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ORIGINAL RESEARCH

Supplementing five-point body condition score with body fat percentage increases the sensitivity for assessing overweight status of small to medium sized dogs

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Background and methods: Currently, five-point body condition scoring (BCS) is widely used by veterinarians and clinicians to assess adiposity in dogs in Japan. However, BCS score assignment is subjective in nature, and most clinicians do not score with half points, instead preferring to round off values, thereby rendering less accurate assessments. Therefore, we sought to determine whether assessing body fat percentage using simple morphometric measurements and supplementing this with five-point BCS can have increased sensitivity for detecting increasing adiposity in overweight small-medium sized dog breeds via plasma metabolite validation.

Results: Overall, lean body fat percentage was determined to be 15%–22% for male (non-neutered/neutered) dogs and 15%–25% for female (nonspayed/spayed). Dogs categorized as overweight by BCS had significantly higher levels of nonesterified fatty acids ($P = 0.005$), whereas animals categorized as overweight by BCS + body fat percentage were observed to have significantly higher levels of nonesterified fatty acids ($P = 0.006$), total cholesterol ($P = 0.029$), and triglycerides ($P = 0.001$) than lean animals. The increased sensitivity due to body fat percentage for gauging alterations in plasma metabolite levels may be due to increased correlation strength. Body fat percentage correlated positively with plasma insulin ($r = 0.627$, $P = 0.002$), nonesterified fatty acids ($r = 0.674$, $P < 0.001$), total cholesterol ($r = 0.825$, $P < 0.0001$), triglycerides ($r = 0.5823$, $P < 0.005$), blood urea nitrogen ($r = 0.429$, $P < 0.05$), creatinine ($r = 0.490$, $P = 0.021$), and total protein ($r = 0.737$, $P < 0.0001$) levels, which all tend to increase as a result of increasing adiposity.

Conclusion: Supplementing body fat percentage with five-point BCS appears to increase the likelihood of validating overweight status in small-medium sized dog breeds by detecting changes in plasma metabolite levels, especially lipids, induced as a result of increasing adiposity.

Keywords: body condition score, body fat percentage, cholesterol, dog, nonesterified fatty acid, triglycerides

Introduction

Excessive body weight (overweight and obesity) is becoming a common medical problem in dogs,[1] and is linked to both a shortened lifespan[2,3] and a host of secondary diseases.[4–6] A growing concern is the alarming increase in prevalence of overweight dogs between 2006 (21%) and 2009 (35%),[7] with almost half of all dogs in the UK currently being overweight.[8]

Correct estimation of body composition in dogs is important in veterinary practice and is a tool that the veterinarian can use to diagnose overweight status and provide owners

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with proper advice on feeding and weight management strategies. Body weight does not take differences in body composition into account, but is reasonably well estimated using the body condition scoring (BCS) system.[4,9] BCS is an established, inexpensive, and noninvasive technique for assessing body fat percentage and is widely used in veterinary practice.[10] A number of BCS charts are available, and provide a simplified index (typically a five-point or a nine-point scale) of the amount of muscle and degree of fatness of a particular animal. However, dogs deposit significant amounts of fat subcutaneously in the thoracic, lumbar, and coccygeal areas as well as intra-abdominally,[11] making the typical palpation technique associated with BCS systems less accurate. In addition, BCS assignment is a subjective method, and although scoring systems using defined criteria can attempt to objectify the process, they cannot completely eliminate all subjectivity involved in assigning a score to a particular animal.

Currently in Japan, the five-point BCS is the dominant system, in spite of the fact that the nine-point BCS correlates well ($r^2 = 0.92$) with more objective methods for evaluating body fat percentage, such as dual-energy x-ray absorptiometry, in both cats[12] and dogs.[9] Although some have argued that using the five-point BCS with half points corresponds to a BCS score with 9 points, many veterinary practitioners in Japan do not use half marks, preferring to round off and score with whole numbers instead. In addition, although BCS systems have been evaluated and validated for dogs, the focus in most studies has been on medium to large size dog breeds. Small to medium size dog breeds are the preferred choice of dogs in Japan, and as such, BCS alone may not suffice to assess overweight status. Therefore, borderline and moderately overweight dogs might not be diagnosed as being overweight and would be at risk of no preventative care or intervention for adiposity and weight management.

