Evaluation of a quantitatively derived value for assessment of muscle mass in clinically normal cats

Lisa M. Freeman DVM, PhD
James Sutherland-Smith BVSc
Charles Cummings BS
John E. Rush DVM, MS

Received December 13, 2017.
Accepted April 9, 2018.

From the Department of Clinical Sciences, Cummings School of Veterinary Medicine, Tufts University, North Grafton, MA 01536.

Address correspondence to Dr. Freeman (Lisa.Freeman@tufts.edu).

OBJECTIVE
To evaluate use of an ultrasonographically and radiographically determined value, the vertebral epaxial muscle score (VEMS), for assessing muscle mass in cats.

ANIMALS
30 healthy neutered cats of various body weights and between 1 and 6 years of age.

PROCEDURES
Mean epaxial muscle height was calculated from 3 transverse ultrasonographic images obtained at the level of T13. Length of T4 was measured on thoracic radiographs, and the VEMS (ratio of epaxial muscle height to T4 length) was calculated and compared with body weight. Ratios of epaxial muscle height to various anatomic measurements also were compared with body weight as potential alternatives to use of T4 length.

RESULTS
1 cat was excluded because of a heart murmur. For the remaining 29 cats, mean ± SD body weight was 5.05 ± 1.40 kg. Mean epaxial muscle height was 1.27 ± 0.13 cm, which was significantly correlated ($r = 0.65$) with body weight. The VEMS and value for epaxial muscle height/(0.1 X forelimb circumference) were not significantly correlated ($r = -0.18$ and -0.06, respectively) with body weight, which is important for measures used for animals of various sizes.

CONCLUSIONS AND CLINICAL RELEVANCE
The VEMS and value for epaxial muscle height/(0.1 X forelimb circumference) can both be used to normalize muscle size among cats of various body weights. Studies are warranted to determine whether these values can be used to accurately assess muscle mass in cats with various adiposity and in those with muscle loss. (*Am J Vet Res* 2018;79:1188–1192)

Loss of lean body mass, known as cachexia, is commonly associated with chronic diseases (eg, congestive heart failure, chronic kidney disease, and cancer) as well as acute illness or injury in cats.[1] This process differs from sarcopenia, which is the loss of lean body mass associated with aging in the absence of disease.[1] Cachexia in humans is a separate, negative predictor of survival and has been associated with impaired immune function, wound healing, and strength.[1–4] One common definition of cachexia in humans is loss of 5% of body weight within the previous 1 year along with functional and inflammatory changes.[5] However, because muscle loss may be hidden by gains in fat mass or fluid, and muscle loss begins very gradually, the criterion of weight loss of 5% makes it challenging to detect cachexia at its earliest stages.

In veterinary medicine, diagnostic criteria and research on cachexia and sarcopenia have focused on muscle, which is the primary tissue lost in those conditions.[1,6–9] Clinically, muscle mass can be assessed with a subjective muscle condition scoring system that is available for dogs and cats.[10] Quantitative assessment of muscle mass can also be performed by use of CT or dual-energy x-ray absorptiometry.[6,11] These techniques, although useful, are limited by cost and the need for an animal to be anesthetized or heavily sedated. In addition, dual-energy x-ray absorptiometry relies on assumptions that may not be accurate for acute and chronic illnesses.[12] Ideally, muscle mass could be quantitatively assessed noninvasively to detect early stages of cachexia and sarcopenia in cats. In another study[6] conducted by our research group, epaxial muscle size in young and old dogs of a single breed was compared by use of ultrasonography and CT. To address differences in size of dogs, even within a single breed, muscle size was normalized on the basis of vertebral size.[6] Another study[13] was conducted by our research group to evaluate healthy dogs of various breeds and sizes by use of the ratio of epaxial muscle height (which was measured ultrasonographically) to length of T4 (which was measured radiographically) to calculate a VEMS. Results of that study[13] indicate that the VEMS is reproducible and a valid measure for dogs of various sizes. However, it is

ABBREVIATIONS

BCS	Body condition score
FLEMS	Forelimb epaxial muscle score
VEMS	Vertebral epaxial muscle score

not known whether this same value would be a valid measurement for a population of cats of various sizes. Therefore, the objective of the study reported here was to evaluate the ability of the VEMS to be used as a quantitative assessment of muscle mass in clinically normal cats independent of body size.

