Validity of goniometric joint measurements in cats

Gayle H. Jaeger, DVM, MSpVM; Denis J. Marcellin-Little, DEDV; Venita DePuy, MStat; B. Duncan X. Lascelles, BVSc, PhD

Objective—To compare and validate goniometric joint measurements obtained from nonsedated and sedated cats with measurements from radiographic evaluation.

Animals—20 adult cats with no evidence of joint disease.

Procedures—Measurements of flexion and extension of the carpus, elbow, shoulder, tarsus, stifle, and hip joints and of carpal and tarsal joints during varus and valgus angulation were made by a single investigator before and after sedation of cats. Measurements were made by use of a goniometer with a masked dial. Joint angle measurements were compared between nonsedated and sedated cats and also with measurements from radiographs made while cats were sedated. Each series of measurements was repeated 4 times. To evaluate repeatability, Cronbach α values were calculated for repeated measure results of goniometric joint measurements of nonsedated and sedated cats. An intraclass correlation was calculated to determine reliability among the 3 measurement types (ie, measurements from nonsedated and sedated cats and on radiographic evaluation).

Results—Joint measurements did not differ significantly by measurement type, when comparing radiographic measurements with goniometric measurements in sedated and nonsedated cats. Cronbach α values were > 0.99 for goniometric joint measurements within individual nonsedated and sedated cats and also for comparison of mean meaurements obtained from sedated cats versus nonsedated cats versus radiographs. An intraclass correlation of 0.999 revealed high reliability among measurement types.

Conclusions and Clinical Relevance—Results indicated that goniometric joint measurements in nonsedated and sedated cats are repeatable and valid. (*Am J Vet Res* 2007;68:822–826)

Goniometry provides a rapid and reliable method to quantify the ROM of joints.[1] The reliability and reproducibility of goniometry have been well documented for human and canine patients.[1-6] Goniometry is a clinical method frequently used by orthopedic surgeons and physical rehabilitation clinicians in human and veterinary medicine to evaluate the severity of joint injuries and to monitor the progression of joint disease and the response to treatment.[7-9] In dogs, goniometry has been used to assess joint disease and treatment efficacy for several joints including carpus,[10] elbow,[11-14] tarsus,[15] stifle,[16] and hip joints.[17,18] To our knowledge, goniometry has not been validated for use in cats and only one study[15] has used goniometry in this species.

In contrast to common knowledge concerning osteoarthritis and other joint diseases in dogs, awareness and understanding of arthrology in cats are still in their infancy. The awareness of joint diseases in cats and treatment modalities have recently increased, and several reports[19-23] have investigated the incidence of joint disease in cats via retrospective evaluation of radiographs of cats admitted to veterinary hospitals for a variety of reasons. Osteoarthritis has a suggested incidence of 20% to 30% in cats, increasing to 90% in cats > 12 years old, although this is not based on complete radiographic evaluations of cats and includes axial skeleton degenerative joint disease.[22] Evaluating only the appendicular joints, 64 of 100 cats (mean age, 15 years) had radiographic evidence of appendicular joint osteoarthritis.[22] Results of a similar study[20] revealed that 22% of 262 cats had radiographic evidence of appendicular joint osteoarthritis when ≥ 1 synovial joint was included on the radiograph, and a third study[19] found that 16.5% of 218 cats had radiographic evidence of appendicular osteoarthritis. With the appreciation that appendicular joint disease in cats is common, an increasing interest exists in medical and surgical modalities for treatment of osteoarthritis and other joint diseases of cats, including the administration of nonsteroidal anti-inflammatory drugs[24] and arthroscopic and surgical evaluation and treatment.[15,25] However, no

Abbreviation

ROM	Range of motion

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From California Veterinary Specialists, 100 N Rancho Santa Fe Rd, Ste 133, San Marcos, CA 92069 (Jaeger); the Orthopedics Research Laboratory (Marcellin-Little) and Comparative Pain Research Laboratory (Lascelles), Department of Clinical Sciences, College of Veterinary Medicine, North Carolina State University, Raleigh, NC 27606; and Biostatistics, INC Research, 4700 Falls of Neuse Rd, Ste 400, Raleigh, NC 27609 (DePuy).
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Address correspondence to Dr. Lascelles.

