# Studies on clinical assessment of nutritional status in dogs

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# CHAPTER 1

## Introduction

The rate of indoor breeding dogs has been steadily increasing. According to the Japan Pet Food Association, the rate was 84.4 % in 2017 [1]. In an indoor breeding dog, the energy consumed for environmental adaptation decreases [2, 3], while opportunities to receive table food and snacks increase. As a result, obesity increases. According to our previous survey, approximately 60 % of dogs breeding in general households had a body fat percentage of 30 % or more [in preparation].

In dogs, obesity does not cause metabolic syndrome that occurs in humans, dogs are not capable of developing arteriosclerosis. However, obesity not only increases the burden on the heart, lungs and joints, but also the risk of illnesses such as otitis externa, pyoderma and mammary tumors [4, 5].

Physiologically active substances such as adiponectin, leptin, interleukin 6, and tumor necrosis factor are secreted from adipose tissue,

and physiologically active substances are strongly associated with various diseases [6-19].

Therefore, the quantitative measurement of fat mass in clinical practice has become very important. Dual energy x-ray absorptiometry [20, 21], computed tomography [22-26], and deuterium oxide dilution method [27] are known techniques for the measurement of fat mass. However, these cannot be used in daily clinical practice.

In humans, a body composition analyzer applying the bioelectrical impedance method has been developed [28, 29], making it possible to easily measure body fat percentage and muscle mass not only in the clinic, but also in general households. Body fat analyzers using the bioelectrical impedance method have even been developed for dogs [30, 31], however, they are not very popular in clinical practice.

Clinical veterinarians assess the nutritional status of dogs by using the body condition score (BCS) [32]. This is a method to evaluate nutritional status on a 5 or 9 point scale, evaluated by visual assessment and palpation with reference to the illustration of difference in body shape for dogs and the description of the evaluation point [33, 34]. As this is a sensory evaluation

method, variations in diagnostic results by the evaluator cannot be avoided. Nonetheless, BCS has been recognized as one of the screening method by the American Animal Hospital Association (AAHA) and the World Small Animal Veterinary Association (WSAVA) [33, 34]. The reasons why AAHA and WSAVA recommend the BCS is that anyone can assess BCS anytime without special tool.

In addition, morphometric nutrition assessment methods have also been developed. This involves the estimation of percent body fat from the distance between the hock and stifle, as well as pelvic circumference [35]. However, this method is also not used in clinical animals because its application is dependent on the type of breed.

Herein, we report the development of a more quantitative and reproducible BCS assessment technique compared to the conventional sensory evaluation method. Two different methods were evaluated in this study: an auxiliary tool for palpation (BCS palpation model) in BCS assessment, and the assessment technology for BCS by morphometric method.

# CHAPTER 2

## The effectiveness of the body condition score model for the nutritional assessment in dogs

### Introduction

As shown in chapter 1, BCS is a method that is commonly used in the assessment of nutritional status in small animals. However, veterinarians recognize that BCS assessment be inconsistent. This is because that BCS is subjective method due to its evaluation being assessed by visual and palpatory manner. Therefore, it is challenging to improve the precision of the BCS assessment. In addition, not only veterinarians but also animal nurses or pet owners require training of the BCS assessment. It is ideal to develop a devise which anyone can assess BCS easily and precisely. Thus, we developed a BCS model to improve the precision of the BCS assessment and test the effectiveness of BCS model in dogs.

## Materials and Method

### Preparation of BCS model

The BCS model was developed with resin molded artificial ribs. Polychloroprene sponge sheet and natural rubber sheet were chosen as a polymer sheet like tactile sense of the canine costal part. Appropriate numbers of rubber sheets were stacked on the molded ribs to represent thickness and hardness of each body condition scoring in dog (Table 1). Relative hardness of stacking rubber sheets in each BCS was measured by Durometer MJ-DUA-C2 (SATOTEC Tokyo, Japan). Each BCS was determined with palpation and relative hardness.

**Table 1.** Combination of rubber materials in each BCS and their relative hardness

| BCS | Bone → Skin | | | RH* |
|---|---|---|---|---|
| | Natural rubber Thickness 0.5mm | Polychlo-roprene sponge Thickness 3mm | Natural rubber Thickness 0.5mm | |
| 1 | 1 | | | 87 |
| 2 | 1 | 1 | | 52 |
| 3 | 1 | 1 | 2 | 28 |
| 4 | 1 | 2 | 1 | 21 |
| 5 | 1 | 3 | | 18 |

*RH: Relative hardness

## Assessment of BCS in dogs

Twenty four healthy dogs were used for this study. A detail description of the dogs was shown in Table 2. All dogs were bred in a general family in Tokyo and visited Animal Care Center in Teikyo University of Science for BCS assessment. The BCS was assessed by students in the department of animal nursing were divided into two groups. One group of students assessed BCS without the BCS model, and another group of students assessed using the BCS model. Five students assessed BCS for one dog. The BCS score of the dog was shown with a mean of BCS score assessed by five students.

**Table 2.** Detail description of the dogs

| No. | Breed | Gender/ Neuter | Age (year) | Body weight (kg) | Body fat (%) |
|---|---|---|---|---|---|
| 1 | Boston terrier | F/- | 4 | 12.3 | 28.0 |
| 2 | Cavalier king charles spaniel | F/- | 1 | 9.0 | 25.0 |
| 3 | Chihuahua | F/- | 10 | 2.4 | 25.0 |
| 4 | Chihuahua | F/+ | 3 | 2.9 | 28.0 |
| 5 | Chihuahua | F/- | 7 | 3.3 | 38.0 |
| 6 | French bulldog | M/- | 2 | 11.0 | 22.0 |
| 7 | Miniature dachshund | F/+ | 4 | 6.3 | 37.0 |
| 8 | Miniature dachshund | M/- | 9 | 6.6 | 25.7 |
| 9 | Miniature dachshund | F/- | 6 | 3.6 | 31.0 |
| 10 | Miniature dachshund | M/+ | 2 | 7.3 | 31.0 |
| 11 | Miniature schnauzer | F/- | 7 | 7.2 | 38.0 |
| 12 | Mix | M/- | 5 | 6.0 | 20.9 |
| 13 | Mix | M/+ | 6 | 17.2 | 43.0 |
| 14 | Mix | M/- | 1 | 4.1 | 22.0 |
| 15 | Mix | M/+ | 1 | 5.3 | 35.0 |
| 16 | Mix | F/- | 1 | 2.5 | 40.0 |
| 17 | Mix | M/+ | 1 | 4.9 | 29.0 |
| 18 | Mix | F/- | 1 | 2.6 | 34.0 |
| 19 | Mix | F/+ | 6 | 13.5 | 29.0 |
| 20 | Pomeranian | M/+ | 2 | 4.2 | 35.0 |
| 21 | Toi poodle | F/- | 8 | 7.6 | 38.0 |
| 22 | Toi poodle | F/+ | 7 | 4.2 | 38.0 |
| 23 | Toi poodle | F/- | 8 | 8.4 | 39.0 |
| 24 | Welsh corgi pembroke | M/- | 7 | 12.2 | 35.7 |

## Measurement of body fat percentage in dogs

The BCS of dog with / without BCS models, were evaluated by the students. The body fat percentages of the subject dogs were measured by a Body Fat Analyzer for Dogs (Healthlab BIP-02, Kao, Tokyo, Japan). in advance. The measurement was performed following the manufactural instruction. The body fat percentage in each BCS, was shown on the box plot. The variations of the body percentage with / without BCS models are statistically analyzed, using F test. Statistical differences of $P<0.05$ were considered as significant.

## Evaluation of BCS model by dog owner

The survey was conducted to the dog owners (n=28) to understand their perception toward the usage of the BCS model while measuring a BCS to their dogs.

## Results and discussion

Fig.1-a and Fig.1-b show a diagram and a photograph of the BCS model respectively. The combination of rubber sheets in each BCS and their physical property was shown in Table 1. Relationship between BCS and the hardness of the stacked rubber sheets was not a linearly regressed but logarithmically regressed (Fig. 2).

As shown in Table 2, an average age of the dogs was 4.5 years old with a range of 1 to 10 years old. The number of male and female dog was ten and fourteen, respectively. Thirty-eight percentages of dogs in this study was either spayed or neutered.

Fig. 3 showed boxplot relationship between body fat percentage and a BCS in dogs. Only few dogs were diagnosed as BCS of 1 and BCS of 5. The variability of body fat percentage assessed with the BCS model was significantly lower ($P<0.01$) than without the BCS model in the dogs that were assessed as BCS of 3. In the group of BCS of 4, the variability of body fat percentage diagnosed with the BCS model was significantly smaller ($P<0.05$) than without the BCS model. There was no significant difference in

BCS of 2 groups with and without using the BCS model.

These results show that the BCS model improves the reproducibility of BCS assessment. However, body fat percentage of dogs assessed using the BCS model was higher than body fat percentage of previous reports in each BCS group. According to previous reports [36], the relationship between BCS and body fat percentage are as follows; BCS1: < 5 %, BCS2: 5-15 %, BCS3: 15-25 %, BCS4: 25-35 %, BCS5: 35 % <. Therefore, further improvement on the BCS model is required.

