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Radiography, Ultrasound, and Anthropometry in Dog Nutrition Evaluation

Radiografia, ultrassonografia e antropometria como métodos de avaliação nutricional de cães

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Abstract
The nutritional status of dogs is a prominent theme nowadays because it is considered one of the five vital parameters of animals. There are several techniques that allow diagnosing disorders or disturbances in the body condition of these patients. Although it has some subjectivity, as it is a visual and palpation evaluation, the body condition score (BCS) is the most used for this purpose. The present study evaluated radiographic, sonographic and anthropometric measurements of subcutaneous fat deposited in the dorsal region over the seventh lumbar vertebra of 100 dogs, compared to a double-blind classification of patients on the numerical scale of the BMC. There was a positive correlation of the sonographic measurements with the body condition score (p-value below 2 x 10^{-16} and R = 0.54) and the same was observed with the radiographic measurements (p-value below 2 x 10^{-16} and R = 0.56) and anthropometric evaluations (whose p-value ranged from 1.55 x 10^{-7} to 2.34 x 10^{-11} and its R was 0.24 to 0.36). With this, it was possible to identify greater intensity in the relationship of imaging exams with ECC. It is concluded that radiography and ultrasonography have great potential for use in clinical routine as a more accurate and affordable way to diagnose nutritional disorders. This is the first study to use such equipment together with imaging tests to contribute to the early diagnosis of changes in nutritional status and promote improvements in the follow-up of weight gain or weight loss programs.
Keywords: adipometer; canine; obesity; radiology; ultrasound

Resumo
O estado nutricional dos cães é um tema de destaque na atualidade por ser considerado um dos cinco parâmetros vitais dos animais. Diversas são as técnicas que permitem diagnosticar afecções ou distúrbios da condição corporal desses pacientes. Embora tenha certa subjetividade, por ser uma avaliação visual e de palpação, o escore de condição corporal (ECC) é o mais utilizado para essa finalidade. O presente estudo avaliou medidas radiográficas, ultrassonográficas e antropométricas da gordura subcutânea depositada na região dorsal sobre a sétima vértebra lombar de 100 cães, comparando-se com uma classificação duplo-cega dos pacientes na escala numérica do ECC. Houve correlação positiva das medidas ultrassonográficas com o escore de condição corporal (p-valor abaixo de 2 x 10^{-16} e R = 0,54) e o mesmo foi observado com as medidas radiográficas (p-valor abaixo de 2 x 10^{-16} e R = 0,56) e avaliações antropométricas (cujo p-valor variou de 1,55 x 10^{-7} a 2,34 x 10^{-11} e seu R foi de 0,24 a 0,36). Com isso, foi possível identificar maior intensidade na relação dos exames de imagem com o ECC. Conclui-se que a radiografia e a ultrassonografia apresentam grande potencial de utilização na rotina clínica como uma forma mais precisa e acessível de diagnosticar distúrbios nutricionais. Este é o primeiro estudo a utilizar tais equipamentos juntamente com exames de imagem para contribuir para o diagnóstico precoce de mudanças no estado nutricional e promover melhorias no acompanhamento de programas de ganho ou perda de peso.
Palavras-chave: adipômetro; canina; obesidade; radiologia; ultrassom.

1. Introduction

Nutritional status has become the 5th Vital Assessment (5VA) of an animal, as proposed by the WSAVA (World Small Animal Veterinary Association)[(1)]. Thus, nutritional assessment has been combined with temperature, pulse, respiration, and pain assessment[(1)]. The nutritional assessment of dogs comprises several methods, and the most used for this purpose is the Body Condition Score (BCS), proposed by Laflamme (1997). The system, which classifies dogs on a scale ranging from one to nine, is easily applicable thanks to its visual evaluation and palpation, as well as non-invasive. However, BCS is highly subjective due to the great inherent human bias, as different veterinarians can classify the same animal differently[(2, 3, 4)].

