Both the World Small Animal Veterinary Association and American Animal Hospital Association have developed nutritional assessment guidelines to aid veterinary health-care teams in determining the nutritional needs of companion animals. Body composition is the sum of various biological components, which include fat, bone, and lean tissue. Lean tissue encompasses water, muscle tissue, nervous tissue, organs, tendons, and ligaments. Accurate measurement of body composition can be challenging because body components are not compartmentalized; instead, they are mixed in various tissues in the body. However, body composition assessments are crucial for preventing excess storage of BF and loss of lean BM in pets of all ages.

Importance of Assessing Body Condition

It is imperative that the body condition of each pet (regardless of that pet’s health status) is assessed at every veterinary visit to minimize the onset of problems associated with an unhealthy BW and abnormal body composition. Accumulation of excess adipose tissue associated with disease is defined as obesity, and it is an escalating problem in companion animals. Obesity is the most common form of malnutrition in companion animals; approximately 34% to 58% of cats and dogs are overweight or obese. Pets with an ideal BW should have approximately 15% to 20% BF; however, limited data are available on body composition at ideal BW. A pet is considered overweight when BW exceeds ideal BW by 15% and obese when BW exceeds ideal BW by 30%. Nevertheless, there are no absolute divisions in BF percentage for obese, overweight, and underweight body conditions. Instead, body composition is assessed on a continuum from severely emaciated to morbidly obese.

In addition to the accumulation of excess adipose tissue, obesity is associated with an increase in concentrations of inflammatory cytokines, which causes a low-grade inflammatory state. Thus, obesity can exacerbate a variety of diseases, which include metabolic abnormalities, endocrinopathies, orthopedic disorders, cardiorespiratory diseases, urogenital diseases, and cancers. A study of Labrador Retrievers found that dogs with an ideal BCS lived approximately 2 years longer than did overweight dogs. In addition, dogs with an ideal BCS had later onset of muscle wasting and chronic diseases than did overweight Labrador Retrievers. In obese client-owned dogs, scores for a quality-of-life questionnaire were low prior to instituting a weight loss plan, but they improved after dogs had successful weight loss. Therefore, continuous assessment of body composition throughout a pet’s lifetime is crucial to prevent obesity and minimize the onset of obesity-related comorbidities.

Moreover, body composition should be monitored in obese pets undergoing weight loss to ensure that the animals primarily lose BF, not lean BM or bone mineral content. The amount of lean BM lost in obese client-owned cats and dogs undergoing weight loss is positively associated with the proportion of BW lost; however, this can depend on the rate of weight loss, protein content of the diet, and amount of exercise. If loss of lean BM is detected in pets undergoing weight loss, interventions may include reevaluating the weight loss plan and increasing exercise to maintain muscle mass.

ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>BCS</td>
<td>Body condition score</td>
</tr>
<tr>
<td>BF</td>
<td>Body fat</td>
</tr>
<tr>
<td>BM</td>
<td>Body mass</td>
</tr>
<tr>
<td>BW</td>
<td>Body weight</td>
</tr>
<tr>
<td>DEXA</td>
<td>Dual-energy x-ray absorptiometry</td>
</tr>
<tr>
<td>MCS</td>
<td>Muscle condition score</td>
</tr>
<tr>
<td>QMR</td>
<td>Quantitative magnetic resonance</td>
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</tbody>
</table>
Assessment of body composition is also essential to prevent muscle loss. Cachexia describes the loss of lean BM resulting from chronic disease, which can be accompanied by weakness, anorexia, and weight loss.\textsuperscript{22,25} In a healthy animal subjected to simple starvation, fat is used as an energy source to conserve lean tissue; however, in ill animals, lean BM is used as the primary source of energy, which results in a continued loss of lean BM.\textsuperscript{22} Diseases that cause muscle and fat loss include cancer, congestive heart failure, hyperthyroidism in cats, and chronic kidney disease.\textsuperscript{22,24–26} Low BCS or MCS (or both) has been linked to a poor prognosis and decreased survival time for these disease states.\textsuperscript{24,25,27–29} Moreover, anorexia and weight loss are common reasons pet owners decide to euthanize pets, as was reported for a study\textsuperscript{10} of dogs with congestive heart failure. Geriatric pets are also prone to loss of lean BM and BW as a result of age-related changes in energy metabolism.\textsuperscript{31,32} This is defined as sarcopenia and can occur in the absence of clinical illness.\textsuperscript{31,32} Cats that are emaciated because of cachexia and sarcopenia have a decreased survival time, compared with the survival time for cats at a lean or optimal BCS.\textsuperscript{33} Cachexia and sarcopenia are not distinguishable on the basis of results of physical examination; however, both can be differentiated on the basis of a patient’s medical history and disease status. Although the treatment approach may differ for each of these conditions, both will require a dietary intervention.\textsuperscript{22}

