Development of a body condition scoring system for nonhuman primates using *Macaca mulatta* as a model

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The nutritional status of individual monkeys in research projects is an important yet sometimes overlooked variable that complicates the interpretation of research findings. The authors offer a framework for scoring fatness and muscularity in a semiquantitative manner without special equipment and in a way that could easily be accomplished during a routine physical examination. Body condition scoring can be used to assess the health of individual animals as well as determine nutritional adequacy within groups of animals.

Body condition scoring (BCS) is a subjective, semiquantitative method of assessing body fat and muscle[1]. Scoring of body condition assesses overall health, nutrition, and performance in a wide variety of species including sheep, cattle, horses, dogs, cats, and mice[1–12], and can readily be incorporated into a routine physical examination. BCS is generally independent of weight or frame size, and can provide additional animal health information[1,8].

Body condition scoring typically employs a 1–5, 1–6, or 1–9 scale, with mid-range values representing more optimum body condition, lower values representing lean or emaciated conditions, and higher values representing excessive body fat. Regardless of the scale used, some assessments will always fall between two scores, but for all practical purposes half-scores are sufficient[8]. Relative to most physical examination techniques, there is a learned art to assessing body condition. However, most protocols are easy to learn, especially when the scale is well described.

Body condition scoring can be useful in making recommendations pertaining to nutrition or in assessing the health status of an individual animal. BCS can also be a useful guide to the nutritional adequacy of an animal or group of animals and reflects the consequences of food and nutrient intake during the previous weeks or months[1]. Extremes in BCS may correlate with, or be predictive of, certain disease conditions. Dogs and cats seen at the University of Pennsylvania that required nutritional support had the classification of cachectic (BCS 1) or underweight (BCS 2) using a BCS scale of 1–5 (refs. 4, 5). Overweight or obese cats (BCS of 5 or 6, respectively, on a scale of 1–6) were found to be more likely to develop diabetes mellitus, lameness, and nonallergic skin disease. Underweight cats (cachectic or lean, BCS of 1 or 2, respectively, on a scale of 1–6) were more likely to have diarrhea[9]. In a research setting, the use of a 1–5 BCS scale for mice can aid in the determination of experimental endpoints, with euthanasia recommended for those animals having a BCS of 2 or 1 (thin or emaciated). The scoring system is useful in mice in which weight loss may be masked by organomegaly, a growing tumor, or pregnancy[3]. BCS is an important part of dairy herd management and is used to make decisions regarding future feeding, breeding, and health management. On a 1–5 scale, with 1 being very thin with no fat reserves and 5 being severely overconditioned, optimal scores are 3.5–4.0 at dry off and calving, and 2.5–3.0 at peak lactation, with no cows changing by more than one condition score over any lactation period[11,12].

OTHER MEASURES OF BODY COMPOSITION

Body composition may be assessed by morphometric data such as crown-rump or crown-heel length, arm circumference, waist circumference, skin-fold thickness, and body weight. A body mass index can be calculated using crown-rump or crown-heel length and body weight measures. Imaging techniques such as

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dual-energy x-ray absorptiometry (DEXA) to measure specific body compartments such as fat and lean body mass, and ultrasound to measure abdominal fat thickness, have also been used to assess body composition[13–16]. Unlike BCS, these measures require additional tools and imaging equipment. BCS can be a useful adjunct to these measures or provide a way to assess body composition without additional tools or equipment.

THE USE OF BCS IN NONHUMAN PRIMATES

This paper provides a well-described scoring system to evaluate body condition in nonhuman primates (NHPs) based on similar systems that have been used in other species. The BCS system provided (**Table 1**) uses a 1–5 scale including half-scores with detailed descriptions of each score. The scale design involves a one-page format with illustrations. A 'stylized' rhesus monkey (*Macaca mulatta*) is used to depict the prominence of bony structures and the amount of muscle and fat that one palpates when assessing body condition, with the caveat that an animal may not visually appear as drawn because of the presence of the haircoat. The one-page summary provides a concise yet descriptive training tool for others who wish to adopt this system to evaluate nonhuman primates.

