

Reliability of goniometry in Labrador Retrievers

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Objective—To evaluate the reliability of goniometry by comparing goniometric measurements with radiographic measurements and evaluate the effects of sedation on range of joint motion.

Animals—16 healthy adult Labrador Retrievers.

Procedure—3 investigators blindly and independently measured range of motion of the carpus, elbow, shoulder, tarsus, stifle, and hip joints of 16 Labrador Retrievers in triplicate before and after dogs were sedated. Radiographs of all joints in maximal flexion and extension were made during under sedation. Goniometric measurements were compared with radiographic measurements. The influence of sedation and the intra- and intertester variability were evaluated; 95% confidence intervals for all ranges of motion were determined.

Results—Results of goniometric and radiographic measurements were not significantly different. Results of measurements made by the 3 investigators were not significantly different. Multiple measurements made by 1 investigator varied from 1 to 6° (median, 3°) depending on the joint. Sedation did not influence the range of motion of the evaluated joints.

Conclusions and Clinical Relevance—Goniometry is a reliable and objective method for determining range of motion of joints in healthy Labrador Retrievers. (*Am J Vet Res* 2002;63:979–986)

Goniometry is the measurement of angles, particularly those formed by joints. These angles may be measured in a standing position or in flexion or extension.¹⁻³ Goniometry is performed with a measuring device, typically a transparent plastic goniometer. Goniometry is a simple, affordable, and noninvasive method to quantitate the range of motion of joints. The accuracy and reproducibility of goniometry in humans have been documented,^{4,13} and various goniometric methods have been compared.^{5,6,14-21} Goniometry is used extensively by orthopedic surgeons and physical therapists in human medicine to the quantify baseline limits of joint motion, to aid decisions on appropriate therapeutic interventions, and to document the effectiveness of these interventions.^{9,11,20,22} Goniometry has been similarly used in canine orthopedics to assess treatment efficacy for problems involving the carpal,² elbow,²³⁻²⁷ stifle,²⁸ and hip joints.^{1,29,30} In dogs, however, goniometry has not been validated, and only scant information is available regarding goniometric meth-

ods and reference values.³¹⁻³³ Ranges of motion in dogs have been measured in 10 mixed-breed dogs in 1 report and 15 mixed-breed dogs in another report.³¹⁻³³

The objective of the study reported here was to evaluate the reliability of goniometry by comparing measurements made with goniometry with measurements made with radiography, assessing inter- and intratester reliability, and evaluating the effects of sedation on the range of joint motion. We intended to establish reference ranges for joint range of motion in adult Labrador Retrievers free of orthopedic diseases. We hypothesized that goniometry was valid and reliable and that the range of motion evaluated under sedation was not significantly different from the range of motion evaluated in awake dogs. We hypothesized that less variation between measurements was present when distal joints (carpal and tarsal joints) were evaluated than when proximal joints (shoulder and hip joints) were evaluated. We also hypothesized that there is a steep learning curve associated with the goniometric method, and subsequently, there would be less variation in the measurements for the last 5 dogs evaluated, compared with those of the first 5 dogs evaluated in this study.

Materials and Methods

Dogs—Sixteen Labrador Retrievers (6 males and 10 females) were included in the study. Median age was 3 years (range, 2 to 7 years) and median weight was 32 kg (range, 27 to 46 kg). The 16 dogs were randomly selected from our local breed club for inclusion in the study. Sample size was determined prior to the onset of the study by conducting a statistical power analysis (type-1 error, 0.05; type-2 error, 0.8) to determine the minimal number of dogs necessary to conduct statistical comparisons between study groups. The criteria for inclusion in the study were that dogs were ≥ 18 months of age, registered by the American Kennel Club, had no direct blood relationship with other dogs in the study, had no lameness or history of orthopedic disease or trauma, had normal results of an orthopedic examination, and had no radiographic evidence of joint disease. All dogs were evaluated within a 1-week period.

Study design—One forelimb and the ipsilateral hind limb were evaluated on each dog. The side of evaluation was randomly chosen by use of a draw for the first dog and alternated for each subsequent dog. Fourteen joint positions were evaluated 3 times each by each investigator, including flexion and extension of the carpal, elbow, shoulder, tarsal, stifle, and hip joints, as well as valgus and varus movements of the carpus. The 3 investigators independently made goniometric measurements of each dog awake and under sedation, which yielded 4,032 measurements. To assess intratester variation, 5 sets of 3 goniometric measurements were performed for all joint positions on 1 awake dog by 1 investigator with an interval of 15 minutes or more between each set of measurements.

Goniometry—The arms of a transparent plastic goniometer were aligned with anatomic landmarks on the

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limbs (Fig 1 and 2). The goniometer had 1° gradations. Prior to joint angle measurement, each joint was moved through a complete range of motion to determine the axis of joint rotation; the center of the goniometer was placed over that axis. The axis of rotation did not always overlie the joint of interest; for example, in the carpus it is dorsal to the joint. Carpal flexion (Fig 3) and carpal extension (Fig 4) were evaluated by placing 1 arm of the goniometer along the long axis of metacarpal bones III and IV and the other arm along the longitudinal axis of the antebrachium, defined as the line joining the cranial to caudal midpoint of the antebrachium at the level of the ulnar styloid process and the lateral humeral condyle. Carpal valgus (Fig 5) and varus (Fig 6) angles were determined by measuring the angle between the longitudinal axis of metacarpals III and IV and the longitudinal axis that extended parallel to the medial border of the radius. Elbow joint flexion (Fig 7) and extension (Fig 8) were measured by measuring the angle formed by the antebrachial longitudinal axis with the humeral longitudinal axis, defined as the line that joined the lateral epicondyle to the point of insertion of the infraspinatus muscle on the greater tubercle of the

humerus. Shoulder joint flexion (Fig 9) and extension (Fig 10) were determined by measuring the angle between the humeral longitudinal axis and the spine of the scapula. Tarsal flexion (Fig 11) and extension (Fig 12) were determined by measuring the angle between the longitudinal axis of metatarsal bones III and IV and the tibial shaft. Stifle joint flexion (Fig 13) and extension (Fig 14) were determined by measuring the angle between the tibial shaft and the longitudinal axis of the femur, defined as the line that joined the lateral femoral epicondyle and the greater trochanter. Hip joint flexion (Fig 15) and extension (Fig 16) were determined by measuring the angle between the longitudinal axis of the femur and a line that joined the tuber sacrale and ischiadicum. Investigators could see the arms of the goniometer, but the gradations of the instrument and measurements obtained were masked. All measurements were made in triplicate and were read and recorded by an independent observer.