In addition to muscle loss as a result of generalized muscle wasting, localized muscle loss can also occur as a result of orthopedic or neurologic problems.\textsuperscript{31,32,34} Because disease and age play a large role in weight loss and muscle loss, it is crucial that both body composition and BW are assessed often.

## Methods for Assessing Body Composition

There are many methods for assessing body composition. The methods most commonly used in veterinary practice include determination of BW and BCS.\textsuperscript{35} In research settings, the criterion-referenced standard is ex vivo chemical analysis, whereby homogenized parts of a cadaver are analyzed to determine the exact chemical composition of bone, fat, and lean tissues.\textsuperscript{3,36} Because chemical analysis requires a deceased animal, it cannot be used for pets in veterinary practice. Other methods available for use in clinical practice may enhance a practitioner’s ability to assess body composition; however, they differ in cost, ease of use, invasiveness, precision, and accuracy.\textsuperscript{6} In 2001, the precision and practicality of body composition assessments for companion animals were described.\textsuperscript{5} However, results of recent studies and the development of nutritional assessment guidelines have enabled the authors to provide updated information on the methods available and the practicality for the use of each method by veterinary practitioners. There are advantages and disadvantages for the various methods\textsuperscript{12,13,34–48} (Table 1).

### Table 1—Methods for assessing body composition of dogs and cats.

<table>
<thead>
<tr>
<th>Method</th>
<th>Clinically validated with DEXA</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical analysis\textsuperscript{a}</td>
<td>No</td>
<td>Most accurate method</td>
<td>Performed on cadavers, laborious</td>
<td>36</td>
</tr>
<tr>
<td>BW</td>
<td>Yes</td>
<td>Easy to measure, can indicate weight change</td>
<td>Does not quantify fat versus lean mass, scales not calibrated</td>
<td>35</td>
</tr>
<tr>
<td>BCS</td>
<td>Yes</td>
<td>Easy to use, conveys degree of BF</td>
<td>Subjective</td>
<td>12, 13</td>
</tr>
<tr>
<td>MCS</td>
<td>Yes</td>
<td>Easy to use, conveys degree of muscle wasting</td>
<td>Subjective, descriptions not published</td>
<td>34</td>
</tr>
<tr>
<td>Morphometric measurements</td>
<td>Yes</td>
<td>Easy to use (girth), estimates BF percentage</td>
<td>Subjective, challenging if multiple measurements or animal movement</td>
<td>37–39</td>
</tr>
<tr>
<td>Ultrasoundography</td>
<td>Limited</td>
<td>Can visualize subcutaneous fat</td>
<td>Cannot quantify BF</td>
<td>40</td>
</tr>
<tr>
<td>Radiography</td>
<td>Limited</td>
<td>Can visualize subcutaneous fat</td>
<td>Cannot quantify BF</td>
<td>41</td>
</tr>
<tr>
<td>DEXA\textsuperscript{†}</td>
<td>Limited</td>
<td>Accurate for assessing BF and lean BM, small radiation dose</td>
<td>Requires sedation or anesthesia, expensive, depends on hydration status and patient position</td>
<td>36</td>
</tr>
<tr>
<td>CT</td>
<td>No</td>
<td>Can visualize subcutaneous and visceral fat and lean BM</td>
<td>Requires sedation or anesthesia; large radiation dose</td>
<td>42, 43</td>
</tr>
<tr>
<td>MRI</td>
<td>No</td>
<td>Can visualize BF and lean BM</td>
<td>Expensive, requires sedation or anesthesia</td>
<td>44</td>
</tr>
<tr>
<td>QMR</td>
<td>No</td>
<td>Does not require sedation</td>
<td>Large radiation dose, depends on hydration status</td>
<td>45, 46</td>
</tr>
<tr>
<td>Deuterium oxide dilution</td>
<td>No</td>
<td>Noninvasive</td>
<td>Depends on hydration status</td>
<td>47</td>
</tr>
<tr>
<td>Bioelectrical impedance</td>
<td>No</td>
<td>Noninvasive</td>
<td>Depends on hydration status</td>
<td>48</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Ex vivo criterion-referenced standard. \textsuperscript{†}In vivo criterion-referenced standard. 
— = Not applicable.
Methods Commonly Used in Veterinary Practice