validated objective measures exist to quantitate severity of joint disease and response to treatment, although some are being investigated.[26] Reliable measures of joint ROM are needed to further understand joint disease in cats and the effects of treatments. In humans and dogs, goniometry has been validated by comparing manual goniometric and radiographic measurements.[1,4] Once validated, goniometry could potentially be used to monitor the progression of joint disease in cats and improvement in joint motion in response to treatment modalities.

The purpose of the study reported here was to evaluate the validity and repeatability of goniometry in orthopedically normal cats. We hypothesized that goniometry would be a valid, repeatable, and reliable method for use in cats, and that goniometric joint measurements in nonsedated cats would not be significantly different from goniometric and radiographic measurements made in sedated cats. Specifically, aims of this study were the following: to evaluate the reliability of goniometry by validating measurements obtained in nonsedated and sedated cats against measurements obtained on radiographic evaluation, evaluate the repeatability of multiple measurements made by a single person, and report reference range values for normal joint motion in cats.

Materials and Methods

Animals—Twenty cats were recruited from staff members of the California Veterinary Specialists, San Marcos, Calif, by direct solicitation of staff members. Owners were fully informed of the study protocol and provided consent. The practice animal care and use committee approved 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) by use of previously published data to determine the minimal number of cats necessary to conduct statistical comparisons between study groups.[1,15] Cats were included in the study if they were ≥ 1 year of age (no upper age limit), had no signs of lameness or joint pain (as assessed by a full orthopedic evaluation), had no history of orthopedic disease or trauma, and had no radiographic evidence of degenerative joint disease or any other radiographic joint abnormalities.

Study design—One investigator (GHJ) performed the goniometric joint measurements on a forelimb (initial side on cat 1 decided by coin toss, and in subsequent cats, alternate sides chosen) and the ipsilateral pelvic limb in awake cats without sedation and then with sedation, by use of a detailed predetermined protocol based on previous work in dogs.[1] To assess joint ROM, the carpus, elbow, shoulder, tarsus, stifle, and hip joints were evaluated in flexion and extension. Carpal and tarsal joint varus and valgus ROM were also measured. Measurements were made from distal to proximal with flexion preceding extension, and the forelimb measurements were performed before the hind limb measurements. One reader independently recorded all goniometric joint measurements. The same measurements were then repeated with cats under sedation but after radiographs had been obtained. Each series of goniometric joint measurements on each cat was made in quadruplicate, taking 1 measurement of each joint position and repeating this series (carpal through hip joint) of measurements 4 times. At least 15 minutes separated each series of measurements. All cats in the study were evaluated within a 1-week period. A subjective temperament score ranging from 1 to 5 was used to rank subject willingness to undergo goniometry without sedation and to further define the population of cats in the study. Temperament was scored as follows: 1 = neutral attitude, purring, kneading; 2 = resistance to restraint; 3 = resistance to restraint, growling and hissing; 4 = resistance with biting and scratching, hissing, spitting, and vocalizing; and 5 = resistance with biting, scratching, vocalizing, spitting, hissing, urinating, or defecating.

Goniometric method—The center of rotation of a plastic handheld translucent goniometer was placed over the center of motion for the joints of interest (**Appendix**).[a] Each arm of the goniometer measured 4 × 18 cm, with 2° gradations. Joints were flexed and extended throughout their ROM to determine the center of rotation, and measurements were taken at full extension and flexion. The investigator could see the arms of the goniometer but was blinded to the gradations of the instrument or the measurements; the goniometer that was used had a dial that was masked on its upper surface but not its lower surface. One assistant read the dial and recorded all measurements.