Thus, there is a need for more objective methods to assess this vital parameter. Moreover, tools that are easy to implement and cost-effective in nutritional

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consultations for dogs have been sought. Fitting into these demands is the use of imaging tests, which have already gained ground in the area, such as ultrasonography, which yielded good results when used for this purpose by Wilkinson and McEwan (1991). In addition, the use of anthropometric equipment, such as skinfold calipers, has also been tested in veterinary medicine for this purpose.

The present study thus aimed to correlate measurements of subcutaneous fat in dogs, obtained by ultrasound and radiography, with their body condition score. Additionally, anthropometric measurements made with a caliper, skinfold caliper, and anthropometric tape were correlated in the study patients with BCS to determine which of the measurements best correlated with this method, which is widespread in Veterinary Medicine.

2. Material and methods

2.1 Sample

This research was approved by the Commission for Ethics in the Use of Animals (CEUA) of the School of Dentistry, Araçatuba Campus (approval no. 00599-2019). The study involved 100 animals of the canine species cared for at the institution's veterinary hospital, with authorization from their guardians to participate in the project.

The selection of participating dogs did not include patients with dysfunctions that would interfere with their body condition, such as hyperadrenocorticism, hyper or hypothyroidism, and leishmaniasis, among other diseases with the aforementioned characteristics. In addition, we sought to keep in the research only dogs within an age group for which the body condition score (BCS) is most indicated. Thus, puppies (less than six months old) were also excluded from the study. General screening was performed and patient history information was collected, and each dog was classified according to its BCS. Then, radiography, ultrasonography, and measurement with anthropometric equipment were performed. All these measurements were performed in the lumbar region of the analyzed dogs, as it is considered one of the best regions to assess subcutaneous fat by ultrasound[5].

2.2 Body condition score

All dogs in the study were classified according to their body condition score, using the numerical 9-point scale proposed by Laflamme (1997). This was a double-blind procedure, that is, two professionals (evaluator 1 = man and evaluator 2 = woman) evaluated the same animals but did not communicate with each other about the patients' BCS, thus reducing the influences on the sample classification to increase the reliability of the study, in addition to allowing a better visualization and analysis of the differences between the scores proposed by each observer.

2.3 Imaging examinations

2.3.1 Radiographic examination

The radiograph was taken in the right latero-lateral projection using a CRX 3 X-ray machine with a capacity of 150 mA, equipped with a Potter-bucky anti-scatter grid. The captured images were digitized using a CR device.

The radiographic technique applied relates milliampere-second and kilovoltage to the thickness of the region to be radiographed[6]. The animals were positioned by their guardians, observing radiological protection standards such as the use of thyroid protectors and lead aprons. The subcutaneous layer of the patient's dorsal region was measured through radiographic examination. This measurement was performed on the seventh lumbar vertebra (L7), starting from its spinous process, through an image obtained from radiography.

2.3.2 Ultrasound examination

Shaving in the region between the lumbar and sacral vertebrae preceded the ultrasound examination and was only performed after the consent of the guardian. The animal remained in a quadrupedal position and the ultrasound probe was positioned transversely over the dorsal region, at the level of the lumbosacral region. No pressure was applied to the animal's back during the ultrasound examination, preventing deviations from the actual sampling. The generated image allowed the measurement of subcutaneous fat from the spinous process of L7. The ultrasound examination was performed using a MyLab70 VET XV Esaote device. The examinations were performed in B mode, using a linear transducer with a frequency between 4 and 13 MHz.