Several methods are commonly used in veterinary practice because of ease of use, practicality, and lower cost.15 These methods include BW, BCS, MCS, morphometric measurements, ultrasonography, and radiography; they are commonly used, as determined on the basis of their prevalence in the literature, and are applicable to veterinary practice.

BW

Body weight is an objective and repeatable measure that is useful for identifying changes over time.7,49 Body weight is an objective and repeatable measure that is useful for identifying changes over time.7,49 An animal’s BW relative to its ideal BW or breed standard has been used as a defining criterion for obesity because BW is easier to measure and can be measured more rapidly than BF.4 However, BF and lean BM cannot be quantified by use of a weigh scale.6,49,50 Body weight will be variable for animals within a breed or species; therefore, it is not sufficient to determine a pet’s body composition by use of BW alone.6

Determining an animal’s ideal BW is helpful before starting it on a weight loss or weight gain program. Although no evidence exists regarding the accuracy of methods for determining ideal BW, various methods have been reported. Determining the ideal BW on the basis of information in an animal’s medical record is 1 option, but only if a concurrent ideal BCS is also available in the medical record. The BW at 1 year of age is often used, but this does not take into account that pets may be underfed or overfed during growth.2,4 If an accurate and simultaneous recording of BW and BCS is not available from the medical record, an estimation of ideal BW can be calculated by use of the following equation:11–14

\[
\text{ideal BW} = \text{current BW} \times \left( \frac{100 - \text{BF} \%}{80} \right)
\]

This equation is based on the fact that a healthy cat or dog with an ideal BW has approximately 20% BF and 80% lean BM.4,11 Both BCS and morphometric measurements can be used to estimate the BF percentage used in this equation. Alternatively, ideal BW can be determined by subtracting 10% to 15% of BW for each BCS unit > 5 (on a BCS scale of 1 to 9).11 Also, the use of breed standards has been proposed, but this may not provide an accurate assessment of ideal BW, considering the variability among purebred animals. It has been reported that 19% to 26% of show dogs51,52 and 46% of show cats53 are overweight. Show dogs with sturdy or muscular characteristics, such as Beagles, Newfoundlands, Pugs, English Bulldogs, Bassett Hounds, and Labrador Retrievers, have a substantially higher BCS.51,52 Breeds with slender or elegant characteristics, such as Great Danes, Greyhounds, Whippets, and Borzois, have a lower BCS.52 By attempting to align with the breed standard, dogs may be at risk of being underweight or overweight.51,52 Finally, a superficial estimation of the ideal BW can be made on the basis of the current BW or BCS or the assessor’s experience (or a combination of these factors)54; however, the authors do not recommend the use of such an estimate.