Radiographic evaluation—Cats were sedated with an IM injection of a combination of butorphanol (0.1 mg/kg), medetomidine (10 μg/kg), and ketamine (5 mg/kg). Mediolateral radiographic views of all evaluated joints were made in full flexion and extension, and dorsoventral radiographic views were made of the tarsal and carpal joints undergoing varus and valgus stress. Joints were positioned and held stationary during radiography with a combination of tape and sandbags. The investigator performing the goniometric measurements also obtained all radiographs. Joint angles were measured by use of landmarks identical to the landmarks used during goniometry and were performed by the same investigator. Digital radiographs were imported by use of a computer graphics software program, and a measuring tool was used to calculate joint angles.[b] Landmarks selected were easily palpable for obtaining goniometric measurements and were identifiable on radiographs.

Statistical analysis—Goniometrically measured joint angles obtained during flexion, extension, varus angulation, and valgus angulation were compared with the same measurements obtained on radiographic evaluation (considered as the gold standard). Goniometric joint measurements from cats without sedation and during sedation were compared by use of a repeated-measures model.[c] To evaluate reliability of test results, Cronbach α values were calculated for repeated-measure results of goniometric joint measurements of nonsedated and sedated cats. A Cronbach α value of 0.95 was used as the criterion for repeatability.[27] Intraclass correlation was calculated via the Shrout-Fleiss method to determine reliability among the 3 measurement types (ie, measurements from nonsedated and sedated cats and on radiographic evaluation).[28,d] Mean, SD, 95% confidence intervals of the mean, coefficient of variation, and median angles were used to describe each joint position measurement from nonsedated and sedated cats and obtained on radiographic evaluation. Analyses were performed by use of computer software.[d,e]

Results

Twenty neutered cats, 7 females and 13 males, were included in the study. Sixteen were domestic shorthair, and 4 were domestic longhair cats. None were considered brachycephalic. The median age was 9 years (range, 4 to 14 years), and median weight was 5.5 kg (range, 3.2 to 8.1 kg). Mean ± SD temperament score was 2.8 ± 1.2 (range, 1 to 5).

Measurements did not significantly ($P = 0.816$) vary by measurement type, when comparing joint measurements obtained by radiographic evaluation and goniometry in nonsedated cats and sedated cats. The Cronbach α value was > 0.99 for goniometric joint measurements within individual nonsedated and sedated cats and also for comparison of mean measurement values obtained from sedated cats versus nonsedated cats versus radiographs. An intraclass correlation of > 0.999 indicated high reliability for different measurement types (ie, radiographic joint measurements and goniometric joint measurements of nonsedated and sedated cats) on the same joint. Mean, SD, 95% confidence intervals of the mean, coefficient of variation, and median angles for each joint position were determined from measurements obtained from nonsedated cats, from sedated cats, and on radiographic evaluation **(Table 1)**.

Discussion

We selected a random sample of orthopedically normal cats. Although we cannot guarantee that this population is completely homogeneous in regard to joint motion, the generally low coefficient of variation for many ROM measurements in our study suggests that the cats were homogenous with regards to joint motion. Whether our study population is representative of the overall cat population in the United States is unknown, but we have no reason to believe that they are not representative of the general domestic shorthair and longhair cat population. Individual within-cat data were analyzed for consistency so that the conclusions regarding assessment of the goniometric method would remain valid even if the study population was not completely homogeneous in regard to joint motion. Sedation effects in cats were minor and seemingly unimportant in comparison to the challenges present when measuring resistant nonsedated cats. The time allowed to ensure accurate placement of the center of the goniometer over the axis of rotation and determine maximal joint motion was limited when dealing with the more difficult to handle cats in our study. Experience in the goniometric method or the practice of sedating cats may be required for accurate assessment of joint ROM in more difficult to handle cats; however, this was not objectively assessed in our study.

One investigator performed all measurements in our study. Results of a previous study[1] that assessed interobserver variability in goniometric joint measurements revealed no significant differences in measurements made by 3 independent investigators. As-

Table 1—Angle measurements of joints to determine ROM in 20 cats without sedation, during sedation, and on radiographic evaluation.