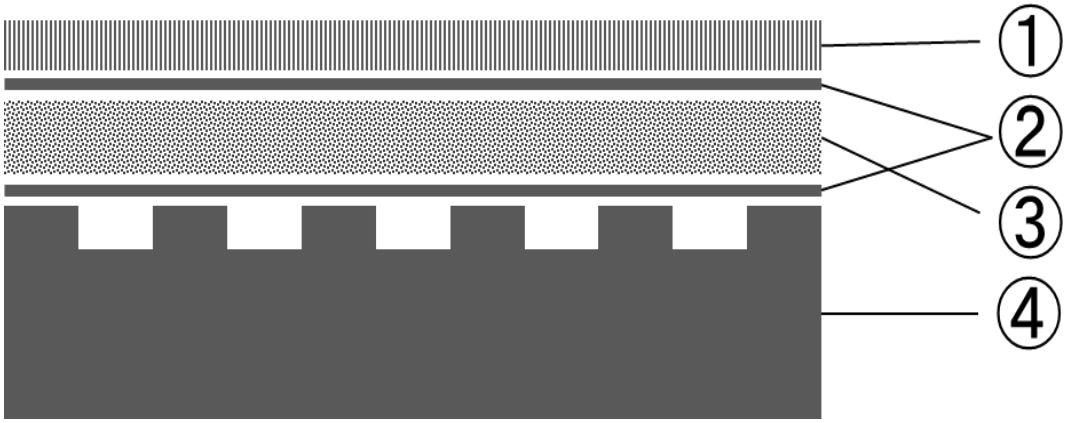



**Fig. 1-a** Diagram of the BCS model

① : Boa fur

② : Natural rubber sheet

③ : Polychloroprene sponge sheets

④ : Artificial rib


**Fig. 1-b** Photograph of the BCS model

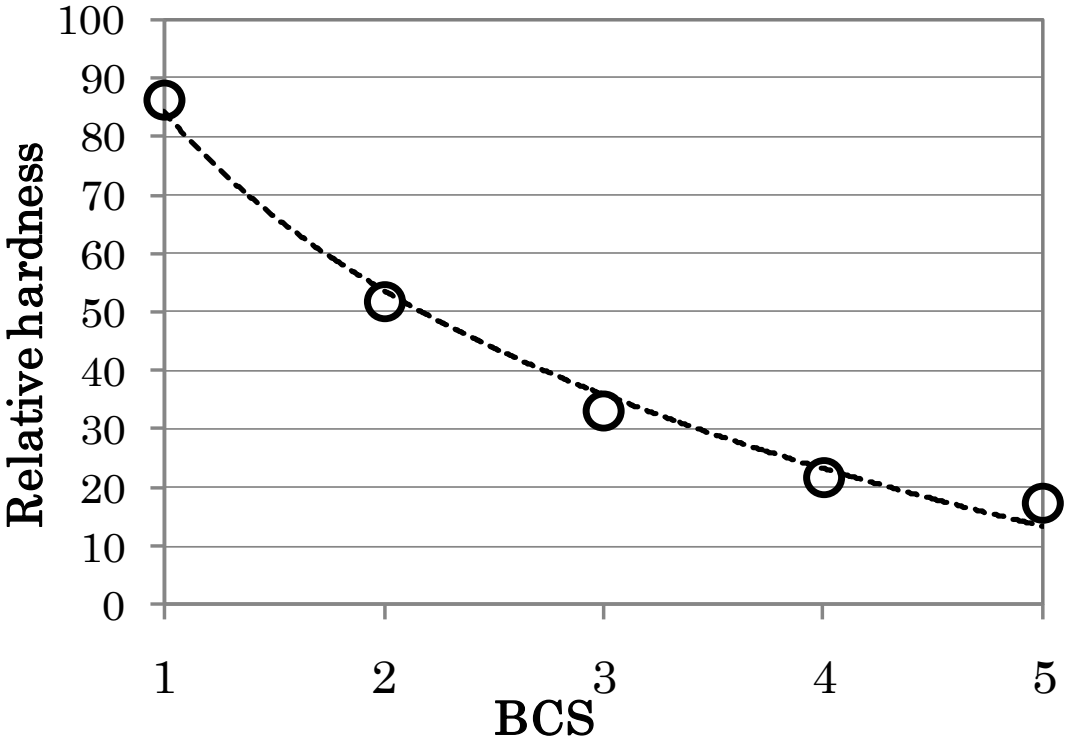



**Fig. 2** Relationship between BCS and relative hardness of the stacked rubber sheets

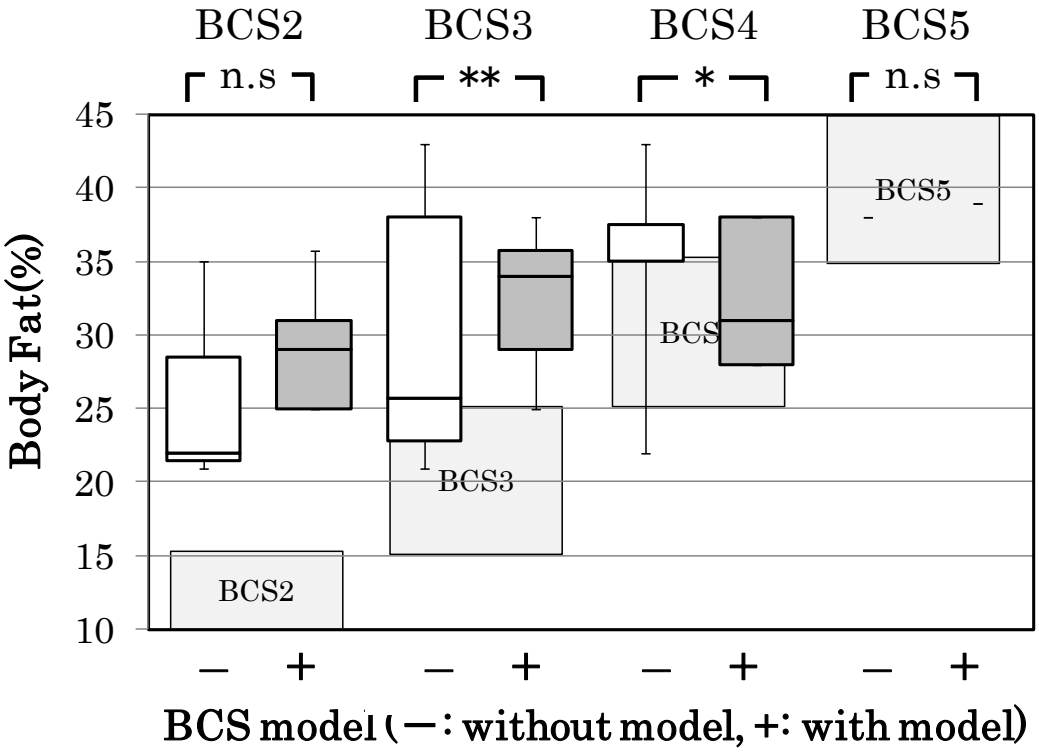
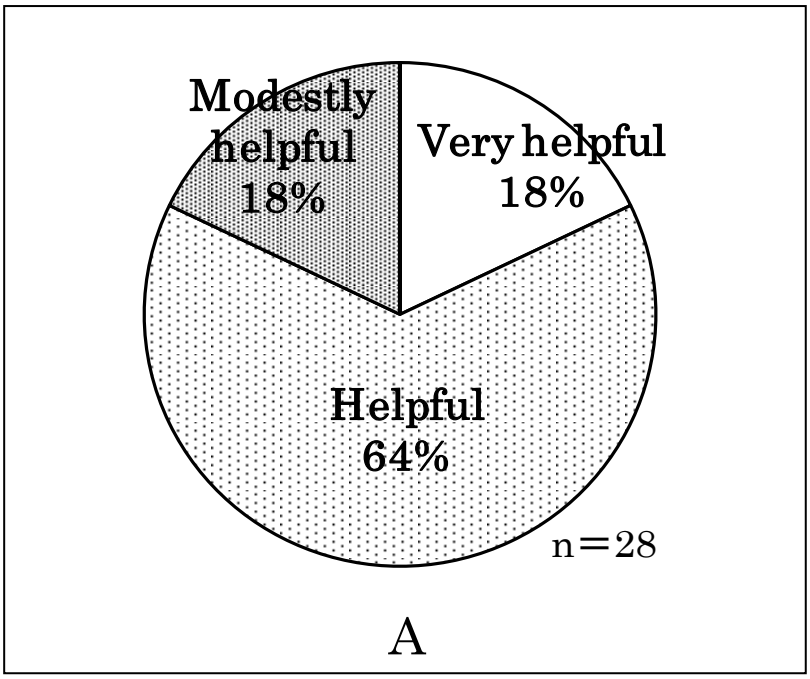



**Fig. 3** Relationship between the body fat percentage and the BCS in dogs

Relations between BCS and the percent of body fat are as fallows;
BCS1 : > 5 %, BCS2 : 5-15 %, BCS3 : 15-25 %, BCS4 : 25-35 %, BCS5 : 35 % <

We asked dog owners to assess a BCS of their dog by using the BCS model. Eighty two percent of owners answered that the BCS model was useful for the diagnosis of nutritional status of their dog (Fig. 4A). Furthermore, 66 % of the owners answered that they were able to assess BCS more precisely by using the BCS model (Fig. 4B). These results suggest that the BCS model is useful for pet owners to grasp their dog's nutritional status.



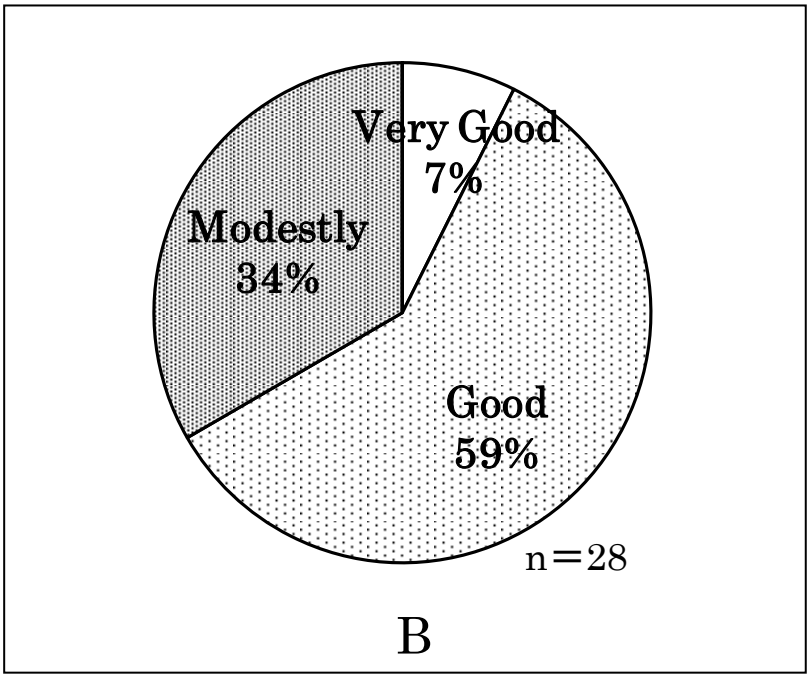




**Fig. 4** Impression of pet owners when they diagnose their own dogs by using BCS model

A: Do you think that the BCS model helped the diagnosis of nutritional status in your dog?

B: Could you diagnose the nutritional status of your dog by using BCS model well?

# CHAPTER 3

## Effectiveness of the body condition score model for nutritional assessment in dogs (the 2nd report): a questionnaire survey of veterinary practitioners and dog owners

### Introduction

In the previous study, it was clarified that BCS assessment, using the BCS model, improved the accuracy of BCS evaluation. Compared to the previous BCS model, the average of body fat percentage was shifted to the higher one's. In this study, the prototype BCS model was applied to improve the model as follows: the combinations of materials, such as rubber sheet and sponge rubber sheet, were varied. Those combinations of the materials in each model are shown in Table 3. Using a durometer, the palpation sensation was digitally qualified for objective evaluations. The results are shown in Fig. 5. In terms of the values of rubber hardness, the wider range

in the improved model was indicated, compared to the prototype model. In order to develop the commercialized model and to confirm its effectiveness, a questionnaire survey was conducted among veterinarians and dog owners.

**Table 3.** Combination of rubber materials in each BCS and their relative hardness in the improved model

| BCS | Bone → Skin | | |
|---|---|---|---|
| | Natural rubber Thickness 0.5mm | Polychlo-roprene sponge Thickness 3mm | Natural rubber Thickness 0.5mm |
| 1 | 1→0 | | |
| 2 | 1→2 | 1→0 | |
| 3 | 1→0 | 1→1 | 2→0 |
| 4 | 1→0 | 2→2 | 1→0 |
| 5 | 1→0 | 3→3 | 0→1 |

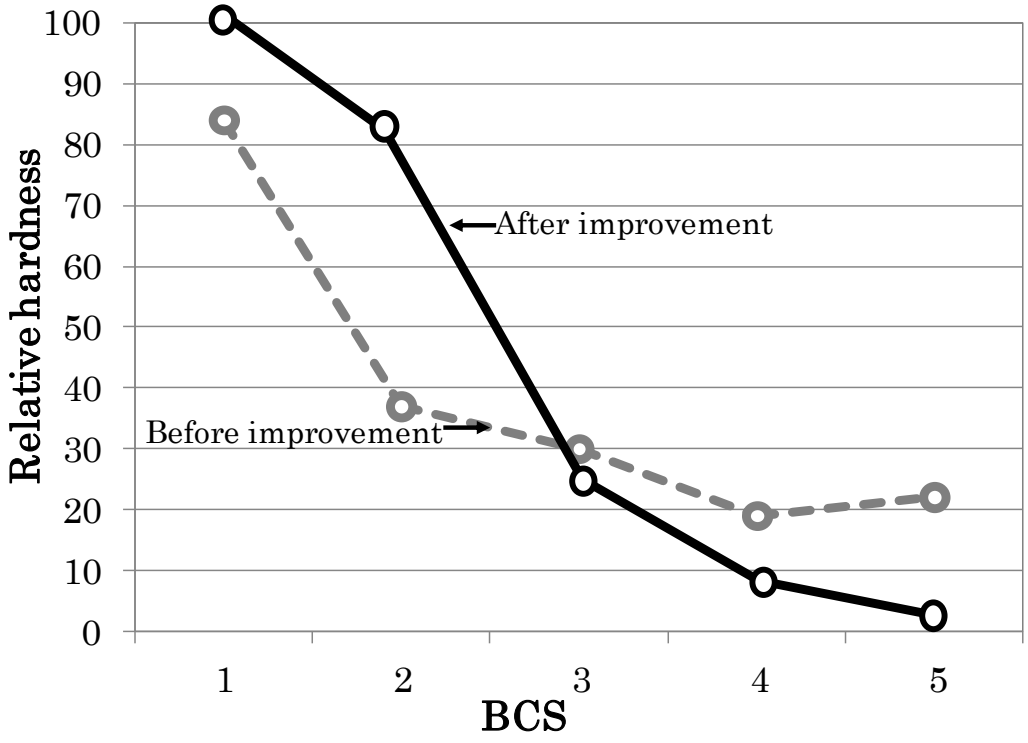



**Fig. 5** Relationship between BCS and relative hardness of the stacked rubber sheets (Boa fur Mounting)

## Materials and methods

### BCS model

The commercialized version of the BCS palpation model was used (Fig. 1). A standard five-point scale system which was mainly used by clinical veterinarians in Japan was used for assessment of BCS. BCS: 1 = very thin; 2 = underweight; 3 = ideal; 4 = overweight; and 5 = obese.


