

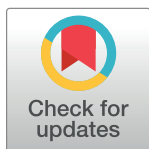
RESEARCH ARTICLE

Profile qualitative variables on the dynamics of weight loss programs in dogs

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Abstract

Obesity is the most common nutritional disorder in dogs and it is associated with many comorbidities. Some obesity risk factors have already been established, however, the evaluation of the effect of different individual variables on weight loss induced by calorie restriction, although very important, is still poorly explored. The weight loss protocol can be updated and improved by more precise and adjusted equations throughout the weight loss program in the clinical routine practice. Therefore, the objective of this study was to analyze weight loss program dynamics in groups according to reproductive status, age, body size, and breed, as well as to define more accurately the amount of calories per target metabolic weight throughout the program. Data of 1,053 cases, presented between 2012 and 2019 at the Veterinary Hospital of the School of Veterinary Medicine and Animal Science of the University of São Paulo (FMVZ-USP) were retrospectively analyzed. A total of 77 obese dogs (body condition scores 8/9 or 9/9) of different ages, breeds, sizes, and reproductive status were selected. These dogs did not have any concomitant illnesses and successfully completed the weight loss program. Statistical analysis was performed and values of $p \leq 0.05$ were considered significant. The proposed weight loss program was based on an energy restriction protocol where daily energy intake (in kcal) was estimated as $70 \text{ kcal} \times \text{target weight}^{0.75}$. The target weight (TW) was defined as 80% of the animal's current weight. The average calorie intake for weight loss (calories \times target weight^{0.75}) was lower for spayed females (62.36), differing from intact males (66.14) and neutered males (65.41), while intact females (63.66) showed intermediate values without differing between groups ($p = 0.015$). There were no differences between weight loss calories according to age ($p = 0.473$) or body size ($p = 0.084$), allowing the use of the same mathematical equation for intact and neutered dogs; for dogs older than 1 year and of different body sizes. Regarding the breed, the average calorie intake was lower ($p = 0.002$) in mixed breed dogs ($61.54 \times \text{TW}^{0.75}$) when compared to obesity-prone purebred dogs ($64.17 \times \text{TW}^{0.75}$) and other purebreds ($65.27 \times \text{TW}^{0.75}$). It was concluded that spayed females and mixed breed dogs have greater difficulty in losing weight, that is, they need fewer calories per metabolic body weight for the

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weight loss program to succeed. A more accurate equation for energy requirement for weight loss can improve chances of success, therefore improving compliance and helping clinical management of obesity in dogs.

Introduction

Canine obesity is a complex condition with a high prevalence (around 40% to 50%) among the worldwide population of dogs [1–5]. Overweight is associated with certain diseases, such as orthopedic [6–8], cardiovascular [9–13] and respiratory [14–17], metabolic disorders like insulin and leptin resistance [18, 19], hyperlipidemia [20–22], immunoinflammatory response alterations [23], and reduced lifespan [24], which can be partially or completely reversed after weight loss despite reaching ideal body condition score [23]. Additionally, overweight also relates to an increased risk for anesthesia [25].

Previous studies have already identified some factors associated with obesity in dogs such as female gender, neutering, increased age, medium body sized dogs, and specific breeds, being Labrador Retrievers and Beagles the most susceptible [1–3, 22–31]. However, the comparison of the behavior and the dynamics of the weight loss program in these different groups has been insufficiently studied.

The first step to promote weight loss is the establishment of a negative energy balance [32]. The use of mathematical equations that can be customized throughout the program can help achieve success during weight loss plans. The objectives of this study were to evaluate a canine weight loss program to identify the effect of differences in reproductive status, age, body size, and breed and to suggest equations according to these results.

Material and methods

The experimental procedures were approved by the Animal Use Ethics Committee (AUEC) from the School of Veterinary Medicine and Animal Science of the University of São Paulo (protocol number 4883300921).

Data from 1,053 cases of obesity atendidos from the Nutrition Staff of the Internal Medicine Service of the Veterinary Hospital of the University of Sao Paulo, Brazil, between 2012 and 2019 were retrospectively analyzed. A total of 112 cases of dogs with body condition score $\geq 8/9$ [26], with no other diseases and which underwent a weight loss program were selected. Thirty-five dogs (35) were removed from the study because owners did not strictly comply with the proposed dietary management (limited portion size of commercial diet and limitation of treats). Therefore, this study was completed with 77 dogs.

