)	144.0 (130.3–150)	140.0 (128.7–149.2)	144.0 (127.0–150.0)	142.0 (134.0–150.7)
	Right	146.0 (127.2–154.7)	146.0 (130.7–154.7)	145.5 (125.5–150.7)	145.0 (126.0–150.0)	147.0 (134.5–156.0)
Elbow Flexion	Left	35.5 (27.0–40.7)	36.0 (30.7–41.7)	34.5 (23.5–16.5)	40.0 (37.5–44.0)#	24.0 (22.0–32.5)#
	Right	32.0 (25.2–13.7)	36.0 (29.5–42.0)	29.5 (23.0–34.5)	39.0 (34.0–46.5)*	23.0 (23.0–29.0)*
Elbow Extension	Left	138.5 (127.2–146.2)	145.5 (131.5–151.7)	129.0 (125.5–141.5)	143.0 (130.0–151.5)	128.0 (126.0–140.0)
	Right	135.0 (123.5–145.5)	145 (127.2–151.5)	132.5 (120.7–137.0)	140.0 (124.0–151.0)	133.0 (127.0–138.0)
Hip Flexion	Left	69.5 (58.2–75.5)	72.5 (58.2–82.7)	67.5 (61.5–72.0)	72.0 (67.0–80.0)	59.0 (55.0–68.5)
	Right	68.0 (55.0–78.5)	75.5 (60.0–80.5)	61.0 (49.5–70.5)	77.0 (68.0–81.0)*	55.0 (51.0–61.0)*
Hip Extension	Left	157.5 (148.2–162)	154.0 (148.2–161.2)	161.0 (148.2–162.7)	149.0 (144.5–157)##	162.0 (159.5–163.5)##
	Right	154.5 (150.0–161.5)	150.5 (149.2–158.2)	157.0 (155.0–166.0)	151.0 (147.5–154.5)*	164.0 (160.0–167.0)*
Stifle Flexion	Left	33.5 (29.5–36.7)	34.0 (28.2–36.0)	32.0 (30.5–37.2)	34.0 (31.5–36.0)	31.0 (28.0–37.5)
	Right	32.0 (29.2–37.5)	30.5 (28.2–34.2)	34.5 (31.7–38.0)	32.0 (29.5–36.5)	32.0 (30.0–37.0)
Stifle Extension	Left	130.0 (121.7–136.7)	131.0 (121.7–136.7)	130.0 (123.0–135.7)	132.0 (122.5–138.0)	128.0 (115.0–134.5)
	Right	131.5 (128.0–136.7)	132.0 (128.0–135.7)	131.0 (122.2–137.0)	132.0 (128.0–136.0)	131.0 (124.5–136.5)

IQR, interquartile range; PROM, passive range of motion.
*Significant difference ($p < 0.001$) between groups; #Significant difference ($p = 0.001$) between groups; ##Significant difference ($p = 0.02$) between groups.

flexion ($p < 0.001$) and for both left and right-side shoulder flexion ($p < 0.001$); left and right-side elbow flexion ($p = 0.001$ and $p < 0.001$) and hip extension ($p = 0.02$ and $p < 0.001$) respectively.

Illustrated for shoulder joint, the elbow joint, the hip joint figures and the stifle joint (Table 2).

The shoulder joint showed greatest PROM asymmetry (SI = 3.63%). Joint asymmetry was minimal for elbow (SI = 0.1%), stifle (SI = 0.63%) and hip (SI = 1%) joints.

Discussion

The aim of this study was to investigate laterality within dog's joints in relation to their passive joint ROM, identifying any asymmetries between the LHS and the RHS. This could allow the identification of sub-clinical changes within the joints; this knowledge could lead to early treatment intervention, reducing the effects of degenerative joint disease.

This study was undertaken using a morphologically homogeneous group of dogs of the same breed that live and work together thus minimalizing genetic and environmental influences. The mean animal weight for the Siberian Husky dogs and bitches was consistent with breed standards suggested by the Kennel Club.

Measures were taken of the shoulder, elbow, hip and stifle joints in flexion and extension of the LHS and the RHS and from these the PROM of the joints were calculated to investigate if the sample showed any asymmetries between their LHS and RHS. Research into canine laterality or asymmetry is not extensive and as predatory animals they mask and lameness and compensate with either ipsilateral or contralateral limbs [21].

Although it has been suggested that the influence of gender on joint PROM is unknown [22]. There is some conflict in research, it has been suggested joint PROM was not significantly affected by gender in the joints measured elbow, carpal, hip, stifle and tarsus other than in the shoulder ($p < 0.05$) [23]. However it has also been found that gender has a significant effect on joint PROM ($p < 0.001$) finding intact females $p = 0.013$ and spayed females $p = 0.034$ had a greater joint PROM than neutered males [24]. Human studies on joint ROM show the heavier muscle mass of males can limit PROM in certain joints, which goes on to suggest increased weight can limit joint PROM [22]. This was contrary to the results of a study on German Shepherd dogs and Labrador Retrievers where the mean weight of both German Shepherds and Labrador Retrievers was identical [22].

In this study of joint PROM in flexion and extension of the shoulder, elbow, hip, and stifle joints, gender had no significant effect ($p > 0.05$) on joint measures for passive flexion or extension of all joints, this supports evidence that gender would not adversely influence age-related results.

