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Goniometric Evaluation and Passive Range of Joint Motion in Chondrodystrophic and Non-Chondrodystrophic Dogs of Different Sizes

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Abstract

Objective This study aimed to evaluate angle values in maximal flexion and extension; the passive range of motion (PROM) of the shoulder, elbow, carpal, hip, stifle and tarsus; and the carpal abduction and adduction of chondrodystrophic (CD) and non-chondrodystrophic (NCD) dogs of different sizes.

Study Design Goniometric evaluation was performed in triplicate using a universal goniometer. CD dogs were categorized into miniature, small, medium, large and giant sizes, whereas NCD dogs were allocated to small- and medium-size groups. Hence, each of the seven subgroups comprised 11 clinically healthy dogs. For data analysis, the Levene test was used to evaluate homoscedasticity. The means of each joint angle with the means in each group as well as the PROM between the CD and NCD groups was compared by the Student's *t*-test; meanwhile, the means of the joint angles and ROM among the sizes were compared by analysis of variance, followed by the Tukey test. In those cases, when no homogeneity variance was observed, the Bonferroni test was used. In every case, $p \leq 0.05$ was considered significant.

Results The articular angles and PROM differed according to the dog size and type, that is, CD or NCD.

Conclusion The goniometric values and PROM of dogs depend on the joint type, dog size and chondrodystrophy status. Further studies are necessary to increase the accuracy of the results and to establish the predominant factors governing the differences discovered.

Keywords
- dog
- goniometry
- chondrodystrophy
- passive range of motion

Introduction

Goniometry, in general, is a technique for measuring angles. It is a simple, viable, non-invasive and inexpensive method that is often used by orthopaedic surgeons and physiotherapists to assess the severity of joint injuries and to monitor a patient's clinical evolution.[1,2] In this technique, articular angle measurements are captured using a goniometer, which can be the universal, fluid or pendula type, or an electronic goniometer from a smartphone.[3] The universal model appears to be the most typically used in clinical routine owing to its low cost and practicality. It comprises a 180 or 360 degrees protractor system with two plastic or metal arms.[4,5]

Studies have demonstrated goniometry to be highly reliable for the measurement of range of motion compared with visual or radiographic estimation methods,[6,7] which typically performed without sedation.[8,9] Passive range of motion (PROM) refers to the maximal angulation between antagonistic joint

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functions, such as flexion and extension or adduction and abduction without muscle contractions, performed by external forces, thereby maintaining the integrity of the anatomical stabilizers of the movement, such as ligaments, tendons and capsules.[10,11] Goniometric information can be useful in determining the presence of dysfunction, establishing differential diagnoses,[12] developing the goals of physical rehabilitation treatment,[13] documenting progress,[14] modifying treatment and manufacturing orthotics.[15,16]

In veterinary medicine, goniometry has been studied in several species, such as dogs,[8,17–21] cats,[22] calves,[23] sheep,[24] horses[25,26] and pacas.[27] Especially in dogs, it has been reported that universal data can be used as a parameter for goniometric evaluation[28]; however, variations in joint angulations have been discovered between small chondrodystrophic (CD) breeds, such as the Dachshund, and giant-sized non-chondrodystrophic (NCD) breeds, such as the Irish Wolfhund.[21,29] As the expression of FGF4 retrogene is associated with breed-defining chondrodysplasia,[30,31] some breeds are typically considered CD, such as the Basset Hound, Dachshund, English Bulldog, French Bulldog, Pug, Shih Tzu and Welsh Corgi.[32–34]

The present study aims to compare the goniometric measurements and range of motion of the shoulder, elbow, carpal, hip, stifle and tarsus joints between CD and NCD of different sizes.

Materials and Methods

After obtaining approval by the Ethics Committee on the Use of Animals from a local committee under protocol number 0996/2015, the study was performed at the Hospital Unit for Companion Animals at the University, in which 77 young sound adult and female dogs were evaluated. The exclusion criteria used in the study were as follows: immature skeleton (age $<$ 12 months for miniature-sized dogs and 18 months for other sizes); age greater than 7 years, body condition below ($<$4) or above ($>$6) the optimal score from a nine-point body condition scoring system[35]; presence of injury; and metabolic, nervous, muscular, or skeletal diseases. The epidemiological profile and goniometric measurements of each animal were registered in an evaluation form.