The physical examination can readily incorporate the assessment of body condition. Animal care staff can be trained to score animals, providing them with additional skills and expanding their role in promoting animal well-being. The use of this BCS system can help veterinarians make recommendations to investigators regarding nutrition, endpoints, or additional diagnostics.

Assessment of body condition in NHPs should be conducted by palpation of an immobilized animal. There should be no attempt to visually score nonimmobilized animals, because haircoat and activity may make visualization of bony prominences and muscle mass difficult if not impossible. For more reliable scoring, it is helpful to develop a consistent routine for the evaluation of each animal. Different individuals may choose different routines, but each routine should incorporate palpation of the following key elements:

- Hips/Pelvis (ilium, sacrum, ischium)
- Spine (thoracic and lumbar)
- Thorax (ribs and scapula)
- Muscle mass (epaxials, gluteals, deltoids)
- Subcutaneous fat
- Fat deposits (abdominal, inguinal, axillary)

Palpation of hips/pelvis

Palpate over the wings of the ilium, sacrum, and ischium. Assess their prominence, presence of subcutaneous fat layer, and muscle mass. The contours of the wings are easily palpable in thin to emaciated animals. In animals with little to no muscle mass, the wing and gluteal surface of the body of the ilium will feel concave because there is no muscle mass overlying the bony structures. The contours of the sacrum and ischium are easily palpable in thin to emaciated animals. In overweight or obese animals, the borders of the wings of the ilium will be obscured and identifiable only with deep palpation. The sacral region will be rounded and soft, with bony structures difficult to identify.

Visually assess the ischial callosities and rectal area. In thin to emaciated animals the ischial callosities may be more prominent, while the anus is recessed into the bony hollow between the callosities. In optimum to obese animals, no bony hollow is evident between the callosities and the anus is at or near the level of the ischial callosities.

Palpation of spine

Palpate over the lumbar and thoracic spine. Assess the prominence of spinous processes, presence of subcutaneous fat layer, and epaxial musculature. The spinous processes are easily palpable in thin to emaciated animals. These animals also tend to have little to no muscle mass, which makes the processes more pronounced than they would be when evaluating an optimum or obese animal. Transverse vertebral processes in the lumbar area are also easily palpable in thin to emaciated animals. For animals in optimum condition, the epaxial musculature will be well developed and a subcutaneous fat layer will be present giving the area over the spine a firm, rounded feel. Spinous processes can be distinguished on palpation but are not prominent whereas transverse vertebral processes may only be identified with firm palpation. Obese animals will typically have well developed musculature and an abundant subcutaneous fat layer. On palpation, these areas will feel rounded and soft. Bony structures may only be identifiable with deep palpation.

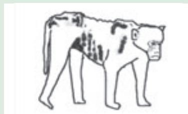
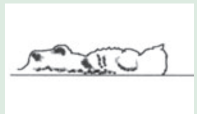
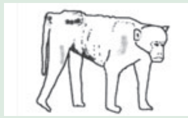
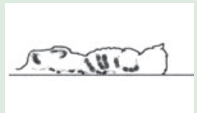
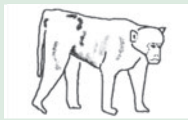
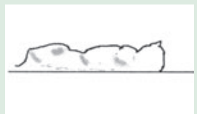
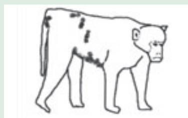
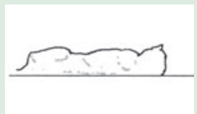
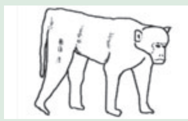
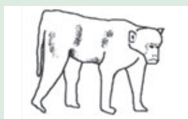
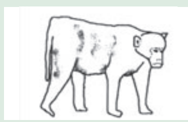
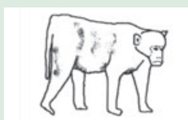
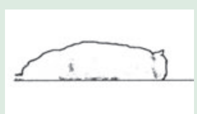
Palpation of thorax

Palpate over the rib cage and scapulae. Assess the prominence of the ribs and the presence of subcutaneous fat. Palpate the scapulae for prominence, muscle mass, and subcutaneous fat. The thorax is an optimal area to assess the subcutaneous fat layer, since there is normally little muscle overlying the ribs. Any smoothing or obscuring of rib contours is predominantly due to the presence of a subcutaneous fat layer.