		Angle measurement for ROM											
		Mean ± SD (°)			95% CI of the mean (°)			CV (%)			Median (°)		
Joint	Position	Non	Sed	Rad	Non	Sed	Rad	Non	Sed	Rad	Non	Sed	Rad
Carpal	Flex	22 ± 2	22 ± 1	21 ± 3	22–23	21–22	19–22	7	6	13	22	22	20
	Ext	198 ± 6	198 ± 5	197 ± 5	196–199	197–199	195–199	3	2	2	198	198	197
	Val	10 ± 2	11 ± 2	11 ± 1	9–10	10–11	11–12	23	19	12	10	10	11
	Var	7 ± 2	7 ± 2	7 ± 1	6–7	6–7	6–8	25	30	20	7	6	7
Elbow	Flex	22 ± 2	22 ± 1	23 ± 2	22–23	22–22	22–24	8	6	9	22	22	23
	Ext	163 ± 4	165 ± 3	167 ± 3	162–164	164–165	166–169	3	2	2	162	164	168
Shoulder	Flex	32 ± 3	32 ± 2	36 ± 6	31–32	31–32	34–39	8	8	16	32	32	36
	Ext	163 ± 6	167 ± 3	162 ± 4	162–165	167–168	160–163	4	2	2	164	168	163
Tarsal	Flex	21 ± 1	22 ± 1	19 ± 1	21–22	21–22	19–20	7	5	7	22	22	19
	Ext	167 ± 4	168 ± 2	169 ± 4	166–168	167–170	167–170	3	1	2	167	168	170
	Val	7 ± 2	7 ± 2	9 ± 3	7–8	7–8	8–11	32	22	32	7	7	8
	Var	10 ± 3	11 ± 3	12 ± 2	10–11	11–12	11–13	26	23	19	10	11	12
Stifle	Flex	24 ± 2	24 ± 3	21 ± 2	24–25	24–25	20–22	9	13	11	24	24	21
	Ext	164 ± 4	164 ± 3	159 ± 9	163–165	164–165	155–163	2	2	6	166	164	162
Hip	Flex	33 ± 3	33 ± 2	36 ± 4	32–33	32–33	34–38	9	7	11	32	33	36
	Ext	164 ± 4	166 ± 4	163 ± 4	163–165	165–167	161–164	2	2	3	164	166	164

CI = Confidence interval. CV = Coefficient of variation. Non = Nonsedated cats. Sed = Sedated cats. Rad = Radiographs. Flex = Flexion. Ext = Extension. Val = Valgus angulation. Var = Varus angulation.

sessing joint motion by use of single measurements is considered to be as accurate as assessing joint motion by selecting the median value of multiple measurements.[4] We chose to assess the intraobserver repeatability of measurements by comparing single series of measurements made of all joints repeated 4 times at the same assessment (on the same day) rather than by comparing the median values of a series of ≥ 3 measurements made on different occasions (different days). Results of our study indicate that a high degree of agreement existed between each series of measurements. On the basis of this finding, mean and median values were used for subsequent analyses. It could be argued that goniometric joint measurements would vary substantially if performed on the same cat on different days. We consider this unlikely because measurements were taken from all other joints before repeating measurements on any individual joint. This meant that cats were moved and changed position considerably between measurements for any particular repeated joint measurement. Reliability was evaluated by use of the Shrout-Fleiss method for a fixed set of raters, which we equated to measurement types (those obtained from nonsedated cats, from sedated cats, and on radiographic evaluation). We set the cutoff for high reliability as an intraclass correlation > 0.95.