Radiography—The dogs were sedated by IV administration of oxymorphone^a (0.05 mg/kg) combined with medetomidine^b (5 µg/kg). Radiographs of the limbs were made with the joints in maximal flexion and extension and with the carpus in maximal valgus and varus. This was achieved by use of manual limb manipulation, heavy sand bags, or tape. Goniometric measurements were then repeated while the dogs were sedated.

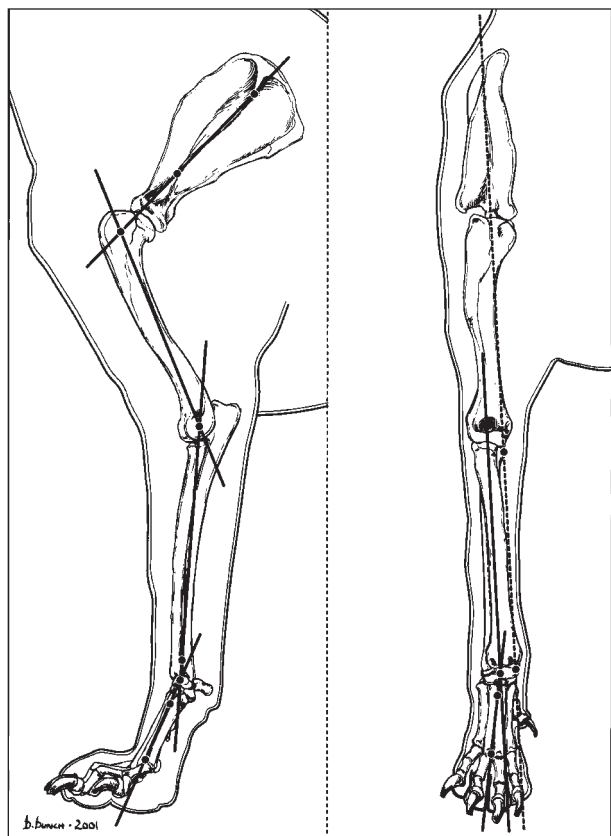


Figure 1—Goniometry of the forelimb. Carpal flexion and extension are measured as the angles formed by the long axis of metacarpal bones III and IV and the line joining the cranial to caudal midpoint of the antebrachium at the level of the ulnar styloid process and the lateral humeral epicondyle. Elbow flexion and extension are measured as the angles formed by the line joining the cranial to caudal midpoint of the antebrachium at the level of the ulnar styloid process and the lateral humeral epicondyle and a line joining the lateral epicondyle to the point of insertion of the infraspinatus muscle on the greater tubercle of the humerus. Shoulder flexion and extension are measured as the angles formed by the line joining the lateral humeral epicondyle and the point of insertion of infraspinatus muscle and the spine of the scapula. Carpal varus and valgus are measured as the angles formed by the long axis of metacarpals III and IV and the long axis of the medial border of the radius.

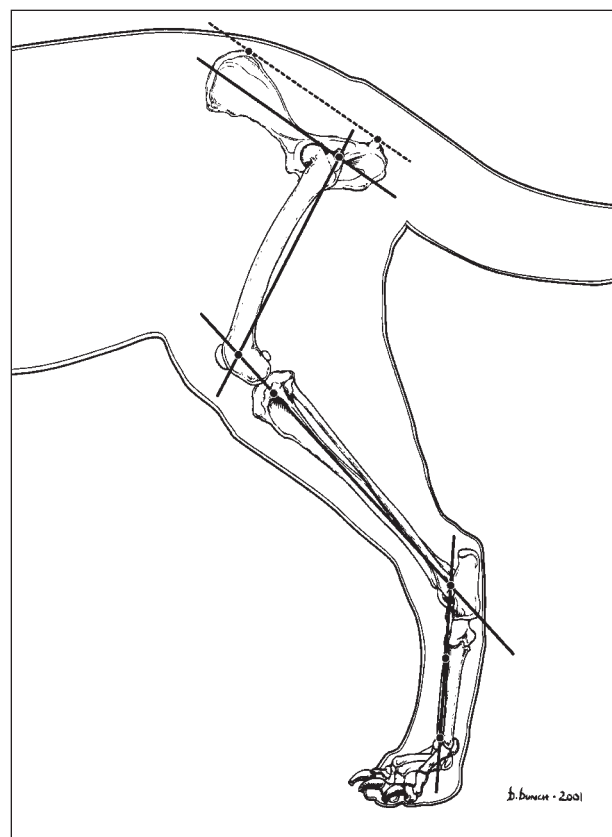


Figure 2—Goniometry of the hind limb. Tarsal flexion and extension are measured as the angles formed by the long axis of metatarsal bones III and IV and the long axis of the tibial shaft. Flexion and extension of the stifle joint are measured as the angles formed by the long axis of the tibial shaft and the line joining the lateral femoral epicondyle and greater trochanter. Hip joint flexion and extension are measured as the angles formed by the line joining the lateral femoral epicondyle of the femur and greater trochanter and a line joining the tuber sacrale and ischiadicum.

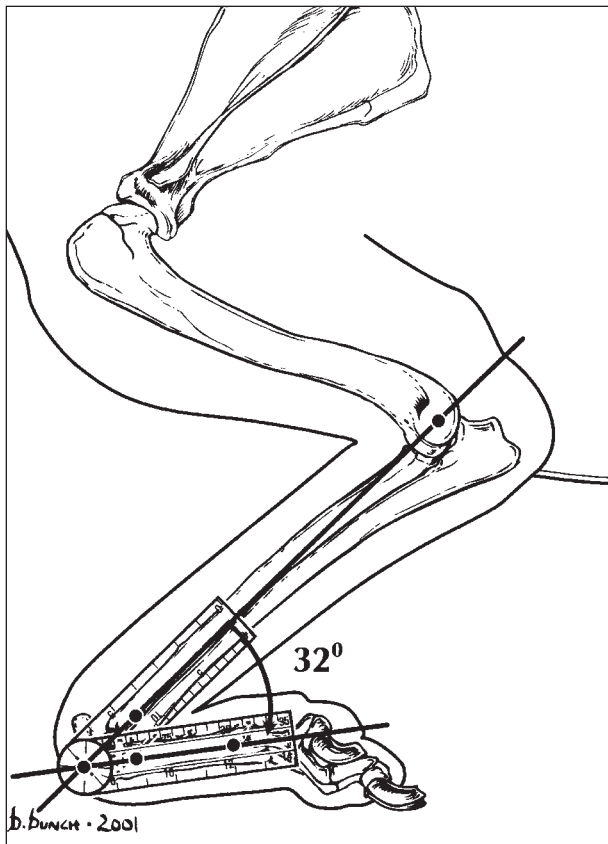


Figure 3—Carpal flexion.