Palpation of muscle mass

It is best to assess muscle mass in association with the palpation of the bony prominences (hips, spine, scapulae). In these areas muscle mass or lack thereof contributes to the degree of prominence. Additional muscle masses that may be evaluated include the quadriceps, hamstrings, biceps, or triceps although

TABLE 1 | Body condition scoring system for nonhuman primates. Stylized drawings of ambulating animals and animals in right lateral recumbency attempt to visually depict bony prominences, muscle, and fat that are palpated when scoring animals. Note that animals may not actually appear as drawn because of the presence of the haircoat.

		Ambulating	Right lateral viewed from back
1	**EMACIATED** – Very prominent hip bones (easily palpable and likely visible), prominent facial bones, spinous processes, and ribs. Minimal to no muscle mass is palpable over ilium or ischium. Anus may be recessed between ischial callosities. Body is very angular, no subcutaneous fat layer to smooth out prominences.		
1.5	**VERY THIN** – Hips, spinous processes, and ribs are prominent. Facial bones may be prominent. There is very little muscle present over the hips and back. Anus may be recessed between ischial callosities. Body is angular, no subcutaneous fat to smooth out prominences.		
2	**THIN** – Very minimal fat reserves, prominent hip bones and spinous processes. Hips, spinous processes, and ribs are easily palpable with only a small amount of muscle mass over hips and lumbar region		
2.5	**LEAN** – Overlying muscle gives hips and spine a more firm feel. Hip bones and spinous processes are readily palpable, but not prominent. Body is less angular because there is a thin layer of subcutaneous fat.		
3	**OPTIMUM** – Hip bones, ribs, and spinous processes are palpable with gentle pressure but generally not visible. Well-developed muscle mass and subcutaneous fat layer gives spine and hips smooth but firm feel. No abdominal, axillary, or inguinal fat pads.		
3.5	**SLIGHTLY OVERWEIGHT** – Hip bones and spinous processes palpable with firm pressure but are not visible. Bony prominences smooth. Rib contours are smooth and only palpable with firm pressure. Small abdominal fat pad may be present.		
4	**HEAVY** – Bony contours are smooth and less well defined. Hip bones, spinous processes, and ribs may be difficult to palpate because of more abundant subcutaneous fat layer. May have fat deposits starting to accumulate in axillary, inguinal, or abdominal areas.		
4.5	**OBESE** – This animal will often have prominent fat pads in the inguinal, axillary, or abdominal region. Abdomen will be pendulous when animal is sitting or ambulating. Hip bones and spinous processes difficult to palpate. Bony contours smooth and poorly defined.		
5	**GROSSLY OBESE** – Obvious, large fat deposits in the abdominal, inguinal and axillary regions. Abdominal palpation is very difficult due to large amount of mesenteric fat. Pronounced fat deposits may alter posture/ambulation. Hip bones, rib contours, and spinous processes only palpable with deep palpation.		

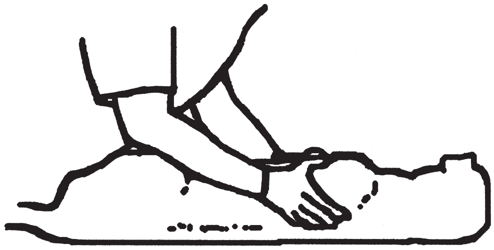


FIGURE 1 | Method of scoring an animal in lateral recumbency.

evaluating muscle loss over long bones may be misleading, because the muscle atrophy may be the result of a primary condition (such as osteoarthritis) and may not be indicative of nutritional status.

Palpation of subcutaneous fat and fat deposits

One can palpate the subcutaneous fat layer over all locations described earlier. Presence of a subcutaneous fat layer will tend to smooth out or obscure bony prominences and contours. Fat will often accumulate or form deposits in overweight to obese animals. The first area for fat to accumulate or deposit is typically in the abdominal fat pad. Other areas include the inguinal, axillary, or cervical region.

