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Characteristics of obese or overweight dogs visiting private Japanese veterinary clinics

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ABSTRACT

Objective: To characterize obese or overweight dogs that visited private Japanese veterinary clinics located in humid subtropical climate zones.

Methods: Dogs were categorized into four body condition score groups and five body size groups based on their breed. Multilevel logistic regression models were applied to the data. A *Chi*-squared test was used to examine whether the percentage of obese or overweight dogs differed between breeds.

Results: There were 15.1% obese dogs and 39.8% overweight dogs. Obese dogs were characterized by increased age and female sex, whereas overweight dogs were characterized by increased age and neuter status ($P < 0.05$). Peak probabilities of dogs being either obese or overweight were between 7 and 9 years of age, with the probabilities then declining as the dogs got older. For example, in toy sized dogs, the probability of dogs being overweight increased from 33.4% to a peak of 55.1% as dog age rose from 1 to 8 years old. Also, in medium, small and toy sized dogs, neutered dogs were more likely to be overweight than intact dogs, whereas neutered small sized dogs were more likely to be obese than intact small sized dogs ($P < 0.05$). Additionally, the percentages of obese or overweight dogs differed between the 10 selected breeds with the highest percentage of obese or overweight dogs.

Conclusions: By taking age, body size, sex and neuter status into account, veterinarians can advise owners about maintaining their dogs in ideal body condition.

1. Introduction

Numbers of obese and overweight people are increasing in developed countries [1,2]. Also, excessive body weight is a growing problem in dogs [3], and has been implicated in a range of medical concerns such as diabetes mellitus, cardiovascular diseases, dyslipidemia and osteoarticular diseases [4–6]. Dog obesity in developed countries is also a widespread problem. The prevalence (%) of dogs being obese and overweight in the USA, the UK, Australia and China reported was estimated to be 34.1% [5], 59.3% [7], 25.0% [8] and 44.4% [9], respectively.

Factors commonly associated with dogs having excessive body weight are middle age, neutering, female sex, low physical activity and also low human population density [4,5,7,9]. Specific breeds, such as Labrador Retrievers, Beagles and Shetland Sheepdogs, have also been reported as being at highest risk of either obesity or being overweight [5,10]. For example, Cocker Spaniels have been reported as having the highest risk for being overweight, whereas Shetland Sheepdogs were at the highest risk of obesity [5].

Dogs could also be categorized into different size groups based on their breed [4,11], such as large, medium and small size; this would take account of some breed effects. However, no studies in Japan have used medical records in a single model to quantify the characteristic factors (body size, age, sex, neuter status and human population density) associated with

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dogs being either obese or overweight, and the interactions between these factors.

Dogs' veterinary medical records are in a multi-level structure because health related checks, guidance and treatments on an individual dog are all performed in a clinic. The clinic is a variable that includes some unique information, such as a dog's location, the average social and economic status of owners coming with their dogs to the clinic, and veterinary health guidance. Therefore, the objective of the present study was to examine characteristic or risk factors and interactions associated with obese dogs and overweight dogs in Japan by using a mixed-effects model with clinics as a random intercept.

2. Materials and methods

2.1. Dog database including dog characteristics and body condition score (BCS)

Institutional Animal Care and Use Committee approval at Meiji University (IACUC 15-0013) was obtained for this study. A dog database has been created at Meiji University (Kawasaki, Japan) by cooperating with a veterinary service (Spectrum Lab Japan, Tokyo, Japan). The veterinary service recorded information about individual dog's characteristics (BCS, age, sex, neuter status and breed) when they received serum samples for lipoprotein analysis from veterinarians in private clinics throughout Japan. The veterinarians who submitted the samples were not informed about the specific purposes of the present study. The serum samples were collected from clinically non-diseased dogs that received a health check and from dogs that were being assessed for suspected dyslipidemia. The dogs' health conditions were diagnosed by their veterinarians when the serum samples were taken. The BCS for each dog was evaluated by the dog's veterinarian using a five-point scale system (1: thin, 2: underweight, 3: ideal, 4: overweight and 5: obese). The BCS five-point scale system is widely used in Japan [12], and website information and brochures about the system are widely available to veterinary clinics across Japan, provided by the Pet Food Institute (Washington D.C., USA) and a nutrition company [Hill's-Colgate (Japan) Ltd., Tokyo, Japan].