The proposed weight loss program was based on an energy-restriction protocol, in which the daily calorie intake corresponded to 60% of their maintenance energy requirement [33], corresponding to the energy requirement for weight loss (ERWL): $70\text{kcal} \times \text{target weight}^{0.75}$ per day [18, 34, 35]. The target weight (TW) was defined as 80% of the animal's current weight. All cases were managed with different commercial dry extruded diets recommended for the treatment of obesity, as indicated by the manufacturers [32].

In order to avoid insufficient or excessive weight loss and the loss of muscle mass, the minimum and maximum weekly weight loss rates (WWLR) were set between 1 and 2% of current body weight per week [36]. When weight loss was not between the calculated interval, ERWL was reduced or increased in 10% [34, 36].

Animals were reassessed and weighed every two weeks to adjust the weight loss protocol if needed and to ensure that it was strictly followed. Time variables were set at the beginning (0), 30, 60, 90, 120, and 150 days after the start of the weight loss program for comparison purposes.

All weight loss programs were carefully followed by experienced professionals. Therefore, it was possible to plot and determine the weight loss curve and the energy requirement over time using the same equation [17, 18, 34] to determine the amount of calories per $TW^{0.75}$, as well as the development of an adjusted equation based on the results for each one of them.

Dogs were listed in 4 different groups distinguished by reproductive status (neutered male; intact male; spayed female; and intact female), age (from 1 to 8 years old or older than 8 years), breed (mixed breed dogs; purebred dogs popularly known as obesity-prone like Golden Retriever, Labrador, Beagle, English Bulldog, Pug, Cavalier King, Cocker Spaniel, and Dachs-hund; and purebred dogs not obesity-prone), and body size [small size (up to 15 kg); medium size (15 to 25 kg); large and giant size (over 25 kg)]. The definition of size based on the animal's weight was adapted from Hosgood & Scholl [37].

Statistical analysis was performed with PROC MIXED from the Statistical Analysis System (SAS) software version 9.3. When differences between the averages were detected, these were compared using the Tukey test. The effects of group (reproductive status, age, body size, and breed), time (the variation throughout the weight loss program), and the interaction between group and time were verified; the interaction between the groups (reproductive status, age, body size, and breed) was not verified due to the variety of combinations and possibilities. For the preparation of the curves and regression analysis, the PROC REG tool of the same statistical software was used. Values of $p \leq 0.05$ were considered significant.

Results

Reproductive status

Spayed females needed fewer calories per $TW^{0.75}$ when compared to neutered and intact males ($p = 0.015$). The energy requirement was, on average, 62.36, 65.41, and 66.14 per $TW^{0.75}$ for spayed females, neutered males, and intact males, respectively (Table 1); intact females (63.66 per $TW^{0.75}$) showed intermediate values without differing between groups.

There was no difference in the interaction between reproductive status and time ($p = 0.5282$). There was, however, an effect of time ($p < 0.001$) throughout the weight loss program and the need for fewer calories as the program progressed. This result was also verified in other variables: reproductive status, age, body size, and breed.

Table 1. Calorie intake per target weight^{0.75} according with reproductive status.

Variable	Spayed female	Intact female	Neutered male	Intact male	Average	SEM	<i>P</i> ¹		
	(n = 38)	(n = 17)	(n = 14)	(n = 8)			Reproductive status	Time	Group* time
Total weight loss	62.36 ^B	63.66 ^{AB}	65.41 ^A	66.14 ^A	64.77	0.333	0.015	<0.001	0.5282
Beginning of weight loss	70	70	70	70	70	0	-	-	-
30 days	66.39	67.16	68.19	67.66	67.03	0.491	-	-	-
60 days	62.61	64.48	65.90	66.00	63.99	0.617	-	-	-
90 days	60.86	62.99	65.27	63.93	62.53	0.799	-	-	-
120 days	58.23	60.59	62.09	65.22	59.96	1.028	-	-	-
150 days	57.37	57.56	60.25	69.94	58.29	1.224	-	-	-

^{A-B} Averages in the same line followed by different letters differed by 5% in the Tukey test adjusted by PROC MIXED.

¹Probability for reproductive status, time, and reproductive status* time interaction.

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Table 2. Calorie intake per target weight^{0.75} according with age.

Variable	1 to 8 years (n = 40)	> 8 years (n = 37)	Average	SEM	P ¹		
					Age	Time	Age* time
Total weight loss	64.60	64.95	64.76	0.333	0.473	<0.001	0.587
Beginning of weight loss	70.00	70.00	70.00	0.000	-	-	-
30 days	66.59	67.50	67.03	0.491	-	-	-
60 days	63.10	64.94	63.98	0.617	-	-	-
90 days	62.56	62.50	62.53	0.799	-	-	-
120 days	60.37	59.48	59.96	1.028	-	-	-
150 days	59.17	57.22	58.29	1.225	-	-	-

¹Probability for effect of age, time, and age* time interaction.