The coefficient of variation for measurements was generally small and within acceptable limits (< 10%). However, the variability of measurements was greatest and outside acceptable limits for measurements of carpal and tarsal joint varus and valgus angulation. This is probably because the angles measured in these situations are small, and so differences of a few degrees represent large percentages and lead to large coefficient of variation. This is supported by the fact that coefficient of variation for measurements obtained from nonsedated cats, from sedated cats, and on radiographic evaluation were similarly low for several joints (ie, carpal and elbow joint extension) and similarly high for other joints (ie, carpal and tarsal joint varus angulation). Obtaining measurements of distal joints, including carpal and tarsal joints during varus and valgus angulation and extension and flexion, was subjectively more difficult than obtaining measurements of proximal joints because of the large size of the arms of the goniometer relative to the limbs, especially in nonsedated cats with poor temperament as a confounding factor. The goniometer used in our study was selected because of its transparency, low cost, and overall commercial availability. A smaller goniometer may be easier to use in cats.

Results of radiographic evaluation of joints during extension and flexion were used as the gold standard in our study. The coefficient of variation of radiographic measurements was high (> 10%) for flexion of the carpus, shoulder, stifle, and hip joints. The seemingly large variability of some radiographic measurements in our study may be the result of inaccurate positioning of joints from cat to cat rather that actual variability among cats. This may be attributable to the small size of the patient and difficulty holding flexed positions with sandbags, spoons, and tape as a means to prevent radiation exposure of investigators. We observed that positioning the proximal joints in full flexion may have resulted in a rotation of the entire cat, potentially influencing measurements. Rotation may also have been a factor when evaluating carpal and tarsal joint valgus and varus angulation on radiographs.

The potential use of goniometry in cats would include the measurement of joint angles to evaluate the effects of various joint diseases and treatment on joint motion. Goniometry is simple and affordable and provides a clinical measure of joint ROM. In our study, we found goniometry to be a valid and repeatable objective method to assess joint ROM in orthopedically normal cats, and we believe it could potentially be used to evaluate joint disease and monitor progression. Subjectively, sedation facilitates obtaining goniometric measurements in cats without joint disease but does not alter the measurements.

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a. Bayer SpA, Animal Health, Milano, Italy.
b. Adobe Photoshop 5.0, Adobe Systems Inc, Mountain View, Calif.
c. Mixed Procedure, SAS System Software, SAS Institute Inc, Cary, NC.
d. SAS samples, SAS Institute Inc, Cary, NC. Available at: support.sas.com/ctx/samples/index.jsp?sid=537. Accessed Jan 23, 2007.
e. SAS System Software, version 9.0, SAS Institute Inc, Cary, NC.

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Appendix

Landmarks for performing goniometric joint measurements in appendicular joints of cats.

Joint	Motion	Distal axis	Proximal axis	COR
Carpus	Flex-Ext	Long axis of metacarpal bones III and IV	Longitudinal axis of the antebrachium (line joining the craniocaudal midpoint of the antebrachium at the ulnar styloid process to the lateral humeral epicondyle)	NA
	Val-Var	Between the longitudinal axes of metacarpal bones III and IV	Longitudinal axis of the antebrachium along the medial aspect of the radius	NA
Elbow	Flex-Ext	Longitudinal axis of the antebrachium	Longitudinal axis of the humerus (from the lateral epicondyle to the point of insertion of the infraspinatus muscle on the greater tubercle)	Lateral epicondyle
Shoulder	Flex-Ext	Longitudinal axis of the humerus	Spine of the scapula	NA
Tarsus	Flex-Ext	Longitudinal axis of metatarsal bones III and IV	Longitudinal axis of the tibia (from the lateral malleolus to the midpoint between the fibular head and tibial tubercle)	Lateral malleolus
	Val-Var	Between the longitudinal axes of metatarsal bones III and IV	Longitudinal axis of the tibia	NA
Stifle	Flex-Ext	Longitudinal axis of the tibia	Longitudinal axis of the femur (from the lateral femoral epicondyle to the greater trochanter)	NA
Hip	Flex-Ext	Longitudinal axis of the femur	A line parallel to a line joining the tuber sacrale and tuber ischiadicum over the greater trochanter	NA

COR = Center of rotation. Flex-Ext = Flexion and extension. Val-Var = Valgus and varus angulation. NA = Not applicable.