We sought to determine whether body fat percentage calculated using morphometric measurements can increase the sensitivity for assessing overweight small-medium sized breed dogs when used in conjunction with the five-point BCS, as validated by plasma metabolite testing. Overweight status or obesity in dogs is commonly validated by plasma metabolite testing, looking in particular for significant changes in levels of plasma metabolites commonly associated with lipid metabolism.[13] Therefore, the focus is on values for triglycerides, total cholesterol, and nonesterified fatty acids. In addition, body fat percentage calculated using morphometric measurements has been shown to produce results in agreement with dual-energy x-ray absorptiometry values when dogs with different genetic backgrounds and morphologic characteristics are used.[14]

Materials and methods

Animals

Twenty-five dogs taken to three different veterinary clinics in Tokyo between June and August 2011 were prospectively recruited as subjects for this study. Because the study was cross-cultural, the main inclusion criterion for the animals was good health (other than obesity). All dogs were tested for concurrent diseases by examination of complete blood count and serum biochemistry tests. In addition, the medical histories of all animals were investigated in order to confirm their health status. Two dogs were excluded because of diabetes mellitus, as was another dog with markedly high triglyceride and total cholesterol levels, with 22 dogs finally participating in the study. The remaining animals were clinically diagnosed to be healthy (except for obesity) according to their owner's reports, case histories, and clinical signs at the time of presentation. Table 1 presents detailed information on dog age, gender, breed, BCS, and body fat percentage.

Written informed consent was obtained from all dog owners after a detailed explanation of the purpose, nature, and potential risks and benefits of the study, and publication of this case report and accompanying images. Approval for this work was given by the Nippon Veterinary and Life Science University animal research committee.

Subjective and objective body measurements

A veterinarian from each of the three clinics assigned a BCS on a previously described five-point scale[11] to each dog, using the amount of fat covering the rib area as judged by visual inspection and palpation. The five-point scoring system ranges from: 1, very thin; 2, underweight; 3, ideal; 4, overweight; to 5, obese. Body fat was calculated according to the following formulae:[9,11]

$$\text{Male body fat (\%)} = -1.4\,(\text{HS}) + 0.77\,(\text{PC}) + 4$$

$$\text{Female body fat (\%)} = -1.7\,(\text{HS}) + 0.93\,(\text{PC}) + 5$$

$$\text{Either gender body fat (\%)} = [-0.0034\,(\text{HS}^2) + 0.0027\,(\text{PC}^2) - 1.9]/\text{body weight}$$

Using a simple tape measure, anthropometric measurements, in cm, were calculated as described elsewhere,[9,11] using pelvic circumference (PC) and length of the right rear limb from the calcaneum tuber to the mid-patellar ligament (hock to stifle, HS). When performing measurements, a

Table 1 Physical characteristics of the dogs used in this study

Breed	Spaying/ neutering	Gender	Age	Body weight	Body condition score	Anthropometric measurements		Body fat %
	Status		(years)	(Kg)	(BCS out of 5)	PC (cm)	HS (cm)	(BF %)
Beagle	–	Female	9	11.9	2.5	42	19	11.76
Labrador	–	Male	2	31.0	3	57	22	17.09
Chihuahua	–	Female	2	2.7	3	27	5.5	19.37
Shih Tzu	+	Male	3	5.4	3	29.5	6	18.32
Beagle	–	Female	5	13.1	3	45.5	19	15.02
Miniature dachshund	–	Female	5	5.0	3	31.5	4.5	26.65
Beagle	–	Female	7	13.8	3	49.5	19	18.74
Miniature dachshund	–	Male	7	4.7	3	31.5	6.5	19.16
Beagle	–	Female	9	12.1	3	46	19	15.48
Beagle	+	Female	7	14.5	3.5	52	17.5	23.61
Beagle	+	Female	7	14.5	3.5	48	18	19.04
Miniature dachshund	–	Female	6	5.0	4	31	6.5	22.78
Long foot chihuahua	+	Male	7	6.3	4	36	9	19.12
Chihuahua	+	Female	8	2.7	4	25.5	5.5	19.37
Yorkshire terrier	+	Male	9	4.2	4	40	7	25.00
Beagle	–	Female	9	14.7	4	55	18	25.55
Shih tzu	+	Female	13	7.6	4	37	9.5	23.26
Shih tzu	–	Male	14	6.3	4	39	6	25.63
Miniature dachshund	–	Male	5	8.4	4.5	45.6	12	22.31
Chihuahua	+	Female	7	5.65	4.5	43	11	26.29
Mix	–	Female	10	20	5	71	14.5	46.38
Beagle	+	Male	15	15	5	65	12	37.25