Based on breed classification, NCD dogs were classified into the following sizes: miniature ($\leq$5 kg), small (5.1–10.9 kg), medium (11–25.9 kg), large (26–44.9 kg) and giant ($\geq$45 kg). The CD dogs were of small (5.1–10.9 kg) and medium (11–25.9 kg) sizes. Therefore, each of the seven subgroups comprised 11 dogs for a total of 77 dogs.

Using a universal plastic goniometer (Carci—Industry and Commerce of Surgical and Orthopaedic Apparatus Ltda., São Paulo-SP, Brazil), goniometry was performed on awake dogs in lateral recumbency in triplicate measurements, in which their mean value was considered for statistical analysis. Measurements were obtained by the same examiner, who is experienced and specialized in cat and dog physical therapy to ensure homologous evaluations.

To obtain the joint angular values, the vertex, mobile and static arm of the goniometer was placed over specific anatomical reference points for each joint,[36] as described in ►**Table 1**.

Another evaluated parameter was the PROM, which is an important factor for assessing joint function, because larger amplitudes are required for walking, trotting and galloping as the speed increases during locomotion. The PROM was calculated by the difference between the maximum extension and the maximum flexion of the joint; meanwhile, it was necessary to add up measurements of both adduction and abduction to obtain the PROM in the transverse plane.[37]

For data analysis, the Levene test was used to evaluate homoscedasticity. The mean of the joint angles and PROM between the CD and NCD groups were compared using the Student's *t*-test, whereas the mean of the joint angles and the range of motion between the groups were compared using analysis of variance, followed by the Tukey test. In cases where no variance in homogeneity was observed, the Bonferroni test was used.[38] In all cases, $p < 0.05$ was applied for significance. Mean values with standard errors were presented. All data were analysed using the Statistical Package for Social Sciences software.

Results

Differences in joint angles and PROM were observed within dogs of different sizes in the CD and NCD groups. The mean

Table 1 Anatomical references for the correct positioning of parts of the goniometer for each evaluated joint

Joint	Goniometer parts		
	Static arm	Vertex	Mobile arm
Shoulder	Spine of the scapula	Subacromial space	Lateral epicondyle of the humerus
Elbow	Major tubercle of the humerus	Lateral epicondyle of the humerus	Lateral border of the radius
Carpus LL	Radius axis	Carpi axis	Longitudinal axis of the III and IV metacarpal bones
Carpus CC	Lateral epicondyle of the humerus	Styloid process of the ulna	V metacarpus lateral axis
Hip	Iliac spine	Greater trochanter	Femoral longitudinal axis
Stifle	Femoral longitudinal axis	Lateral epicondyle of the femur	Lateral malleolus
Tarsus	Longitudinal axis of the tibia	Space between talus and calcaneus	V metatarsus lateral axis

Abbreviations: CC, craniocaudal: for sagittal plane movements; LL, laterolateral: for transversal plane movements.

Table 2 Mean and standard deviation of articular angles of CD and NCD dogs

	CD		NCD				
Joint position	Small	Medium	Miniature	Small	Medium	Large	Giant
Shoulder flexion	59 ± 13[1]	73 ± 14[1,3]	37[a] ± 11	59[b] ± 11	62[bc] ± 10[3]	70[c] ± 10	58[b] ± 4
Shoulder extension	139 ± 13	138 ± 13	151[c] ± 5	140[b] ± 9	137[b] ± 8	126[a] ± 12	158[d] ± 7
Elbow flexion	31 ± 8	36 ± 11[3]	17[a] ± 3	31[b] ± 7	28[b] ± 3[3]	36[c] ± 8	29[b] ± 5
Elbow extension	153 ± 30[2]	135 ± 14	142[ab] ± 7	151[bc] ± 11[2]	140[a] ± 8	146[abc] ± 22	154[c] ± 9
Carpal flexion	44 ± 5	43 ± 7[3]	29[a] ± 2	40[bc] ± 9	33[ab] ± 6[3]	47[c] ± 13	44[c] ± 9
Carpal extension	193 ± 7[2]	176 ± 18	189[c] ± 2	187[bc] ± 6[2]	185[ab] ± 5	184[ab] ± 4	182[a] ± 5
Carpal adduction	18 ± 10[1,2]	4 ± 6[1,3]	9[a] ± 2	9[a] ± 9[2]	18[b] ± 6[3]	16[ab] ± 9	8[a] ± 3
Carpal abduction	53 ± 7[2]	48 ± 10[3]	51[d] ± 15	35[c] ± 15[2]	32[bc] ± 9[3]	24[ab] ± 6	18[a] ± 5
Hip flexion	52 ± 19	54 ± 15	47[a] ± 13	55[a] ± 12	56[a] ± 11	57[a] ± 11	68[b] ± 10
Hip extension	156 ± 25[2]	132 ± 26	151[c] ± 6	129[ab] ± 17[2]	135[b] ± 9	120[a] ± 15	149[c] ± 10
Stifle flexion	41 ± 9	42 ± 7[3]	37[ab] ± 5	34[a] ± 7	30[a] ± 7[3]	42[bc] ± 14	49[c] ± 8
Stifle extension	135 ± 15	140 ± 6	151[bc] ± 9	130[a] ± 12	142[ab] ± 8	146[b] ± 14	156[c] ± 9
Tarsus flexion	49 ± 11	50 ± 12[3]	29[a] ± 6	37[ab] ± 10	33[a] ± 6[3]	48[b] ± 12	50[b] ± 14
Tarsus extension	178 ± 18	153 ± 23	156[a] ± 21	168[ab] ± 25	162[ab] ± 9	175[ab] ± 17	161[b] ± 9

