Use of a Bioelectric Impedance Device in Obese and Lean Healthy Dogs to Estimate Body Fat Percentage

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CLINICAL RELEVANCE

A hand-held bioelectric impedance device was used to obtain body fat percentages from obese and lean healthy client-owned dogs. Bioelectric impedance values were compared with body condition scores assigned on a 9-point scale during physical examination to evaluate the correlation of these two methods for assessing body composition. A good correlation was revealed between body fat percentage as measured by the bioelectric impedance device and body condition score. The results of this study suggest that bioelectric impedance measurements of body fat percentage could be used by veterinary practitioners as an objective measure of adiposity when diagnosing and managing obese dogs.

INTRODUCTION

Obesity in dogs is defined as an excess of adipose tissue resulting in a body weight in excess of ideal by 20%. Current estimates place the combined prevalence of overweight and obese dogs in the United States between 30% and 40%, a staggering statistic that mirrors the prevalence of obesity in humans. Numerous risk factors for obesity in dogs have been identified, including neutering, endocrinopathies, genetic factors, reduced activity levels, and owner feeding behaviors. Ultimately, many of these risk factors result in dietary intake of calories in excess of that required for a given level of energy expenditure. The chronic positive energy balance leads to excessive weight gain and eventually increases the potential for obesity-related illness.
Numerous medical conditions are associated with obesity in dogs. Early onset of degenerative orthopedic disease has been documented in obese individuals. In addition, canine obesity can result in such metabolic conditions as insulin resistance and altered handling of serum triglycerides and cholesterol. Increased incidences of numerous other conditions, including respiratory disorders, certain neoplasias, reproductive disorders, and decreased heat tolerance, have also been described. Recent studies have shown increased serum concentrations of certain hormones and inflammatory cytokines, also known as adipokines, in dogs with experimentally induced obesity. The systemic effects of these adipokines have not been fully elucidated, but they demonstrate the potential for obesity to affect a variety of body systems simultaneously. Perhaps the most dramatic illustration of obesity’s cumulative impact is a reduction in median life expectancy by 15%, or nearly 2 years, in obese dogs when compared with lean dogs. Clearly, obesity reduces quality of life and longevity, emphasizing the need for accurate, objective methods for quantifying animal adiposity.

There are various methods to evaluate body composition, including deuterium oxide dilution, dual energy x-ray absorptiometry (DEXA), bioelectric impedance analysis (BIA), dimensional evaluations, and body condition scoring. Deuterium oxide dilution, which involves measuring the concentration of a known quantity of isotope after it reaches a state of equilibrium with total body water, requires expensive laboratory equipment, there-
be conducted. Thus, as adiposity increases, so does an individual's impedance to current flow. This detectable voltage drop is then translated into a measure of body composition, such as body fat percentage. The low-voltage, high-frequency current applied by the bioelectric impedance device is not perceived by the animal, and only surface contact with the electrodes is needed for conduction. The rapid, noninvasive nature of this technology makes it very appealing for clinical use.

Convincing clients that their dog is overweight can be challenging for veterinary practitioners. BIA is a convenient, objective measure of body composition and could provide compelling objective evidence of obesity to owners that are otherwise skeptical of BCS accuracy. By using a technology that is accepted in human medicine and has been specifically adapted to dogs, veterinarians could help improve owner awareness of pet body composition, which in turn could improve owner compliance with canine weight-loss programs. A hand-held bioelectric impedance device designed for use in dogs (IBF-D02, Kao Corporation, Haga, Tochigi, Japan; Figure 1) was evaluated for this study. A previous abstract describes good correlation between this bioelectric impedance device and body fat percentage as measured by deuterium oxide dilution.

The objectives of this study were to evaluate the correlation between the body fat percentage measured by a bioelectric impedance device and body condition scoring in dogs and to determine whether a regression model can be established to estimate body fat percentage based on BCS.

**MATERIALS AND METHODS**

**Animals**

Forty-six healthy client-owned dogs with either a lean or obese body condition were included in this study. Participants presenting for wellness evaluations from November 2007 to February 2008 were selected based on a client questionnaire screening for the following criteria: Dogs enrolled were required to be at least 1 year of age at the time of evaluation, have no known endocrine or infectious disease, and not currently be on any medications other than a heartworm or flea preventive. Patients presenting to the teaching hospital for an active medical problem were not considered suitable participants for this study. All dogs were required to have a lean or obese body condition based on BCS, as discussed below.