dog should be standing square, looking straight forward with its head in a normal carriage position. The tape measure is stretched and pulled tight until the dog's coat is just compressed against its skin. Circumferences are measured without excessive pressure or slack on the tape.

Blood sampling

A blood sample (3–4 mL, ≥4 hours postprandially) was collected from the cephalic vein of each dog without sedation into heparinized plastic tubes, for immediate centrifugation for 10 minutes at 1200 g and 4°C to obtain plasma, which was immediately stored at −80°C until further use.

Plasma metabolites, hormone levels, and enzyme activity

Alkaline phosphatase, alanine aminotransferase, aspartate aminotransferase, and lactate dehydrogenase activity, and blood urea nitrogen, creatinine, glucose, total cholesterol, total protein, and triglyceride concentrations were measured using an AU680 autoanalyzer (Olympus Corporation, Tokyo, Japan) with the manufacturer's reagents. Adiponectin, nonesterified fatty acids, and insulin were determined, respectively, using a dog adiponectin enzyme-linked immunosorbent assay kit (CircuLex Co Ltd, Nagano, Japan), the C test for nonesterified fatty acids (Wako Pure Chemical Industries Inc, Tokyo), and an Lbis dog insulin kit (Shibayagi Co, Gunma, Japan).

Statistical analysis

Plasma metabolite data are presented as the median and range. Lipid metabolite values for lean and overweight animals are presented as vertical box plots indicating the mean, median, and 10th, 25th, 75th, and 90th percentiles. Statistical significance was determined using the Mann-Whitney U test for comparing differences between two groups. The significance level was set at $P < 0.05$. Correlation strength was determined using the Pearson product-moment correlation (r) at $P < 0.05$. All tests were performed using Sigmaplot version 11.2, Build 11.2.0.5 (Systat Software Inc, San Diego, CA).

Results and discussion

Assessing body fat percentage using morphometric measurements and a gender-specific formula is a quick and inexpensive way to estimate body fat percentage in a dog. However, because the absolute results of body composition analysis differ depending on the methodology used,[14] we needed to define a working range for our study using

morphometric measurements. We set our working normal reference ranges for body fat percentage at 15%–22% for male (neutered/non-neutered) dogs and at 15%–25% for female (nonspayed/spayed) dogs. Body fat percentage exceeding 22% in males and 25% for females was considered overweight (Table 2). Our working ranges were determined taking the following information into account. In humans, the ideal body fat percentage is 12%–20% for men and 20%–30% for women,[15] suggesting that gender is a factor to be considered. Humans are judged to be obese when body fat percentage exceeds 20%–30% of total weight,[16] whereas dogs having approximately 15%–20% body fat have been previously judged to be in optimal body condition, not factoring gender into account.[11] However, the Kao Corporation did report an influence of gender on body fat percentage when measuring the body fat percentage of 5401 dogs using the IBF-D02, a bioelectric impedance analysis device. Female (spayed/nonspayed) and neutered male dogs had approximately 4% more body fat, on average, than intact male dogs,[17] which reinforces the fact that spaying/neutering can influence body condition.[5]