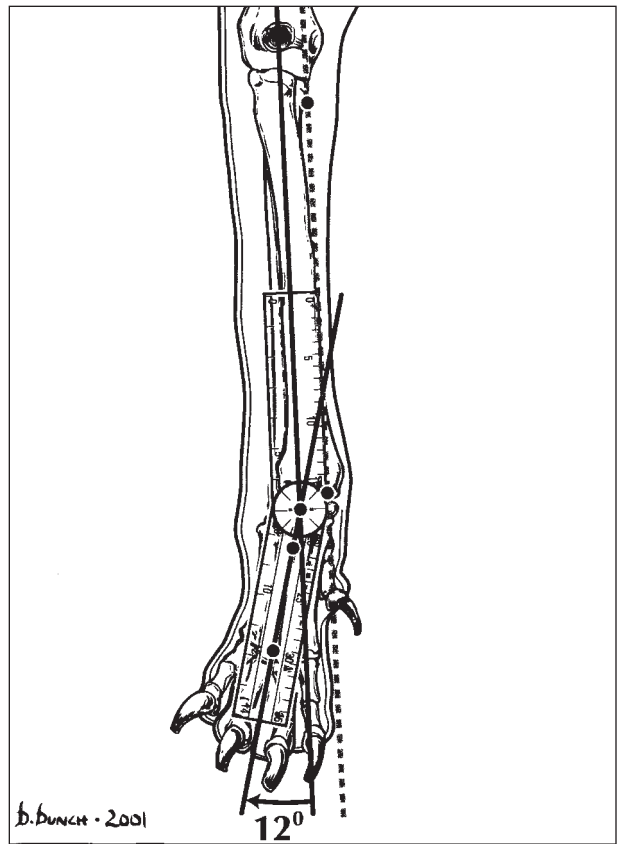


Figure 5—Carpal valgus.

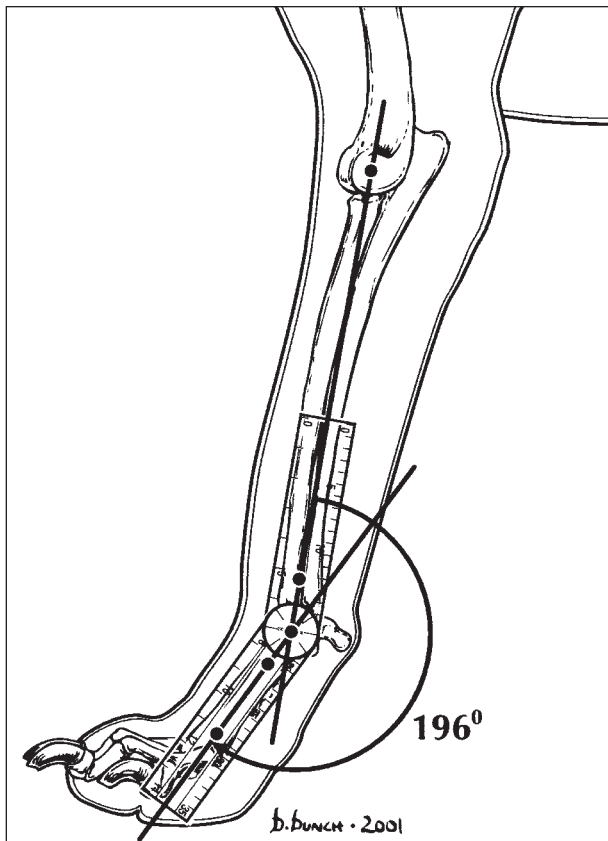


Figure 4—Carpal extension.

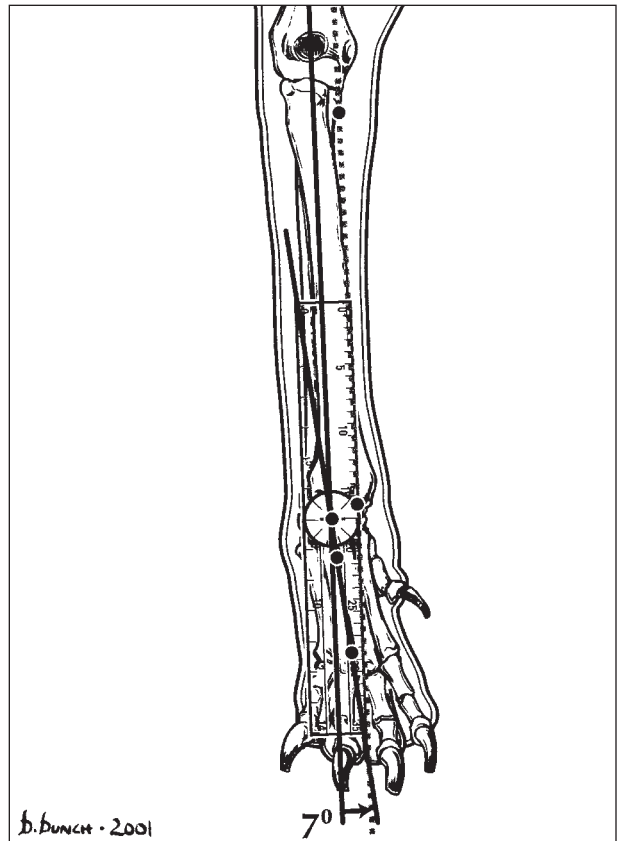


Figure 6—Carpal varus.