**Fig. 1** Commercialized BCS model

## Questionnaire survey

Questionnaires were collected from 57 small animal practitioners working mainly in the Kanto area (some in the Hokkaido, Tohoku, Chubu and Kinki areas) and 45 dog owners in the Kanto area. We conducted questionnaire survey using a 5-option Likert scale ranging from 1 to 5 on the following questions. Veterinarians were asked the first nine questions (1-10), while dog owners were asked the next five questions (11-14) as follows:

1) Do you perform nutritional assessment during consultation at your clinic?
2) What is the obesity rate among dogs receiving outpatient treatment?
3) What is the success rate of your weight control program?
4) Did you think the palpation feeling of the BCS model matched the actual patient?
5) Did you think the BCS model was useful in the clinical setting?
6) Did you think that the BCS model was useful to explain the nutritional status of dog to dog owner?
7) Did you think that the BCS model should be in an animal hospital?

8) Can you recommend easier the weight loss program to dog owner, if BCS model is the animal hospital?

9) Do you think the success rate of weight loss program will rise if BCS model is in the animal hospital?

10) How will you use the BCS model in your clinic? (multiple answers allowed)

11) What is your concern about your dog's health? (multiple answers allowed)

12) Did you know about the BCS?

13) Were you able to assess the nutritional status of your dog using the BCS model?

14) Will you consult the clinic staff about weight loss if you find out your dog is obese?

## Results and discussion

### Veterinarian's response

1) Do you perform nutritional assessment during consultation at your clinic?

Eighty percent of veterinarians answered that they always or often performed a nutritional assessment on their patients, while 16 % of them performed when necessary (Fig. 2). For the majority of veterinarians, therefore, nutritional assessment was a part of routine clinical examination, and the results were shared with owners whenever necessary.

2) What is the obesity rate among dogs receiving outpatient treatment?

The percentage of dogs with a BCS of 6 or more ranged from 10 to 30 % among 36 % of the veterinarians and from 30 to 50 % among another 36 % of veterinarians (Fig. 3).

3) What is the success rate of your weight control program?

The success rate of the weight loss program, 39 % of veterinarians answered 10 to 30 % and other 29 % of them answered 30 to 50 %. The veterinarians perceived that the success rate of weight loss was not very

high (Fig. 4).

4) Did you think the palpation feeling of the BCS model matched the actual patient?

Twenty-four percent of veterinarians answered that the palpation feeling of the BCS model was consistent with those of the actual dogs, while 67 % said that they were similar. Combined, 91 % of the veterinarians thought that the model was identical or well matched to the actual patients (Fig. 5).

5) Did you think the BCS model was useful in the clinical setting?

Most veterinarians (88 %) answered that the BCS model was either very useful or helpful for BCS assessment (Fig. 6).

6) Did you think that the BCS model was useful to explain the nutritional status of dog to dog owner?

Ninety-five percent of veterinarians answered that the BCS model was either very helpful or useful for explaining the nutritional status of the dog to the owners (Fig. 7).

7) Did you think that the BCS model should be in an animal hospital?

Ninety-six percent of veterinarians replied that the BCS model should

be used in animal hospitals (Fig. 8).

8) Can you recommend easier the weight loss program to dog owner, if BCS model is the animal hospital?

Eighty-one percent of veterinarians perceived that the BCS model made it easier for them to recommend weight loss programs (Fig. 9).

9) Do you think the success rate of weight loss program will rise if BCS model is in the animal hospital?

Forty-three percent of veterinarians suggested that the success rate of the weight loss program would increase by the BCS model (Fig. 10).

10) How will you use the BCS model in your clinic?

Seventy-nine veterinarians answered that they would use the BCS model to explain the nutritional status or provide nutritional education to dog owners. Unexpectedly, few veterinarians answered that they would use it for the staff education or as an aid in BCS assessment (Fig. 11). Because BCS assessment results are often different between veterinarians and their clients [37], the BCS model seems useful as a communication tool between them.

From the veterinarian's answers, it was clear that they always or often performed a nutritional assessment on their patients; however, the success rate of weight loss was not very high. The veterinarians answered that the model was identical or well matched to the actual patients and the model was very helpful or useful for explaining the nutritional status of the dog to the owners.

Because BCS assessment results are often different between veterinarians and their clients. The BCS model seems useful as a communication tool between them.