2.2. Data and exclusion criteria

The database comprised data of 9 120 dogs from 116 breeds, collected from 1 198 veterinary clinics between 2006 and 2013, amounting to 10.9% of the 11 032 small animal clinics in Japan [12]. The samples were submitted from all the 47 prefecture regions, which are mostly located in humid subtropical climate zones. The proportions of the samples in Northern Japan, East Japan (including Tokyo), West Japan and Kyushu were 9.6%, 56.7%, 28.1% and 5.6%, respectively. Additionally, the proportions of the samples submitted in January to March, April to June, July to September and October to December were 20.9%, 29.5%, 24.9% and 24.7%, respectively.

Records of second or later visits were not used in the present study (2 170 records). Records of dogs having diabetes mellitus, hypothyroidism or hyperadrenocorticism health problems, which would influence body condition, were excluded from the dataset (563 records) if the veterinarians had made a diagnosis of endocrine diseases from blood and urinary tests, on the basis of clinical signs such as polydipsia and polyuria. Also, the records of dogs with BCS 1 were excluded (12 records) because those dogs were few and were suspected of having a health problem. With the exception of the above exclusion criteria, all the other cases submitted by the clinics were included in the present study.

Two datasets were created in the present study. Dataset 1 (including BCS 2, 3, 4 and 5 dogs) contained the records of 5 605 dogs in 108 breeds from 1 094 clinics, and was used to investigate characteristic factors associated with obese dogs. In Dataset 2 (including only dogs of BCS 2, 3 and 4), dogs with BCS 5 were excluded (844 records) because this dataset was used to examine factors only related to overweight dogs with BCS 4. Hence, Dataset 2 included the records of 4 761 dogs in 103 breeds from 1 020 clinics.

2.3. Categories and definitions

Obese and overweight dogs were defined as dogs having BCS 5 and BCS 4, respectively. Additionally, dogs were classified into two sex groups (male dogs or female dogs) and also two neuter status groups (intact dogs or neutered dogs). The dogs in the 103 breeds were grouped into six body size categories (breed body size) based on their breed [6]: giant (*e.g.* Saint Bernard), large (*e.g.* Labrador Retriever), medium (*e.g.* Beagle, Pembroke Welsh Corgi), small (*e.g.* Miniature Schnauzer, Shetland Sheepdog), toy (*e.g.* Chihuahua, Miniature Dachshund, Pomeranian, Shih Tzu, Yorkshire Terrier) and unknown. In the present study, giant sized dogs (23 records) were included in the large sized dog group because there were relatively few samples. Finally, the unknown group consisted of mixed breed dogs. In addition, human population density (people per km^2) values were based on the population density of the city where each clinic was located, and were obtained from the Statistics Bureau in the Ministry of Internal Affairs and Communications, Japan [13].

2.4. Statistical analysis

All statistical analyses were performed using SAS software (SAS Institute Inc., Cary, USA). Two-level analysis was applied, using a clinic at level 2 and an individual dog at level 1, to take account of the hierarchical structure of the individual dogs within a clinic. A two-level mixed-effects logistic regression model, using the GLIMMIX procedure with logit link function, was performed to determine risk factors for obese or overweight dogs. Also, ILINK (inverse link function) was used to convert the logit to a probability [14]. Pairwise multiple comparisons were performed using the Tukey–Kramer test.