No specific breed requirements were considered for inclusion of the dogs in this study, and numerous breeds were evaluated. Among the 46 dogs were 12 mixed-breed dogs, 6 miniature dachshunds, 2 Australian shepherds, 3 beagles, 3 boxers, 3 Labrador retrievers, 2 Doberman pinschers, 2 Parson Russell terriers, 2 Chesapeake Bay retrievers, and 1 each golden retriever, Australian heeler, Italian greyhound, Pembroke Welsh corgi, rat terrier, chow chow,
Chihuahua, Cavalier King Charles spaniel, Lakeland terrier, Scottish terrier, and Weimaraner. Informed consent was obtained from each owner prior to his or her dog’s inclusion in the study. The study was reviewed and approved by the Texas A&M Clinical Research Review Committee.

**Study Design**

A physical examination was performed and a BCS (based on a 9-point scale) was assigned by the same observer (R.S.) for all enrolled dogs. Dogs with a BCS of 4 or 5 were classified as lean and those with a BCS of 7 or greater as obese. A complete blood count (CBC) and plasma biochemical analysis, including cholesterol and triglyceride concentrations, and a heartworm antigen test were conducted on each dog. Total serum thyroxine (T₄) was measured for all dogs; for any participant with a T₄ level below the normal range, serum free T₄ (fT₄) and thyroid-stimulating hormone (TSH) concentrations were also evaluated. Heartworm-negative dogs with no significant physical, biochemical, or CBC abnormalities were considered healthy for the purposes of this study. Dogs were evaluated with the bioelectric impedance device after physical examination and blood collection. A single operator (R.S.) performed all bioelectric impedance assessments.

**Mean plasma cholesterol concentrations and median plasma triglyceride concentrations differed significantly between the lean and obese groups.**

**Sample Collection and Analysis**

Blood samples were collected via jugular venipuncture after withholding food from the dogs for at least 12 hours. CBCs and plasma biochemical analyses were conducted by the Clinical Pathology Laboratory at the Texas A&M Veterinary Medical Teaching Hospital using automated analyzers (CBC: Celldyne analyzer, Abbott Diagnostics, Abbott Park, IL; plasma chemistry: Vitros 250, Ortho Clinical Diagnostics, Rochester, NY). Plasma heartworm antigen tests (Dirochek Heartworm ELISA, Synbiotics Corp., San Diego, CA) were conducted in the Clinical Immunology Laboratory at the teaching hospital. All serum T₄, fT₄, and TSH testing was performed by the Gastrointestinal Laboratory at Texas A&M University (T₄ and TSH: Immulite 2000 Analyzer, Siemens Healthcare Diagnostics, Deerfield, IL; fT₄: ED test kit, Antech Diagnostic, Irvine, CA).

**Bioelectric Impedance Analysis**

Dogs remained in a standing position for BIA. The dog’s dorsal lumbar region just caudal to the last rib and 2 cm off midline was saturated with 70% isopropyl alcohol. A comb was used to part the hair overlying the epaxial musculature in this region, exposing the underlying skin. The bioelectric impedance device was then applied, with the four electrodes making direct contact with the skin in a longitudinal fashion. Five consecutive readings for body fat percentage were obtained for each dog over the course of approximately 60 seconds. Mean body fat values were then calculated for each individual.

**Statistical Analysis**

Commercially available statistical analysis software (GraphPad Prism 5.00, GraphPad Software, San Diego, CA) was used to analyze
all data. Comparison of mean plasma cholesterol concentrations, mean serum T₄ concentrations, and body fat percentages between the lean and obese groups was performed using an unpaired t-test. Comparison of median plasma triglyceride concentrations between the two groups was performed using a Mann–Whitney test. The correlation between BCSs and body fat percentage measurements was calculated using a Spearman correlation. A simple linear regression model was constructed to evaluate whether body fat percentage could be predicted by the BCS. A P value < .05 was considered statistically significant for all analyses.

### RESULTS

Of the 46 dogs that qualified for the study, 25 were classified as lean and 21 as obese based on BCS (Tables 1 and 2). No significant physical examination abnormalities beyond obesity were detected for any of the dogs enrolled. No clinically significant CBC or plasma biochemistry analysis abnormalities were present, with the exception of increased plasma cholesterol and triglyceride concentrations. All heartworm antigen test results were negative.