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Age

In this study, age was not a determining factor for weight loss since no differences were observed for dogs aged 1 to 8 years when compared to dogs older than 8 years ($p = 0.473$) (Table 2).

Body size

There was no effect of size ($p = 0.084$) and interaction of size and time ($p = 0.476$) during the evaluation of the weight loss program (Table 3).

Breed

An effect of breed was observed during the weight loss program ($p = 0.002$), where mixed breed dogs required lower calorie intake (Table 4). The breeds popularly known as prone to obesity [Golden Retriever (n = 6); Labrador Retriever (n = 17); Beagle (n = 2); English Bulldog (n = 2); Pug (n = 2); Cavalier King (n = 1); Cocker Spaniel (n = 1); and Dachshund (n = 2)] showed no differences when compared to the remaining evaluated breeds [Weimaraner (n = 1); Yorkshire (n = 1); Schnauzer (n = 1); Lhasa Apso (n = 2); German Shepherd (n = 1); Shetland Shepherd (n = 1); Pinscher (n = 4); and Poodle (n = 7)]. Also, there was no difference in the breed by time interaction ($p = 0.078$).

Table 3. Calorie intake per target weight^{0.75} according with body size.

Variable	Small ¹ (n = 28)	Medium ² (n = 12)	Large and giant ³ (n = 37)	Average	SEM	P ⁴		
						Body size	Time	Body size* time
Total weight loss	64.82	62.51	62.92	64.76	0.333	0.084	<0.001	0.476
Beginning of weight loss	70.00	70.00	70.00	70.00	0.000	-	-	-
30 days	67.41	65.34	67.19	67.03	0.491	-	-	-
60 days	65.53	62.60	63.32	63.99	0.617	-	-	-
90 days	64.96	63.22	60.75	62.53	0.799	-	-	-
120 days	61.70	59.37	58.98	59.96	1.028	-	-	-
150 days	59.59	60.23	57.11	58.29	1.225	-	-	-

¹Small sized animals (up to 15 kg)

²Medium sized animals (15 to 25 kg)

³Large or giant animals (over 25 kg)

⁴Probability for effect of size, time and interaction size* time.

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Table 4. Calorie intake per target weight^{0.75} according with breed.

Variable	Predisposition to obesity ¹ (n = 33)	Mixed breed (n = 26)	Other purebreds ² (n = 18)	Average	SEM	P ³		
						Breed	Time	Breed* time
Total weight loss	64.17 ^A	61.54 ^B	65.27 ^A	64.77	0.333	0.002	<0.001	0.078
Beginning of weight loss	70.00	70.00	70.00	70.00	0.000	-	-	-
30 days	66.85	66.32	68.38	67.03	0.491	-	-	-
60 days	64.64	62.83	64.63	63.99	0.617	-	-	-
90 days	63.08	60.08	64.6	62.53	0.799	-	-	-
120 days	61.61	56.26	62.06	59.96	1.028	-	-	-
150 days	60.68	53.95	62.00	58.29	1.224	-	-	-

^{A-B} Averages in the same line followed by different letters differed by 5% in the Tukey test adjusted by PROC MIXED.

¹Breeds popularly classified as prone to obesity [Golden Retriever (n = 6), Labrador (n = 17), Beagle (n = 2), English Bulldog (n = 2), Pug (n = 2), Cavalier King (n = 1), Cocker Spaniel (n = 1), Dachshund (n = 2)]

²Other breeds [Weimaraner (n = 1), Yorkshire (n = 1), Schnauzer (n = 1), Lhasa Apso (n = 2), German Shepherd (n = 1), Shetland Shepherd (n = 1), Pinscher (n = 4), Poodle (n = 7)]

³Probability for effect of breed, time and breed*time interaction.

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Adjustment of the weight loss equation based on the weight loss period

Regarding the development of a weight loss mathematical equation adjusted for the weight loss period, a general equation for an accurate energy requirement prediction ($p < 0.001$) was proposed (Fig 1). The regression analyses and complete distribution of the kcal x TW^{0.75} according to reproductive status (Fig 2), age (Fig 3), body size (Fig 4), and breed (Fig 5) were also significant ($p < 0.001$).