Using BCS or BCS + body fat percentage as filters, the animals in our study were separated into two groups, ie, lean and overweight. Plasma metabolite levels, especially those related to lipid metabolism, were then compared between the lean and overweight groups according to either BCS or BCS + body fat percentage (Table 3). When using BCS alone to categorize the animals, of all the plasma lipid metabolites examined, only nonesterified fatty acid levels in the overweight group were significantly higher than in lean animals (Figure 1), with a mean ± standard deviation of 2.86 ± 2.48 mEq/L as compared with 0.93 ± 0.81 mEq/L. Further, nonesterified fatty acid, total cholesterol, and triglyceride values in the overweight group were significantly higher than in lean animals when using BCS + body fat percentage for filtering (Figure 1). Dogs categorized as overweight on the basis of BCS + body fat percentage demonstrated four times higher nonesterified fatty acid levels (3.70 ± 2.56 mEq/L versus 0.87 ± 0.40 mEq/L), 0.5 times greater total cholesterol (311.38 ± 139.87 mg/dL versus 192.86 ± 43.21 mg/dL), and three times greater triglycerides (226.00 ± 180.78 mg/dL versus 73.50 ± 47.11 mg/dL) when compared with lean animals.

Table 2 Body fat reference ranges by morphometric measurements

	Normal	Overweight
Female (intact/spayed)	15%–25%	>25%
Male (intact/neutered)	15%–22%	>22%

As such, these results demonstrate that BCS supplemented with body fat percentage has increased sensitivity for detecting plasma lipid metabolite changes resulting from increased adiposity in overweight animals. Our results are supported by those of a previous study also using body fat percentage as a filter,[18] which detected significant differences in total cholesterol and triglyceride levels between obese and lean dogs. The authors of that study used a KAO IBF-D02 bioelectric impedance analysis device to determine body fat percentage in their animals, and the mean values for lean and obese dogs were calculated to be 25.5% ± 3.0% and 39.6% ± 1.9%, respectively. These ranges were comparable with those in our animals.

The increased sensitivity of BCS + body fat percentage as opposed to five-point BCS alone to gauge changes in lipid metabolite levels may be due to an increased correlation strength. Significant positive correlations were observed with BCS or body fat percentage used alone; however, the strength of correlation between body fat percentage and glucose and lipid metabolites appeared to be greater than for the correlation using BCS alone (Table 4). For example, body fat percentage was positively correlated with insulin ($r = 0.627$, $P = 0.002$, versus $r = 0.567$, $P = 0.006$ for BCS), nonesterified fatty acids ($r = 0.674$, $P < 0.001$ versus 0.614, $P = 0.002$ for BCS), total cholesterol ($r = 0.825$, $P < 0.0001$ versus $r = 0.643$, $P = 0.013$ for BCS), and triglycerides ($r = 0.5823$, $P < 0.005$ versus $r = 0.533$, $P = 0.011$ for BCS). In addition, body fat percentage showed positive correlations with blood urea nitrogen ($r = 0.429$, $P < 0.05$), creatinine ($r = 0.490$, $P = 0.021$), and total protein ($r = 0.737$, $P < 0.0001$ versus $r = 0.500$, $P = 0.02$ for BCS), which all tended to increase as a result of liver damage incurred by increasing adiposity. BCS correlated negatively with lactate dehydrogenase ($r = -0.470$, $P = 0.03$), a marker for energy metabolism, which has been shown to decrease with increasing adiposity.[19] Overall, because five-point BCS and body fat percentage exhibit different correlation strengths with different plasma metabolites, both parameters complement one another and should be used in tandem for more accurate assessment of overweight status in dogs.

Interestingly, adiponectin levels did not differ significantly between lean and overweight animals when categorized by either BCS or BCS + body fat percentage. However, animals categorized as overweight by BCS alone showed a trend towards reduced adiponectin (median 16.09 mg/dL versus 24.00 mg/dL), whereas those categorized as overweight on BCS + body fat percentage showed a trend of increasing adiponectin (median 28.57 mg/dL versus 18.76 mg/dL)