2.4 Anthropometric equipment

The following devices were used to obtain the anthropometric data of the dogs:

a) Prime Med body caliper with double acrylic sliding jaws and special aluminum scale. The equipment was positioned in the dorsal region of the dog, close to the pelvis region, allowing the measurement.

b) Prime Med 15-m anthropometric body tape, with an independent tip completing 1.8 m, pressure-reducing elastic, retention lock, and automatic return, used to measure the animal's abdominal circumference in the lumbar region, close to the pelvis.

c) Neo Prime Med clinical skinfold caliper with neutral body, double-sided display, measuring opening up to 60 mm, constant pressure spring of 9.8 g/mm^2, made of solid aluminum, tolerance of 0.3 to 60 mm, and dimensions of 245 x 85 mm.

d) DGI Prime Med scientific skinfold caliper with maximum opening of 60 mm, scientific precision watch, precision, ultralight build, and tolerance from 0.3 to 60 mm. Two skinfold calipers (scientific and non-scientific) were used to measure the subcutaneous fat of the skin fold in the lumbar region of the animal, on its back. Measurements were performed three times in a row on the same dog to obtain the mean subcutaneous fat for each animal.

Figure 1 shows all the measurements used in this research.

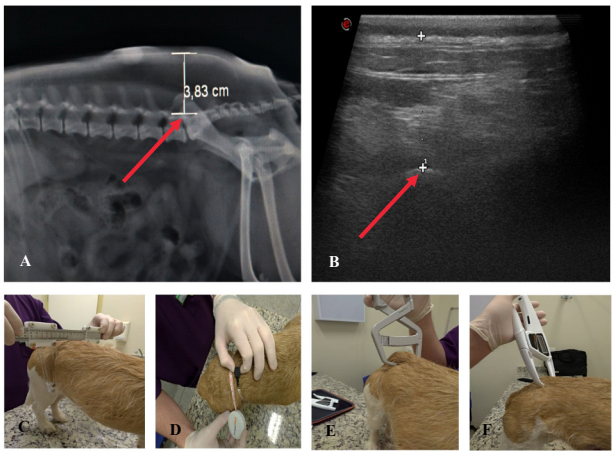

Figure 1. A – Radiographic image of the measurement of the subcutaneous fat layer over the spinous process of the L7 vertebra (red arrow). **B –** Ultrasonographic image of the measurement of the subcutaneous fat layer over the spinous process of the L7 vertebra (arrowhead). **C –** Demonstration of caliper positioning. **D –** Demonstration of the measurement of abdominal circumference with an anthropometric tape. **E** and **F –** Demonstration of the use of clinical and scientific skinfold calipers in the measurement of subcutaneous fat in the skin fold in the animal's lumbar region. **Image source:** Personal archive, used with permission from the guardian.

2.4 Statistical analysis

The free statistical software RStudio was used to carry out the statistical analysis, adopting a value of α equal to 5%. The recommended test was linear regression, in which the predictor (body score as determined by the veterinarian) was compared with the measurements obtained using ultrasound, radiography, and anthropometric equipment. Thus, we sought to visualize the existence of a positive relationship between this predictor and these response variables. In addition, a percentage calculation was explored relating the number of variations of the scores between the different evaluators and the total number of animals in the project to demonstrate the hypothesis of subjectivity of the BCS and how it changes according to the evaluator.

3. Results

There was a higher prevalence of females (53%) and uncastrated animals (52%). In addition, the number of mesocephalic and pure-bred patients was higher. Weight showed a wide distribution, ranging from 2.5 to 50 kg (Table 1).

Table 1. Sample distribution according to skull shape, age group, weight, and breed.

Variable		N
Skull shape	Brachycephalic	14
	Mesocephalic	80
	Dolichocephalic	6
Age group	0–1 year	21
	1–9 years	60
	Above 9 years	19
Weight (kg)	0–10	46
	10–25	28
	Above 25	12
Breed	Border Collie	4
	Boxer	3
	French bulldog	2
	Chihuahua	1
	Chow Chow	1
	Cocker	1
	Golden Retriever	1
	Jack Russel	1
	Labrador	3
	Lhasa Apso	2
	Maltese	2
	Pinscher	1
	Pit Bull	1
	Poodle	11
	Pug	2
	Rottweiler	1
	Schnauzer	7
	Shih Tzu	6
	Mixed breed	43
	Teckel	5
	Whippet	2

The following arrangement was obtained when evaluating the data on diet, supply of snacks, practice of exercises, and environment in which the animal lives:

• Diet: 65% of the animals were fed only on commercial food, 4% ate homemade food, and the remaining 31% had a combined diet of commercial and homemade food.