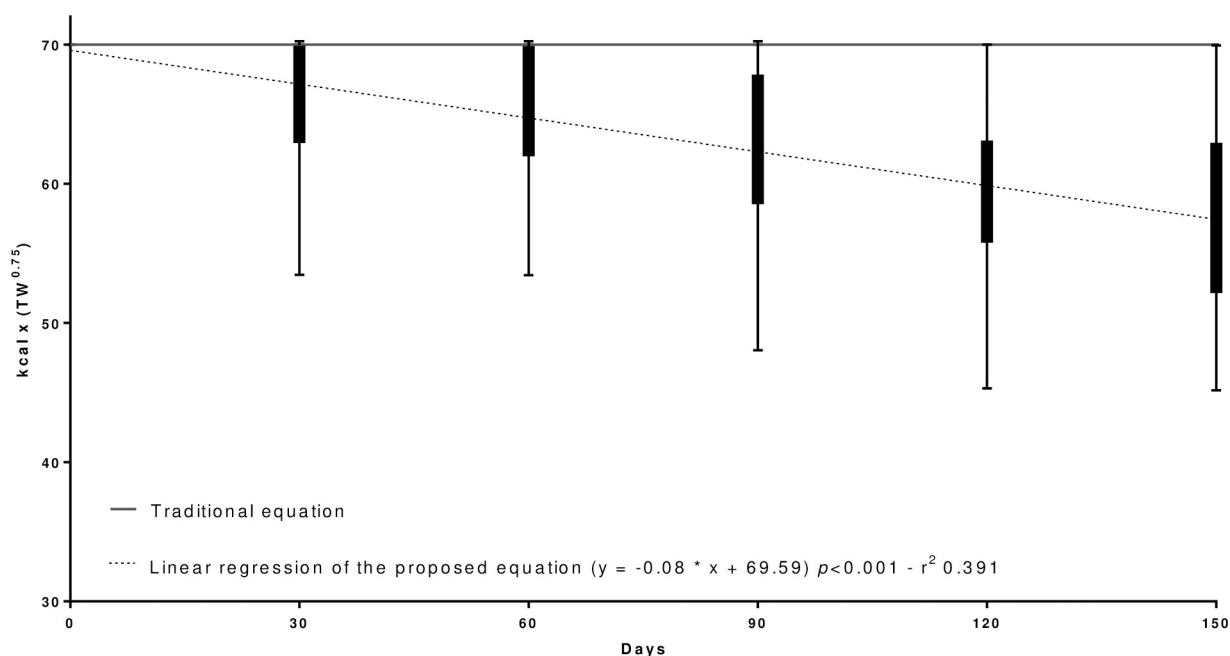


Fig 1. Regression analysis and complete distribution of the general weight loss equation [kcal x (TW^{0.75})] adjusted during the weight loss period.

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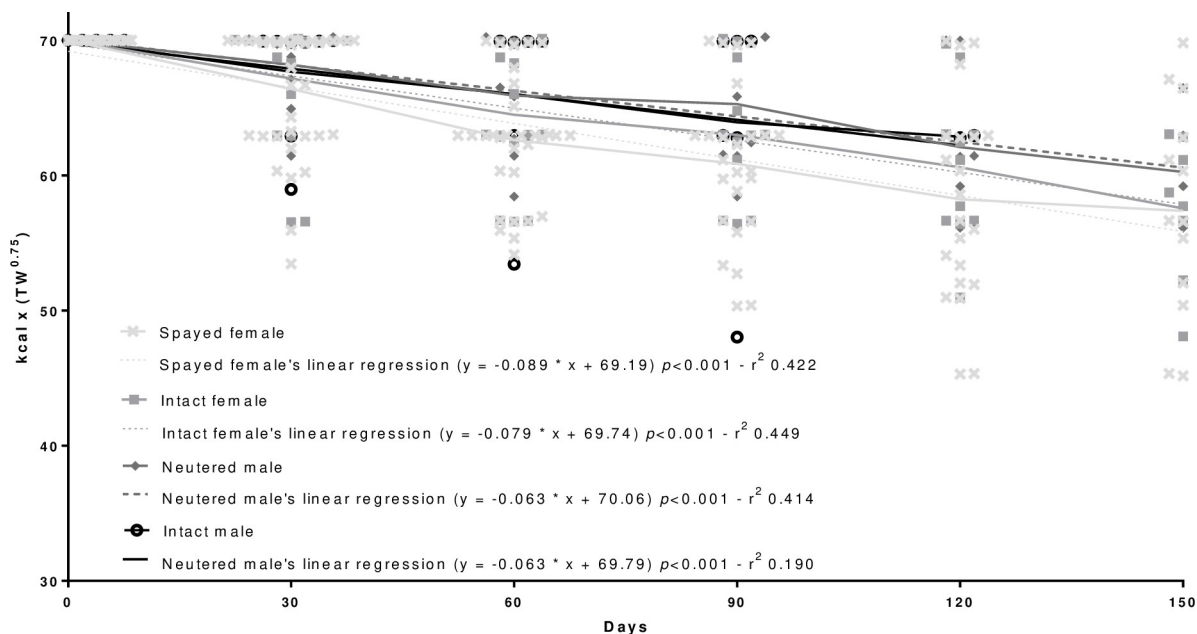