The age range of the study sample (n = 18) was 1.4 to 11.8 years which enabled an investigation into age effects as well as gender on joint PROM measures. At the time of this research there were no publications with 'normal' goniometric PROM measures for the Siberian Husky dog; there was limited research in other working breeds of dog (Labrador Retrievers [9], Shepherd dogs [22]. It is suggested 6 years of age as the mean age when musculoskeletal conditions begin to affect dogs [25]. Canine Brief Pain Inventory and the Helsinki Chronic Pain Index are known outcome measures to assess a pain response to osteoarthritis in dogs, along with video analysis. A decrease in ROM reduces the noxious stimuli (pain) associated with degeneration of a joint [2,25]. Degenerative joint disease prevalence is suggested to reach 52% of dogs at 5 years of age [26]. with some showing decrease in ROM with or without lameness. It is thought that 80% of companion animals have osteoarthritis with a suggestion that 20% are middle aged when evaluated using weight distribution, ROM, thigh circumference and radiographs [27]. The gold standard to assess progression of degenerative joint disease would be palpation [26]. Radiographs can aid clinical diagnosis; however they are expensive, labour intensive and not always practical [2]. PROM goniometric measures aid in evaluation of asymmetry and decrease in ROM of the joint, this is a valid [9] and sensitive physiotherapeutic evaluation method [27] and comparing to breed norms would enhance monitoring and possible outcome measures.

In this study dogs age had a significant effect on passive joint ROM. The angle of the shoulder joint during passive flexion for both the LHS and RHS was significantly higher for dogs < 6 years age compared to dogs > 6 years.

When working, however, these dogs wear a 'non-restrictive' harness and there is some evidence that harness wear may be a factor to affect shoulder joint ROM [28]. Previous limited research measuring active ROM in harness-wearing dogs found that a non-restrictive harness was identified as having a greater impact on shoulder joint ROM (4.73° at walk and 9.31° at trot) when compared to a non-restrictive harness (2.16° at walk and 4.92°. Future research into the effect on PROM of harness-wearing in working and pet dogs could identify if there is a correlation between harness-wear and decreased PROM.

Elbow joint flexion angle was significantly higher for dogs < 6 years age for both the LHS and RHS. The RHS hip joint angle in flexion was significantly higher for dogs < 6 years age. Joint extension movement was significantly higher for the hip

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joint on both the LHS and the RHS in dogs > 6 years age. Young dogs remain in a developmental growth state until maturity and as such may have a greater flexibility within the joints [11]. This flexibility could have the possibility of skewing any results, however in this current research sample only 2 dogs < 2 years old were used, limiting this factor. It is thought that between 2 and 6 years old is where musculature can be at its peak. Muscle mass decreases as dogs' age, this atrophy impacts joint ROM [11]. Muscles' function using 'torque' with antagonistic muscles working together this is most notable at the shoulder with extension appearing restricted and flexion increased [12]. The aging process causes natural osteological changes within the joint regardless of any additional exertion the joints have received through workload or weight [11].

This current research found there was a no significant difference in either shoulder flexion ($p = 0.7$) or extension ($p = 0.6$) in the > 6-year-old cohort, contrary to previous research [12].

When on the line WSHDs run out at a lope (canter) (asymmetrical gait) for as long as energy allows before falling into a trot, this could be a contributary factor in limb asymmetry for this breed. Very rarely do the limbs of the dog move in synchrony, there is always a slight asynchrony [29].

The SI result of this research suggest that this sample population (n = 18) show asymmetry between LHS and RHS. The shoulder joint shows the highest asymmetry (SI = −3.63%) this could be due to the age range of this sample of dogs (1.4– 11.8 years) with a larger numer of dogs < 6 years old (n = 11).

The LHS stifle joint had less mean joint motion than the RHS (SI = −0.63%). A difference in symmetry was detected in the hip joint mean PROM between LHS and RHS (SI = 1%) the RHS hip joint had less mean joint motion than the LHS.

Previous research into joint PROM has concentrated on the hindlimbs and osteological changes [16,25], whereas, the results of this study indicate that future research should also investigate the shoulder joint (this is the area of the dogs body which recieves the greatest of load [8]). Consideration should be given not only to any sub-clinical osteological changes, but to the possibility of myological changes during the ageing process.

The measurement of joint PROM is widely and commonly used by human therapists for injury rehabilitation, deviations from a perceived 'normal' joint PROM can indicate changes to joint pathologies.

The measurement of PROM in dogs could aid early detection of joint changes; goniometric changes to joint PROM, particularly in older dogs could be used in conjunction with other modalities to assess joint dysfunction.

A database of breeds would allow professionals to identify changes to joint ROM. Knowing the perceived 'normal' joint PROM for any given breed would help to identify sub-clinical changes.

The IQR for median values of joint PROM in flexion and extension ranged from 4°–27.5° (95% CI, 3°–7.3°) which are suggestive that the results of this study may be representative in predicting breed population means of joint PROM for the Working Siberian Husky when in standing position compared to lateral recumbency.

Further research into the joint PROM via goniometry could be enhanced with thigh circumference measurements [24] which would highlight changes in muscle mass of the hind limbs of dogs.

The novel method of measuring joint PROM in a standing position is a potential way of improving the welfare for future research of joint PROM via goniometry. Further study into the welfare implications of this positioning compared to lateral recumbency should be made via behavioural observations centred on the stress response.

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