Materials and Methods

Animals

Thirty healthy neutered client-owned cats that were between 1 and 6 years of age were included in the study. It was required that all cats have a BCS between 4 and 6 on a scale of 1 to 9. Cats with various body weights were enrolled to ensure a wide distribution of body sizes. Sample size calculations conducted with results from a similar study[13] of healthy dogs conducted by our research group revealed that 30 cats would provide the ability (power = 80%; $\alpha = 0.05$) to detect significant correlations. Health status of cats was confirmed via physical examination and basic laboratory testing (ie, PCV and concentrations of total solids, BUN, and glucose). Owners provided informed consent prior to enrollment. The study was approved by the Cummings School of Veterinary Medicine at Tufts University Clinical Studies Review Committee and the Tufts University Institutional Animal Care and Use Committee.

Study design

For each cat, body weight was obtained, BCS was assessed by use of a 9-point scale, and muscle condition was assessed by use of a 4-point scale (normal muscle condition or mild, moderate, or severe muscle loss).[10,14] Cats with a BCS < 4 or > 7 or with evidence of any muscle loss were excluded from the study. Cats with evidence of underlying disease during physical examination or laboratory testing were similarly excluded from further participation in the study. A right lateral thoracic radiograph (which included T4) was obtained by use of 1 of 2 digital radiography systems.[a,b] The length of T4 was used because that vertebra is usually centrally positioned on thoracic radiographs and therefore subject to minimal distortion. The length of T4 was measured by 1 investigator (JSS) on a lateral thoracic radiograph that was centered on T4. The line tool of a DICOM workstation[c] was used to obtain measurements of calibrated images. The mean of 3 separate measurements was used as the final T4 length. No correction for radiographic magnification was performed.

Ultrasonographic measurements were obtained at the level of T13 with a 5- to 12-MHz, multiple-frequency, 50-mm linear transducer.[d] Measurements were obtained with each cat in both a standing position and crouching position to compare whether there was a difference in muscle height on the basis of posture. Cats were gently manually restrained in position during the measurements. The coat of each cat was not clipped, but the site was prepared with isopropyl alcohol and ultrasonography gel. Measurement of muscle height was performed by use of a previously described technique.[13] Briefly, the trans-