BCS

Body condition scoring is a subjective, semiquantitative method of evaluating body composition by taking into account an animal’s body frame independent of BW.4,6 It involves a simple assessment of visual and palpable characteristics of BF at various locations on the body.7,48,55 Assessment locations for cats include the rib cage, lumbar area, abdomen (including abdominal fat pad), and waist.15 Assessment locations for dogs include the rib cage, pelvic bones, lumbar area, abdomen, and waist.12

Currently, a variety of BCS systems exist, all of which involve the use of similar visual and palpable characteristics but that differ by the range of the scale for each scoring system. Three scoring systems12,13,56 are commonly referred to in the literature (Figure 1). The validated BCS assessment is the 9-point system, whereby each increase in BCS is associated with a mean increase in BF of 5%.12,13,50 This scoring system strongly correlates with DEXA for measurement of BF in both cats and dogs12,13 and it has low interobserver variation.50 The 5-point system is also commonly used,49,57 but this system has not been validated with DEXA.49 However, there was good reproducibility when the 5-point system was used for cats by both experienced and inexperienced scorers.59 The Size, Health, And Physical Evaluation (ie, S.H.A.P.E.) system is an algorithm for owners that uses visual and palpable characteristics similar to those for other BCS systems56 to determine the amount of BF. The S.H.A.P.E. system was designed to minimize interobserver variability and the amount of experience required, which allows owners to evaluate their cat or dog at home.56 A strong correlation between S.H.A.P.E and DEXA, similar to the correlation between DEXA and the 9-point BCS, has been noted.56

Because BCS can be determined inexpensively and noninvasively,57 it is the most practical and most frequently used method49 to assess BF in clinical settings. The 9-point BCS, 5-point BCS, and S.H.A.P.E systems are effective tools for assessing body composition in clinical practice.12,13 Advantages of a BCS system include ease of use, repeatability, and availability of a visual image of the appearance of a clinically normal versus overweight or underweight animal.12,13 Limitations include interobserver variation and subjectivity; however, when trained individuals and veterinarians use BCS systems, results correlate well with DEXA.7,48,49 A disadvantage is that BCS is intended to only assess fat deposition but not muscling.7 It is recommended that an MCS system be used concurrently with a BCS system to determine muscle quality.1,2 Furthermore, the BCS does not provide the exact amount of BF (which is in contrast to DEXA), but it does provide a range of BF percentages determined by use of the scoring system.14 Another limitation is that dogs and cats with 40%, 50%, or 60% BF are provided with a BCS of 5/5 or 9/9.12,13,50 which makes it challenging to calculate an ideal BW when using a BCS because the BF percentage is not exactly known.2 Morphometric measurements may provide additional benefit in these cases because they might be used to differentiate the amount of BF for an animal with > 40% BF.37,58
Both overweight and underweight animals can catabolize lean BM, which would not be detected in a BCS system. The most commonly used MCS consists of 4 scores (normal muscling and mild, moderate, and severe muscle loss). Agreement between MCS and DEXA is substantial for cats, with reasonable repeatability between scorers. However, the MCS system