•Snacks: most dogs received snacks from their guardians during the day (79%).

• Practice of exercises: 14% of the animals did not practice exercises; 37% had an exercise practice described as light by their guardians; 38% had a moderate practice of exercises; and the remaining 10% had an intense practice.

• Environment: two animals lived on a rural

property with their guardians, nine lived in an apartment, and the others lived in houses with access to a cemented backyard and/or lawn.

3.1 Body condition score

Table 2 shows the distribution of the BCS proposed by the evaluators. According to evaluator 1, 54% of the dogs were out of the ideal body condition score (BCS 5). Among them, about 85% of the animals (46/54) were classified as obese or overweight, corresponding to 46% of the total number of dogs. In contrast, 69% of the dogs were identified as out of the ideal score by evaluator 2. Among them, approximately 85.5% were above the weight considered ideal (59/69), that is, 59% of the total.

Table 2. Body condition score (BCS) of the 100 dogs evaluated in the study, according to the evaluators.

BCS	Evaluator 1	Evaluator 2
	n	
2	0	1
3	1	0
4	7	9
5	46	31
6	19	22
7	13	19
8	7	14
9	7	4
Total	100	100

A discrepancy was observed between the BCS proposed by evaluators 1 and 2 in 52% of cases. About 10% differed in more than one point in the numerical classification when considering the 52 dogs. Moreover, evaluator 2 classified the dogs at a higher score than evaluator 1 in approximately 65% of cases (34/52).

3.2 Comparison between methods

The results of statistical analysis are shown in the image below, which represents a correlation graph between all evaluated variables (Figure 2). The scores proposed by the two evaluators indicated a difference in their classifications, but their correlation strength was extremely high (83%). In addition, among all the methods and techniques tested in this experiment, the measurements of subcutaneous fat by ultrasound and radiography had the strongest correlation with BCS, with no influence from the evaluator. Regarding the anthropometric equipment, the highest correlation with BCS was found with the caliper, with a mean of 59%, followed by the scientific skinfold caliper, the clinical skinfold caliper, and the measuring tape. In this case, the use of anthropometric equipment, even with an acceptable correlation with the body condition score, needs further studies and research.

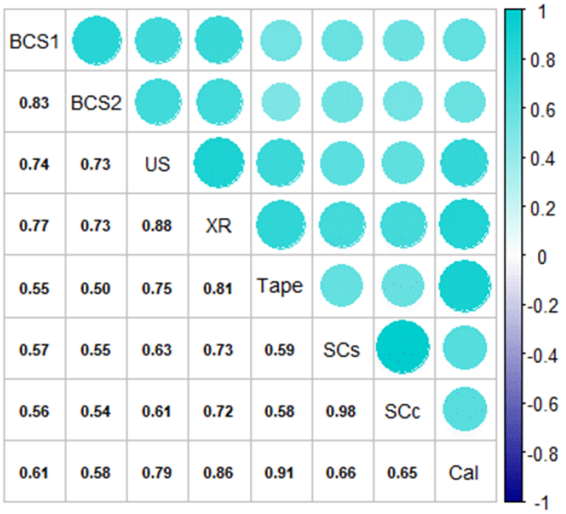

Figure 2. Strength of correlation between all methods of assessing the nutritional condition of the patient used in the study. BCS1 and BCS2 represent the scores of evaluators 1 and 2, respectively; US and XR indicate the correlation values of measurements obtained by ultrasound and radiography; Tape represents the correlation of abdominal circumference values measured with the measuring tape; SCs represents the correlation of scientific skinfold caliper measurements; SCc represents the correlation of clinical skinfold caliper measurements; Cal indicates the correlation of measurements obtained using the caliper.

Figure 3 shows the values found in radiographic and ultrasonographic measurements of subcutaneous fat in dogs with different body condition scores.