Fig 2. Regression analysis and complete distribution of the calories (kcal) applied to the weight loss equation [kcal x (TW^{0.75})] according with reproductive status.

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Discussion

Females are more susceptible for obesity in the canine population of Australia, United States, France, Sweden, China, Japan, and Spain [1–3, 29–31, 38], and the results are linked to the particularities of the male's and female's endocrine system. In this study, it was observed that

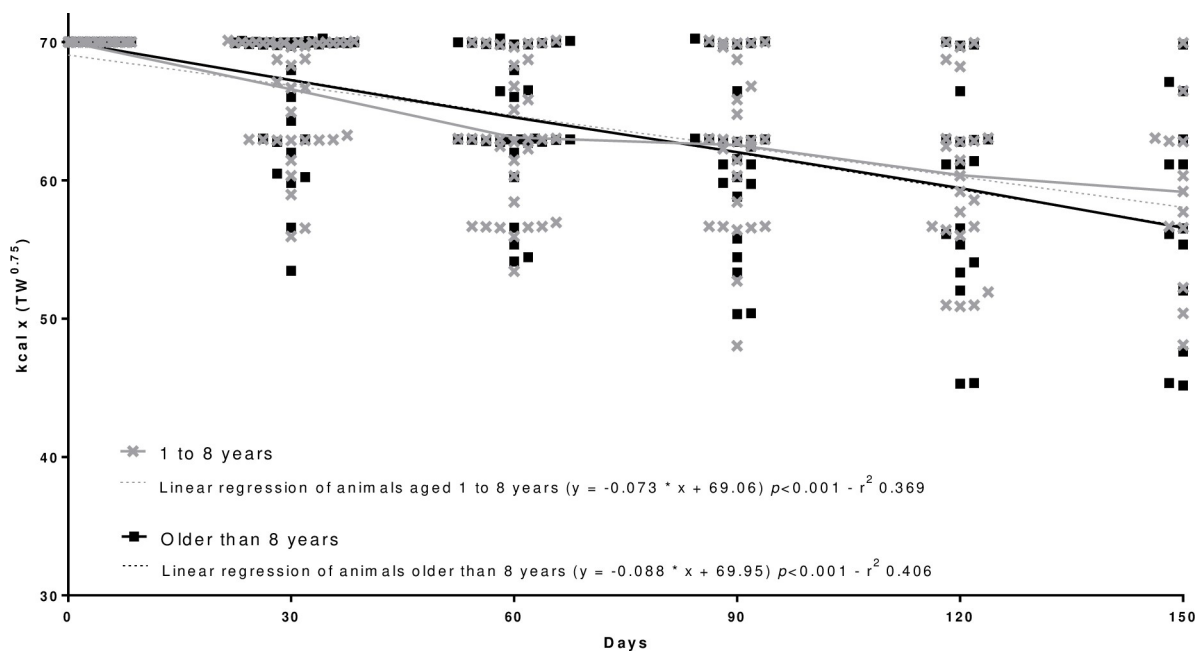


Fig 3. Regression analysis and complete distribution of the calories (kcal) applied to the weight loss equation [kcal x (TW^{0.75})] according with age.