Other areas

Head. In very thin to emaciated animals, the facial bones (zygomatic arch, orbital bones) may be prominent. It is important to distinguish the 'sunken-eyed' look in emaciation from possible dehydration. This appearance may not be as consistent, but, if present, can aid in a body condition determination.

Abdomen. A deep abdominal palpation can provide additional information with regard to body fat. In general, as the BCS of an animal increases it becomes more difficult to localize individual structures within the abdomen. Very thin or emaciated animals generally have little mesenteric fat. The decreased amount of mesenteric fat deposits in these animals makes individual bowel loops readily palpable. Thin animals, while having minimal subcutaneous fat, will tend to have some mesenteric fat that will make the individual bowel loops less prominent. In lean animals, there is a thin layer of subcutaneous fat and the abdomen typically has adequate mesenteric fat, giving the abdomen a more 'doughy' feel. Abdominal palpation of obese animals can be very difficult. The mesenteric fat deposits may make the abdominal wall taut and obscure the borders of internal structures. The abdominal fat pad is soft and pendulous, lying just outside of the body wall and can extend from the xyphoid to the pubis.

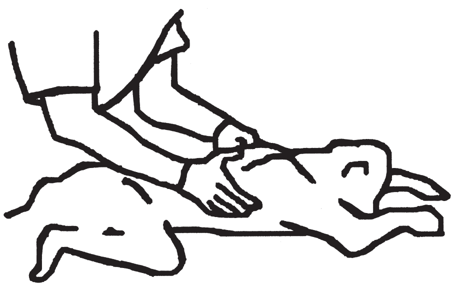


FIGURE 2 | Method of scoring an animal in sternal recumbency.

POSITIONING AND EVALUATING THE ANIMAL

For consistency, it may be best to place any animals evaluated in the same position every time. However, with practice it is possible to score animals in either lateral or sternal recumbency.

One technique is to place the animal in lateral recumbency (**Fig. 1**), with the animal's head opposite or angled away from the evaluator. If the animal is in right lateral recumbency, use the right hand to palpate over the shoulder and spine, ilium, sacrum, and ischium while the left hand palpates over the ribs and across the abdomen. If the animal is in left lateral recumbency, use the left hand to palpate over the shoulder and spine, ilium, sacrum, and ischium while the right hand palpates over the ribs and across the abdomen.

When placing the animal in sternal recumbency (**Fig. 2**), keep the animal as straight as possible, head away from the evaluator with the knees flexed on either side of the body. The evaluator should place his or her hands on each side of the thorax with the thumbs over the spine and the fingers extended down across the ribs and run the hands down the length of the body and over the hips.

SCORING THE ANIMAL

After the initial evaluation, the evaluator should be able to determine a tentative score for the animal based on the descriptive criteria and scale (**Table 1**). Certain areas may need to be reevaluated with the tentative score in mind to reaffirm the criteria for that particular score. It may be necessary to reposition the animal to better evaluate certain anatomic sites, particularly if the animal is in sternal recumbency. Other areas may be assessed depending on the tentative score. For example, a tentative score of 2.0 for an animal may prompt a reexamination of the wing and body of the ilium for evaluation of muscle mass or deep abdominal palpation to evaluate mesenteric fat. The appearance of the perianal region should also be a matter for consideration. In another example, a tentative score of 4.0 for an animal may prompt a reevaluation of the abdominal, axillary, or inguinal regions for fat accumulation or deposits.

Once a score is determined, it should become part of the physical examination data. Because the scoring system represents discrete values on a continuum of possible body conditions, there may be times when it is difficult to settle on one score. A decision-making process should exist for determining a default score for animals that have features placing them between two defined scores. The individuals working at a particular institution or with a particular model can define how to determine the default score. Since the BCS may be used to make recommendations pertaining to the animals' care or use, consistency in determining the default score is particularly important. The recommendation is to use the score that is most representative. For example, if an animal is between a score of 2.0 and 2.5 but does not have a majority of characteristics associated with a 2.5 score, then the animal's score is a 2.0. Conversely, if an animal is between a score of 2.0 and 2.5 and has a majority of characteristics associated with a 2.5 score, then the animal's score is a 2.5. If it is helpful, the evaluator can make a note next to the entry indicating that the animal is between the two scores or approaching the higher score. The scale used should appear in the record as in a score of 2.0 out of 5.0 (2.0/5.0), so that where the animal falls on the scale is more apparent to someone reading the examination record.