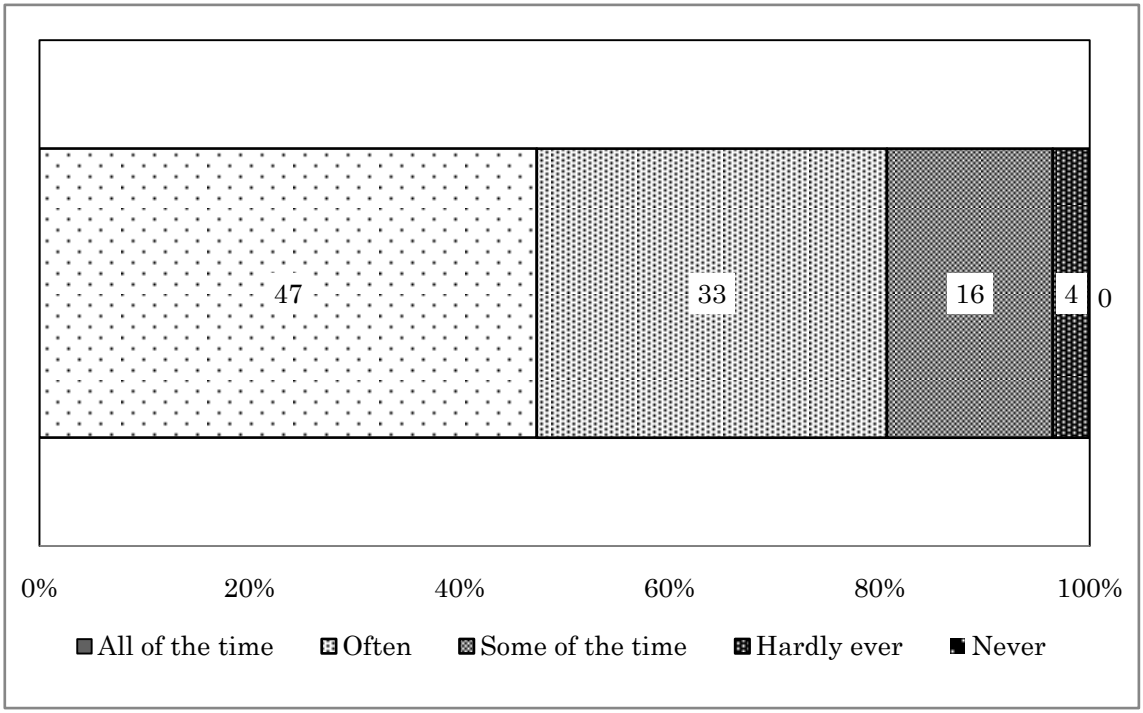



**Fig. 2** Do you perform nutritional assessment during consultation at your clinic? (n=57)

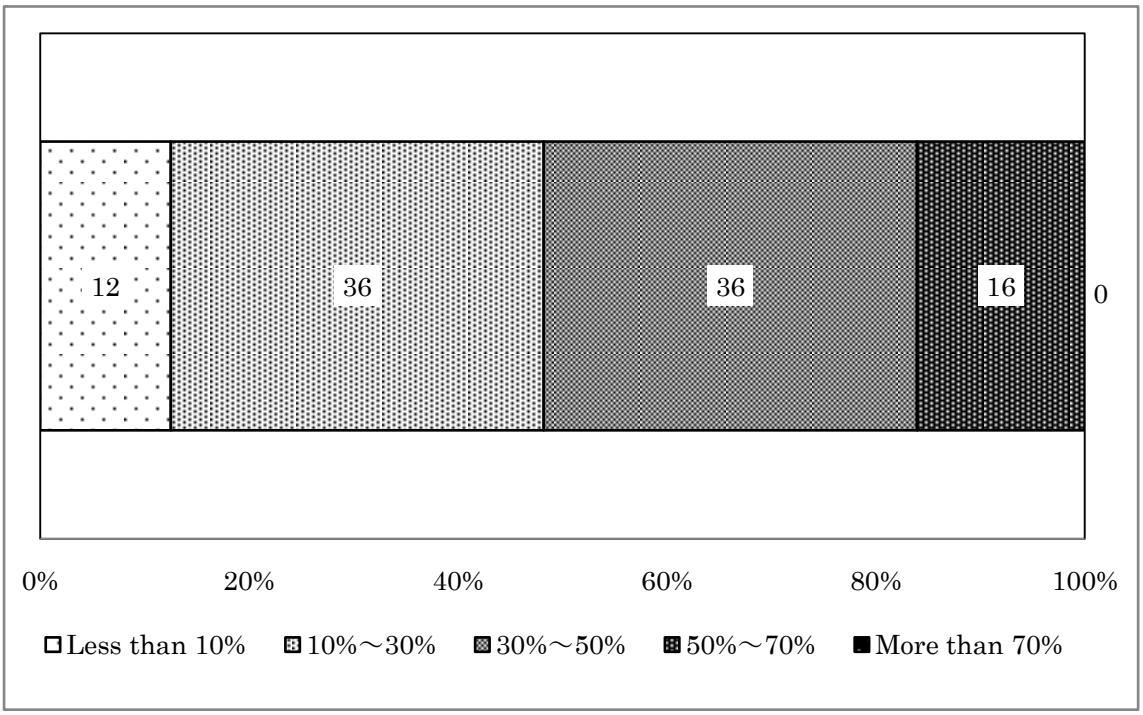



**Fig. 3** What is the obesity rate among dogs receiving outpatient treatment? (n=56)

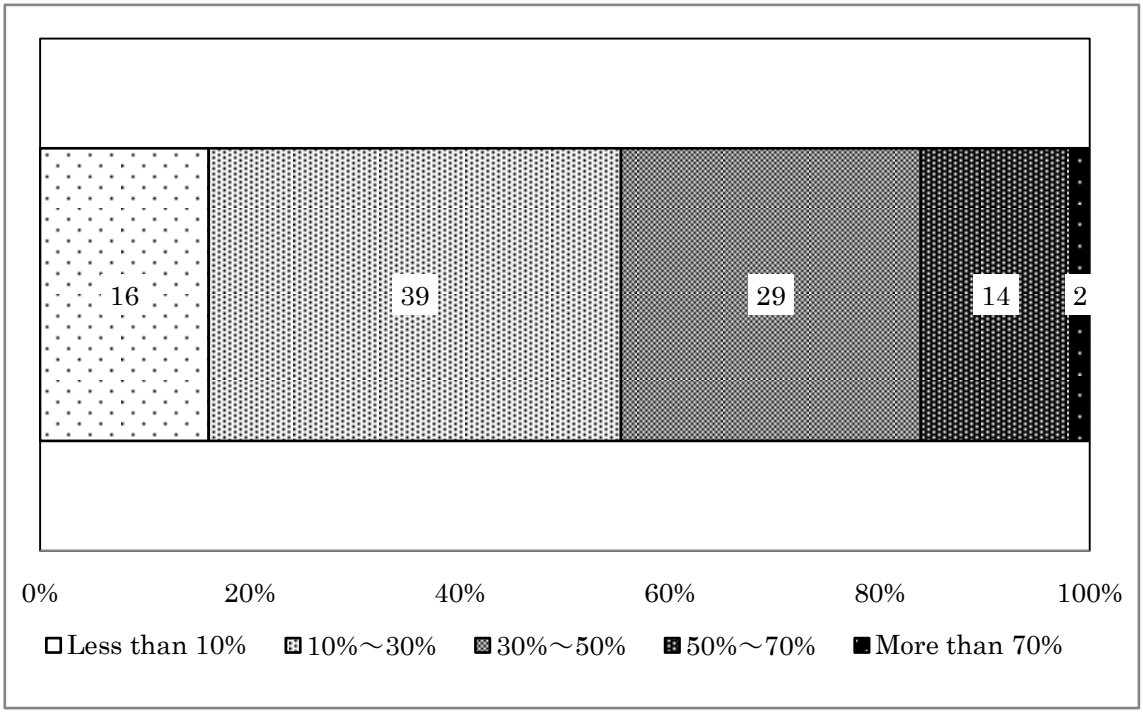



**Fig. 4** What is the success rate of your weight control program? (n=56)

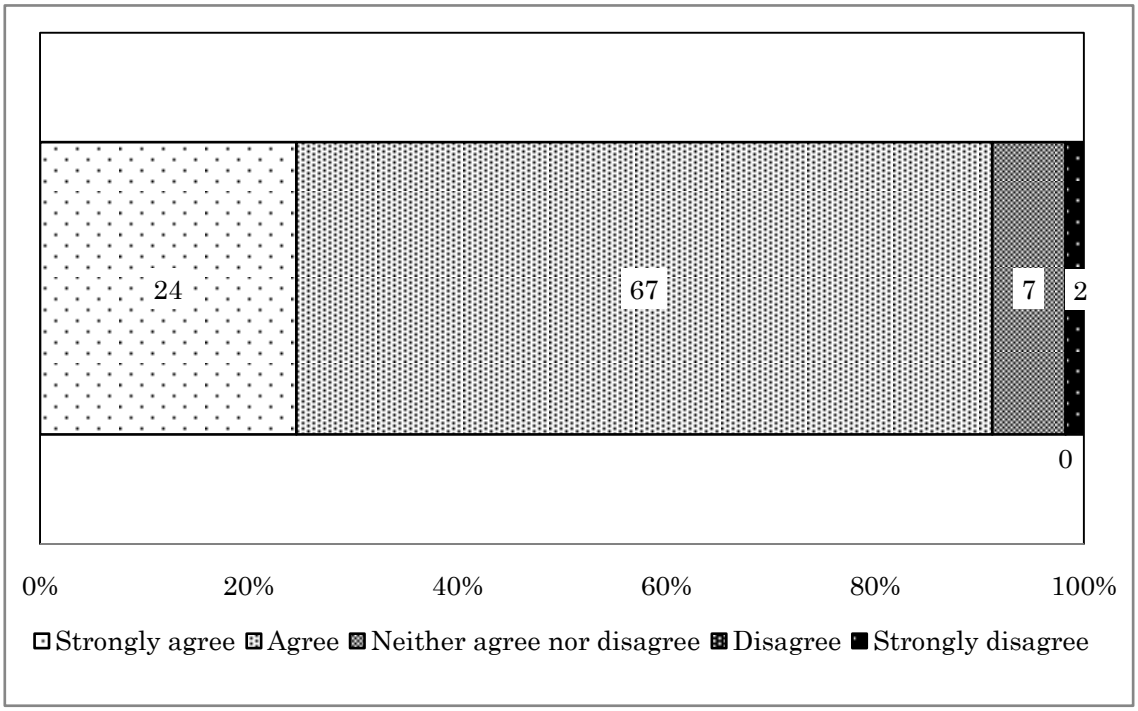



**Fig. 5** Did you think the palpation feeling of the BCS model matched the actual patient? (n=57)

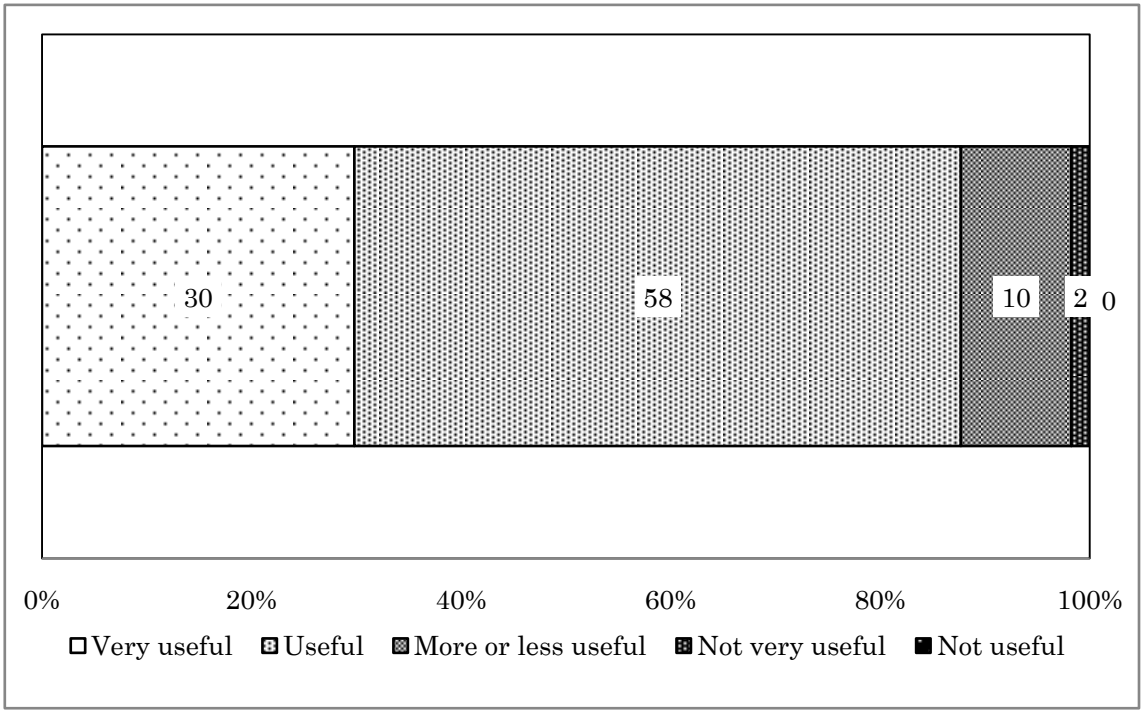



**Fig. 6** Did you think the BCS model was useful in the clinical setting? (n=57)

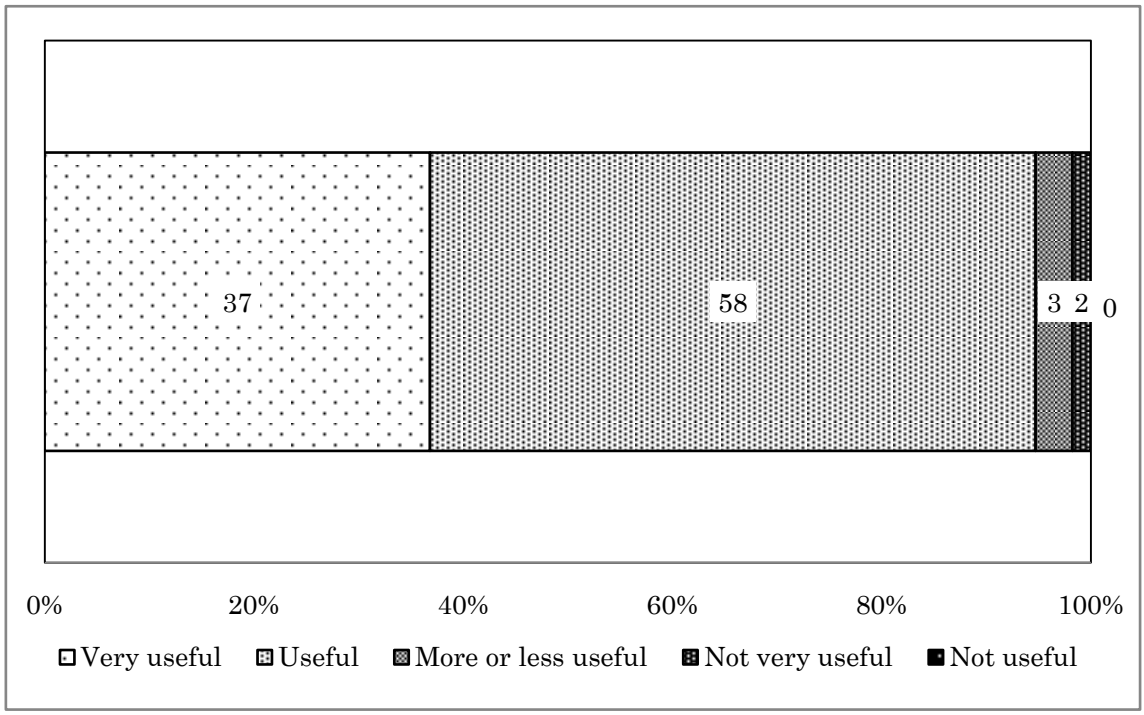



**Fig. 7** Did you think that the BCS model was useful to explain the nutritional status of dog to dog owner? (n=57)

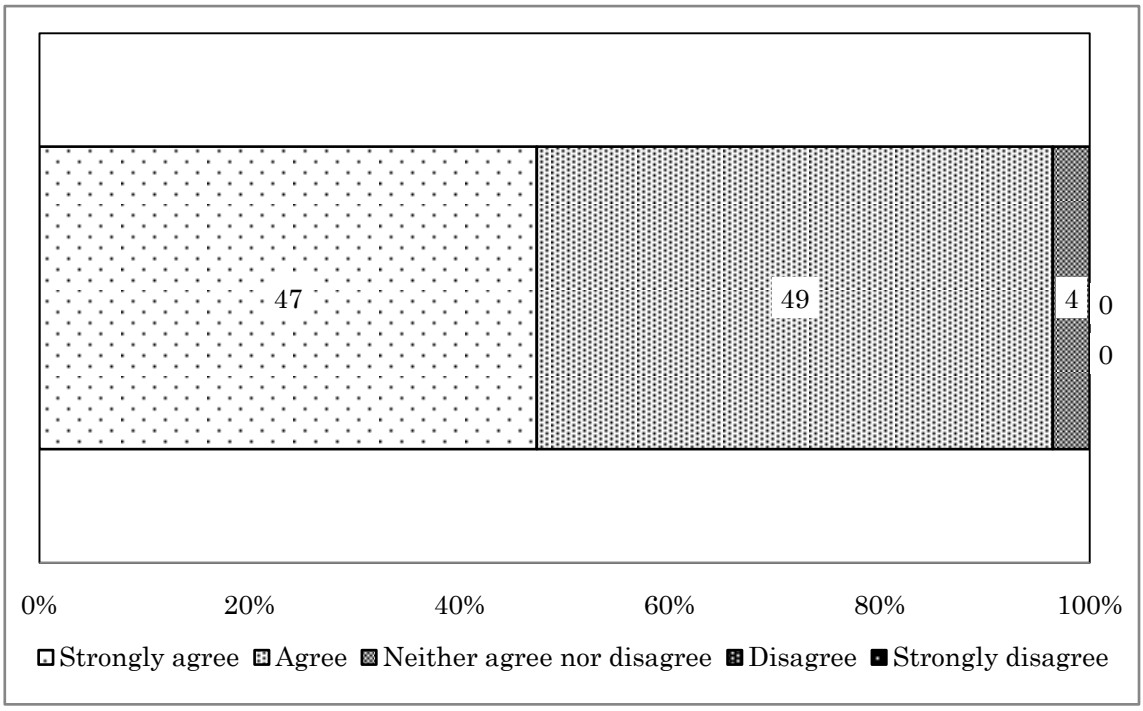



**Fig. 8** Did you think that the BCS model should be in an animal hospital? (n=57)

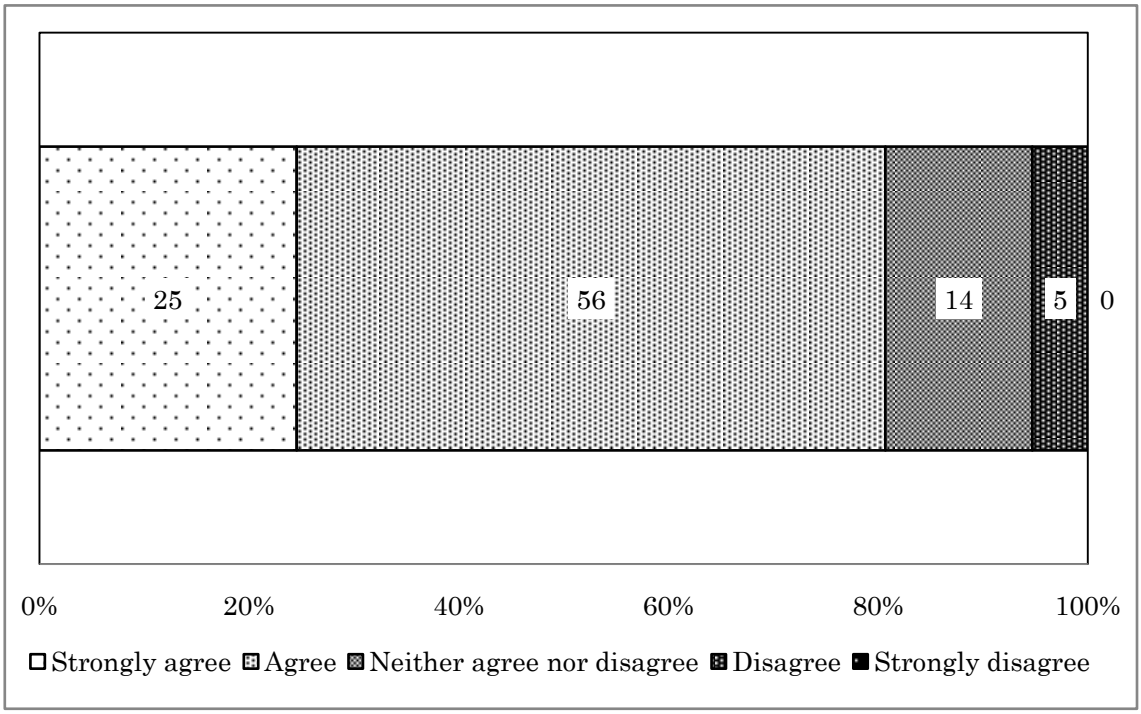



**Fig. 9** Can you recommend easier the weight loss program to dog owner, if BCS model is the animal hospital? (n=57)

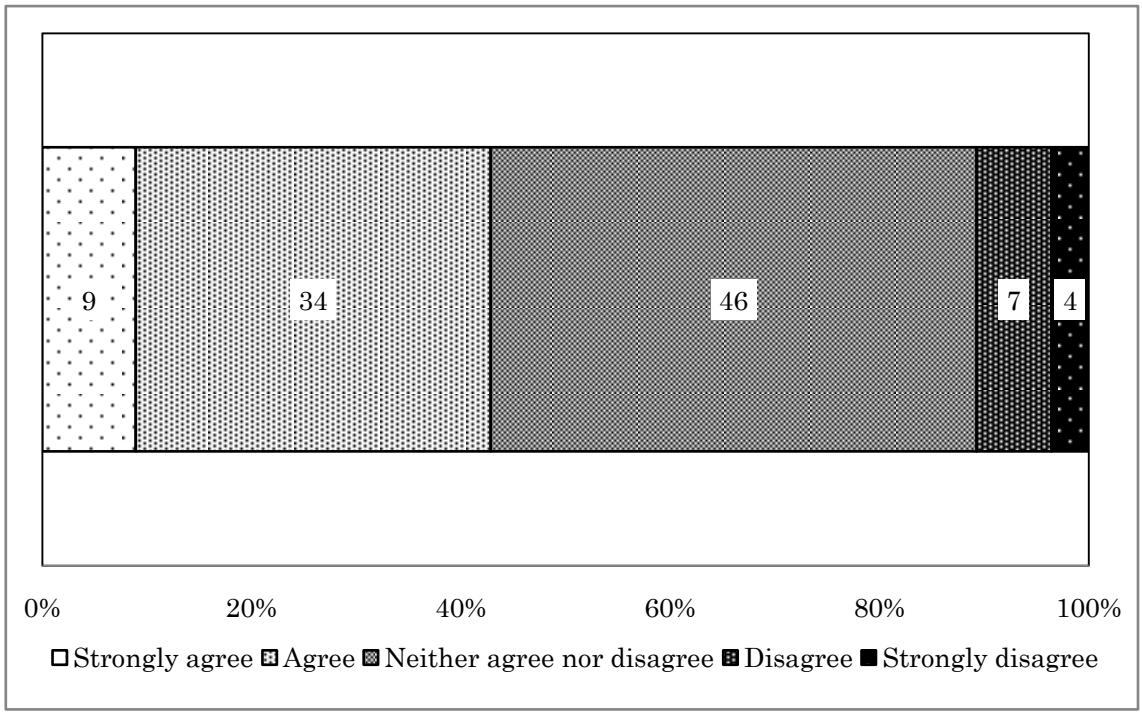



**Fig. 10** Do you think the success rate of weight loss program will rise if BCS model is in the animal hospital? (n=57)

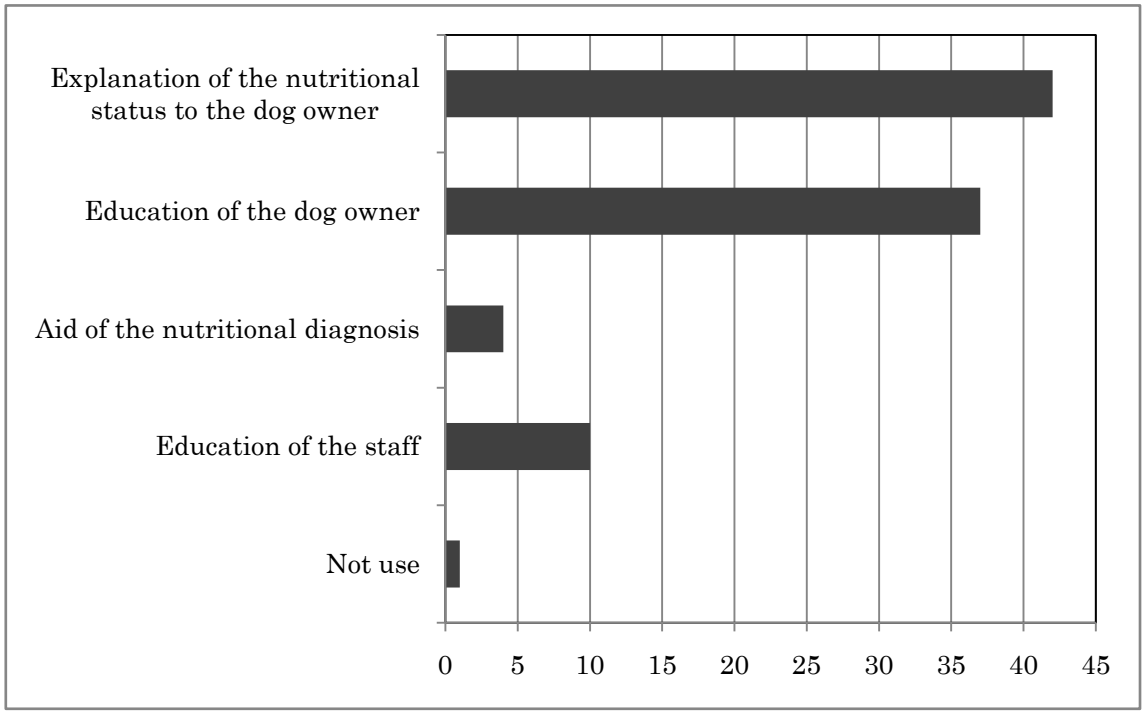



**Fig. 11** How will you use the BCS model in your clinic? (multiple answers allowed)

## Dog owner's responses

11) What is your concern about your dog's health?

Diet, exercise, weight management and cleanliness were the most frequent answers among others. Many owners were concerned especially about the diet (Fig. 12).

12) Did you know about the BCS?

Few dog owners knew about the BCS (Fig. 13), despite that most veterinarians were assessing the BCS and discussing the results with the owners (see Question 1). These results suggested that dog owners did not fully understand what the BCS was by veterinarian's explanation alone.

13) Were you able to assess the nutritional status of your dog using the BCS model?

By using the BCS model, 13 % and 54 % of the dog owners thought that they understood the nutritional status of their dog very well and moderately well, respectively (Fig. 14). Most owners answered that they would be able to perform BCS assessment on their own by using the model even at the first attempt.

14) Will you consult the clinic staff about weight loss if you find out your dog is obese?

Eighteen percent and 42 % of the dog owners answered definitely and probably, respectively. The percentage of dog owners who did not want to consult was 22 % (Fig. 15). The reason why the dog owners did not want to consult was not asked in this survey.

From the owners' answers, it was clear that they were most concerned about the nutrition in daily health care, but their knowledge about the BCS was inadequate. Dog owners were interested in the BCS model, and they thought that the BCS model would be useful for nutritional management. Since 60 % of the dog owners were interested in consulting the clinic staff if their dogs were obese.

