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

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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

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 ≤ 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

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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.\textsuperscript{10,11} Goniometric information can be useful in determining the presence of dysfunction, establishing differential diagnoses,\textsuperscript{12} developing the goals of physical rehabilitation treatment,\textsuperscript{13} documenting progress,\textsuperscript{14} modifying treatment and manufacturing orthotics.\textsuperscript{15,16}

In veterinary medicine, goniometry has been studied in several species, such as dogs,\textsuperscript{8,17–21} cats,\textsuperscript{22} calves,\textsuperscript{23} sheep,\textsuperscript{24} horses\textsuperscript{25,26} and pacas.\textsuperscript{27} Especially in dogs, it has been reported that universal data can be used as a parameter for goniometric evaluation\textsuperscript{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 Wolfhound.\textsuperscript{21,29} As the expression of FGF4 retrogene is associated with breed-defining chondrodysplasia,\textsuperscript{30,31} some breeds are typically considered CD, such as the Basset Hound, Dachshund, English Bulldog, French Bulldog, Pug, Shih Tzu and Welsh Corgi.\textsuperscript{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\textsuperscript{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 (≤5 kg), small (5.1–10.9 kg), medium (11–25.9 kg), large (26–44.9 kg) and giant (≥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 \textsuperscript{36}(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,\textsuperscript{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.\textsuperscript{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.\textsuperscript{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                     |
|-----------|--------------------------------------|
| Shoulder  | Static arm: Spine of the scapula; Vertex: Subacromial space; Mobile arm: Lateral epicondyle of the humerus |
| Elbow     | Static arm: Major tubercle of the humerus; Vertex: Lateral epicondyle of the humerus; Mobile arm: Lateral border of the radius |
| Carpus LL | Static arm: Radius axis; Vertex: Carpi axis; Mobile arm: Longitudinal axis of the III and IV metacarpal bones |
| Carpus CC | Static arm: Lateral epicondyle of the humerus; Vertex: Styloid process of the ulna; Mobile arm: V metacarpal axis |
| Hip       | Static arm: Iliac spine; Vertex: Greater trochanter; Mobile arm: Femoral longitudinal axis |
| Stifle    | Static arm: Femoral longitudinal axis; Vertex: Lateral epicondyle of the femur; Mobile arm: Lateral malleolus |
| Tarsus    | Static arm: Longitudinal axis of the tibia; Vertex: Space between talus and calcaneus; Mobile arm: V metatarsal axis |

Abbreviations: CC, craniocaudal: for sagittal plane movements; LL, laterolateral: for transversal plane movements.
Different sizes (small and medium) within CD group:

1. Differences in PROM between small and medium-sized CD dogs.

2. Differences in PROM between medium CD and NCD dogs.

3. Differences in PROM between small CD and NCD dogs.

Table 2 Differences in joint angles between NCD dogs of different sizes.

| Joint position          | CD                  | NCD                  |
|-------------------------|---------------------|----------------------|
| Shoulder flexion        | 59 ± 13             | 37 ± 11              |
| Shoulder extension      | 139 ± 13            | 151 ± 5              |
| Elbow flexion           | 31 ± 8              | 17 ± 3               |
| Elbow extension         | 153 ± 30            | 142 ± 7              |
| Carpal flexion          | 44 ± 5              | 29 ± 2               |
| Carpal extension        | 193 ± 7             | 189 ± 2              |
| Carpal adduction        | 18 ± 10             | 9 ± 2                |
| Carpal abduction        | 53 ± 7              | 51 ± 15              |
| Hip flexion             | 52 ± 19             | 47 ± 13              |
| Hip extension           | 156 ± 25            | 151 ± 6              |
| Stifle flexion          | 41 ± 9              | 37 ± 5               |
| Stifle extension        | 135 ± 15            | 151 ± 9              |
| Tarsus flexion          | 49 ± 11             | 29 ± 6               |
| Tarsus extension        | 178 ± 18            | 153 ± 23             |

Abbreviations: CD, chondrodystrophic; NCD, non-chondrodystrophic.

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.

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

| PROM       | CD                  | NCD                  |
|------------|---------------------|----------------------|
| Shoulder   | 79 ± 20             | 75 ± 8               |
| Elbow      | 121 ± 31            | 112 ± 7              |
| Carpus CC  | 149 ± 8             | 146 ± 9              |
| Carpus LL  | 71 ± 14             | 70 ± 13              |
| Hip        | 104 ± 18            | 79 ± 15              |
| Stifle     | 94 ± 18             | 112 ± 12             |
| Tarsus     | 129 ± 33            | 129 ± 11             |

Abbreviations: CD, chondrodystrophic; NCD, non-chondrodystrophic; PROM, passive range of motion.

1Differences in PROM between small and medium-sized CD dogs.

2Differences in PROM between NCD dogs of different sizes.

3Differences in PROM between small CD and NCD dogs.

4Differences in PROM between medium CD and NCD dogs.
greatest and smallest mobility of the shoulder was pre-
sented 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 ad-
duction 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; 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.

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.

The difference between the shoulder joint amplitude in
medium and small CD dogs can be explained by the relation-
ship 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.

Carpal changes in small-sized CD dogs can be explained by
the characteristic angular deformity of CD dogs. 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. Furthermore, medium CD breeds have marked
developmental characteristics of curved radius, which
increases carpal abduction and limits carpal adduction. Addi-
tionally, the difference in the adduction and abduction of
the carpal joint in CD dogs may be due to the abnormal develop-
ment of the radius and ulna, which limits carpal adduction and
exacerbates carpal abduction.

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**Fig. 1** Means and standard deviation of angular measurements of shoulder, carpal and elbow flexion in non-chondrodystrophic dogs with varying size.
Differences in hip PROM between CD dogs of different sizes discovered in the present study have not been described sufficiently hitherto.\textsuperscript{43} Other studies regarding Dachshund\textsuperscript{21} and French Bulldogs\textsuperscript{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.\textsuperscript{21,36}

Results of stifle angles of large NCD dogs were compatible with those of a study of Greyhounds;\textsuperscript{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.\textsuperscript{21,39} Further studies regarding tarsal articulation in dogs are required to compare the results obtained in the present study.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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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