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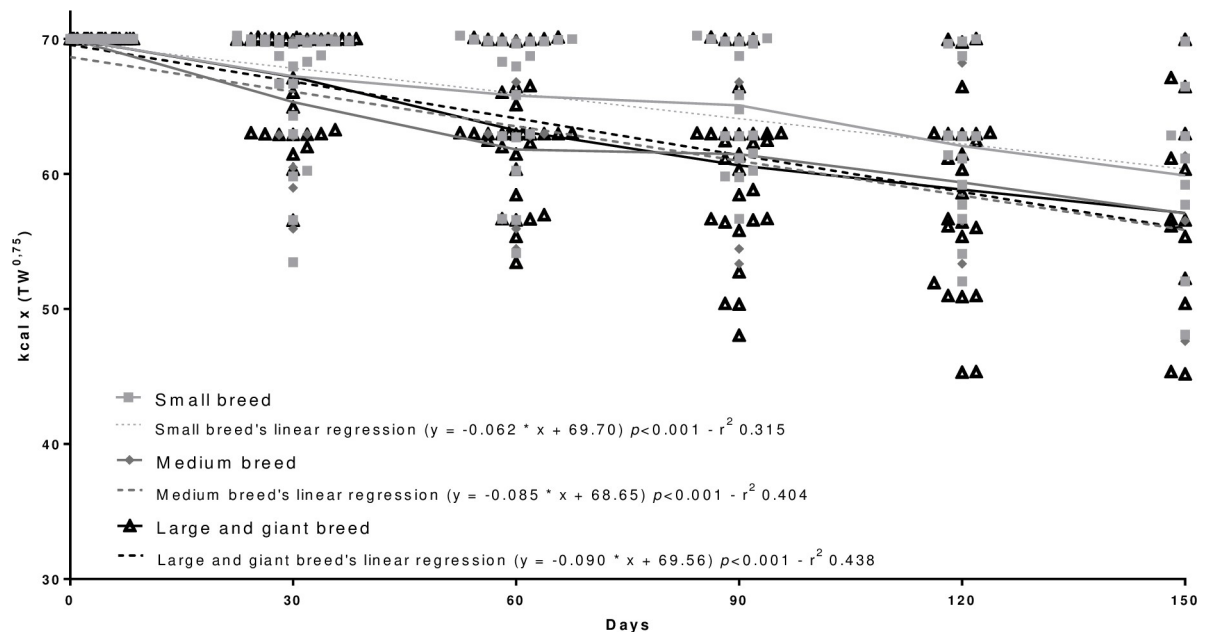


Fig 4. Regression analysis and complete distribution of the calories (kcal) applied to the weight loss equation $[kcal \times (TW^{0.75})]$ according with body size.

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spayed females required greater calorie restriction to lose weight in a weekly rate of 1 to 2%. This justifies the need to create an adapted equation that fits with the specific requirements to lose weight in an appropriate rate.

In males there is an abundant synthesis and circulation of androgen hormones (testosterone) with anabolic function, which promote an increase in lean mass. The muscle is a tissue

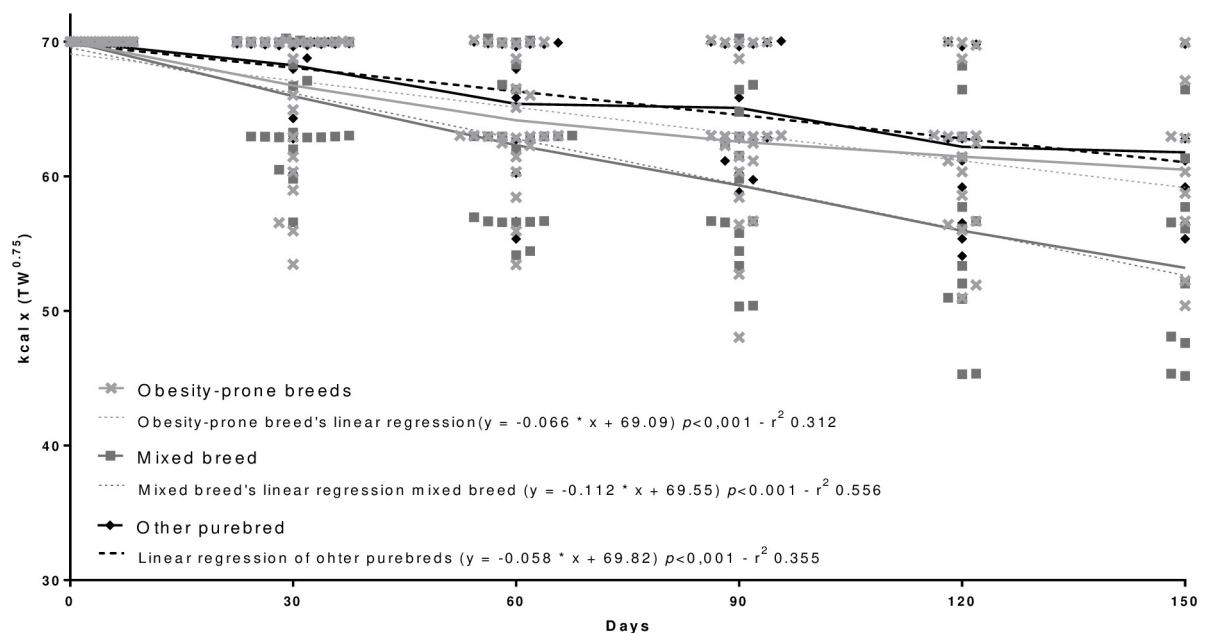


Fig 5. Regression analysis and complete distribution of the calories (kcal) applied to the weight loss equation $[kcal \times (TW^{0.75})]$ according with breed.