Table 3 Clinical characteristics and plasma metabolite concentrations

Clinical parameters	Determined by BCS		Determined by BCS + BF%	
	Lean (n = 11)	Overweight (n = 11)	Lean (n = 14)	Overweight (n = 8)
Physical indexes				
Age (years)	7.0 (2.0–9.0)	9.0* (5.0–15.0)	7.0 (2.0–13.0)	9.0 (5.0–15.0)
Body condition score (1–5)	3.0 (2.5–3.5)	4.0* (4.0–5.0)	3.0 (2.5–4.0)	4.3* (3.0–5.0)
Amount body fat (%)	18.74 (11.76–26.65)	25.0* (15.94–46.38)	19.08 (11.76–23.61)	25.96* (22.31–46.38)
Pelvic circumference (cm)	45.5 (27.0–57.0)	40.0 (25.5–71.0)	39.5 (25.5–57.0)	44.3 (31.5–71.0)
Hock to stifle joint length (cm)	18.0 (4.5–22.0)	9.5 (5.5–18.0)	13.5 (5.5–22.0)	11.5 (4.5–18.0)
DM				
Glucose (mg/dL)	95.0 (80.0–111.0)	97.0 (78.0–116.0)	98.0 (80.0–116.0)	92.0 (78.0–110.0)
Insulin (ng/mL)	1.05 (0.16–2.33)	1.59 (0.32–5.44)	1.23 (0.16–5.15)	1.53 (0.32–5.44)
Obesity				
Adiponectin (mg/mL)	24.00 (9.04–65.09)	16.09 (6.23–49.86)	18.76 (7.40–65.09)	28.57 (6.23–49.39)
Nonesterified fatty acids (mEq/l)	0.73 (0.23–3.14)	1.50* (0.78–9.01)	1.01 (0.23–1.50)	3.39* (0.78–9.01)
Total cholesterol (mg/dL)	191.0 (133.0–290.0)	245.0 (145.0–594.0)	188.00 (133.0–290.0)	314.50* (149.00–594.00)
Triglycerides (mg/dL)	67.0 (31.0–215.0)	105.0 (19.0–645.0)	67.0 (19.0–215.0)	184.0* (87.0–645.0)
Hepatic and renal injury				
Alanine aminotransferase (U/l)	45.0 (32.0–186.0)	56.0 (29.0–214.0)	50.5 (32.0–186.0)	64.0 (29.0–214.00)
Alkaline phosphatase (U/l)	211.0 (83.0–373.0)	161.5 (68.0–871.0)	216.0 (83.0–788.0)	111.0 (68.0–871.0)
Aspartate aminotransferase (U/l)	27.2 (16.4–74.9)	25.9 (18.6–32.5)	27.2 (16.4–74.9)	25.8 (18.6–32.5)
Blood urea nitrogen (mg/dL)	15.1 (14.0–23.5)	15.4 (11.9–32.7)	15.1 (11.9–32.7)	17.8 (13.4–27.7)
Creatinine (mg/dL)	0.82 (0.56–1.01)	0.69 (0.49–1.24)	0.75 (0.49–1.01)	0.76 (0.69–1.24)
Lactate dehydrogenase (U/l)	185.0 (69.0–404.4)	106* (34.0–247.0)	145.5 (69.0–404.0)	109.0 (34.0–247.0)
Total protein (g/dL)	6.5 (6.1–7.1)	6.8 (5.9–7.7)	6.5 (6.1–7.1)	7.0 (5.9–7.7)

Notes: Values are presented as median with (range). *Denotes significance when compared against corresponding healthy group ($P < 0.05$, Mann-Whitney U-test).
Abbreviation: DM, Diabetes Mellitus.

when compared with lean animals. The relationship between adiposity and plasma adiponectin levels in dogs has yet to be unequivocally demonstrated, with some studies indicating an inverse relationship,[20–23] no relationship, [24–26] and even a positive relationship.[27,28] Four possible factors which may confound the relationship between adiposity and adiponectin concentration in dogs are neutering status,[29] type of obesity,[30] breed and gender,[27,28] and diet.[31,32] Our BCS-filtered overweight group consisted of 11 animals, being five males (four neutered/one intact) and six females (three spayed/three intact), whereas our overweight group filtered by body fat percentage consisted of eight animals, being four males (three neutered/one intact) and four females (one spayed/three intact). The increased polarity of the female hormonal profile in animals filtered by body fat percentage, as compared with the BCS-filtered group, may explain the observed trend of increasing adiponectin.[27,28] Hence, details concerning the three aforementioned factors may be required for any future adiposity studies in dogs involving adiponectin in order to explain their results better, given that the