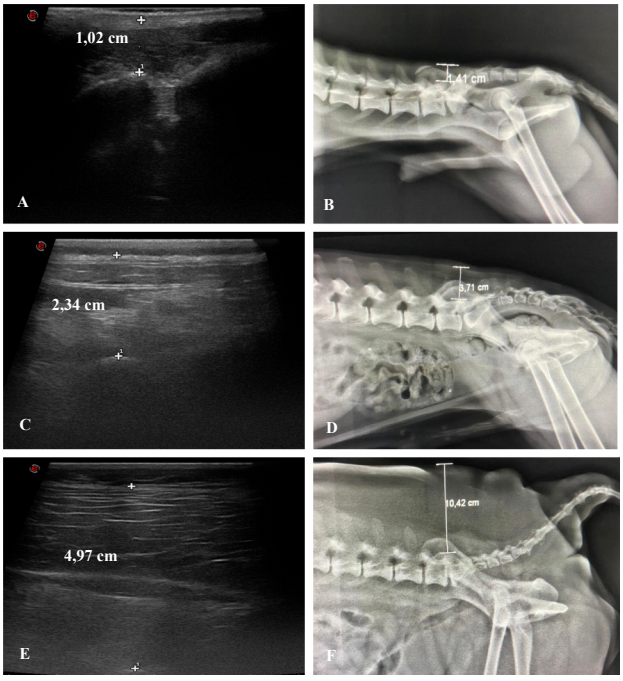

Figure 3. Ultrasound and radiographic images of the measurement of the subcutaneous fat layer over the spinous process of the L7 vertebra in dogs classified as BCS 3/4 **(A and B)**, BCS 5 **(C and D)**, and BCS 9 (obese) **(E and F)**. **Image source:** Personal archive, used with permission from the guardian.

4. Discussion

The ideal body condition (from 46 to 54%) results in the dogs under study are consistent with observations from studies conducted over the last decade, which evaluated the occurrence of canine obesity in different countries. These studies demonstrated that 40 to 60% of the canine population were in a state of obesity or overweight[7, 8, 9, 10, 11, 12]. In Brazil, 17% of dogs in the city of São Paulo (SP) were obese in 2002, a much lower percentage than that observed in this study[13]. This high number of obese dogs in the study may be related to the fact that most dogs have factors that predispose them to obesity such as the supply of snacks, low exercise, and housing with little space for adequate daily physical exercise.

Similarly, the reliability of BCS has been highlighted by other studies, which demonstrated that this method had a high correlation with the percentage of fat obtained by dual-energy x-ray absorptiometry – DEXA[14]. The body condition score is known to be a subjective and semi-quantitative method, but research has already demonstrated good inter-and intra-observer reproducibility of BCS[2, 15]. Variations in BCS between the two evaluators may be due to the anatomical and physiological difference between men's and women's vision. Importantly, research has detected that the female vision is more accurate when acting on objects close to its central point, i.e., at about 0.5 m[16]. On the other hand, the male vision is more accurate when it comes to objects located at a distance of 100 m[16]. Thus, it could be assumed that the score proposed by the female professional is more accurate, as the dogs must be very close to the veterinarian to carry out the palpation and visual evaluation in the measurement of BCS. In contrast, another study identified that men have a higher ability to focus on moving objects, unlike women[17]. This may be important in classifying the dogs' scores, as the behavioral nature of some animals is to keep in constant motion in the veterinarian's office. Thus, the question arises whether the sex of the professional who performs the nutritional assessment of dogs becomes an important variable affecting the accuracy and effectiveness of BCS. Further studies are required to thoroughly investigate the existence of this variation, its underlying reasons, and whether genders exhibit differences in their ability to carry out this classification.

The correlation found between the measurements of the imaging examinations and BCS is attributed to the fact that nutritional assessment methods that use imaging exams allow a better assessment of fat deposits[18]. Furthermore, these methods allow a better assessment of adipose changes, as fat generates a change in image quality (mainly ultrasound), facilitating its identification[18].