Outcome variables in Models 1 and 2, respectively, were whether or not dogs were obese (1 or 0; reference category = dogs with BCS 2 – 4), and whether or not dogs were overweight (1 or 0; reference category = dogs with BCS 2 and 3). Age, sex, neuter status, breed body size groups and human population density were included in both Models as possible factors (explanatory variables). Quadratic expressions of continuous variables (*e.g.* age) and all possible Two-way interactions between explanatory variables were also examined in both Models, and were then removed from the Models if they were not significant ($P > 0.10$). The years when BCS was evaluated were taken as a fixed effect in the Models, even though in preliminary analysis the year was not associated with the probability of dogs being obese or overweight ($P \geq 0.11$). Additionally, both Models included the clinic as a random intercept. To assess the variations in the probability of dogs being obese or overweight that could be explained by the clinic, intraclass correlation coefficients (ICC) were calculated by the following equation [15],

$$\rho = \frac{\sigma^2_{\text{Clinic}}}{\sigma^2_{\text{Clinic}} + (\pi^2/3)}$$

where ρ represents the ICC, σ^2_{Clinic} is the between-clinic variance and $\pi^2/3$ is the assumed variance at the individual dog level. Normality of the residuals in the final Models was evaluated by using normal probability plots [14]. Finally, for the 10 breeds with the highest percentages of obese or overweight dogs and with at least 60 dogs in Dataset 1, a *Chi*-squared test was used to examine whether or not the percentage of obese or overweight dogs differed between the 10 breeds.

3. Results

BCS (mean ± SEM) and median BCS in the 5 827 dogs, excluding BCS 1 dogs, were 3.6 ± 0.01 and 4.0, respectively. Also, mean age at sampling was 8.4 ± 0.05, ranging from 0 to 18 years old. Relative frequencies (%) of BCS 2, 3, 4 and 5 were 3.7%, 41.4%, 39.8% and 15.1%, respectively (Table 1). Mean population density (people per km^2) was 5 859 ± 76 people, ranging from 29 to 21 882 people.

Table 1

Relative frequency of 5 605 dogs categorized on the basis of BCS* and breed body size.

Measurements		*N*	%
BCS	2: underweight	207	3.7
	3: ideal	2 325	41.4
	4: overweight	2 229	39.8
	5: obese	844	15.1
Breed body size†	Giant	24	0.4
	Large	281	5.1
	Medium	408	7.4
	Small	1 676	30.6
	Toy	2 696	49.3
	Unknown‡	397	7.2

*: Dogs with BCS 1 (12 dogs) were excluded because those dogs were suspected of having a health problem; †: The remaining records (5 605) were treated as missing values; ‡: Unknown group consisted of mixed breed dogs.

Obese dogs were characterized by increased age and being female, whereas overweight dogs were characterized by increased age and neuter status (Table 2; $P < 0.05$). Increased age was non-linearly associated with a higher probability of dogs being obese or overweight ($P < 0.05$). The probability of dogs being either obese or overweight peaked between 7 and 9 years of age, and then declined (Figure 1). Female dogs were 1.3 times (odds ratio = 1.3; $P < 0.01$; Table 3) more likely to be obese than male dogs, but no such association was found between the groups for being overweight ($P = 0.29$; Table 2).

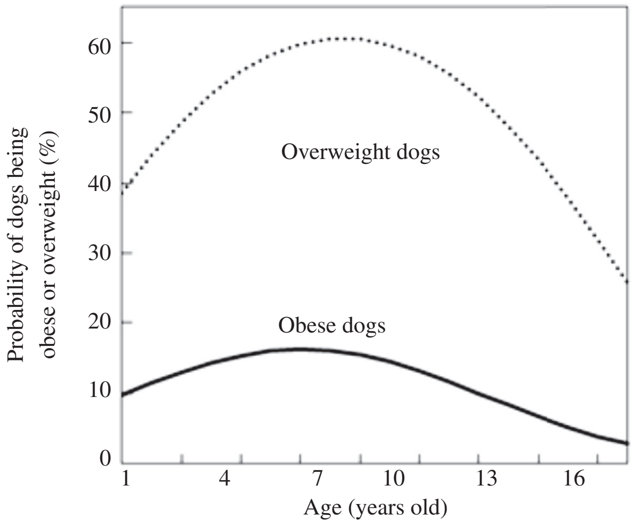

Figure 1. Estimated probability of dogs being obese or overweight at different age.