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with a high metabolic rate that, when associated with the low deposition of adipose tissue, prevents premature aging, locomotor diseases, and delayed decline in the metabolic activity [38]. This suggests that muscle mass helps to maintain an increased energy expenditure and therefore may help to prevent obesity. Furthermore, lean mass stimulates testosterone secretion, resulting in positive feedback. Thus, due to the lack of testosterone in the female, the beneficial effects mentioned above are attenuated, making the weight loss more efficient in male dogs [39].

In human medicine, although several studies also mentioned differences in weight loss success between men and women [40, 41], there is still no consensus on whether and how these physiological differences play a role. The adrenal is an important source of androgens in females [42], which means that even after the procedure for removing the gonads, there is a difference between females and males, which can be enhanced by reducing the energy demand after the procedure.

There are few reports in the literature comparing neutered and intact animals during weight loss programs. Flanagan et al. [43] demonstrated that sexually intact dogs undergoing weight loss programs lost more weight than neutered dogs ($p = 0.001$), while female dogs lost more weight than male dogs ($p = 0.007$). McGreevy et al. [29], Colliard et al. [30], Lund et al. [1], Mao et al. [2], Usui et al. [3], and Vendramini et al. [44] observed that neutered animals are more predisposed to obesity. These findings have the same explanation based on the role of the sex hormones because after neutering there is a decrease in circulating anabolic hormones and, consequently, a decrease in the animal's metabolic rate [39]. Thus, the increase in food intake and the decrease in energy demand after neutering [45] influence the energy mobilization for weight loss in a more impactful way on females. There is also an imbalance between the groups, which can be considered a possible limitation.

Many important physiological changes involving body composition and basal metabolic rate occur with aging [46]. The difference in body composition of dogs can be explained by the increase in the frequency of obesity observed over the years, with body fat increasing from 18% in dogs younger than 1.5 years to 27% in dogs older than seven years [47].

The lower basal metabolic rate may be explained by the decrease in the secretion of anabolic and thermogenic hormones, such as triiodothyronine (T3), thyroxine (T4), growth hormone (GH), and insulin-like growth factor-1 (IGHF1) plus the increased circulation of inflammatory cytokines and physical inactivity [48]. In other studies, age was a risk factor for obesity in dogs [1–3, 29–31]. In this study, age was not a determining factor for weight loss. It is worth mentioning that the dogs included in the study, unlike those included in the above-mentioned studies, were diagnosed only with obesity and not with other comorbidities. The metabolic adaptations of obese animals allow fat to be used as a primary source of energy during the weight loss program, which may differ from obese dogs with chronic diseases. Obesity accompanied by other comorbidities is commonly observed in elderly dogs and decreases the body's ability to make the necessary metabolic adaptations necessary for a healthy weight loss program, and may use lean mass as source of energy and then compromise the weight loss program [48, 49].

The assessment of the possible relationship between body size and predisposition to obesity is scarce in the literature [3]. Sallander et al. [31] and Usui et al. [3] found, respectively, that large breeds are more predisposed to obesity and that medium-sized breeds are 1.4 times more likely to be obese when compared to miniature-sized dogs. When weight loss is considered, the data available in the literature are very similar to those observed in our study, and there were no differences between the groups ($p = 0.084$).

The results of the present study partially agree with some results found in the literature regarding breeds. Cocker Spaniels, Cavalier Kings, Dachshunds, and Labrador Retrievers are

more prone to obesity [1, 29–31, 50, 51] and, therefore, may have more difficulty losing weight. It is important to note that purebred animals were divided into two groups, one with the breeds most popularly known as predisposed to obesity, and the other with the remaining breeds.

The breed division made in this study was based on popular and unscientific communication and may limit our interpretation of the results. However, as already seen in our results, obesity-prone factors may not necessarily be linked to factors that facilitate or impair weight loss. Therefore, more research is required to answer this question. In addition, the caloric restriction required for weight loss was similar in the purebred groups, but higher in mixed breed dogs, thus demonstrating their difficulty to lose weight when compared to purebred.