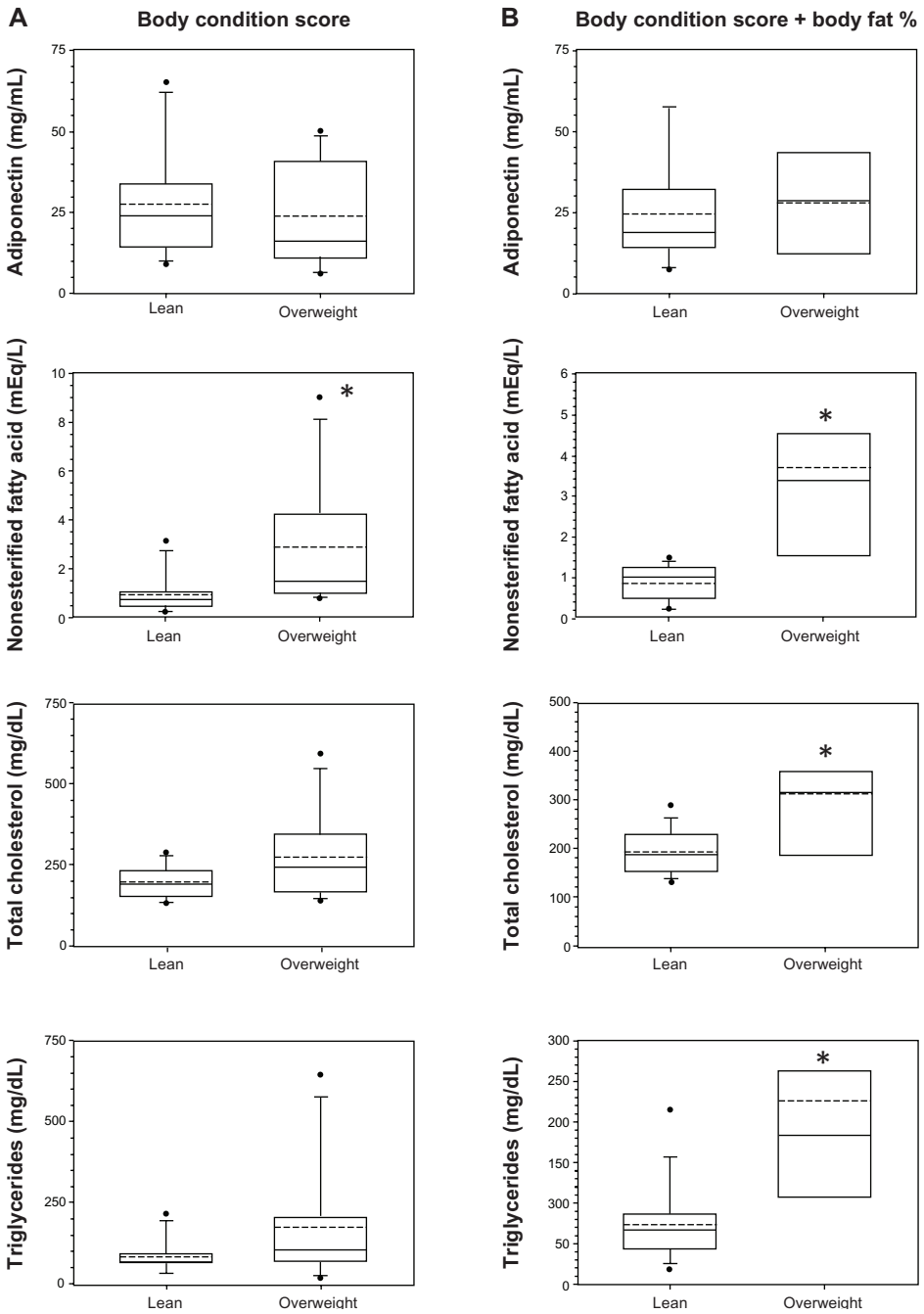

Figure 1 Comparison between plasma lipid metabolites in lean and overweight animals filtered using body condition scoring (**A**) or body fat percentage (**B**).
Notes: Data are shown as vertical box plots indicating the 10th, 25th, 75th, and 90th percentiles with error bars. The median and mean are indicated by solid and dashed horizontal lines, respectively, whereas outliers are represented as dots. *Significantly higher versus lean group (Mann-Whitney U test, $P < 0.05$).

relationship between adiposity and adiponectin in dogs is not clear as yet. As it stands currently, plasma adiponectin levels cannot be used reliably to gauge adiposity in dogs.