<table>
<thead>
<tr>
<th>9-point BCS&lt;sup&gt;12,13&lt;/sup&gt;</th>
<th>S.H.A.P.E.&lt;sup&gt;56&lt;/sup&gt;</th>
<th>5-point BCS&lt;sup&gt;12,13&lt;/sup&gt;</th>
<th>Canine</th>
<th>Feline</th>
<th>BF percentage&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/9</td>
<td>A</td>
<td>1/5</td>
<td><img src="image1" alt="Canineadder" /></td>
<td><img src="image2" alt="Felineadder" /></td>
<td>&lt; 5%</td>
</tr>
<tr>
<td>2/9</td>
<td>B</td>
<td>1.5/5</td>
<td><img src="image3" alt="Canineadder" /></td>
<td><img src="image4" alt="Felineadder" /></td>
<td>5%–9%</td>
</tr>
<tr>
<td>3/9</td>
<td>B</td>
<td>2/5</td>
<td><img src="image5" alt="Canineadder" /></td>
<td><img src="image6" alt="Felineadder" /></td>
<td>10%–14%</td>
</tr>
<tr>
<td>4/9</td>
<td>C–D</td>
<td>2.5/5</td>
<td><img src="image7" alt="Canineadder" /></td>
<td><img src="image8" alt="Felineadder" /></td>
<td>15%–19%</td>
</tr>
<tr>
<td>5/9</td>
<td>D</td>
<td>3/5</td>
<td><img src="image9" alt="Canineadder" /></td>
<td><img src="image10" alt="Felineadder" /></td>
<td>20%–24%</td>
</tr>
<tr>
<td>6/9</td>
<td>E</td>
<td>3.5/5</td>
<td><img src="image11" alt="Canineadder" /></td>
<td><img src="image12" alt="Felineadder" /></td>
<td>25%–29%</td>
</tr>
<tr>
<td>7/9</td>
<td>F</td>
<td>4/5</td>
<td><img src="image13" alt="Canineadder" /></td>
<td><img src="image14" alt="Felineadder" /></td>
<td>30%–34%</td>
</tr>
<tr>
<td>8/9</td>
<td>G</td>
<td>4.5/5</td>
<td><img src="image15" alt="Canineadder" /></td>
<td><img src="image16" alt="Felineadder" /></td>
<td>35%–39%</td>
</tr>
<tr>
<td>9/9</td>
<td>G</td>
<td>5/5</td>
<td><img src="image17" alt="Canineadder" /></td>
<td><img src="image18" alt="Felineadder" /></td>
<td>≥ 40%</td>
</tr>
</tbody>
</table>

**Figure 1**—Systems for scoring of BCS of dogs and cats. S.H.A.P.E. = Size, Health, And Physical Evaluation. Images in the Canine and Feline columns provided by Royal Canin. (Image Source: © ROYAL CANIN® SAS 2017. All rights reserved. Reprinted with permission.)
has not yet been validated for dogs. Both MCS and BCS should be used simultaneously to obtain a reasonable estimation of overall body composition.1,2

Morphometric measurements

Morphometry is used to evaluate various anatomic lengths and circumferences by measuring parts of the body, and it is also used to examine the manner by which these dimensions change over time.3,59 Most studies that have involved the use of morphometry to evaluate body composition have been conducted on cats. The use of morphometry on dogs has been limited, likely because of differences in breed size and conformation.6,37

Girth measurements are obtained by measuring the circumference of the body with a tape measure.6 Girth measurements include the cranial thoracic circumference, pelvic circumference, and circumference at the last rib.6 Findings have been contradictory with regard to the correlation between thoracic circumference and BF or lean BM of cats.6,60,61 Alternatively, pelvic circumference is positively correlated with BF percentage and negatively correlated with lean BM, when compared with results for ex vivo chemical analysis of feline cadavers.60 Girth measurements can be used to convey changes in body size to owners when a pet is losing or gaining weight.59

Body mass index systems have been developed for use on dogs and cats. Two feline BM indices have been developed. The equation for 1 BM index is as follows:61

\[ \text{feline BM index} = \frac{\text{BW in kilograms}}{(\text{body length in meters} \times \text{height in meters})} \]

where body length is the distance between the point of the shoulder and the tuber ischium, and height is the distance from the point of the shoulder to the ventral aspect of the metacarpal pad. The equation for the other BM index is as follows:60

\[ \text{feline BM index} = \frac{\text{BW in kilograms}}{\text{PCL in meters}} \]

where PCL is the distance from the proximal aspect of the patella to the distal aspect of the calcaneus. However, results for these 2 equations have not been validated with results for DEXA or another reference method.60,61