Abbreviations: CD, chondrodystrophic; NCD, non-chondrodystrophic.
[1]Differences in joint angles between small and medium-sized CD dogs.
[a–d]Differences in joint angles between small- and medium-sized CD dogs. $p < 0.05$.
[2]Differences of joint angles between small CD and NCD dogs.
[3]Differences in joint angles between medium CD and NCD dogs.

and standard deviation of the CD and NCD dog's articular angles and PROM are summarized in ►**Tables 2** and **3** respectively. According to the compared parameters, the following findings were obtained:

1. *Different sizes (small and medium) within CD group:* small CD dogs revealed a greater carpal adduction and shoulder flexion, represented by lower values, compared with medium breed dogs. Comparing the PROM CD dogs of different sizes, the small breeds presented greater mobility in carpus and hip joints than the medium ones.
2. *Different sizes (miniature, small, medium, large and giant) within NCD group:* the maximum flexion angle of the shoulder, elbow and carpus increased according to the size of the animals, that is, the flexion range of these joints in dogs of larger sizes was smaller, except for giant dogs that presented the same flexor range as that of small dogs, as shown in ►**Fig. 1**. The maximal extensor angles in the giant breed dogs indicated greater or equal angle measurements compared with those of the other sizes in all joints, except for the carpus, that is, greater extension measurements were recorded in the miniature-sized dogs. The PROM among NCD dogs of different sizes showed no differences in the elbow, stifle and tarsus joints. However, the miniature NCD dogs presented greater mobility in the hip and both planes of the carpus. The

Table 3 Angular measurements of articular PROM of CD and NCD dogs represented in mean and standard deviation

	CD		NCD				
PROM	Small	Medium	Miniature	Small	Medium	Large	Giant
Shoulder	79 ± 20	65 ± 20	114[b] ± 9	81[b] ± 16	75[b] ± 8	Shoulder	79 ± 20
Elbow	121 ± 31	99 ± 20	125[a] ± 8	120[a] ± 14	112[a] ± 7	Elbow	121 ± 31
Carpus CC	149 ± 8[1,2]	133 ± 19[1,3]	160[ab] ± 2	146[ab] ± 9[2]	151[b] ± 9[3]	Carpus CC	149 ± 8[1,2]
Carpus LL	71 ± 14[1,2]	53 ± 15[1]	60[c] ± 14	45[b] ± 19[2]	50[b] ± 13	Carpus LL	71 ± 14[1,2]
Hip	104 ± 18[1]	77 ± 27[1]	103[b] ± 9	74[a] ± 25	79[a] ± 15	Hip	104 ± 18[1]
Stifle	94 ± 18	98 ± 8[3]	113[a] ± 12	102[a] ± 12	112[a] ± 12[3]	Stifle	94 ± 18
Tarsus	129 ± 33	103 ± 28[3]	127[a] ± 19	130[a] ± 26	129[a] ± 11[3]	Tarsus	221 ± 33

Abbreviations: CD, chondrodystrophic; NCD, non-chondrodystrophic; PROM, passive range of motion.
[1]Differences in PROM between small- and medium-sized CD dogs.
[a,b,c]Differences in PROM between NCD dogs of different sizes.
[2]Differences in PROM between small CD and NCD dogs.
[3]Differences in PROM between medium CD and NCD dogs.