Breed distribution for the 25 lean dogs was as follows: 8 (32.0%) mixed-breed dogs, 3 (12.0%) Labrador retrievers, 3 (12.0%) boxers,
2 (8.0%) Parson Russell terriers, 2 (8.0%) miniature dachshunds, 2 (8.0%) Doberman pinschers, 1 (4.0%) golden retriever, 1 (4.0%) Italian greyhound, 1 (4.0%) Pembroke Welsh corgi, 1 (4.0%) Australian shepherd, and 1 (4.0%) Chesapeake Bay retriever. Breed distribution for the 21 obese dogs was as follows: 4 (19.0%) mixed-breed dogs, 4 (19.0%) miniature dachshunds, 3 (14.3%) beagles, 1 (4.8%) Australian heeler, 1 (4.8%) chow chow, 1 (4.8%) Chesapeake Bay retriever, 1 (4.8%) rat terrier, 1 (4.8%) Chihuahua, 1 (4.8%) Cavalier King Charles spaniel, 1 (4.8%) Lakeland terrier, 1 (4.8%) Australian shepherd, 1 (4.8%) Scottish terrier, and 1 (4.8%) Weimaraner.

Mean plasma cholesterol concentrations differed significantly \( (P = .0184; \text{Figure 2}) \) between the lean and obese groups, with concentrations of 210 and 249 mg/dl, respectively (reference range, 120 to 247 mg/dl). Median

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*Based on a 9-point scale.
CV = coefficient of variation.
plasma triglyceride concentrations for lean and obese dogs were 39 and 79 mg/dl, respectively (reference range, 11 to 140 mg/dl). The median difference between these concentrations was also statistically significant ($P = .0014$; Figure 3). Visible lipemia was noted in four plasma samples from obese dogs and three plasma samples from lean dogs.

Serum $T_4$ concentrations were below the reference range in five obese and seven lean dogs. $fT_4$ and TSH concentrations were also evaluated in these animals, and only 1 participant (#57, a dog in the obese group) was found to have an $fT_4$ concentration below the reference range and thus was actually hypothyroid ($T_4$, <0.5 µg/dl [reference range, 1.61 to 3.6 µg/dl]; $fT_4$, 0.576 ng/dl [reference range, 0.7 to 3.1 ng/dl]). This dog was the only participant with a low $T_4$ level to have a serum TSH concentration above the reference range (TSH, 2.53 ng/ml [reference range, 0 to 0.32 ng/ml]). This participant's plasma cholesterol concentration was 186 mg/dl and plasma triglyceride concentration was 48 mg/dl. No lipemia was noted in this particular dog's plasma sample. No other dogs in this study were found to be hypothyroid. The mean serum $T_4$ concentrations for lean and obese dogs were 2.35 and 2.15 µg/dl, respectively. The difference in $T_4$ concentrations was not statistically significant between the two groups ($P = .33$).

Body fat percentages as measured by bioelectric impedance ranged from 19.8% to 42.8%.

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**Figure 2.** Mean plasma cholesterol concentrations for lean and obese dogs (210 and 249 mg/dl, respectively; reference range, 120–247 mg/dl). This difference was statistically significant ($P = .0184$). The horizontal lines indicate the mean for each group.

**Figure 3.** Median plasma triglyceride concentrations for lean and obese dogs (39 and 79 mg/dl, respectively; reference range, 11–140 mg/dl). This difference was statistically significant ($P = .0014$). The horizontal lines indicate the median for each group.
The highest and the lowest body fat percentages for each dog enrolled were within a 3% range before calculation of individual means. Mean ± SD body fat percentages for lean and obese dogs were calculated to be 25.5% ± 3.0% and 39.6% ± 1.9%, respectively, and were significantly different between groups (P < .0001). There was a good correlation between body fat percentage and BCS for the 46 dogs tested (Spearman r = 0.844; P < .0001; Figure 4).

A linear regression model (y = 3.191 + 4.785 × x) was constructed for predicting body fat percentages using mean BCSs (r² = 0.819; P < .0001; Figure 4). According to this model, each 1-point increase in BCS reflects a 4.8% increase in body fat. (BIA = bioelectric impedance analysis)

DISCUSSION

This study provides evidence that BIA can be used in a clinical setting to objectively quantify canine body fat percentage. Rather than relying solely on visual inspection and rib palpation, veterinarians can provide an actual number to dog owners regarding the dog’s body composition. The device used in this study provided instantaneous data for each dog and required no anesthesia or sedation. In addition, no cost-prohibitive equipment or cumbersome assays were used, as would be encountered with deuterium oxide dilution or DEXA. The device used in this study is still considered a prototype; information regarding the actual cost of the device was not available at the time of publication.