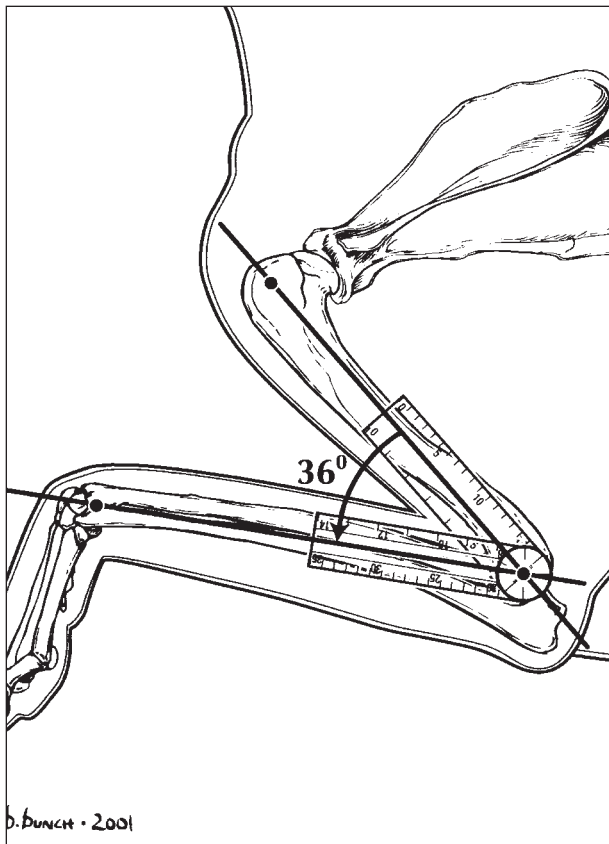


Figure 7—Elbow flexion.

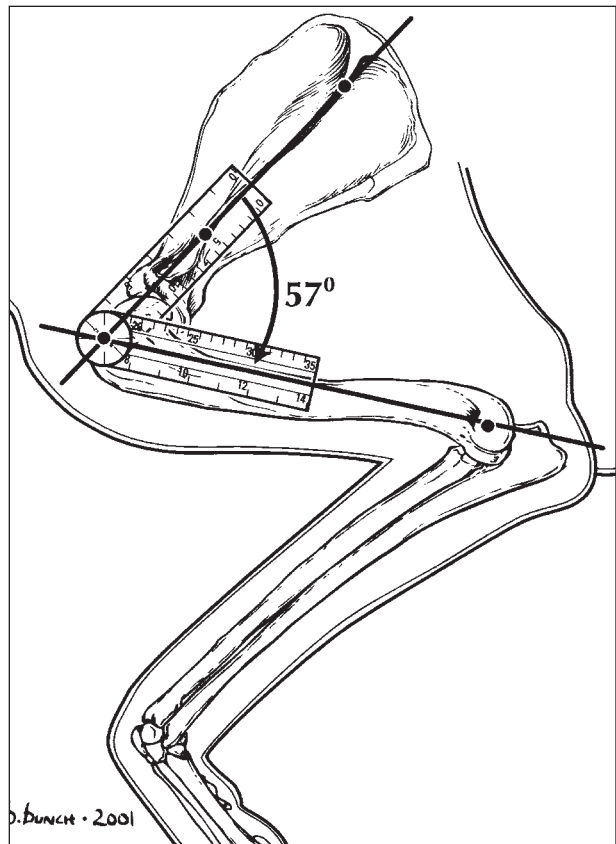


Figure 9—Shoulder flexion.

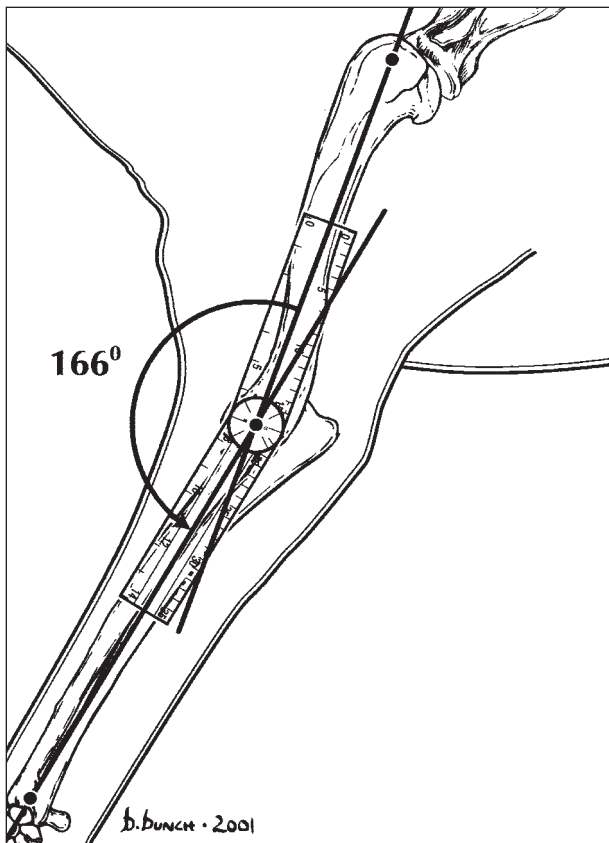


Figure 8—Elbow extension.

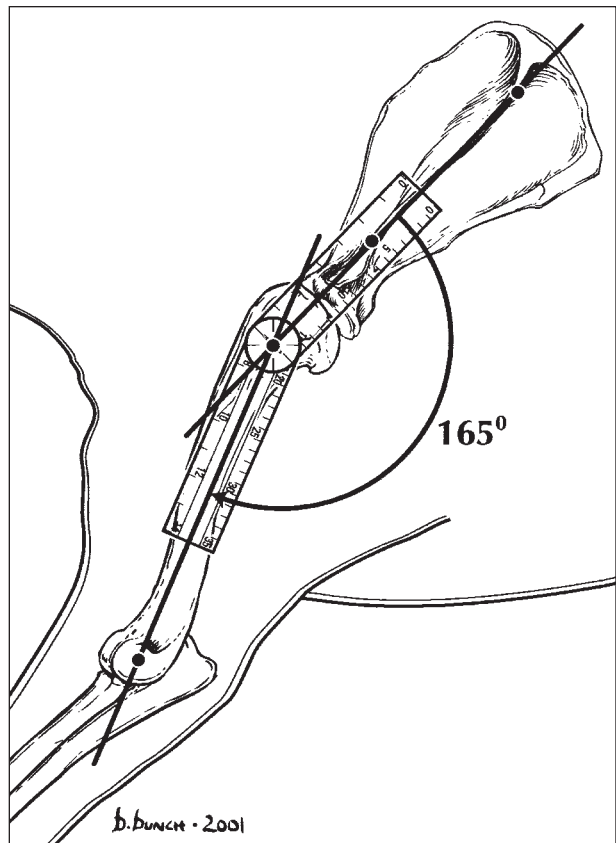


Figure 10—Shoulder extension.