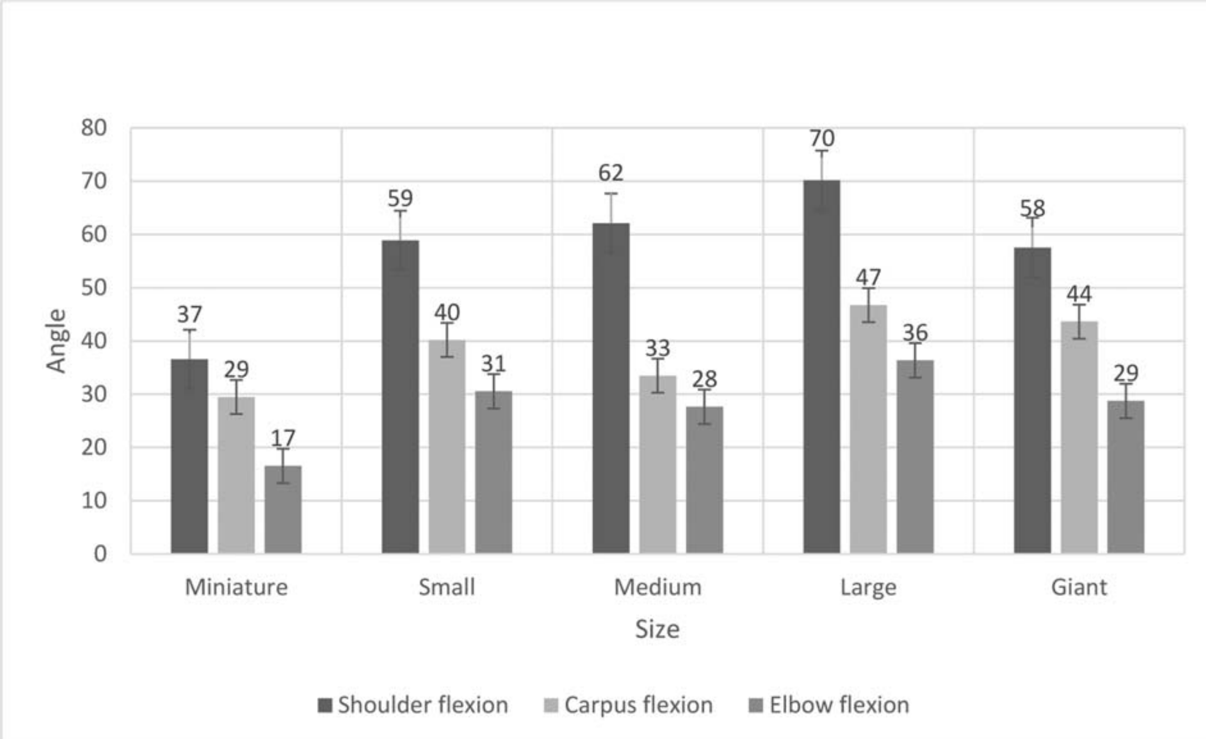

Fig. 1 Means and standard deviation of angular measurements of shoulder, carpal and elbow flexion in non-chondrodystrophic dogs with varying size.

greatest and smallest mobility of the shoulder was presented in the giant and large breed dogs respectively.

3. *Small dogs among CD and NCD groups:* the extension, abduction and adduction of the carpus and hip extension were larger in the CD dogs; however, the flexion of the tarsus in this group was less. Regarding joint mobility, the PROM varied only in the hip and carpus articulation in both planes, with the greatest mobility exhibited in the CD dogs. These results show that the smaller CD dogs have greater joint mobility than the larger CD dogs, that is, the size of the CD dogs is inversely proportional to their joint mobility.
4. *Medium dogs among CD and NCD groups:* medium CD dogs presented greater flexor movements in all joints compared with the NCD dogs, except for the hip joint. The medium NCD dogs showed greater carpal adduction, whereas adduction was greater in the smaller dogs. The hip extension angle in the giant breed dogs was higher compared with those of dogs of other sizes. However, the giant breed dogs had a lower hip flexor capacity than the other groups; therefore, they presented greater flexion angles. Despite the differences between angular measurements of the elbow, carpus and hip and joints of small CD and NCD dogs, only the PROM differed in the carpus joints of the medium CD and NCD dogs. The PROM was the same for the shoulder, elbow, hip and carpus in the transverse plane, that is, the variation in the flexor and extensor maximal angulation did not affect the PROM in those joints. Otherwise, the small CD dogs would have a greater tarsal and carpal mobility in the sagittal plane, whereas the medium NCD dogs would exhibit greater mobility in the stifle joints.