The existence of a correlation between BCS and the ultrasound measurement of lumbosacral subcutaneous fat was already been observed in a study with 20 obese adult dogs. In addition, another study concluded that these measurements made by ultrasound also have a good correlation with the bioimpedance technique in estimating body fat[19]. This proves the effectiveness of the ultrasound method when used for nutritional assessment. However, further research is still needed, as some studies still claim that ultrasound exhibits high discrepancy and low sensitivity in identifying obese animals[20].

This is the first time radiographic examination has been used to provide a nutritional assessment of dogs. The use of radiation for this purpose has already been researched and applied but differently, with dual energy x-ray absorptiometry (DEXA). This method has proven to be accurate and effective in estimating body composition, but its use is expensive and less practical, besides being only experimental[21]. Thus, the use of radiography, as proposed in this study, not only shows good results but also eliminates the obstacles encountered when using DEXA, generating higher accessibility in the veterinarian's routine. However, further studies are required to investigate whether these measures are affected by other variables such as breed, size, weight, and age of the animals. Morphometric measurements are of great importance in the nutritional assessment of dogs. This fact has already been demonstrated when proving that the measurement of abdominal circumference has a direct influence according to the animal weight, varying according to weight gain or loss[22].

The use of skinfold calipers in veterinary medicine is scarce, and this is one of the few studies that used the equipment. Furthermore, researchers used skinfold calipers in sheep in 2013 but no relationship was identified between the measurements of the animals' carcasses and those given by the equipment[23]. These devices provide very accurate data on subcutaneous fat in humans, requiring only measurements to be performed by a trained professional using the appropriate equipment[24]. In addition, studies have concluded that skin fold measurements have a good correlation with other methods of assessing human body condition (hydrostatic weighing and DEXA), as those described in the present study[25, 26]. Thus, there is a vast field of research to be explored on the use of skinfold calipers in veterinary medicine as this method can prove to be effective, safe, and simple to use in the nutritional assessment of dogs.

To date, no studies have utilized the caliper for the measurements presented in this study. However, in medicine, there exists an anthropometric measurement known as the sagittal abdominal diameter (SAD), which is conducted with the patient in the supine position and bears significant resemblance to the measurement employed in the current study. SAD evaluates abdominal obesity, with a strong relationship with visceral fat,

making it a good predictor of metabolic disorders[27]. This measurement has seen growing usage due to its simplicity and ease of acquisition using a caliper[27]. Consequently, the significance of this measure in medicine becomes evident, and the application of the caliper in veterinary medicine can prove to be exceptionally valuable.

5. Conclusions

Body condition score is an extremely reliable method, but it does have some reservations as a potential source of variation based on the evaluator's gender, which should be taken into account during the analysis of the nutritional condition of dogs. In addition, measurements of subcutaneous fat located on the seventh lumbar vertebra of dogs obtained by radiographic and ultrasound examinations showed a strong correlation with body condition score. Therefore, these measurements hold great potential to be introduced into the clinical routine as a way of diagnosing nutritional disorders such as obesity. The use of anthropometric equipment (skinfold caliper, caliper, and measuring tape) also showed a positive correlation with the patients' body condition score, but these correlations were not as intense as those between body condition score and imaging tests.

Conflict of interest statement

The authors have no competing interests.

Authors' contributions

Conceptualization: R.de S. Buzo, G. A. Bispo, W. L. Ferreira e L. D. R. Pinoti. *Data curation:* R.de S. Buzo. *Investigation:* J. F. Tremea, G. A. Bispo, B. S. Oliveira e J. Bizi. *Methodology:* J. F. Tremea, B. S. Oliveira, W. L. Ferreira e L. D. R. Pinoti. *Project administration*: J. F.Tremea, G. A. Bispo, B. S. Oliveira e J. Bizi. *Supervision*: W. L. Ferreira e L. D. R. Pinoti. *Validation*: J. Bizi. *Writing (original draft):* R.de S. Buzo. *Writing (review & editing):* R.de S. Buzo.

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