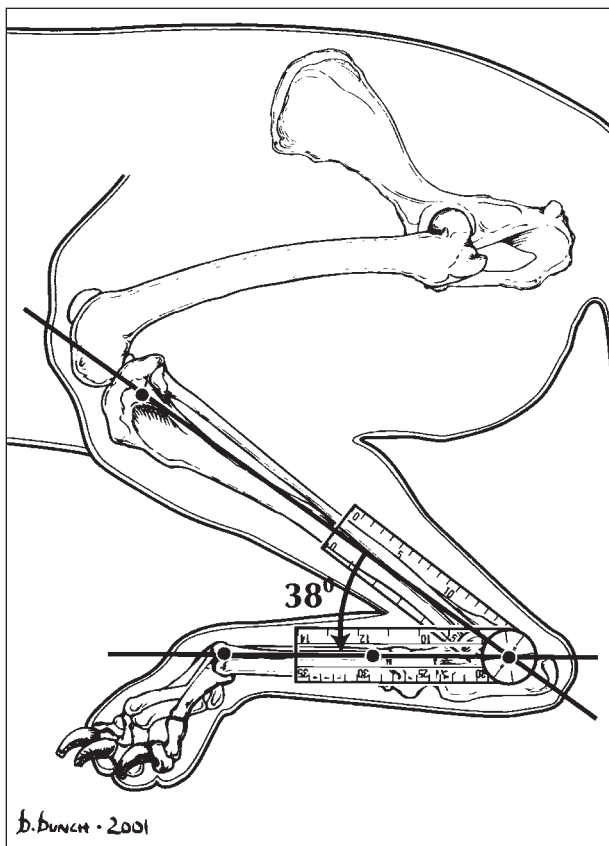


Figure 11—Tarsal flexion.

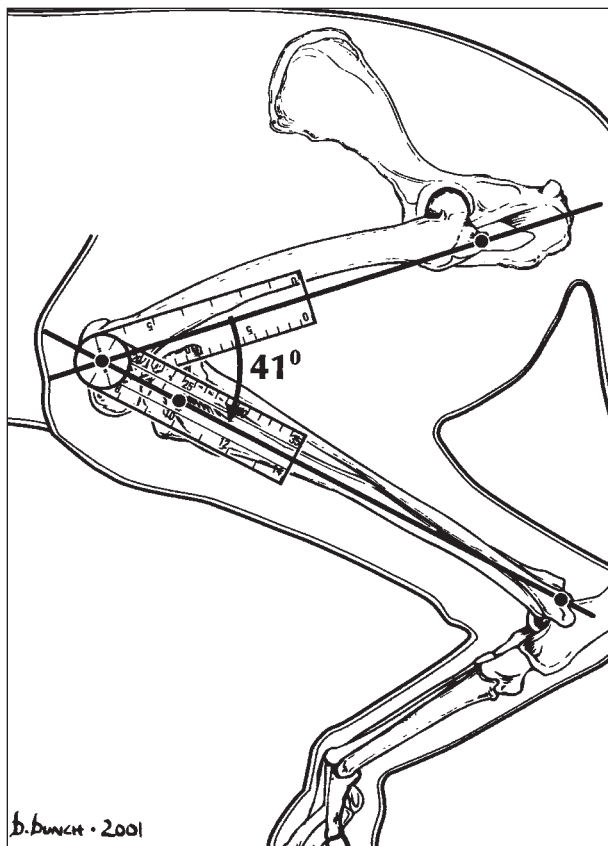


Figure 13—Stifle joint flexion.

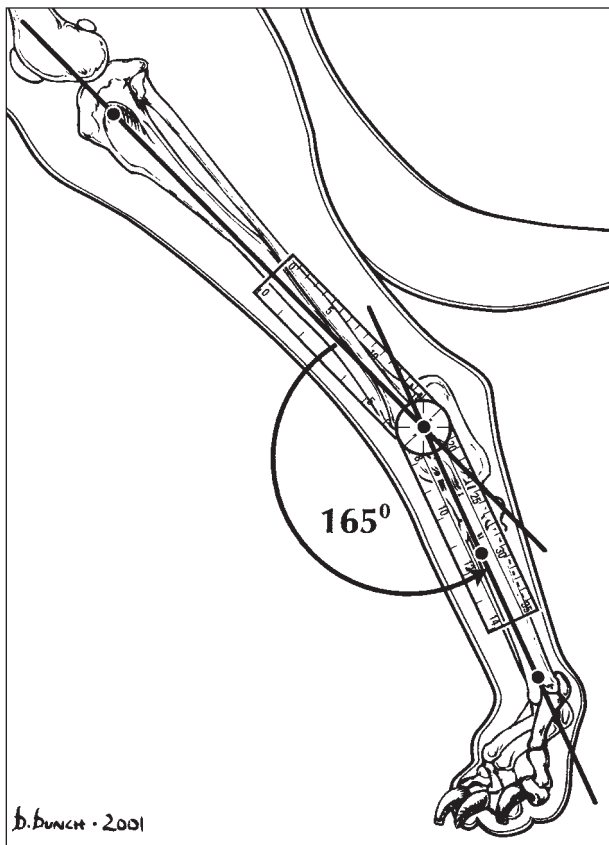


Figure 12—Tarsal extension.