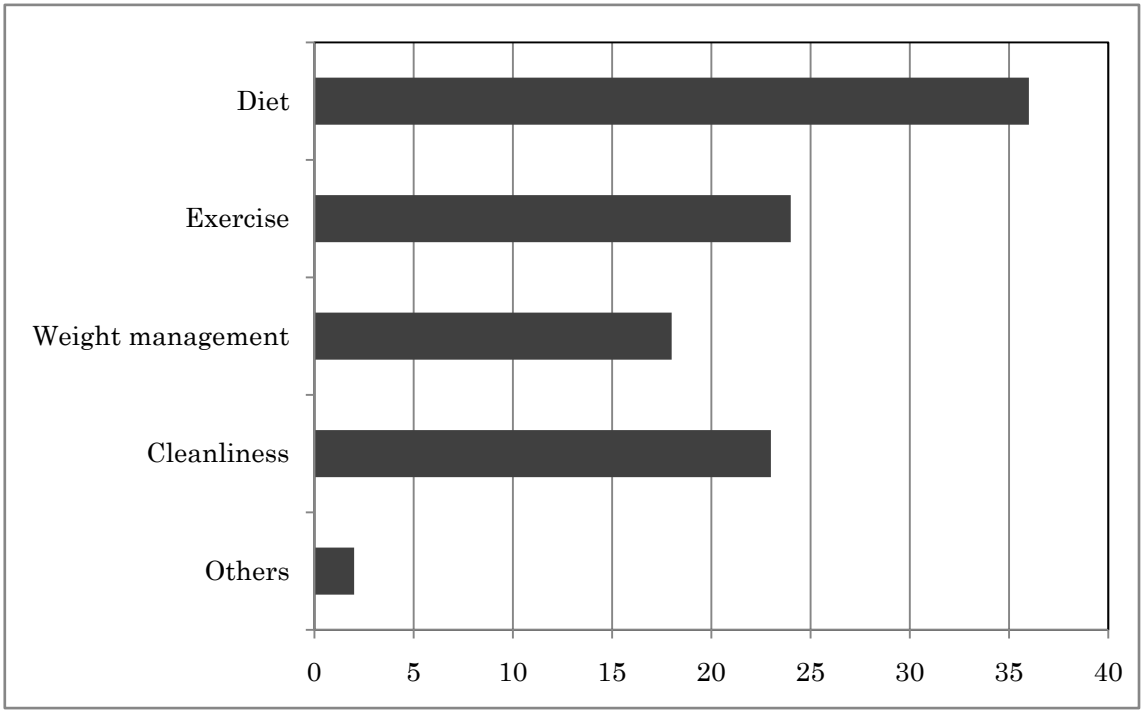



**Fig. 12** What is your concern about your dog's health?
(multiple answers allowed)

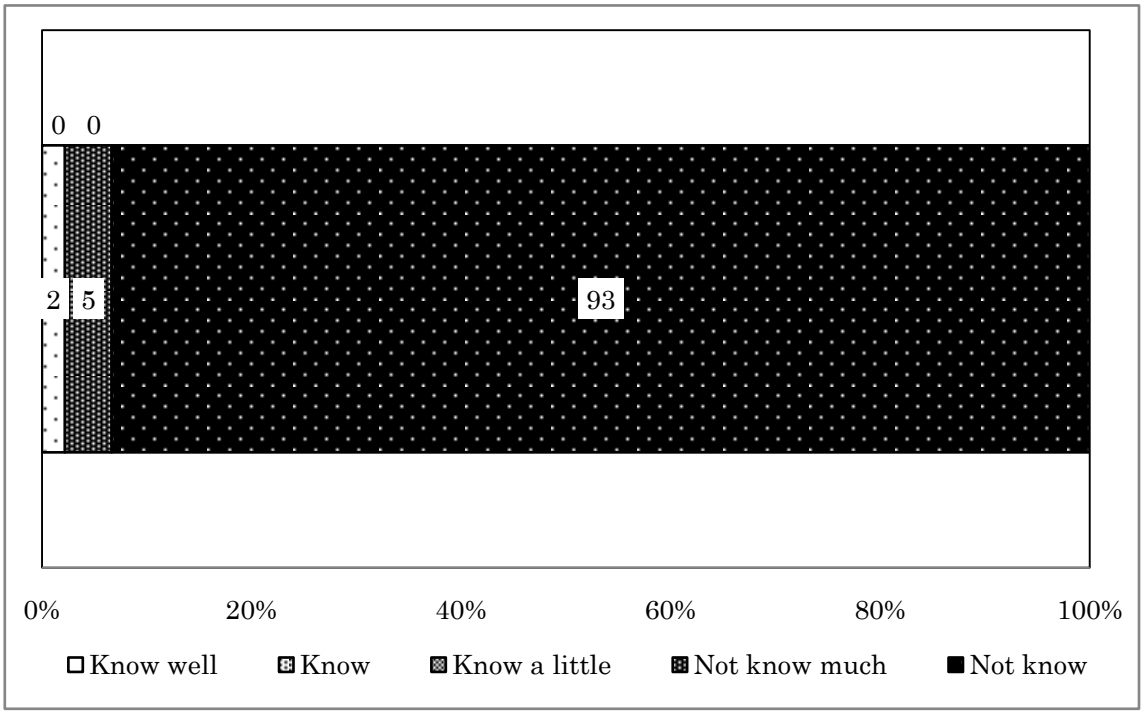



**Fig. 13** Did you know about BCS? (n=45)

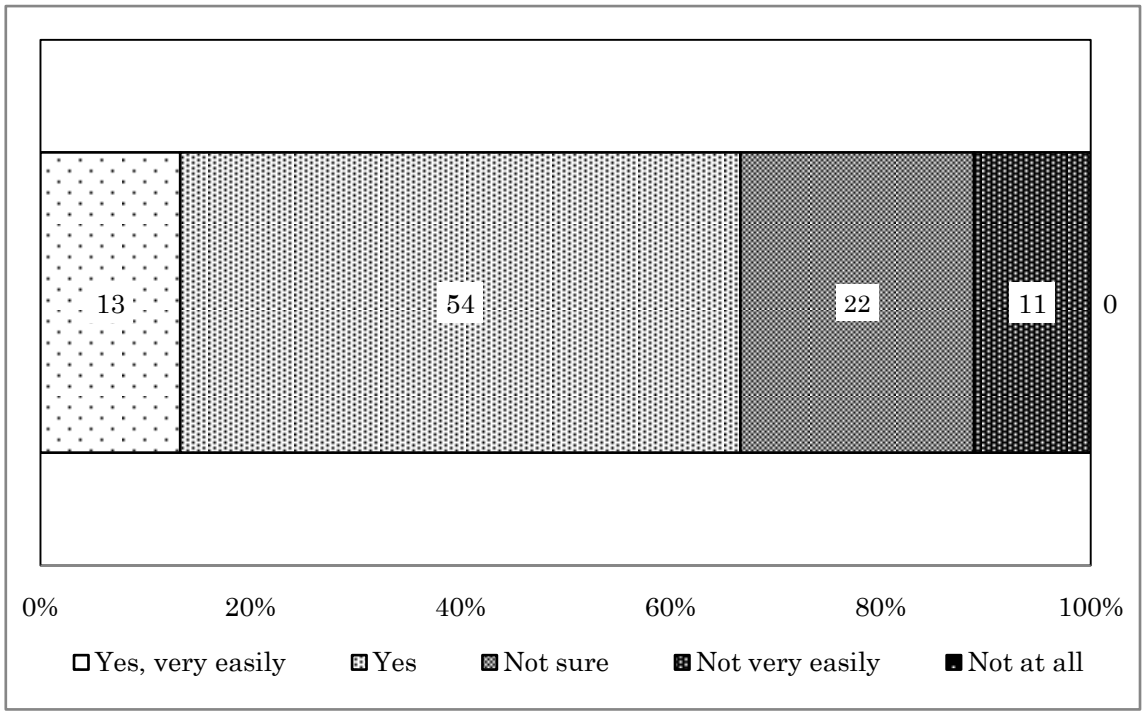



**Fig. 14** Were you able to assess the nutritional status of your dog using the BCS model? (n=45)

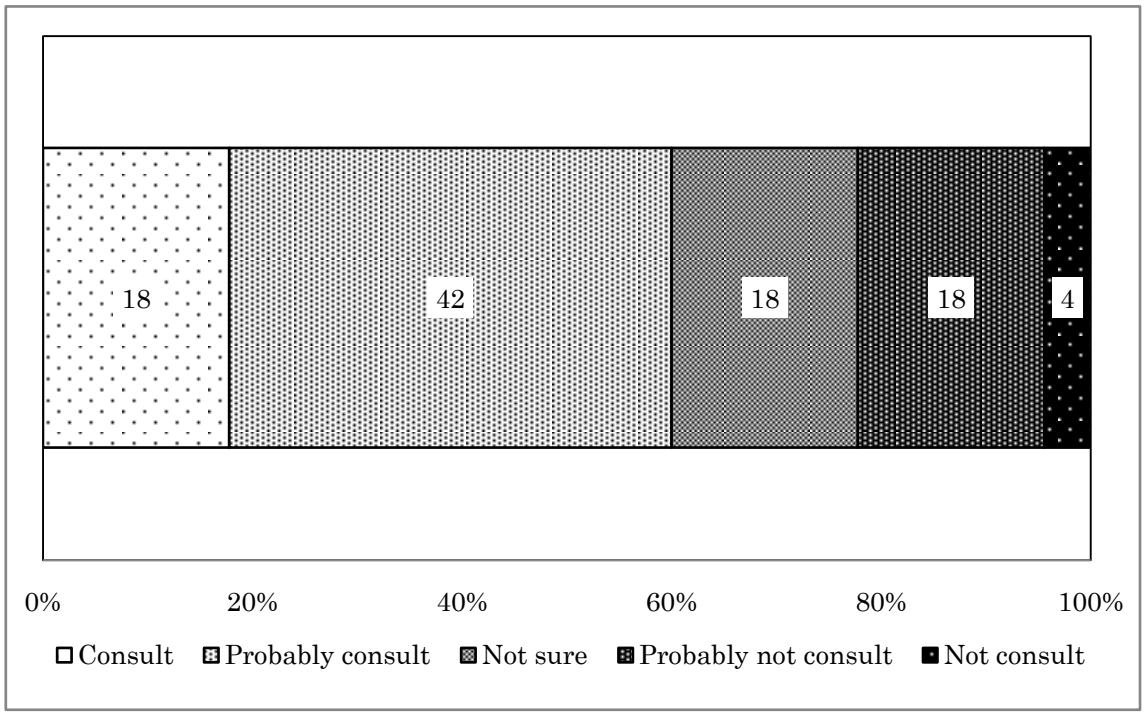



**Fig. 15** Will you consult the clinic staff about weight loss if you find out your dog is obese? (n=45)

In conclusion, our survey results suggest that the BCS model is a good representation of the nutritional status of the dog. Given the discrepancy between the veterinarian's and owner's perceptions, the model is most likely useful for facilitating the communication between veterinarians and their clients and setting a shared goal. This is especially important as most owners did not know how to assess their dog's body condition using the BCS system and the obesity rate was high among dogs presented to the clinics.

# CHAPTER 4

## Possibility of morphometric body condition scoring in dogs

### Introduction

In chapters 2 and 3, the development of BCS model and its usefulness in clinical practice were examined. As a result, it was clarified that the BCS model was in good agreement with the actual palpation sensation of the dogs and at same time, the BCS model was useful for explaining the nutritional status of dog to dog owner. However, the BCS model is never prevalent to all animal hospitals. Therefore, we thought that we needed to develop a method to assess BCS with high accuracy without BCS model.

In human medicine, the body mass index (BMI), which is calculated by BW (kg) / height ($m^2$) has long been used as a part of nutritional assessment. Using this morphometric method, many epidemiological investigations have been conducted and contributed to the progress of medical science. A simple

morphometric analysis like BMI should be equally beneficial in dogs as well, not only for the assessment of the individual nutritional condition but also for statistical and epidemiological purposes. It would also help dog owners to estimate their dog's body condition more accurately for effective weight control. Yet, such a system has not been established for dogs. Burkholder et al. [35] proposed a morphometric method to estimate the percent body fat from the distance between the hock and the stifle and pelvic circumference. However, this method cannot be applied to short-legged breeds such as Dachshund and Welsh Corgi and has not been integrated into small animal practice. The purpose of the present study was, therefore, to develop a clinically feasible, new morphometric method for the assessment of body condition of the dog.

## Materials and methods

### Subjects

Forty-two dogs with varying BCS were included. They were raised and maintained at Tsukuba WanWan Land (Ibaraki, Japan), Teikyo University of Science (Tokyo, Japan) and Kitayama Labes Co., Ltd (Nagano, Japan). Their profiles are summarized in Table1.

This study was approved by the Teikyo University Animal Experiment Committee.