Breed body size groups were associated with obesity ($P < 0.01$; Table 2), but not for being overweight ($P = 0.16$; Table 2). Medium sized dogs were 1.4 times more likely to be obese than toy sized dogs (odds ratio = 1.4; $P = 0.03$; Table 3). In addition, there was a two-way interaction between dog age

Table 2

Estimates of fixed effects, random effect variance and ICC included in the final models for the probability of dogs being obese or overweight*.

Fixed effects (factors), variance and ICC		Being obese		Being overweight	
		Estimate	*P*-value	Estimate	*P*-value
Intercept		−2.452 7 ± 0.254 2	< 0.01	−1.263 3 ± 0.191 4	< 0.01
Age (years old)		0.222 3 ± 0.055 0	< 0.01	0.273 4 ± 0.039 9	< 0.01
Age squared		−0.015 8 ± 0.003 4	< 0.01	0.016 2 ± 0.002 4	< 0.01
Sex groups	Female dogs	0.229 0 ± 0.084 7	< 0.01	–	
Neuter status	Neutered dogs	0.109 6 ± 0.123 7	0.10	0.331 8 ± 0.100 3	< 0.01
Breed body size groups	Large	−0.091 3 ± 0.059 9	< 0.01	0.484 9 ± 0.427 4	0.16
	Medium	−0.050 6 ± 0.047 3		−0.784 9 ± 0.425 6	
	Small	0.034 6 ± 0.033 4		0.422 0 ± 0.217 0	
	Unknown†	0.004 1 ± 0.447 0		−0.074 3 ± 0.432 3	
	Population density (people/km^2)	–		−0.000 1 ± 0.000 0	0.04
Age × breed body size groups	Large	–		−0.098 0 ± 0.042 7	< 0.01
	Medium	–		0.087 5 ± 0.041 3	
	Small	–		−0.058 0 ± 0.022 0	
	Unknown†	–		−0.020 6 ± 0.037 0	
Neuter status × breed body size groups	Large with neutering	0.134 0 ± 0.400 0	0.06	−0.291 9 ± 0.311 4	0.02
	Medium with neutering	−0.523 3 ± 0.307 4		0.216 1 ± 0.293 3	
	Small with neutering	0.363 2 ± 0.225 2		−0.327 2 ± 0.155 7	
	Unknown with neutering†	0.575 7 ± 0.399 6		0.596 4 ± 0.308 1	
Clinic variance		0.510 0 ± 0.093 0		0.260 0 ± 0.093 0	
ICC (%)		15.5		7.9	

*: Sampling year is not shown in the table; †: Unknown group consisted of mixed breed dogs.

Table 3

Comparisons between characteristic variables for the probability of dogs being obese or overweight.