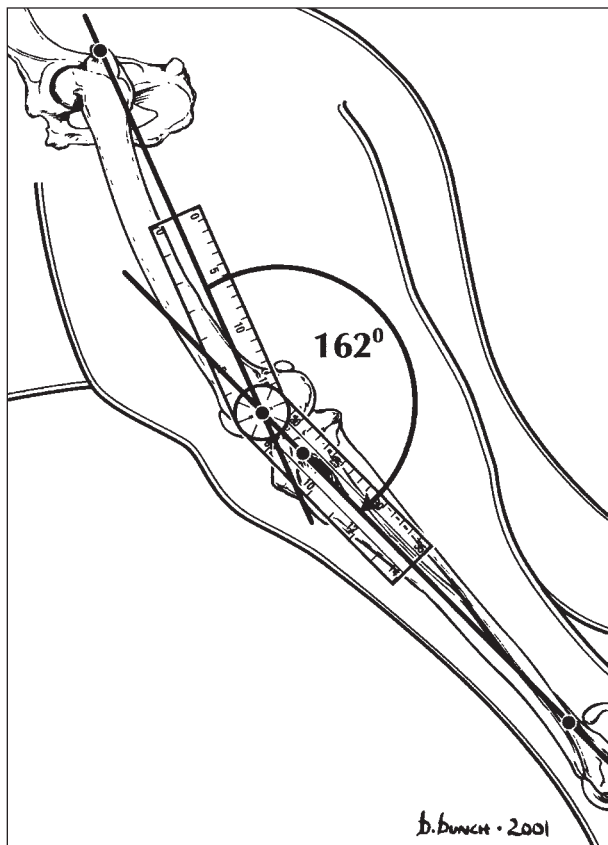


Figure 14—Stifle joint extension.

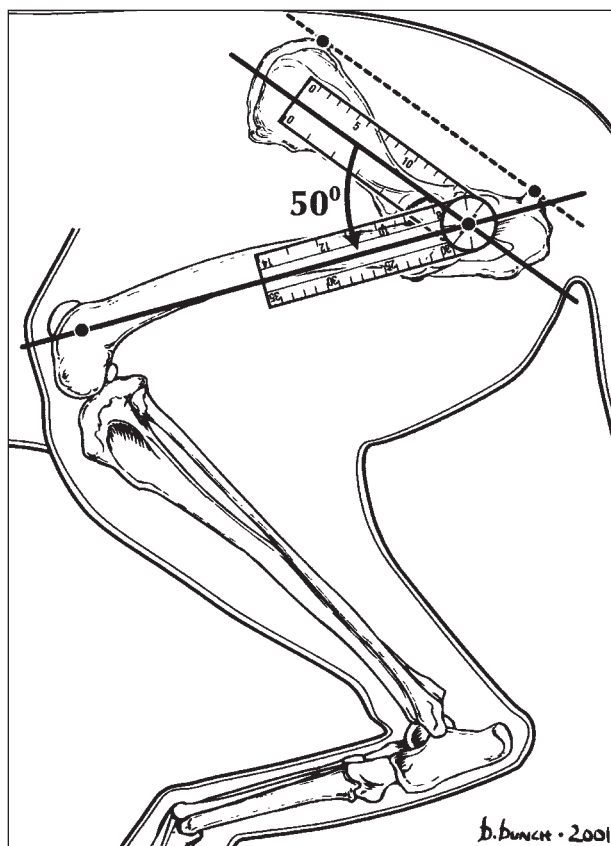


Figure 15—Hip joint flexion.

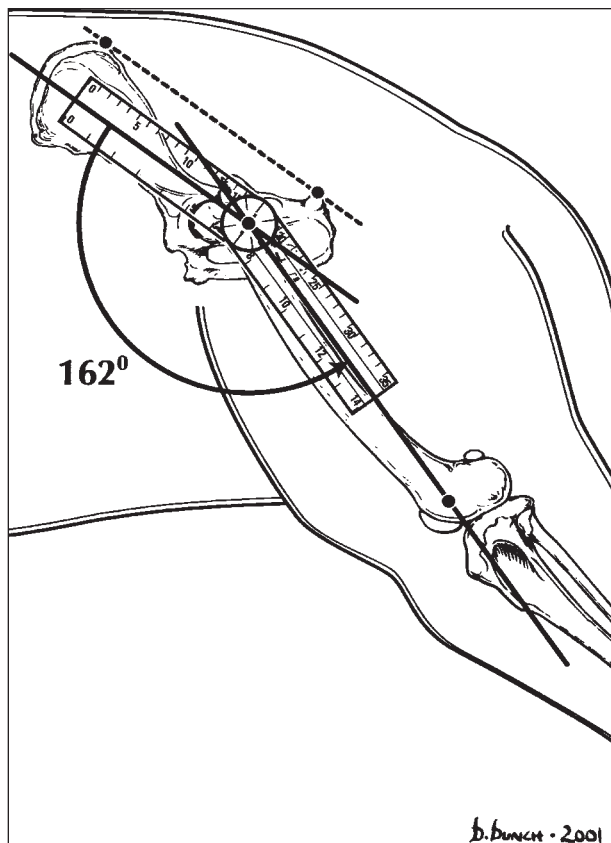


Figure 16—Hip joint extension.

Sedation was reversed by IM injection of atipamezole^c (0.025 mg/kg). Radiographs were assessed for evidence of degenerative joint disease. Joint angles on radiographs were measured and recorded by 1 investigator by use of landmarks identical to the landmarks used for goniometric measurements.

Statistical analysis—To evaluate intertester variability, the median measurements for the 3 investigators were compared by use of paired *t* tests for each joint position.^{34,35} To assess the effect of sedation on the goniometric method, median measurements from evaluated joints were individually compared for each dog awake and sedated by use of paired *t* tests. Median goniometric measurements were compared with radiographic measurements by use of paired *t* tests for each joint position for awake dogs and for sedated dogs. The variability among the 15 measurements made by 1 investigator on 1 dog was determined for each joint. The variability of measurements for each individual joint for the last 5 dogs included in the study was compared with the variability of measurements for the first 5 dogs by use of χ^2 tests for awake dogs and for sedated dogs. To assess goniometric measurements of each joint, the variability of median measurements in flexion and extension of the carpus, elbow, and shoulder joints was compared by use of 1-tail *t* tests for awake dogs and for sedated dogs. The variability of median measurements of the tarsus, stifle, and coxofemoral joints was compared by use of 1-tail *t* tests for awake dogs and sedated dogs separately.

Mean, median, and 95% confidence intervals (CI) of the mean for combined measurements made by each investigator in dogs that were awake and that were sedated were determined. Statistical software^d was used for all analyses. For all comparisons, differences were considered significant at values of $P < 0.05$.