SCORING A WIDE VARIETY OF ANIMALS

The BCS system as described can be applied to almost any animal regardless of age or gender. Interpretation of the significance of the BCS should be in light of the animal's current age or reproductive status. For example, juvenile animals tend to be lean or lanky, often scoring a 2.0 or 2.5. An animal that has just undergone a growth spurt may be evaluated as thin, scoring a 2.0, whereas one whose growth has stabilized may be lean, as muscle mass catches up with previous bone growth. In another example, a pregnant female may score a 3.5 or 4.0 as she accumulates fat during pregnancy. Infants are similar to juvenile animals in that it would be unusual to see an overweight or obese animal. Ideally, an infant should have an adequate subcutaneous fat layer that smooths bony prominences, and good muscle development. Healthy infants may typically score between 2.5 and 3.0.

The age group that may be the exception to routine application of the scoring system is the geriatric animal. In many cases the scoring system as described can be useful in describing geriatric animals. However, some animals in this age group may have incongruities between fat and muscle. For example, a geriatric animal may have a large abdominal fat pad but little muscle over the hips and spine. This particular animal may have muscle atrophy, which has resulted from decreased activity due to arthritis. The inactivity may have contributed in part to the animal's obesity. There is no one score in the described scale that could be used for this scenario. In this case, it may be better to use two scores, one to represent the 'fat' and one to represent the 'muscle'. This particular animal, with a large abdominal fat pad, may score a 4.5 for 'fat'. Because the animal has little muscle over the hips and spine, the 'muscle' score may be a 2.0. This is just one recommended way to use the BCS for animals that do not readily fall within the described scale. Evaluators who employ such a dual scoring system should describe it, indicating which score represents which aspect (*i.e.*, "muscle 2.0/5.0" and "fat 4.5/5.0").

CONCLUSIONS

A wide variety of studies that use NHPs have the potential to affect body condition. For example, animals may have their food restricted as part of a training or operant-conditioning protocol. A program for monitoring animals is an essential part of experimental protocols involving food restriction[17–19]. Careful monitoring is crucial to ensure that food-restricted animals do not become emaciated[19]. Adjustments of the restriction protocol or removing animals either temporarily or permanently from food restriction are sometimes necessary[17–19]. BCS criteria can be used as part of a monitoring program to aid in this decision-making process. Another example is animal models of potentially debilitating diseases. Animals infected with simian immunodeficiency virus (SIV) may experience a decline in body condition. It has been demonstrated that SIV infected juvenile rhesus macaques exhibit changes in body composition depending on the phase of infection. A progressive loss of fat is followed by a loss in lean body mass and then a marked wasting in the terminal phases of the illness[16]. In a colony management situation, body condition assessment can be used to make nutritional recommendations such as, nutritional supplementation for thin or emaciated animals, or calorie restriction for overweight or obese animals. Aging rhesus monkeys may develop spontaneous obesity and diabetes. Dietary management to maintain animals in a more lean body condition has been effective in increasing insulin sensitivity[20,21]. Classifying an animal at either extreme of the BCS spectrum may prompt additional diagnostics. Examples include evaluation of serum chemistry, complete blood count, and urinalysis to check for systemic disease in a thin or emaciated animal or diabetes in an obese animal.

We have found the BCS system to be a useful adjunct to the physical examination. We routinely use the body condition information to make nutritional recommendations for NHPs. In particular, we are able to make nutritional recommendations for animals before they reach the extremes of body condition in an effort to return the animals to a more optimum condition and to maintain them within normal limits as representative research subjects. BCS is also a useful monitoring tool, particularly for animals under experimental protocols in which the animals' food intake may be altered or impaired. We hope that, provided with a well-described BCS system, others can adopt this system and use it for monitoring of animals and to make recommendations regarding nutrition, diagnostics, and experimental endpoints.

COMPETING INTERESTS STATEMENT

The authors declare that they have no competing financial interests.