This study has a number of limitations. First, although body fat percentage can be estimated clinically based on simple gender-specific calculations using morphometric measurements, accuracy is reduced due to the variety of body proportions in different dog breeds. Because breed is a factor in being overweight,[14] tailoring the equation to the actual breed may be necessary for more accurate determination of body composition when using morphometric measurements alone to calculate body fat percentage. Further clinical studies are required to compare body fat percentage calculated from morphometric measurements between different breeds of dog and to determine breed-specific compensatory factors for the formulae. Second, nonfasted blood samples were obtained

Table 4 Correlation between BCS or BF% with plasma metabolite values

Plasma metabolites	BCS (*r*)	*P* value	BF% (*r*)	*P* value
Glucose	–0.001	0.997	–0.175	0.437
Insulin	0.567	0.0059	0.627	0.0019
Adiponectin	–0.098	0.665	0.187	0.405
NEFA	0.614	0.0024	0.674	0.0006
Cholesterol	0.643	0.0013	0.825	<0.0001
Triglycerides	0.533	0.0107	0.583	0.0044
ALT	0.266	0.231	0.301	0.173
ALP	0.059	0.803	–0.016	0.945
AST	–0.274	0.217	–0.249	0.265
BUN	0.386	0.0756	0.429	0.0462
CREA	0.173	0.442	0.490	0.0207
LDH	–0.470	0.0271	–0.370	0.0905
TP	0.500	0.0177	0.737	<0.0001

Notes: Pearson Product Moment Correlation Coefficient (*r*) is expressed to determine correlation strength. Shaded areas indicate a significant strength of correlation with $P < 0.05$.

from client-owned dogs in our study. Although the samples were collected at least 4 hours postprandially, we cannot completely eliminate any postprandial effect, especially for plasma nonesterified fatty acid, total cholesterol, and triglyceride levels. However, because no significant differences in plasma insulin or glucose levels were observed, any postprandial effect would have been minimal. Also, use of nonfasting blood samples may arguably be more representative of a true clinical setting. Third, age was not factored or considered as an influential factor in our criteria for categorizing obesity, although it has been shown to be a risk factor for development of obesity.[5] Fourth, the sample size of the groups was small. A larger sample size of animals should be used in future research to determine the reproducibility of our results and to increase the statistical power of the data. Lastly, the accuracy of five-point BCS or body fat percentage (using morphometric measurements) in assessment of overweight status cannot be evaluated and compared due to lack of comparison with a gold standard method of measuring fat mass, such as nonesterified fatty acid levels. In addition, body fat percentage calculated using morphometric measurements has been shown to produce results in agreement with those from dual-energy x-ray absorptiometry, magnetic resonance imaging, and isotope dilution. We hope in future studies to have access to an IBF-D02 bioelectric impedance device (Kao Corporation, Tochigi, Japan), which has been previously described[18] as being able to measure body fat percentage objectively.

Conclusion

Our data indicate that supplementing five-point BCS with body fat percentage, as calculated using morphometric measurements, can increase the ability to detect overweight in small-medium sized dogs, by increasing the sensitivity for detecting alterations in plasma metabolite levels, especially those of lipid metabolites, such as nonesterified fatty acids, total cholesterol, and triglycerides, induced as a result of increasing adiposity in overweight dogs. Therefore, body fat percentage should be used in tandem to complement the five-point BCS system in order to detect and diagnose overweight in dogs better, allowing for earlier intervention and prevention of progression to more advanced stages of obesity.

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Disclosure

The authors report no conflicts of interest in this work.

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