Explanatory variables		Probability of dogs being obese*		Odds ratio (95% confidence interval)	P-value	Probability of dogs being overweight†		Odds ratio (95% confidence interval)	P-value
		N	Mean ± SE‡ (%)			N	Mean ± SE (%)		
Sex group	Male dogs	2 459	15.8 ± 1.1^{b}	Reference		2 125	44.8 ± 1.6	Reference	
	Female dogs	2 770	13.0 ± 1.0^{a}	1.3 (1.1–1.5)	< 0.01	2 310	43.1 ± 1.7	1.1 (0.9–1.2)	0.29
Neuter status group	Intact dogs	1 756	15.7 ± 1.0	Reference		1 523	39.4 ± 2.2^{b}	Reference	
	Neutered dogs	3 473	13.0 ± 1.4	1.2 (0.9–1.6)	0.10	2 912	48.5 ± 1.6^{a}	1.4 (1.2–1.8)	< 0.01
Breed body size groups	Large	305	11.4 ± 2.2^{bc}	0.7 (0.4–1.0)	0.07	265	36.4 ± 3.8	0.6 (0.8–1.4)	0.75
	Medium	408	21.3 ± 2.5^{a}	1.4 (1.1–1.9)	0.03	324	43.5 ± 3.5	0.8 (0.6–1.1)	0.19
	Small	1 676	9.7 ± 0.9^{c}	0.6 (0.4–0.7)	< 0.01	1 495	42.5 ± 3.4	0.8 (0.7–0.9)	< 0.01
	Toy	2 696	16.0 ± 1.0^{b}	Reference		2 249	48.2 ± 1.6	Reference	
	Unknown§	397	15.4 ± 2.6^{bc}	1.0 (0.6–1.5)	0.82	324	49.5 ± 1.4	1.1 (0.8–1.4)	0.54

*: The remaining records (5 605) were treated as missing values; †: Dogs with BCS 5 were excluded, and the remaining records (4 761) were treated as missing values; ‡: Mean and SE were estimated by mixed-effects multivariable models; §: Unknown group consisted of mixed breed dogs; a–c: Within a column different letters are significantly different ($P < 0.05$).

and breed body size groups for the probability of dogs being overweight ($P < 0.01$; Table 2). In toy sized dogs, the probability of dogs being overweight increased from 33.4% to a peak of 55.1% as dog age rose from 1 to 8 years old (Figure 2). Also, in medium sized dogs, the probability of dogs being overweight increased from 19.5% to a peak of 48.9% as dog age rose from 1 to 10 years old.

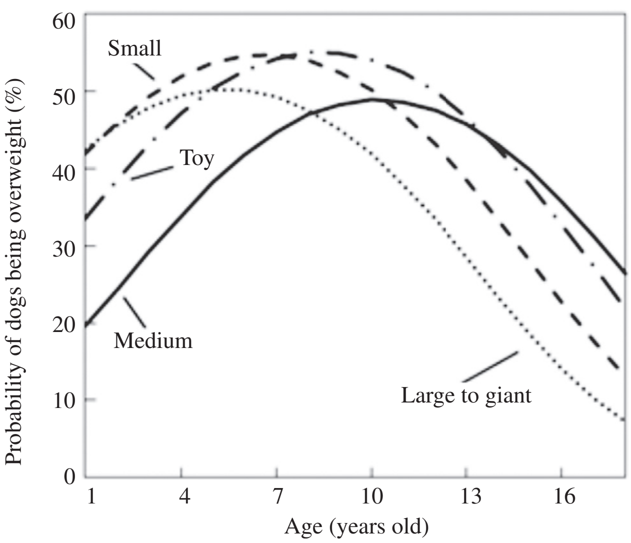

Figure 2. Estimated probability of dogs in different breed body size groups being overweight at different age.

Neuter status was associated with being overweight ($P < 0.01$; Table 2), but not with obesity ($P = 0.10$). Neutered dogs were 1.4 times (odds ratio = 1.4; $P < 0.01$; Table 3) more likely to be overweight than intact dogs. There was a two-way interaction between neuter status and breed body size groups for the probability of dogs being obese ($P = 0.06$; Table 2). Neutered small sized dogs were more likely to be obese than intact small sized dogs ($P < 0.05$; Table 4). In intact dogs, medium sized dogs were more likely to be obese than the other sized dogs. However, for neutered dogs, there were no differences in the probabilities of large, medium, small and toy sized dogs being obese (Table 4). Also, there was a two-way interaction between neuter status and breed body size groups for the

Table 4

Comparisons between neuter status and breed body size groups for the probability of dogs being obese or overweight.