The unprecedented assessment of the dynamics of weight loss in different groups compromise the comparisons to the literature, as well as the justification of the findings obtained. One of the possible justifications is based on evolution, which is the gradual genetic change of living organisms over time [52]. Theoretically, animals that spend less energy than others manage to provide a greater reserve for mating and reproduction and have greater reproductive success as a consequence [53]. Thus, in the context of survival and evolution, the greatest difficulty in weight loss is desirable, and it has become an evolutionary step. Mixed breed dogs (any dog who is not purebred and has a combination of two or more lineages of breeds) can still stand out in this context, when compared to breeds genetically selected for other characteristics (such as coat, size, or behavior). Gácsi, McGreevy, Kara & Miklósi [54] also raised an interesting hypothesis involving genetic influences, which states that the current mixed breeds may originate from a population that was under continuous selection for survival skills.

Among all dog breeds included in this study, Labrador Retrievers had the highest documented prevalence of obesity [1, 55], which has been justified recently by Raffan et al. [56], who observed that the deletion of the proopiomelanocortin (POMC) gene is related to the perception of satiety and, consequently, energy intake. Further studies are needed to clarify and contribute to the results, such as those of genomic and metabolomic evaluation of different breeds or mixed breeds. However, they already provided the basis for possible adjustments in the weight loss equations for an animal with greater difficulty to lose weight.

The equation applied in the obesity treatment routine and used by most veterinarians makes an initial proposal for calorie intake [17, 18, 34]. However, adjustments during the weight loss period are almost always necessary. Thus, the evaluation of all cases included in this study also enabled the development of a general ERWL equation based on the period of the weight loss program that the animal currently is, and makes possible the corrections for the previously proposed equation.

The regression analysis performed determined the amount of kcal per $TW^{0.75}$ by the equation $y = -0.08 * x + 69.59$, where X is the number of days in the weight loss program and Y the amount of calories per kg $TW^{0.75}$. In order to facilitate its use, the equation proposed is $kcal/TW^{0.75} = -0.08 * \text{days in weight loss program} + 70$.

Take for an example a random dog in a weight loss program that returns for a follow-up visit on the 18th day with an inadequate weight loss rate. The equation that best fits the program at that time for an adequate weight loss rate will be: $ERWL = (-0.08 * 18 + 70) \times \text{target weight}^{0.75} = \text{kcal/day}$. This means that on the 18th day, the veterinarian can adjust the weight loss by predicting the ERWL in a more accurate and precise way, using the personalized equation $ERWL = 68.56 \times \text{target weight}^{0.75}$. This equation is applicable as a general reference. However, as already described, equations adjusted over the weight loss period by reproductive status, age, body size, and breed were also developed in this study. These can be applied especially in those scenarios where there was a difference between the groups.

Despite the small determination coefficient, justified by the large individual variation of the animals (which is expected in a retrospective study with client-owned dogs), the regression proved to be significant for all dogs and can be a tool for determination of the amount of calories per $TW^{0.75}$ according with the weight loss period of these specific groups that behave more efficiently than the adjustments currently used in current practice. This is a pioneering study in evaluating the behavior and the dynamics of the weight loss program in dogs; and more studies are needed to better understand it.

It must be acknowledged that, as any other study developed with client-owned dogs, the self-reported compliance to the weight loss protocol is an important limitation. Also, as this was a retrospective study, data about exercise was not considered due to inconsistency of this information in dog's individual files. Furthermore, there was no standardization of the diet of the animals studied, despite all of them having been fed with extruded dry commercial food for weight loss programs. All these factors must be taken into consideration when developing further studies to overcome this problem. However, it must also be taken into consideration the fact that these limitations are a portrait of the real life when there is a team of trained veterinary nutritionists in a veterinary hospital and our results might be more accurate than laboratory and controlled conditions and more accurate for clinical practice.

Conclusion

In conclusion, females and mixed breed dogs have greater difficulty in losing weight, because they require greater energy restriction for the success of the weight loss program. In addition, the adjusted equation for weight loss, based on the proposed weight loss period, can be a tool to facilitate the clinical routine of the veterinarians, improve compliance of the owner, and benefit the overall health status of the dogs improving performance, time, and weight loss rates.

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Animal welfare statement

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to and the appropriate ethical review committee approval has been received. The authors confirm that they have followed EU standards for the protection of animals used for scientific purposes and feed legislation.

Author Contributions

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Writing – review & editing: Thiago Henrique Annibale Vendramini, Márcio Antonio Brunetto.

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