Results

The investigators had 2, 10, and 12 years of professional experience, respectively. Results of goniometric measurements for awake dogs and sedated dogs did not differ significantly from results of radiographic measurements. Results of measurements made by the 3 investigators did not differ significantly. Median variability among the 15 measurements made by 1 investigator for all joint positions was 3° (range, 1 to 6°). Results of measurements made in awake dogs did not differ significantly from results of measurements made in sedated dogs. Significant dif-

Table 1—Range of motion (degrees) of various appendicular joints measured by goniometry in 16 healthy Labrador Retrievers

Joint	Position	Mean	SD	95% CI of the mean	Median
Carpus	Flexion	32	2	31–34	32
	Extension	196	2	194–197	196
	Valgus	12	2	11–13	12
	Varus	7	1	6–8	7
Elbow	Flexion	36	2	34–38	36
	Extension	165	2	164–167	166
Shoulder	Flexion	57	2	54–59	57
	Extension	165	2	164–167	165
Tarsus	Flexion	39	2	37–40	38
	Extension	164	2	162–166	165
Stifle	Flexion	42	2	40–43	41
	Extension	162	3	160–164	162
Hip	Flexion	50	2	48–52	50
	Extension	162	3	160–164	162

CI = Confidence interval.

ferences were not detected between the first and last 5 dogs evaluated ($P = 0.11$ for awake dogs and $P = 0.9$ for sedated dogs). For the forelimb, the mean variability of measurements of the elbow joint was less than the mean variability of measurements of the shoulder joint ($P < 0.03$) in sedated dogs. For the hind limb, mean variability of measurements of the tarsus was less than mean variability of measurements of the stifle ($P < 0.01$) and hip joints ($P < 0.01$) in awake dogs. Because sedation and investigator did not affect the goniometric measurements, results obtained from for all investigators and for awake and sedated dogs were combined to calculate the combined means, medians, and 95% CI of the mean for range of motion of joints in healthy Labrador Retrievers (Table 1).

Discussion

This study relied on the use of simple plastic goniometers to assess ranges of motion. The assessment of joint range of motion can be a complex undertaking. Goniometry is a simple and practical method to assess joint motion. We simplified this task by choosing a morphologically homogeneous dog population and by using precise goniometric methods. We chose to evaluate Labrador Retrievers because they are the most common breed registered by the American Kennel Club (15% of all registered dogs in 2000) and because they have relatively consistent conformation (despite a 70% weight difference between the heaviest and lightest dogs in this study), compared with chondrodystrophic dog breeds.³⁶ Results of our study could potentially be extrapolated to dog breeds with similar conformation (ie, other retriever breeds) but may not be valid in dog breeds with substantially different conformations.

Results of goniometry were not significantly different from results of radiography for dogs in this study. Goniometry appears to have substantial advantages over radiography, including simplicity, rapidity, lower cost, and no need for sedation or exposure to ionizing radiation. Experience with goniometry, either acquired during years of professional experience or acquired during the course of the study, did not appear to affect the reliability of goniometric measurements. This suggests that goniometry does not have a steep learning curve. Sedation did not appear to influence range of motion despite the various anxiety levels in the dogs in this study. Small sample size potentially limited our ability to detect subtle differences between groups.

Physical therapists generally consider the goniometric measurements made in awake patients as indicators of pain-free range of motion and the measurements made in sedated patients as maximal range of motion, because when pain is present during joint manipulation, the protective response of the patient may limit the range of motion of the joint. During pain, range of motion is sensory-limited and not mechanically limited. This sensory limitation may not be present under sedation. In our study, the dogs were healthy and pain free. We therefore assume that we compared the maximal ranges of motion, both awake

and under sedation. These measurements appear to be identical. This may not be true for joints with degenerative joint disease or other diseases in which range of motion may be voluntarily restricted in response to a painful sensation.

The 95% CI of the means for the 14 joint positions were within a narrow 2 to 4° range. This suggests excellent precision and repeatability of goniometry in the population of Labrador Retrievers included in this study. The ranges of the mean values in this study were much smaller than the ranges in certain publications.^{32,33} This may be the consequence of the precise anatomic landmarks and methods used in this study and the homogeneity of the population. When determining the range of motion of a joint, we recommend performing goniometric measurements in triplicate and selecting the median value of these measurements to improve the accuracy of the process. The mean variability in measurements of several proximal joints (shoulder, hip, and stifle joints) was larger than the mean variability in measurements of several distal joints (elbow and tarsus). This may be because a larger amount of soft tissue is present around proximal joints, compared with distal joints, potentially interfering with the palpation of body landmarks, and because the larger muscle mass around proximal joints appears to complicate the goniometric measurements (ie, bulge of the triceps brachii during shoulder flexion).

Although results of this study validated the use of goniometry in a group of healthy dogs, additional research is needed to provide objective information regarding joint angles measured at rest or during locomotion in healthy dogs and those with orthopedic diseases. Standing joint angles in hind limbs of 15 mixed-breed dogs, 16 Labrador Retrievers, and 16 Greyhounds have been reported.^{31,e} Additional information regarding range of motion during locomotion has been collected in several kinematic studies.³⁷ Information regarding these joint angles is particularly important when planning joint arthrodeses or the correction of limb deformities.^{3,38} It may also be important to assess the efficacy of medical and surgical treatments.

^aNumorphan, Endo Pharmaceuticals Inc, Chadds Ford, Pa.

^bDomitor, Pfizer Animal Health, New York, NY.

^cAntisedan, Pfizer Animal Health, New York, NY.

^dSAS, version 8, SAS Institute Inc, Cary, NC.

^eWilke VL, Conzemius MG, Benson T, et al. Tibial plateau angle with respect to the ground in the normal Labrador Retriever and Greyhound (abstr), in *Proceedings. Vet Orthop Soc* 2001;28:7.

References

1. Marcellin-Little DJ, DeYoung BA, Doyens DH, et al. Canine uncemented porous-coated total hip arthroplasty: results of a long-term prospective evaluation of 50 consecutive cases. *Vet Surg* 1999;28:10–20.
2. Marcellin-Little DJ, Ferretti A, Roe SC, et al. Hinged Ilizarov external fixation for correction of antebrachial deformities. *Vet Surg* 1998;27:231–45.
3. Collins KE, Lewis DD, Lanz OI, et al. Use of a circular external skeletal fixator for stifle arthrodesis in a dog. *J Small Anim Pract* 2000;41:312–315.
4. Hamilton GF, Lachenbruch PA. Reliability of goniometers in assessing finger joint angle. *Phys Ther* 1969;49:465–469.
5. Mitchell WS, Millar J, Sturrock RD. An evaluation of

goniometry as an objective parameter for measuring joint motion. *Scott Med J* 1975;20:57-59.