Probability of dogs	Breed body size groups	Intact dogs		Neutered dogs	
		N	Mean ± SE* (%)	N	Mean ± SE (%)
Being obese	Large	91	10.2 ± 3.3^{bc}	196	12.7 ± 2.5^{b}
	Medium	135	24.9 ± 4.2^{a}	242	18.0 ± 2.6^{ab}
	Small	586	7.8 ± 1.2^{cy}	965	11.9 ± 1.2^{bx}
	Toy	806	15.3 ± 1.4^{bc}	1727	16.8 ± 1.1^{ab}
	Unknown†	90	11.5 ± 3.6^{bc}	277	20.4 ± 2.7^{a}
Being overweight‡	Large	81	35.9 ± 5.7	168	36.8 ± 3.7^{d}
	Medium	103	36.9 ± 5.4^{y}	194	47.6 ± 4.0^{cx}
	Small	538	42.4 ± 2.4^{y}	848	50.3 ± 3.9^{cx}
	Toy	680	44.1 ± 2.1^{y}	1427	52.4 ± 1.5^{bx}
	Unknown†	80	38.1 ± 6.0^{y}	218	60.9 ± 3.7^{ax}

*: Mean and SE were estimated by mixed-effects multivariable models; †: Unknown group consisted of mixed breed dogs; ‡: Dogs with BCS 5 were excluded; a–c: Within a column different letters are significantly different ($P < 0.05$); x,y: Within a row different letters are significantly different ($P < 0.05$).

probability of dogs being overweight ($P = 0.02$; Table 2). Neutered medium, small and toy sized dogs were more likely to be overweight than respective sized intact dogs ($P < 0.05$; Table 4). For intact dogs, there were no differences between breed body size groups for the probability of dogs being overweight ($P \geq 0.10$), whereas for neutered dogs, the small and toy sized dogs were more likely to be overweight than large sized dogs ($P < 0.05$). There was an association between overweight dogs and the population density of the cities where the clinics were located ($P = 0.04$; Table 2), although there was no such association between obese dogs and city population density ($P = 0.20$).

Miniature Dachshunds had the highest percentage in obese dogs, whereas Chihuahuas had the highest percentage in overweight dogs. A *Chi*-square test also showed that there were clear differences in the percentages of obese or overweight dogs between different breeds ($P < 0.05$; Table 5). Finally, the ICC showed that the clinic effect explained 15.5% and 7.9% of the total variation for the respective probabilities of dogs being obese or overweight.

Table 5

Top 10 breeds with the highest percentages of obese or overweight dogs out of 103 breeds studied*.

Rank	Obese dogs			Overweight dogs		
	Breeds	N	%	Breeds	N	%
1	Miniature Dachshund	355	29.3	Chihuahua	260	61.2
2	Chihuahua	362	28.2	Pomeranian	195	55.9
3	Pembroke Welsh Corgi	58	25.9	Miniature Dachshund	251	54.6
4	Beagle	130	26.2	Mongrel	324	54.0
5	Shiba Inu	165	24.2	Shih Tzu	443	53.1
6	Labrador Retriever	79	22.8	Beagle	96	53.1
7	Mongrel	397	18.4	Shiba Inu	125	52.0
8	Pomeranian	232	16.0	Maltese	178	48.3
9	Shih Tzu	521	15.0	Yorkshire Terrier	236	46.2
10	Cavalier King Charles Spaniel	132	14.4	Miniature Schnauzer	659	43.1

*: Only selected breeds with more than 60 dogs.

4. Discussion

The present study quantified the effects of increased age on dogs being obese or overweight, and showed that the effects differed between breed body size groups for overweight dogs. It also showed that the probability of dogs being obese or overweight decreased from middle age in dogs of all sizes. Increasing age is related to decreasing physical activity, lean body mass and maintenance energy requirements [16,17]. It appears that energy intake in some young to middle aged dogs of all sizes is not being managed appropriately by their owners. The decline from middle age in the probability of dogs in our study being obese or overweight might be explained by a decline in the appetite of dogs aged 7 years or older, as was found in a previous study [17]. Another possible reason is that dogs of middle age or older are more likely to have unrecorded chronic disease that reduces their digestive capability and causes moderate weight loss.