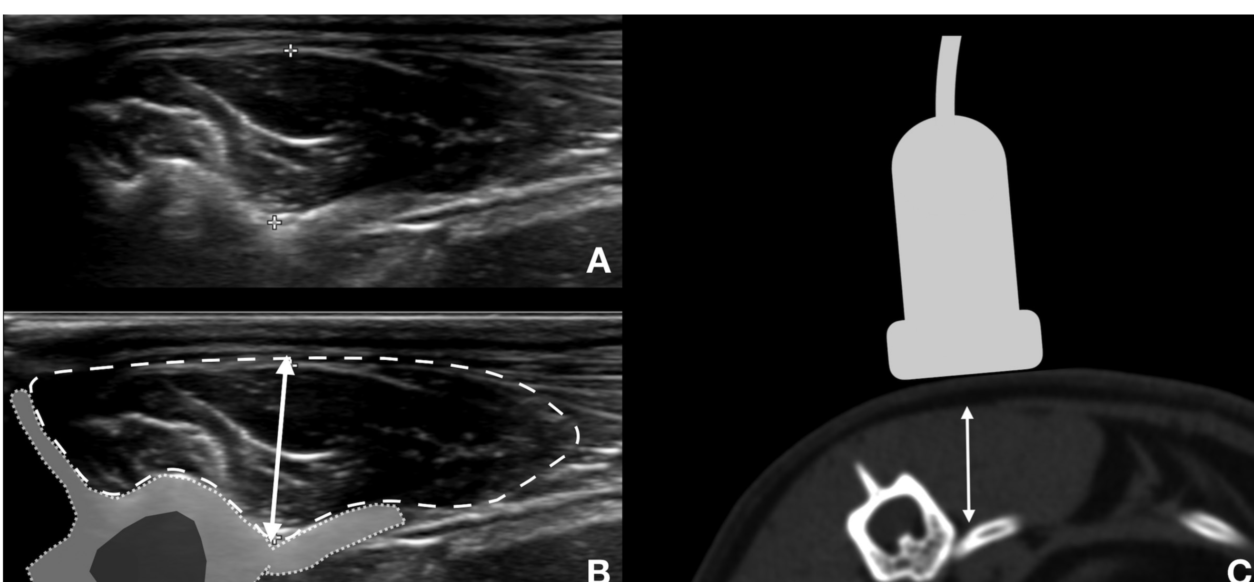

Figure 1—Transverse ultrasonographic (A and B) and CT (C) images obtained at the level of T13 at the junction of the 13th rib of cats. A—Measurement of the right epaxial muscle height is illustrated by the ultrasound cursors (plus signs) placed at the right 13th rib–vertebral junction and at the muscle–subcutaneous fat interface. The angle of this measurement is intended to provide the shortest distance between these 2 landmarks. In this panel, the value calculated from the calibrated DICOM image is 12.4 mm. B—Same ultrasonographic image as in panel A with schematic illustration of the local anatomy. The approximate vertebral shape (shaded gray with dotted line), outline of the right epaxial muscles (dashed line), and measurement (line with arrowheads) are provided. C—Notice that the same epaxial muscle, rib, and vertebral anatomy are evident in this CT image obtained from another cat. The approximate position of the ultrasound transducer is indicated schematically, and a measurement location is indicated (line with arrowheads).

Table 1—Mean ± SD antomic measurements obtained for 29 healthy cats and correlations between body weight and the ratios of epaxial muscle height to each of several anatomic measurements.

Anatomic structure	Measurement (cm)	Ratio of epaxial height to anatomic measurement*	*r*	*P* value†
Forelimb circumference	8.60 ± 0.96	1.49 ± 0.14	–0.06	0.77
Forelimb length	15.19 ± 2.33	0.85 ± 0.14	–0.13	0.52
Total body length	56.67 ± 5.97	0.23 ± 0.03	–0.13	0.50
Head circumference	23.09 ± 1.72	0.55 ± 0.06	0.19	0.32
Hind limb length	9.60 ± 1.17	1.34 ± 0.17	–0.20	0.30
Chest circumference	36.03 ± 3.83	0.36 ± 0.03	–0.21	0.28

Forelimb circumference was measured at the midpoint between the carpus and elbow joint, forelimb length was measured from the point of the elbow to the top of the central metacarpal pad with the carpal joint maintained in a straight line, total body length was measured from the base of the tail to the tip of the nose, head circumference was measured between the eyes and ears at the widest part of the head, hind limb length was measured from the tip of the calcaneus to the top of the metatarsal pad, and chest circumference was measured immediately caudal to the elbow joints.

*Calculated as epaxial muscle height/(0.1 X anatomic measurement). †Values were considered significant at $P < 0.05$.

ducer was located at T13 with the beam angle perpendicular to the longitudinal axis of the vertebral column. Minimal pressure was used when applying the transducer to avoid distorting the shape of the tissues. Muscle height measurements were obtained with the calipers of the ultrasound machine; the first cursor was placed at the 13th rib–vertebral junction at the bone-muscle interface, and the second cursor was placed dorsolaterally at the muscle–subcutaneous tissue interface, which provided the smallest short-axis dimension **(Figure 1)**. Three measurements of the maximal right epaxial muscle height, each obtained by repositioning of the transducer, were recorded with each cat in a standing position, and the mean for the 3 measurements was calculated. A similar process was repeated for the left epaxial muscle height, and the mean of the left and right sides was used to calculate the final mean epaxial muscle height. A similar process was repeated with each cat in a crouching position. Length of T4 was used to calculate the VEMS (ie, ratio of epaxial muscle height to T4 length).

Other metrics for patient size that could be determined without a thoracic radiograph were investigated. Anatomic measurements recorded for each cat included head circumference (measured between the eyes and ears at the widest part of the head), chest circumference (measured immediately caudal to the elbow joints), forelimb circumference (measured at the midpoint between the carpus and elbow joints), forelimb length (measured from the point of the elbow joint to the top of the central metacarpal pad with the carpus joint maintained in a straight line), hind limb length (measured from the tip of the calcaneus to the top of the metatarsal pad), and total body length (measured from the base of the tail to the tip of the nose). Because anatomic measurements (denominator) were numerically much larger than epaxial muscle height (numerator), ratios of epaxial muscle height to each of the anatomic measurements were calculated by use of the following equation: epaxial muscle height/(0.1 X anatomic measurement). This reduced the size of the denominator but still involved use of the anatomic measurements to normalize epaxial muscle height among cats of various sizes.