Any member of the hospital staff could quickly be trained to use the device, making it easy to implement this technology in daily practice. Patients presenting for annual examination and preventive healthcare could be evaluated using bioelectric impedance, which would assist veterinarians and veterinary staff in educating individual clients on the importance of a healthy body composition in dogs. The correlation with BCS in this study suggests that a bioelectric impedance device could serve as a useful measure of progress for individuals enrolled in weight loss plans—as BCS decreases, one would expect a decrease in body fat percentage as measured by bioelectric impedance. However, further studies are necessary to specifically evaluate the use of this de-
vice among the same individuals over time as weight loss occurs.

In this study, each participant was assigned a BCS before BIA evaluation. The goal in assigning the BCS first was to eliminate the possibility of BIA results influencing the assigned BCS. In addition, the same observer assigned the BCS for all participants, eliminating any interobserver variation in body condition scoring. It is possible that having multiple individuals score each animal and averaging the results would have strengthened this portion of the evaluation. However, in a typical small animal practice, only one veterinarian would evaluate a given animal when assigning a BCS, possibly making this study design a more realistic reflection of routine clinical settings.

As described previously, the BIA was performed by taking five consecutive measurements of body fat percentage. To eliminate spurious results, these values were counted when the readings were consistent and consecutive. Factors that affected the results included inadequate contact between the dog’s skin and the device electrodes, inadequate dampening of the skin surface with alcohol, and inadequate parting of the hair to expose the underlying skin. In every case, checking for and correcting these problems as needed allowed for a more precise analysis. The examination surface was kept consistent as well, avoiding conductive surfaces such as stainless steel that could theoretically interfere with the analysis.

The potential for haircoat type to affect BIA measurements was reduced by visually confirming direct and thorough contact with the skin after careful parting of the hair with a fine comb. However, comparison of BIA measurements between various haircoat types or before and after clipping the hair was not attempted in this study. Patients with a notably long or dense haircoat included four dogs in the lean group (one each Australian shepherd, golden retriever, Pembroke Welsh corgi, and Chesapeake Bay retriever) and five dogs in the obese group (one each chow chow, Chesapeake Bay retriever, Cavalier King Charles spaniel, Australian shepherd, and Lakeland terrier). However, this assessment of haircoat is subjective because specific criteria for coat length and density measurements were not established for this study. Specifically evaluating the effect of haircoat length, texture, and density on BIA measurements could help define the potential for error associated with improper patient preparation in specific breeds or coat types when using a BIA device.

The breeds included in this study were diverse, with mixed-breed dogs composing the largest proportion of both the lean (8 of 25) and obese (4 of 21) groups. Some pure breeds were represented in only one group (e.g., beagles were only in the obese group and boxers only in the lean group). However, the number of dogs of each breed in this study is insufficient to comment on how breed affects BCS or BIA measurements. It could be assumed that breeds with a higher obesity prevalence will also have more individuals with a higher body fat percentage as measured by BIA, simply as a result of increased adiposity. A larger number of dogs of each breed will need to be evaluated to establish the prevalence of obesity in specific breeds using BIA measurements or to appreciate whether the breed of dog has any influence on body fat percentage as measured by BIA versus other methods of body composition analysis.

Bioelectric impedance can be affected by the hydration status of the individual, because dehydration could theoretically reduce the ability of tissues to properly conduct electric current. In this study, dogs were screened for any signs of dehydration during the physical examination. In addition, no dogs were found to be significantly hyperproteinemic or azotemic on
biochemical analysis, indicating that all were adequately hydrated.

The absolute results of body composition analysis differ depending on the methodology used. Mawby and colleagues described the estimation of body fat percentage with DEXA, resulting in values that were on average 13% higher than those obtained by deuterium oxide dilution.\(^3\) In that study, a BCS of 5 reflected a body fat percentage of 11% ± 2% by DEXA, with each unit increase in BCS reflecting an approximate 8.7% increase in fat. Correlation between BCS and DEXA was significant (\(r^2 = 0.92\)).\(^3\) Another study performed by Laflamme and associates suggested a body fat percentage of 19% ± 8% for an ideal body condition.\(^16\) An increase in BCS by 1 unit correlated with a 5% increase in body fat; correlation between body fat percentage by DEXA and BCS was 0.9.\(^16\) The results of the current study revealed a calculated body fat percentage of 27% for a BCS of 5, with each unit increase in BCS reflecting a 4.8% increase in body fat.