For dogs, an equation for a BM index equation and equations for sex-specific BF percentage have been developed.62 The equation for the BM index is as follows: canine BM index = BW in kilograms/(height at shoulder in centimeters \times body length in centimeters), where body length is the distance from the occipital protuberance to the base of the tail. The sex-specific equation for BF percentage of male dogs is as follows: male BF percentage = (–1.4 \times TS in centimeters) + (0.77 \times PC in centimeters) + 4, where TS is the distance from the tibiotarsal joint to the stifle joint, and PC is the pelvic circumference at the level of the flank. The sex-specific equation for BF percentage of female dogs is as follows: female BF percentage = (–1.7 \times TS in centimeters) + (0.93 \times PC in centimeters) + 5. Results for these 3 equations have been compared with results for DEXA; however, only the sex-specific equations for BF percentage have a good correlation with results of DEXA.62 Use of these equations is limited because pelvic circumference (used in the equations to determine sex-specific BF percentage) changes the most with weight gain or loss; thus, the BF percentage obtained may not always correlate with the actual BF percentage because of differences in body conformation among dog breeds.62 Because of the variability in results for available BM index equations, further research is needed to develop a consistent BM index system for both cats and dogs.

Another set of morphometric measurements, the BF index system, has recently been developed for use in overweight and obese dogs and cats.37,38 For cats, this system involves measurements of body length, head circumference, forearm circumference, and pelvic circumference.38 For dogs, the measurements include head circumference, forearm circumference, and thoracic circumference.38 The BF index system was validated with DEXA, which revealed an accurate estimation of BF percentage for overweight and obese dogs and cats.37,38 Because of the excellent agreement with results of DEXA, a BF index may be a useful tool for veterinary practitioners when assessing body composition of animals, especially obese patients for which BF percentage exceeds 40%.37,38 However, the BF index was designed and validated by use of only overweight and obese pets.37,38 Therefore, the accuracy of this system for pets with ideal BW or that are underweight is unknown; thus, further validation is required.

Although morphometric measurements generally provide an objective estimation of body composition, there are limitations. These measurements are more useful for cats than dogs because of the relatively similar body conformation and size of cat breeds, compared with those of dog breeds.37,59 For dogs, evaluation of the measurements of pelvic circumference and length of the right hind limb from the tibiotarsal joint to the stifle joint has revealed that the accuracy of these measurements is reduced because of the variation in proportions among breeds.6,37,59 Also, cats and dogs deposit subcutaneous fat in different body regions,3 which must be taken into account. It may also be difficult to obtain accurate measurements on an awake, moving animal; however, results are not affected by sedation of animals.37,50 Time is another limitation because it may require up to 10 minutes to accurately obtain the required measurements.6,37 Moreover, measurements may also be affected by coat thickness.4,1b Investigators may differ in their identification and measurement of anatomic landmarks.6 However, interrater and intrarater variability are low and not significantly different for all measurements for investigators who have not received a training session.37 Practitioners and veterinary technicians may avoid use of these methods of assessment because of the increased time and effort required, compared with the time and effort required to assess BCS. Given these limitations, the accuracy and reliability for the
use of morphometric measurements in clinical practice should be further evaluated.

**Ultrasonography and radiography**

Ultrasonography has been used to evaluate subcutaneous fat thickness in livestock and humans, and its use can be applied to pets. The layer of subcutaneous fat, described as a hypoechoic line between 2 hyperechoic lines (skin and subcutaneous connective tissue), can be measured. Subcutaneous BF measured in the midlumbar region is a good predictor of BF when compared with results for ex vivo chemical analysis and histologic examination of subcutaneous fat biopsy specimens. Although ultrasonography is a simple and noninvasive procedure, it unfortunately has low reproducibility because measurements depend on animal positioning, pressure applied to the probe, and whether the coat is clipped. Ultrasonography was also compared with CT and radiography to evaluate muscle condition between young and old healthy Labrador Retrievers. Although no significant differences were noted between methods of evaluation for the temporal and quadriceps areas, ultrasonography was found to be the most reliable method for assessing changes in epaxial musculature. The same limitations and low reproducibility apply to the use of ultrasonography for assessing muscle condition as described for assessing BF. Further research is needed to validate ultrasonography as a method for assessing body composition in pets.