Statistical analysis

Data distributions were examined graphically. Normally distributed data were reported as mean ± SD, and nonnormally distributed data were reported as median and range. Paired *t* tests were used to compare measurements for the crouching position with those for the standing position. Mean epaxial muscle height, VEMS, and ratios of epaxial muscle height to each of the anatomic measurements were calculated and compared with body weight by use of the Pearson correlation coefficient. To identify the anatomic measurement that most effectively normalized epaxial muscle height among cats of various sizes, the ratio with the lowest *r* value and highest *P* value was selected. Data analysis was performed with commercial statistical software.[e] Values of $P < 0.05$ were considered significant.

Results

Thirty cats were enrolled in the study; however, auscultation revealed a cardiac murmur in 1 cat, and that cat was excluded from the study. Thus, 29 cats (19 castrated males and 10 spayed females) completed the study. Mean ± SD body weight was 5.05 ± 1.40 kg (range, 2.23 to 8.05 kg), and mean BCS was 5.1 ± 0.4. Epaxial muscle heights did not differ significantly between the left and right sides ($P = 0.32$) or between standing and crouching positions ($P = 0.18$). Therefore, measurements for the crouching position were used for all further analysis. Mean epaxial muscle height was 1.27 ± 0.13 cm and was significantly correlated ($r = 0.65$; $P < 0.001$) with body weight. However, the VEMS was not significantly correlated ($r = -0.18$; $P = 0.34$) with body weight. Mean VEMS did not differ significantly ($P = 0.78$) between male and female cats. Mean VEMS for this group of 29 healthy cats was 1.18 ± 0.16 (range, 0.93 to 1.55).

All anatomic measurements were significantly correlated with body weight **(Table 1)**. None of the ratios of epaxial muscle height to anatomic measurements were significantly correlated with body weight; the ratio of epaxial muscle height to forelimb circumference had the lowest *r* value ($r = -0.06$; $P = 0.77$).

Discussion

To the authors' knowledge, the study reported here was the first in which investigators evaluated a noninvasive quantitative method for evaluating muscle mass in cats that would be feasible for use in clinical practice. The original technique for determining VEMS was developed for dogs[13] and addressed differences in muscle size across dogs of various sizes by normalizing muscle height on the basis of T4 length. This technique also appeared to be valid for determining VEMS of healthy neutered cats with a BCS between 4 and 6 (scale of 1 to 9), but additional studies will be needed to further evaluate use of this technique for cats of other populations, including cats with more extreme variations of BCS, sexually intact cats, and cats with muscle loss attributable to cachexia or sarcopenia. Although the technique for determining VEMS does not involve measuring total muscle mass and evaluates only a single muscle group, in the authors' experience, the epaxial muscles are typically the first to be affected by cachexia and sarcopenia and appear to be less affected by activity, compared with results for other muscles (eg, quadriceps muscle).[1] In 1 study,[6] epaxial muscles of healthy older dogs were more affected by sarcopenia than were temporal or quadriceps muscles.

Although T4 length provides a valid denominator to normalize epaxial muscle height among dogs and cats of various sizes and shapes, it requires that a thoracic radiograph be obtained. Thoracic radiographs are often obtained routinely for cats with cardiac or cancer cachexia, but they may not be acquired as part of the routine care for cats with renal cachexia or sarcopenia. Therefore, a method to normalize epaxial muscle height without the need for a radiograph would be valuable.

In the present study, none of the ratios evaluated (eg, epaxial muscle height to forelimb circumference or epaxial muscle height to hind limb length) were significantly correlated with body weight, which suggested that the ratios could be used to normalize epaxial muscle height among cats of various sizes. However, some ratios may be better than others. Chest circumference would be affected by obesity, and head size could be affected by sex or breed. The ratio with the lowest correlation with body weight ($r = -0.06$; $P = 0.77$) was the epaxial muscle height/(0.1 X forelimb circumference), which is referred to as the FLEMS. Therefore, further studies of FLEMS for cats with various body configurations might enable development of a score that does not rely on thoracic radiography. However, testing the VEMS and FLEMS further in a larger population of cats of various breeds and sizes as well as other types of cats (eg, cats with more extreme values for BCS, sexually intact cats, and cats with muscle loss) is warranted before either score could be used more widely.