The body fat percentages obtained using this particular bioelectric impedance device correlated well with BCS (Spearman correlation = 0.844; \(P < .0001\)). The correlation shown for BCS and DEXA in previous studies appears to be slightly better than the correlation between BCS and the bioelectric impedance device used here. However, DEXA is not a clinically useful tool in practice because of the associated expense and the need for anesthesia. Alternative means of objectively measuring body fat are needed, and the correlation between BCS and results from the device used in this study suggest that bioelectric impedance could serve as a useful measure of body composition in a general practice setting. However, evaluation using this device on a larger sample size in an ongoing study could help further define the correlation between BCS and BIA results.

The differing values for body fat percentage by the various methods may be a reflection of where on the animal the readings are taken. In the case of DEXA, tissue densities are based on passage of x-rays through the animal’s whole body. The tissue densities are then used to calculate an average body fat percentage. Deuterium oxide dilution uses an isotope that freely distributes in total body water, thereby allowing quantification of the fat-free mass. The bioelectric impedance device used in this study, however, assessed impedance using only the tissue of the dorsal lumbar region. This selective sampling of one body region could be a potential explanation for the difference in measured body fat percentages between this device and other methods. Despite the localized nature of the body composition analysis provided by this BIA device, it has been shown to reach adequate correlation with the deuterium oxide dilution method (correlation coefficient = 0.88).\(^15\) Furthermore, measurement of lumbar fat deposition as a predictor of total body fat has been described previously, which may explain why this anatomic region is a reasonable choice for BIA evaluation.\(^17\) Additional studies evaluating the use of this device on different areas of the body are needed to know if the site analyzed affects the correlation to BCS. To further evaluate the validity of the statistical model for estimation of

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This study provides evidence that BIA can be used in a clinical setting to objectively quantify canine body fat percentage.
body fat percentage, more dogs will need to be enrolled in this ongoing study.

The plasma cholesterol and triglyceride concentrations measured in this study are similar to those in previous comparisons between lean and obese dogs in that significant differences were documented between the two groups. Obese dogs had significantly higher median plasma triglyceride and mean plasma cholesterol concentrations. These results likely reflect differences in plasma lipid metabolism between lean and obese dogs. However, median plasma triglyceride concentrations in both the lean and obese groups fell within the reference range for our laboratory. Mean serum cholesterol concentration for obese dogs was only slightly above the high end of the reference range. The established reference ranges are not specific for a particular body composition, and thus many obese individuals will fall within reference range for triglyceride and cholesterol despite altered lipid metabolism compared with lean dogs.

Thyroid status was investigated as a potential variable affecting plasma triglyceride and cholesterol metabolism in the dogs included in this study. There was no significant difference in mean serum thyroid concentrations between the lean and obese groups, and only one individual of the 46 total dogs was hypothyroid based on serum T₄, fT₄, and TSH concentrations. This individual was classified as obese; however, the plasma cholesterol concentration was below the mean cholesterol concentration in both lean and obese individuals. The plasma triglyceride concentration for this dog was below the median triglyceride concentration for the obese group. Hypothyroidism in this single dog does not appear to explain the overall difference in lipid metabolism between the lean and obese groups in this study and should have no bearing on how BCS and BIA correlate.

Both the lean and obese groups had participants with visible lipemia after withholding food for a recommended period. It is possible that a 24-hour (rather than a 12-hour) fast could have lessened the likelihood of any lingering postprandial lipemia. There was no difference in the number of lipemic samples between groups (three in lean dogs and four in obese dogs), and these findings could reflect individual variation in lipid metabolism regardless of body condition, differences in the amount of dietary fat, or even a lack of owner compliance with the required fasting period.

CONCLUSION

The results of this study demonstrate that the use of a bioelectric impedance device could aid veterinary practitioners in evaluating animal adiposity. By using a rapid and clinically convenient bioelectric impedance device, practitioners can obtain objective data beyond a BCS. The body fat percentages obtained would provide veterinarians with more convincing and objective evidence of obesity to present to dog owners, ultimately benefiting the health of those obese individuals started on a weight-loss program as a result of the data provided.

ACKNOWLEDGMENT

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REFERENCES