In human and veterinary medicine, radiography (which typically is used for the diagnosis of a variety of conditions) can also be used to assess body composition. A strong association between the amount of subcutaneous fat at the head of the eighth rib and BCS was detected for dogs by use of dorsoventral or ventrodorsal radiographs. However, that study had numerous limitations, such as a small sample size, potential measurements of muscle instead of fat, and differences in radiographic views. Investigators of another study reported that radiography did not provide the precision needed to establish a difference in musculature between young and old dogs. Additional prospective studies should be conducted to establish whether radiography can be used as a method for estimating body composition.

Because they allow visible evidence of fat thickness and musculature, ultrasonographic and radiographic imaging can be used to help convince owners that pets are overweight or losing muscle mass. Unfortunately, because of the various aforementioned limitations, both of these methods currently have minimal application for assessing body composition in veterinary practice.

**Methods Not Commonly Used in Veterinary Practice**

Several methods are not commonly used in veterinary practice because of increased time required, cost, or difficulty. Additionally, methods may not be used in veterinary practice because the intended purpose does not require increased accuracy or precision. These methods include advanced imaging techniques, deuterium oxide dilution, and bioelectrical impedance. They are not commonly used, as determined on the basis of their prevalence in the literature, and are not applicable to veterinary practice.

**Advanced imaging techniques**

Dual-energy x-ray absorptiometry, which was originally developed as a criterion-referenced method for determining bone mineral content and body composition of humans, currently is considered the best available method for in vivo estimation of body composition of cats and dogs. Bone mineral content, bone mineral density, BF, lean BM, and BW can be assessed by the use of x-rays at 2 voltages (70 and 140 kVp) to distinguish the type and amount of tissue scanned. Although x-rays are used, the radiation dose is minimal and measurement time is relatively short (5 to 10 min/scan). Algorithms in the software then calculate the amount of bone mineral content, BF, and lean BM in each pixel of the 2-D image. It is a safe and accurate method that can be rapidly performed to provide results. Limitations that make DEXA less practical for veterinary practice are the cost, need for sedation of patients, and positioning accuracy. Moreover, reference values for body composition of cats and dogs are lacking. Discrepancies can occur, depending on the amount of abdominal and intramuscular fat, because it is difficult to identify fat in skeletal muscle as a result of the proximity of skeletal muscle to bone. In addition, DEXA relies on the assumption that lean BM consists of 75% water, so BF tends to be overestimated as tissue hydration increases. Additionally, the software was developed for use on humans and rodents, not for use on pets. These various limitations must be taken into account when reviewing results for body composition of pets. Nonetheless, other methods used in veterinary practice typically are validated with DEXA. Compared with results of ex vivo chemical analysis, DEXA provides extremely reliable estimates of tissue components.

Computed tomography has been evaluated for assessing body composition of pets because visceral and subcutaneous fat can be evaluated separately in a 3-D manner. On CT images, fat is hypodense and rarely overlaps with other tissues in the image, which allows it to be quantified on the basis of the number of pixels. For both dogs and cats, substantial agreement was noted in BF percentage measured by use of CT, compared with results for DEXA or deuterium oxide dilution. Both CT and DEXA are expensive and require sedation or anesthesia of patients, but the radiation dose and cost are higher for CT, which may explain the reason that DEXA is preferred. However, CT is a reasonable alternative when DEXA is not available. Also, CT has been used with limited success for evaluating changes in muscle condition between young and old dogs.
Magnetic resonance imaging can be used to assess body composition on the basis that there are differences in responses of hydrogen bonds in the body to radiofrequency when placed in a strong magnetic field.\textsuperscript{45,46,70} Limitations of MRI for the assessment of body composition of pets include that it has yet to be validated, there are high equipment costs, and cats and dogs must be anesthetized for the procedure.\textsuperscript{44} However, QMR (which involves methods similar to those for MRI) may be an alternative for assessing body composition. Use of QMR does not require that pets be sedated; instead, they are scanned while in a crate that limits movement.\textsuperscript{46} Other advantages of QMR include that scanning times are short (6 to 8 min/scan) and operation is easy.\textsuperscript{70} Although results for QMR on cats and dogs correlate well with results for deuterium oxide dilution, BF is underestimated for both species.\textsuperscript{45,46} Furthermore, although QMR may be more practical than MRI, it may not be practical for general veterinary practice because of inaccuracy and high cost.