**Table 1.** Profile of subjects

| No. | Breed | Gender / Neuter | Age (year) | Body weight (kg) | Body fat (%) | Body length Position A (cm) |
|---|---|---|---|---|---|---|
| 1 | Beagle | F/- | 3 | 8.9 | 13.6 | 44.5 |
| 2 | Beagle | F/- | 3 | 12.6 | 34.2 | 47.0 |
| 3 | Beagle | F/- | 4 | 12.6 | 27.0 | 48.0 |
| 4 | Beagle | F/- | 4 | 14.9 | 27.3 | 52.0 |
| 5 | Beagle | F/- | 5 | 15.1 | 34.8 | 50.0 |
| 6 | Beagle | F/- | 5 | 15.9 | 32.0 | 46.0 |
| 7 | Beagle | M/- | 7 | 15.3 | 24.1 | 50.0 |
| 8 | Beagle | F/+ | 7 | 15.8 | 30.6 | 51.0 |
| 9 | Beagle | F/- | 7 | 13.2 | 33.2 | 46.0 |
| 10 | Brussels griffon | M/- | 7 | 6.0 | 17.1 | 36.5 |
| 11 | Cavalier king charles spaniel | M/- | 4 | 9.7 | 20.7 | 42.0 |
| 12 | Chihuahua | M/- | 6 | 3.6 | 11.2 | 32.0 |
| 13 | Golden retriever | M/+ | 5 | 20.6 | 22.9 | 62.0 |
| 14 | Golden retriever | M/+ | 6 | 28.5 | 30.3 | 67.0 |
| 15 | Italian greyhound | M/- | 4 | 6.7 | 23.5 | 42.0 |
| 16 | Jack russell terrier | F/- | 1 | 5.1 | 3.5 | 40.5 |
| 17 | Japanese spitz | F/- | 6 | 7.2 | 23.1 | 44.0 |
| 18 | Labrador retriever | F/+ | 1 | 27.9 | 36.2 | 60.0 |
| 19 | Maltese | M/- | 8 | 3.9 | 8.7 | 35.5 |
| 20 | Miniature dachshund | F/- | 1 | 4.4 | 19.9 | 38.5 |
| 21 | Miniature dachshund | M/+ | 2 | 4.7 | 27.2 | 37.0 |
| 22 | Miniature dachshund | F/- | 5 | 4.4 | 6.1 | 43.0 |
| 23 | Miniature schnauzer | F/- | 4 | 6.4 | 25.0 | 38.0 |
| 24 | Miniature schnauzer | M/- | 5 | 6.5 | 18.5 | 36.0 |
| 25 | Miniature schnauzer | F/- | 6 | 6.6 | 12.1 | 40.0 |
| 26 | Papillon | M/- | 4 | 2.3 | 15.3 | 29.0 |
| 27 | Pekingese | M/- | 2 | 5.9 | 11.2 | 41.5 |
| 28 | Pekingese | M/- | 3 | 6.5 | 20.8 | 41.0 |
| 29 | Pekingese | F/+ | 4 | 6.8 | 32.0 | 37.5 |
| 30 | Pug | M/- | 5 | 8.4 | 19.1 | 36.0 |
| 31 | Pug | F/- | 5 | 4.8 | 17.1 | 32.5 |
| 32 | Pug | F/+ | 9 | 4.5 | 12.1 | 32.0 |
| 33 | Shiba | F/- | 1 | 7.2 | 14.8 | 41.0 |
| 34 | Shiba | F/- | 1 | 7.7 | 12.9 | 42.5 |
| 35 | Shih tzu | M/- | 5 | 5.9 | 18.3 | 39.0 |
| 36 | Toi poodle | M/- | 3 | 2.9 | 11.4 | 34.0 |
| 37 | Toi poodle | M/+ | 4 | 5.2 | 27.5 | 35.0 |
| 38 | Toi poodle | F/- | 10 | 3.7 | 20.8 | 40.0 |
| 39 | Toi poodle | M/- | 11 | 6.1 | 23.5 | 39.0 |
| 40 | Toi poodle | M/- | 12 | 4.1 | 15.2 | 40.5 |
| 41 | Welsh corgi pembroke | F/- | 6 | 9.5 | 9.4 | 51.0 |
| 42 | Welsh corgi pembroke | F/- | 9 | 10.0 | 14.9 | 53.0 |

## Measurements:

### Percent body fat

The percent body fat was determined by the deuterium oxide dilution method [38-40]. After blood sampling, 0.2 g / kg of deuterium oxide (Taiyo Nippon Sanso Co., Ltd, Tokyo) was subcutaneously injected, and blood was collected three hours after injection. Blood samples were submitted to Taiyo Nippon Sanso for analysis by radioisotope mass spectrometry.

### Body length

We chose three measurement positions that satisfied the following two criteria. First, the position must be suitable for all breeds of dogs. Second, there must be anatomical landmarks that can be easily identified by examiners. The following three lengths were measured using a ruler: A from the episternum to the ischial tuberosity; B from the cranial angle of the scapula to the base of the tail; C from the cranial angle of the scapula to the sacral tuber of the ilium (Fig. 1).

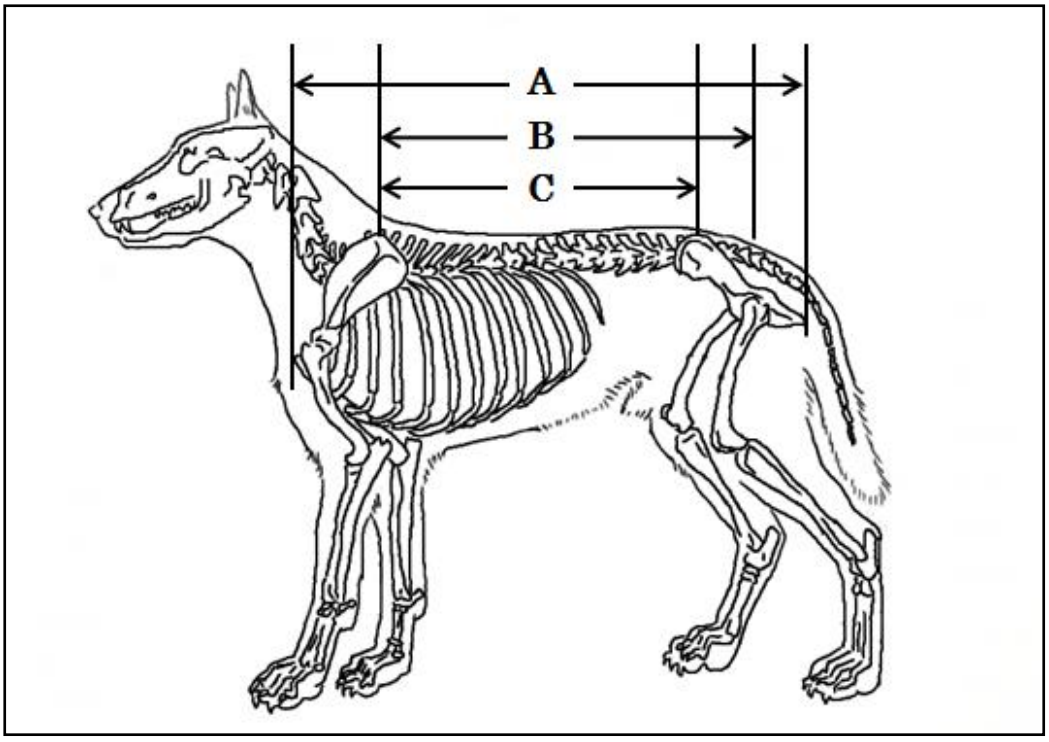



**Fig. 1** The measuring position of body length in dogs

A : episternum — ischial tuberosity

B : cranial angle of the scapula — base of the tail

C : cranial angle of the scapula — sacral tuber of the ilium

## Calculation of IBW

IBW was calculated by following expression:

IBW(kg) = [current body weight(kg) × (100 − current body fat percentage(%)) / 100] / [ (100 − ideal body fat percentage(%)) / 100]

Body fat percentage of 20 % was adopted as ideal body fat percentage [41].

## Definition of BCS

A 5-point BCS scale was defined by the IBW and current BW as follows: BCS of 5, BW > IBW × 1.21; BCS of 4, BW= IBW × 1.11 to 1.20; BCS of 3, BW = IBW × 0.91 to 1.10; BCS of 2, BW = IBW × 0.90 to 0.81; and BCS of 1, BW < IBW × 0.80 [41].

## Statistical analysis

The correlation between body length and IBW was examined by Pearson's correlation coefficient test using the SPSS statistics software 24.0 (IBM). A P value less than 0.05 was considered statistically significant.

## Results and discussion

The study included 42 dogs (19 males and 23 females) across 19 different breeds. Twenty one per cent of male and 17 % of female had been neutered. Their body length ranged from 29 to 67 cm, and the BW from 2 to 29 kg. The body fat percentage ranged from 3.5 to 36.2 % (Table 1)

A high correlation was found between ideal body weights and each of the three measuring positions. The correlation coefficients between IBW and body length measured at A, B and C were 0.945, 0.932 and 0.910, respectively, and P values were $P<0.01$, $P<0.01$, $P<0.01$, respectively (Fig. 2-4). The correlation between body length (position A) and IBW is shown in Fig. 2. From now on, we will use position A as the body length. The regression express using IBW as outcome variable (y) and body length of position A as predictor variable (x) was $y = 0.009x^2 - 0.359x + 5.162$ (Fig. 2).

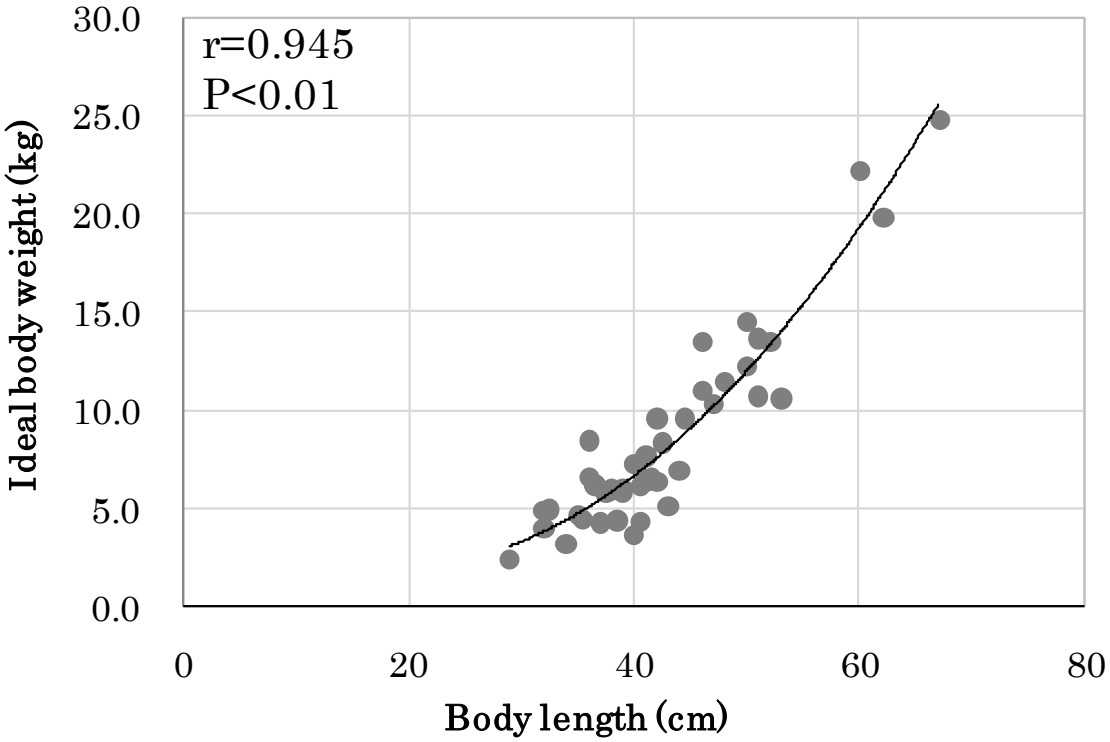



**Fig. 2 Position A**

A scatter diagram of the relation between the body length from the episternum to the ischial tuberosity and the ideal body weight in all subject dogs (n=42)

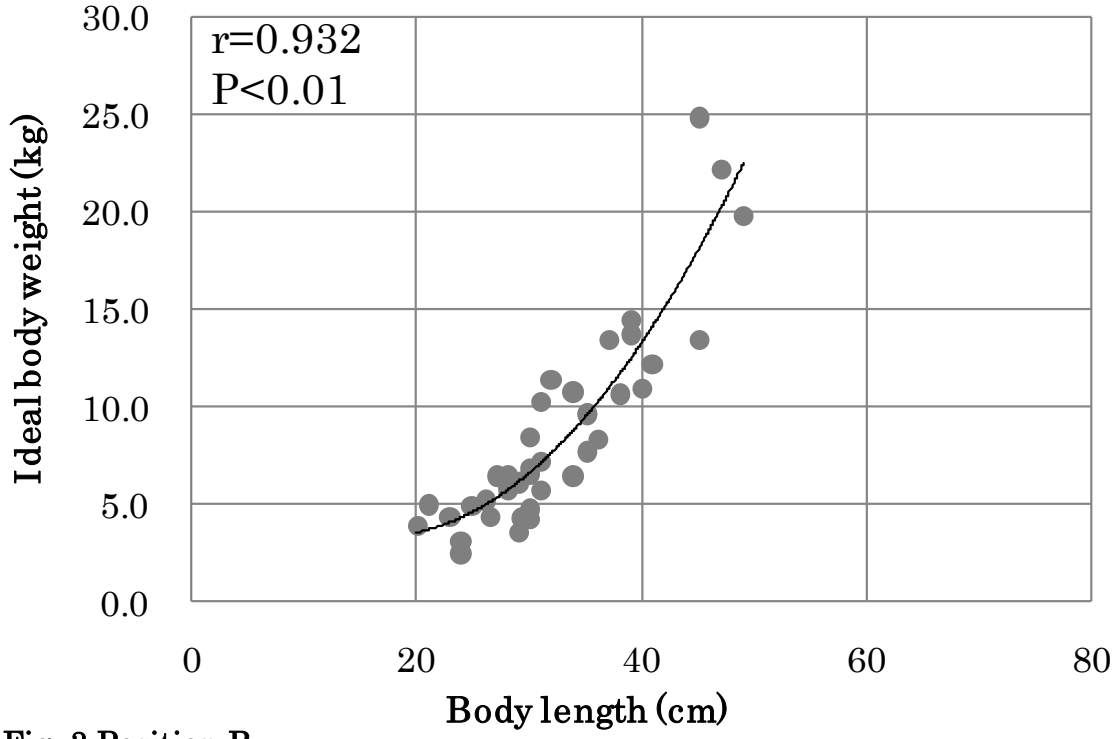



**Fig. 3 Position B**

A scatter diagram of the relation between the body length from the cranial angle of the scapula to the base of the tail and the ideal body weight in all subject dogs (n=42)