Discussion

In general, a few larger coefficients of variation appeared in each joint goniometry compared with other specific breed studies[8,19,39,40]; this could be because groups were classified by size based on body weight regardless of breed in this study. Another study regarding stifle joints in only large breed dogs showed that this variation might occur between breeds.[20] Despite the conformational characteristics of different breeds, other determinant factors related to the joint range of motion to be considered are muscle mass and tone, which are typically inversely proportional to the PROM, unless disuse inherent to aging is avoided and mobility exercises are regularly practiced to maintain elongated periarticular soft tissues.[11,41]

The difference between the shoulder joint amplitude in medium and small CD dogs can be explained by the relationship between the diameter of the rib cage and the limb length, which is greater in medium- than in smaller-sized CD dogs, thereby limiting the movement of shoulder flexion by direct contact with the costal grid.[21,36]

Carpal changes in small-sized CD dogs can be explained by the characteristic angular deformity of CD dogs.[42,43] The early closure of physis in CD dogs may vary according to the size of the animal and may be directly related to the mobility of the carpus.[42–44] Furthermore, medium CD breeds have marked developmental characteristics of curved radius, which increases carpal abduction and limits carpal adduction. Additionally, the difference in the adduction and abduction of the carpal joint in CD dogs may be due to the abnormal development of the radius and ulna, which limits carpal adduction and exacerbates carpal abduction.[43]

Differences in hip PROM between CD dogs of different sizes discovered in the present study have not been described sufficiently hitherto.[45] Other studies regarding Dachshund[21] and French Bulldogs[39] showed similar PROM of the hip compared with results obtained in small CD dogs in the present study. No other significant differences existed among the measurements of CD dogs, which demonstrate the homogeneity of articular angulations in dogs affected by chondrodystrophy.[21,36]

Results of stifle angles of large NCD dogs were compatible with those of a study of Greyhounds[46]; that is, the mean weight was 30 kg; and the mean and standard deviation values of the flexion and extension of stifle were 51 ± 7 and 145 ± 9, respectively, with less than 10 degrees difference in the mean of the stifle flexion 42 ± 14 and extension 146 ± 14 of the present study. The same similarity was observed when comparing the hip extension; however, possibly owing to the different breeds analysed in the present study, the hip flexion of 57 ± 11 differed significantly from the 72 ± 8 observed in the mentioned study, as only Greyhounds were evaluated. The tarsus flexion (48 ± 12) and extension (175 ± 17) angles differed from those obtained in the same study (flexion: 110 ± 10; extension: 158 ± 10).

This might be owing to the 90 degrees angle stifle position methodology in the mentioned study. In the present study, the stifle joint was in total flexion, which facilitated tarsus flexion (as reported in other studies), with similar results inferior to 50 degrees for tarsus flexion.[21,39] Further studies regarding tarsal articulation in dogs are required to compare the results obtained in the present study.[17] The results obtained through the stifle goniometry of NCD large dogs (flexion 42 ± 14 and extension 146 ± 14) were similar to those reported in another study in seven large breed dogs, in which the means ranged from 29–39 degrees and 154–164 degrees for stifle flexion and extension respectively.[20]

The greater mobility in the sagittal and transverse planes of the carpi in the CD dogs relative to the NCD dogs can compensate for the shorter the limbs. Meanwhile, increased joint mobility favoured joint laxity and the misalignment of the thoracic limbs is the main risk factor of secondary osteoarthrosis.[47] However, further long-time follow-up studies are required to better understand joint mobility in CD dogs and its possible clinical implications.

Conclusion

Goniometry is a useful method in dogs to evaluate range and limits of joint motion and may be helpful in planning and executing selected orthopaedic procedures. However, dog size and breed standards should be considered, as the joint angles and PROM differ between CD and NCD healthy dogs of different sizes. Results show that there are differences between PROM and goniometric measurements in CD and NCD dog of different sizes, and this should be considered when applying those evaluation technique.

Authors' Contributions

M.B. executed the experiment and registered the data. M. R. and S.W. did statistical analysis. J.V., M.R., and S.W. interpreted the results and critically revised the manuscript for important intellectual contribution. All the authors approved the final version.

Conflict of Interest

None declared.

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