**Deuterium oxide dilution**

Measuring deuterium oxide (also known as doubly labeled water) dilution is one of the most effective techniques for determining body composition of humans and has been validated against results of ex vivo chemical analysis for dogs.\textsuperscript{45,71} Deuterium oxide dilution assumes that the body can be divided into lean and fat tissue components.\textsuperscript{46} The body water pool can be labeled by use of oral or SC administration of deuterium, and body composition then can be readily analyzed on the basis of the decline of stable isotopes of oxygen \((\text{O}^4\text{O})\) and hydrogen (deuterium \([\text{D}^2\text{H} \text{or D}_2\text{O})\) in body water.\textsuperscript{45,46,62,72} The deuterium content is determined in serum samples obtained 2 to 4 hours after administration, and that content is then used in an equation to calculate total body water, lean BM, and BF (assuming that adipose tissue has minimal water content and that lean BM consists of 73% water).\textsuperscript{7,45,46,58} Deuterium oxide dilution typically is used as a validated, noninvasive reference method for research conducted on companion animals; however, deuterium oxide dilution is not practical for use in general veterinary practice.\textsuperscript{6}

**Bioelectrical impedance analysis**

Bioelectrical impedance analysis has been used for pets and is a safe, noninvasive, and rapidly performed method for assessing body composition; however, it is an unreliable indicator of BF.\textsuperscript{7,48} Bioelectrical impedance involves a portable system that is used to quantify total body water, lean BM, and BF by measuring conductance of body fluid by use of applied electrical current.\textsuperscript{6,48} Because the machinery is portable and noninvasive, bioelectrical impedance analysis has the potential for use in veterinary practice, although it was found to be an unreliable indicator of BF (with both underestimations and overestimations) for dogs of various breeds.\textsuperscript{48,59} Additionally, results may be affected by location of electrodes, skin and air temperature, body positioning of patients, conformation differences among dogs, and contact with conducting surfaces.\textsuperscript{6,48} Because of these limitations, further research should be conducted on the accuracy of bioelectrical impedance analysis for use in estimating body composition of dogs and cats.

**Clinical Summary**

Some methods are more practical for use in veterinary practice than others; however, the various methods for assessing body composition all differ in terms of assessing BF and lean BM of pets. Because each method has its limitations, more research is needed to develop a method that is inexpensive and practical for use in general veterinary practice. The ideal method for assessing body composition should be both accurate and precise; clinicians should be able to use it to provide a noninvasive measurement of BF and lean BM while taking into account age, sex, size, and breed differences of patients. Ideally, the method would not require that patients be anesthetized for accurate measurements. Until such a method can be developed and validated, the American Animal Hospital Association\textsuperscript{2} and World Small Animal Veterinary Association\textsuperscript{1} currently recommend the use of BW, BCS, and MCS as part of each pet’s nutritional assessment at every visit to a veterinary practice to establish patterns over time. This will allow veterinary health-care teams to ensure that each pet remains at an ideal body condition throughout its life, and it also will provide for monitoring of muscle quality in aging or diseased patients. Conducting regular assessments of body composition will serve as a form of preventative medicine by decreasing risks for comorbidities and improving patient health, quality of life, and longevity.

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**Footnotes**


**References**