Furthermore, our study suggests that the changes with age in appetite, energy requirements and energy expenditure also depend on dog body size and breed [18]. Our study revealed that medium sized dogs, including Beagles and Corgis, were 1.4 times more likely to be obese than toy sized dogs. Both Beagles and Corgis had 20% or more obese dogs in our study. These findings are consistent with another study that reported Beagles being prone to obesity [5]. The breed differences of being obese appear to be related to genes related to fat metabolism which are hypothesized to be due to the breed selection process in dogs [19,20].

The high odds ratios of female dogs being obese in our study are consistent with the results of a previous study [9]. Also, our study indicated that neutering accentuates the propensity for medium, small and toy sized dogs to be overweight and accentuates the propensity for small sized dogs to be obese. This could be explained by the fact that neutering appears to cause a reduced metabolic rate [17]. Neutering predisposes dogs to having excessive body weight by reducing the concentrations of androgens and estrogens that act as satiety factors in the central nervous system [3].

Our study showed characteristic factors, including breeds, for obese dogs were not completely same as for overweight dogs. A previous study analyzing specific diseases related to obese and overweight dogs found some differences between obesity and being overweight for diseases [5]. For example, diabetes mellitus was associated with obesity but not with being overweight, whereas hyperadrenocorticism (Cushing's disease) was related to being overweight but not with obesity [5]. Being overweight may be a symptom different from obesity, and may have slightly different characteristics from obesity [7]. Also, our study indicates that breed and genetics differently affect the propensity of dogs being obese or overweight, as shown by the differences in the percentages of obese or overweight dogs between the 10 highest risk breeds. This could explain some of the difference in characteristics for being obese or overweight.

Our study showed the population density of the city where the dogs' clinics were located was associated with the probability of dogs being overweight, but not with the probability of them being obese. Previously, an Australian study using a three-point scale system (underweight, correct-weight or overweight) reported that dogs living in rural and semi-rural areas were at greater risk of being overweight than urban dogs, due to high amounts of feeding and less exercise time [4,8]. The similar results in the two studies suggest that in Japan there is a difference in the lifestyles of dogs and their owners between rural and densely populated areas.

Our study is the first report indicating relatively large differences between clinics in the probability of dogs being obese or overweight, as indicated by the respective ICCs of 15.5% and 7.9% for clinic variance in the probability of dogs being obese and overweight. This suggests that there are relatively large explained effects of the clinic in relation to obese dogs, such as clinic location, dog owner's social status and veterinarians' guidance for dogs' dietary and exercise management [21,22].

In conclusion, our study characterized obese or overweight dogs by age, sex, neutering status and breed body size. This finding could help veterinarians to improve their advice to owners on how to maintain their dogs in ideal body condition, by taking age, body size or dog breed, and neuter status into account.

Finally, it should be noted that there are some limitations in this present study. Dogs were not randomly selected because it was a cross-sectional study using veterinarian-submitted samples from private clinics. Consequently, there was a lack of information on diseases affecting BCS (*e.g.* protein losing nephropathy) because we did not collect specific disease data except for endocrine diseases. Our study may include dogs with false positive test results of endocrine diseases, and diseased dogs which were not tested due to subtle clinical signs. Additionally, the dogs' rearing environments and nutrition were not taken into account in the analyses. The level of agreement between the BCS evaluations conducted by the participating veterinarians was not evaluated. However, our statistical models included the clinic as a random effect. Even with such limitations, this research provides valuable information for veterinarians about the risk factors related to dog obesity and being overweight.

Conflict of interest statement

We declare that we have no conflict of interest.

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