6. Boone DC, Azen SP, Lin CM, et al. Reliability of goniometric measurements. *Phys Ther* 1978;58:1355-1390.

7. Rothstein JM, Miller PJ, Roettger RF. Goniometric reliability in a clinical setting. Elbow and knee measurements. *Phys Ther* 1983;63:1611-1615.

8. Fish DR, Wingate L. Sources of goniometric error at the elbow. *Phys Ther* 1985;65:1666-1670.

9. Enwemeka CS. Radiographic verification of knee goniometry. *Scand J Rehabil Med* 1986;18:47-49.

10. Solgaard S, Carlsen A, Kramhoft M, et al. Reproducibility of goniometry of the wrist. *Scand J Rehabil Med* 1986;18:5-7.

11. Moseley A, Adams R. Measurement of passive ankle dorsiflexion; procedure and reliability. *Aust Physiol* 1991;37:175-180.

12. Goodwin J, Clark C, Deakes J, et al. Clinical methods of goniometry: a comparative study. *Disabil Rehabil* 1992;14:10-15.

13. Harvey L, King M, Herbert R. Test-retest reliability of a procedure for measuring extensibility of the extrinsic finger flexor muscles. *J Hand Ther* 1994;7:251-254.

14. Feldman MC. "Mini-goniometer" for finger range of motion. *Phys Ther* 1970;50:1348.

15. Brinkworth KE. Modified goniometer for the knee joint. *Phys Ther* 1976;56:189-190.

16. Grohmann JE. Comparison of two methods of goniometry. *Phys Ther* 1983;63:922-925.

17. Clapper MP, Wolf SL. Comparison of the reliability of the Orthoranger and the standard goniometer for assessing active lower extremity range of motion. *Phys Ther* 1988;68:214-218.

18. Petherick M, Rheault W, Kimble S, et al. Concurrent validity and intertester reliability of universal and fluid-based goniometers for active elbow range of motion. *Phys Ther* 1988;68:966-969.

19. Ellis B, Bruton A, Goddard JR. Joint angle measurement: a comparative study of the reliability of goniometry and wire tracing for the hand. *Clin Rehabil* 1997;11:314-20.

20. Barker KL, Lamb SE, Burns M, et al. Repeatability of goniometer measurements of the knee in patients wearing an Ilizarov external fixator: a clinic-based study. *Clin Rehabil* 1999;13:156-163.

21. MacDermid JC, Chesworth BM, Patterson S, et al. Intratester and intertester reliability of goniometric measurement of passive lateral shoulder rotation. *J Hand Ther* 1999;12:187-192.

22. Schulte L, Roberts MS, Zimmerman C, et al. A quantitative assessment of limited joint mobility in patients with diabetes. Goniometric analysis of upper extremity passive range of motion. *Arthritis Rheum* 1993;36:1429-1443.

23. Huijbregtse BA, Johnson AL, Muhlbauer MC, et al. The effect of treatment of fragmented coronoid process on the development of osteoarthritis of the elbow. *J Am Anim Hosp Assoc* 1994;30:190-195.

24. Roy RG, Wallace LJ, Johnston GR. A retrospective long-term evaluation of ununited anconeal process excision on the canine elbow. *Vet Comp Orthop Traumatol* 1994;7:94-97.

25. Bouck GR, Miller CW, Taves CL. A comparison of surgical and medical treatment of fragmented coronoid process and osteochondritis dissecans of the canine elbow. *Vet Comp Orthop Traumatol* 1995;8:177-183.

26. Sjöström L, Kasström H, Källberg M. Ununited anconeal process in the dog. Pathogenesis and treatment by osteotomy of the ulna. *Vet Comp Orthop Traumatol* 1995;8:170-176.

27. Cook JL, Tomlinson JL, Reed AL. Fluoroscopically guided closed reduction and internal fixation of fractures of the lateral portion of the humeral condyle: prospective clinical study of the technique and results in 10 dogs. *Vet Surg* 1999;28:315-321.

28. Johnson JM, Johnson AL, Pijanowski GJ, et al. Rehabilitation of dogs with surgically treated cranial cruciate ligament-deficient stifles by use of electrical stimulation of muscles. *Am J Vet Res* 1997;58:1473-1478.

29. Prostredny JM, Toombs JP, VanSickle DC. Effect of two muscle sling techniques on early morbidity after femoral head and neck excision in dogs. *Vet Surg* 1991;20:298-305.

30. de Haan JJ, Goring RL, Beale BS. Evaluation of polysulfated glycosaminoglycan for the treatment of hip dysplasia in dogs. *Vet Surg* 1994;23:177-181.

31. Mann FA, Wagner-Mann C, Tangner CH. Manual goniometric measurement of the canine pelvic limb. *J Am Anim Hosp Assoc* 1988;24:189-194.

32. Riegger-Krugh C, Weigel J. Canine anatomy and biomechanics. II: hind limb. In: Wadsworth C, ed. *Basic science for animal physical therapists*. La Crosse, Wis: Orthopedic Section, American Physical Therapy Association Inc, 2000;2-28.

33. Riegger-Krugh C, Millis D. Canine anatomy and biomechanics. I: forelimb. In: Wadsworth C, ed. *Basic science for animal physical therapists*. La Crosse, Wis: Orthopedics Section, American Physical Therapy Association Inc, 2000;2-27.

34. Hollander M, Wolfe DA. *Nonparametric statistical methods*. Etobicoke, Canada: John Wiley & Sons, 1999;106-123, 458-471.

35. Kramer, MS. *Clinical epidemiology and biostatistics*. New York: Springer-Verlag Inc, 1988;150-154.

36. Paddock A. Annual registration statistics provide vital clues to aid fanciers in maintaining the welfare of purebred dogs. *AKC Gazette* 2001;118:48-50.

37. DeCamp CE. Kinetic and kinematic gait analysis and the assessment of lameness in the dog. *Vet Clin North Am Small Anim Pract* 1997;27:825-840.

38. Cofone MA, Smith GK, Lenehan TM, et al. Unilateral and bilateral stifle arthrodesis in eight dogs. *Vet Surg* 1992;21:299-303.