Received 9 February 2005; accepted 4 April 2005.
Published online at http://www.labanimal.com

1. Burkholder, W.J. Use of body condition scores in clinical assessment of the provision of optimal nutrition. *J. Am. Vet. Med. Assoc*. **217(5)**, 650–654 (2000).
2. Donoghue, S., Khoo, L., Glickman, L.T. & Kronfeld, D.S. Body condition and diet of relatively healthy older dogs. *J. Nutr.* **121(11 Suppl)**, S58–S59 (1991).
3. Foltz, C.J. & Ullman-Cullere, M. Guidelines for assessing the health and condition of mice. *Lab Anim. (NY)* **28(4)**, 28–32 (1999).
4. Kronfeld, D.S., Donoghue, S. & Glickman, L.T. Body condition and energy intakes of dogs in a referral teaching hospital. *J. Nutr.* **121(11 Suppl)**, S157–S158 (1991).
5. Kronfeld, D.S., Donoghue, S. & Glickman, L.T. Body condition of cats. *J. Nutr*. **124(12 Suppl)**, 2683S–2684S (1994).
6. Laflamme, D. Development and validation of a body condition score system for cats: a clinical tool. *Feline Pract.* **25(5/6)**, 13–18 (1997).
7. Laflamme, D. Development and validation of a body condition score system for dogs. *Canine Pract.* **22(4)**, 10–15 (1997).
8. Russel, A. Body condition scoring of sheep. *In Practice* **6(3)**, 91–93 (1984).
9. Scarlett, J.M. & Donoghue, S. Associations between body condition and disease in cats. *J. Am. Vet. Med. Assoc*. **212(11)**, 1725–1731(1998).
10. Wright, B., Rietveld, G. & Lawlis, P. Body condition scoring of horses. Ontario Ministry of Agriculture and Food Factsheet (1998). http://www.gov.on.ca/OMAFRA/english/livestock/horses/facts/98-101.htm.
11. Rodenburg, J. Body condition scoring of dairy cattle. Ontario Ministry of Agriculture and Food (1996). http://www.gov.on.ca/OMAFRA/english/livestock/dairy/facts/92-122.htm.
12. Parker, R. Using body condition scoring in dairy herd management. Ontario Ministry of Agriculture and Food Factsheet (1996). http://www.gov.on.ca/OMAFRA/english/livestock/dairy/facts/94-053.htm
13. Bercovitch, F.B. *et al*. A longitudinal study of age-specific reproductive output and body condition among male rhesus macaques, Macaca mulatta. *Naturwissenschaften* **90(7)**, 309–312 (2003).
14. Colman, R.J., Hudson, J.C., Barden, H.S. & Kemnitz, J.W. A comparison of dual-energy X-ray absorptiometry and somatometrics for determining body fat in rhesus macaques. *Obes. Res.* **7(1)**, 90–96 (1999).
15. Walker, M.L., Schwartz, S.M., Wilson, M.E. & Musey, P.I. Estimation of body fat in female rhesus monkeys. *Am. J. Phys. Anthropol.* **63(3)**, 323–329 (1984).
16. Freeman, L.M. *et al*. Body-composition changes in the simian immunodeficiency virus-infected juvenile rhesus macaque. *J. Infect. Dis.* **189(11)**, 2010–2015 (2004).
17. Institute of Laboratory Animal Resources, National Research Council. *Guide for the Care and Use of Laboratory Animals* (National Academy Press, Washington, DC, 1996).
18. National Research Council. Guidelines for the Care and Use of Mammals in Neuroscience and Behavioral Research (National Academies Press, Washington, DC, 2003).
19. Toth, L.A. & Gardiner, T.W. Food and water restriction protocols: physiological and behavioral considerations. *Contemp. Top. Lab. Anim. Sci.* **39(6)**, 9–17 (2000).
20. Hansen, B.C., & Bodkin, N.L. Primary prevention of diabetes mellitus by prevention of obesity in monkeys. *Diabetes* **42(12)**, 1809–1814 (1993).
21. Gresl, T.A. *et al*. Dietary restriction and glucose regulation in aging rhesus monkeys: a follow-up report at 8.5 yr. *Am. J. Physiol. Endocrinol. Metab.* **281(4)**, E757–E765 (2001).