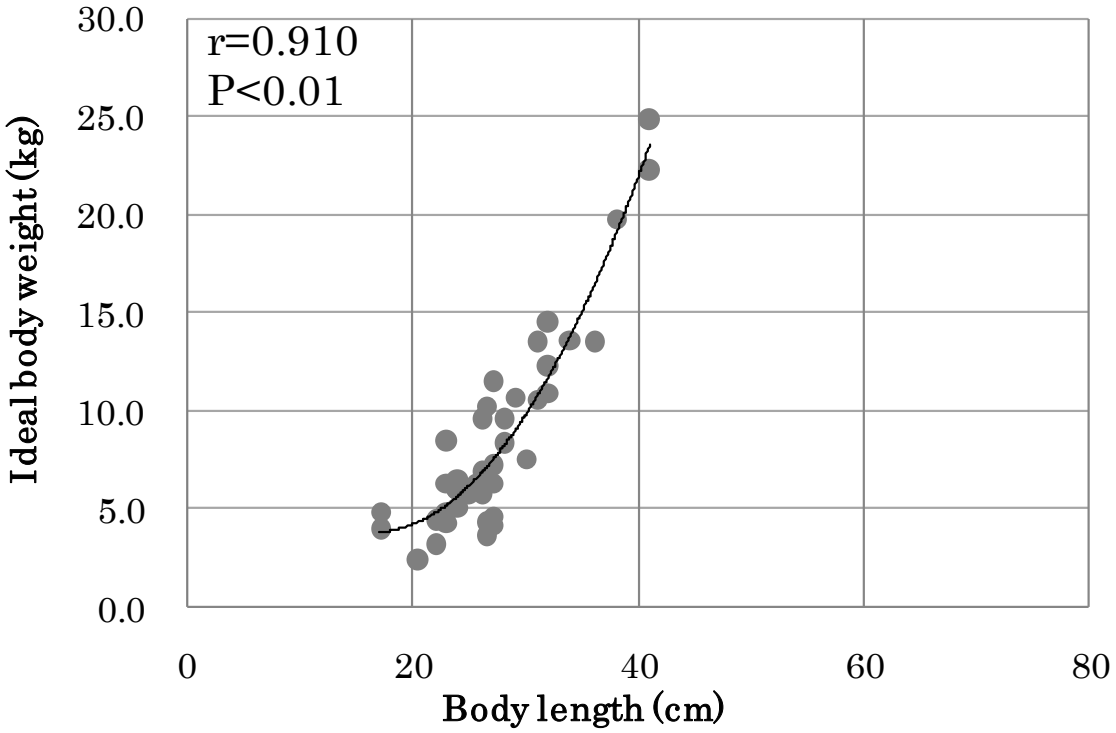



**Fig. 4 Position C**

A scatter diagram of the relation between the body length from the cranial angle of the scapula to the sacral tuber of the ilium and the ideal body weight in all subject dogs (n=42)

Thus, the highest correlation was found between the body length A and IBW. Using the regression equation for this measurement position, we can estimate the IBW of a dog from its body length. For example, the IBW of a dog with a body length of 40cm would be 5.2 kg. If this dog's current BW is 6.0 kg, it is 1.15 times the IBW. This give us a BCS of 4. Table2 shows estimated BCS for a range of body length and BW. Using this table, it can be estimated that a dog with a body length of 45cm and a current BW of 8.5 kg has a BCS of 4. We converted morphometric values to BCS rather than BMI, because BCS is a widely accepted concept among veterinary practitioners. The results presented here are preliminary, but increasing the sample size will certainly enhance the accuracy and reliability of the equation.

Currently in small animal clinics, BCS assessment is performed by visual inspection and palpation that require experience and training but still cannot remove all subjectivity. Body length and BW measurements using a ruler and a weighing scale, on the other hand, can objectify the process and estimate dog's BCS without expensive equipment or skills. Even untrained owners can easily evaluate the BCS. This will help the owners to understand the actual body condition of the dog during weight

management.

In summary, we evaluated whether a simple morphometric measurement could predict the body condition of dogs. We found the highest correlation between the ideal weight and the distance between the episternum to the ischial tuberosity and obtained an equation to estimate IBW from body length. The BCS was then determined based on how far the current BW was from the IBW. Although preliminary, these results suggest that morphometry can be a practical alternative to the current BCS systems. Future studies should include a larger sample size encompassing dogs of various body lengths and types.

**Table 2.** Method of estimating BCS by using a table of the relation between the body length and the current body weight

| | BCSs corresponding to the current body weight (kg) | | | | |
|---|---|---|---|---|---|
| **Body length (cm)** | **BCS1** | **BCS2** | **BCS3** | **BCS4** | **BCS5** |
| 25.0 | 1.4 | 1.5～1.6 | 1.6～2.0 | 2.0～2.2 | 2.2 |
| 26.0 | 1.5 | 1.5～1.7 | 1.7～2.1 | 2.1～2.3 | 2.3 |
| 27.0 | 1.6 | 1.6～1.8 | 1.8～2.2 | 2.3～2.4 | 2.5 |
| 28.0 | 1.7 | 1.8～1.9 | 2.0～2.4 | 2.4～2.6 | 2.6 |
| 29.0 | 1.9 | 1.9～2.1 | 2.1～2.6 | 2.6～2.8 | 2.8 |
| 30.0 | 2.0 | 2.0～2.2 | 2.3～2.7 | 2.8～3.0 | 3.0 |
| 31.0 | 2.1 | 2.2～2.4 | 2.4～3.0 | 3.0～3.2 | 3.2 |
| 32.0 | 2.3 | 2.3～2.6 | 2.6～3.2 | 3.2～3.5 | 3.5 |
| 33.0 | 2.5 | 2.5～2.8 | 2.8～3.4 | 3.5～3.7 | 3.8 |
| 34.0 | 2.7 | 2.7～3.0 | 3.1～3.7 | 3.7～4.0 | 4.1 |
| 35.0 | 2.9 | 2.9～3.3 | 3.3～4.0 | 4.0～4.3 | 4.4 |
| 36.0 | 3.1 | 3.2～3.5 | 3.6～4.3 | 4.3～4.7 | 4.7 |
| 37.0 | 3.4 | 3.4～3.8 | 3.8～4.6 | 4.7～5.0 | 5.1 |
| 38.0 | 3.6 | 3.7～4.1 | 4.1～5.0 | 5.0～5.4 | 5.5 |
| 39.0 | 3.9 | 3.9～4.4 | 4.4～5.3 | 5.4～5.8 | 5.9 |
| 40.0 | 4.2 | 4.2～4.7 | 4.7～5.7 | 5.8～6.2 | 6.3 |
| 41.0 | 4.5 | 4.5～5.0 | 5.1～6.1 | 6.2～6.7 | 6.7 |
| 42.0 | 4.8 | 4.8～5.4 | 5.4～6.6 | 6.6～7.2 | 7.2 |
| 43.0 | 5.1 | 5.2～5.7 | 5.8～7.0 | 7.1～7.6 | 7.7 |
| 44.0 | 5.4 | 5.5～6.1 | 6.2～7.5 | 7.5～8.1 | 8.2 |
| 45.0 | 5.8 | 5.9～6.5 | 6.6～8.0 | 8.0～8.7 | 8.8 |
| 46.0 | 6.2 | 6.2～6.9 | 7.0～8.5 | 8.5～9.2 | 9.3 |
| 47.0 | 6.5 | 6.6～7.4 | 7.4～9.0 | 9.1～9.8 | 9.9 |
| 48.0 | 6.9 | 7.0～7.8 | 7.9～9.5 | 9.6～10.4 | 10.5 |
| 49.0 | 7.3 | 7.4～8.3 | 8.4～10.1 | 10.2～11.0 | 11.1 |
| 50.0 | 7.8 | 7.9～8.7 | 8.8～10.7 | 10.8～11.7 | 11.8 |
| 51.0 | 8.2 | 8.3～9.2 | 9.3～11.3 | 11.4～12.3 | 12.4 |
| 52.0 | 8.7 | 8.8～9.7 | 9.9～11.9 | 12.0～13.0 | 13.1 |
| 53.0 | 9.1 | 9.2～10.3 | 10.4～12.6 | 12.7～13.7 | 13.8 |
| 54.0 | 9.6 | 9.7～10.8 | 10.9～13.2 | 13.3～14.4 | 14.5 |
| 55.0 | 10.1 | 10.2～11.4 | 11.5～13.9 | 14.0～15.2 | 15.3 |
| 56.0 | 10.6 | 10.8～12.0 | 12.1～14.6 | 14.7～15.9 | 16.1 |
| 57.0 | 11.2 | 11.3～12.5 | 12.7～15.3 | 15.5～16.7 | 16.9 |
| 58.0 | 11.7 | 11.8～13.2 | 13.3～16.1 | 16.2～17.5 | 17.7 |
| 59.0 | 12.2 | 12.4～13.8 | 13.9～16.8 | 17.0～18.4 | 18.5 |
| 60.0 | 12.8 | 13.0～14.4 | 14.6～17.6 | 17.8～19.2 | 19.4 |

# CHAPTER 5

## Conclusion

In order to improve the diagnostic accuracy of BCS, a BCS palpation model was developed. The model prototype had a stacking rubber sheet, sponge rubber sheet, and fake fur over the dog's artificial ribs to give a feeling equivalent to each BCS. The analysis of BCS using this prototype model revealed that variation due to the evaluator was significantly smaller.

The BCS prototype model was improved, commercialized, and evaluated by clinical veterinarians and dog owners. Veterinarians reported that the palpation feeling of the model was very similar to that of dogs. In addition, when questioned about clinical usage of this model, veterinarians replied that they will use it to notify dog owners of the results of BCS assessments and explain the nutrition management for their pets. Dog owners replied that the nutrition status could be well understood using the BCS model.

The above results were commercialized as a BCS palpation model in 2016 by Royal Canin, one of the leading manufacturers of pet food. Initially, it was used as a promotional tool for developing prescription diets for canine weight loss program in Japan; however, due to the massive success of the BCS palpation model, a similar promotion will be carried out in 2018, utilizing this tool in animal hospitals around the world . To this point, 14,000 sets of the model have been produced for domestic consumption, as well as 18,000 sets for overseas consumption.

The BCS palpation model cannot support visual inspection in a BCS assessment. Therefore, the challenge was to develop a morphometric BCS assessment method. A strong correlation was discovered between the body length from the sternal to the sciatic process, and the ideal body weight. By using this relationship, ideal body weight can be calculated from the body length. The relationship between the divergence from ideal body weight and BCS has already been clarified; therefore, the BCS can be obtained by the degree of divergence from the standard weight to the current weight, and is easily calculated using the parameters of body length and current weight. Although it has not been commercialized yet, if incorporation into the

electronic medical record is possible, it seems that the morphometric BCS assessment method will spread to animal hospitals with the popularization of electronic medical records.

Similar to dogs, the success rate of weight loss programs in humans is not necessarily high. The relationship between obesity and sickness is evident, and quantitative measurement of fat mass in the clinic is important. Hopefully, the technologies developed from this study will help to improve the quality of life (QOL) of canines.

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