The present study had a number of additional limitations that should be mentioned. No criterion-referenced technique (eg, CT) was performed in the study. Although the study design was based on results of previous studies of dogs in which results for CT were compared with results of ultrasonography for young and old dogs and in which the VEMS was validated for use with healthy young dogs, it would be ideal to include CT measurements of muscles in future studies of cats. Furthermore, only a physical examination and minimal laboratory testing were used to classify cats as healthy. Although all cats were young, had no history of ongoing medical conditions, had no abnormalities detected during physical examination or laboratory testing, and had normal muscle condition scores, they may have had health issues that caused subtle muscle changes that were not detected by use of muscle condition scoring. Therefore, future studies should include more extensive laboratory testing, abdominal ultrasonography, and echocardiography to ensure health status of the cats. The fact that only neutered cats were enrolled in the present study could have artificially decreased the mean VEMS because a lower concentration of androgens can result in less muscle mass. In addition, the sex ratio was 2:1 (males:females), although the VEMS did not differ significantly between male and female cats. Finally, activity level of the cats was not controlled, and differences in the amount or type of activity could have an impact on epaxial muscle measurements.

Routine use of a muscle condition scoring system is valuable in clinical practice for qualitative assessment of muscle and identification of muscle loss. Additional studies are needed, but the VEMS and FLEMS appear to be promising values that can be used to provide a more quantitative evaluation of muscle mass in both clinical and research settings.

Acknowledgments

Presented in abstract form at the 10th International Conference on Cachexia, Sarcopenia, and Muscle Wasting, Rome, December 2017; and the American College of Veterinary Internal Medicine Forum, Seattle, June 2018.

Footnotes

a. Kodak CR800, Carestream Health Inc, Rochester, NY.
b. TruDR cSeries, Sound, Carlsbad, Calif.
c. Carestream Vue PACS, version 11.4, Carestream Health, Rochester, NY.
d. Philips Epic 7, Philips Medical Systems, Bothell, Wash.
e. Systat, version 13.0, Systat Software Inc, San Jose, Calif.

References

1. Freeman LM. Cachexia and sarcopenia: emerging syndromes of importance in dogs and cats. *J Vet Intern Med* 2012;26:3–17.
2. Lang T, Streeper T, Cawthon P, et al. Sarcopenia: etiology, clinical consequences, intervention, and assessment. *Osteoporos Int* 2010;21:543–559.

3. Fearon K, Strasser F, Anker SD, et al. Definition and classification of cancer cachexia: an international consensus. *Lancet Oncol* 2011;12:489–495.
4. von Haehling S, Lainscak M, Springer J, et al. Cardiac cachexia: a systematic overview. *Pharmacol Ther* 2009;121:227–252.
5. Evans WJ, Morley JE, Argiles J, et al. Cachexia: a new definition. *Clin Nutr* 2008;27:793–799.
6. Hutchinson D, Sutherland-Smith J, Watson AL, et al. Assessment of methods of evaluating sarcopenia in old dogs. *Am J Vet Res* 2012;73:1794–1800.
7. Geddes RF, Biourge V, Chang Y, et al. The effect of moderate dietary protein and phosphate restriction on calcium-phosphate homeostasis in healthy older cats. *J Vet Intern Med* 2016;30:1690–1702.
8. Peterson ME, Castellano CA, Rishniw M. Evaluation of body weight, body condition, and muscle condition in cats with hyperthyroidism. *J Vet Intern Med* 2016;30:1780–1789.
9. Story AL, Boston SE, Kilkenny JJ, et al. Evaluation of weight change during carboplatin therapy in dogs with appendicular osteosarcoma. *J Vet Intern Med* 2017;31:1159–1162.
10. World Small Animal Veterinary Association Global Nutrition Committee. Muscle condition score charts for dogs and cats. Available at: www.wsava.org/Guidelines/Global-Nutrition-Guidelines. Accessed May 17, 2018.
11. Michel KE, Anderson W, Cupp C, et al. Correlation of a feline muscle mass score with body composition determined by dual-energy x-ray absorptiometry. *Br J Nutr* 2011;106(suppl 1):S57–S59.
12. Freeman LM, Kehayias JJ, Roubenoff R. Dual-energy x-ray absorptiometry (lett). *J Vet Intern Med* 1996;10:99–100.
13. Freeman LM, Sutherland-Smith J, Prantil LR, et al. Quantitative assessment of muscle in dogs using a vertebral epaxial muscle score. *Can J Vet Res* 2017;81:255–260.
14. Laflamme DP. Development and validation of a body condition score system for cats. *Feline Pract* 1997;25(5/6):13–17.