Cohort study of the success of controlled weight loss programs for obese dogs

Alexander J. German; Joanne Titcomb; Shelley L. Holden; Yann Queau; Penelope J. Morris; Vincent Biourge

From the Department of Obesity and Endocrinology (German, Holden) and the School of Veterinary Science (German, Titcomb), University of Liverpool, Leahurst Campus, Chester High Road, Neston, Wirral CH64 7TE, United Kingdom; Royal Canin Research Center (Queau, Biourge), B.P.4 – 650 Avenue de la Petite Camargue, 30470 Aimargues, France; and the WALTHAM Centre for Pet Nutrition (Morris), Freeby Lane, Waltham-on-the-Wolds, Melton Mowbray, LE14 4RT, United Kingdom.

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Corresponding author

Dr Alexander J German. Department of Obesity and Endocrinology, University of Liverpool, Leahurst Campus, Chester High Road, Neston, CH64 7TE, UK.

ajgerman@liv.ac.uk

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Abstract

Background: Most weight loss studies in obese dogs assess rate and percentage of weight loss in the first 2-3 months, rather than the likelihood of successfully reaching target weight.

Objective: To determine outcome of controlled weight loss programs for obese dogs, and to determine the factors associated with successful completion.

Animals: 143 obese dogs undergoing a controlled weight loss program.

Methods: This was a cohort study of obese dogs attending a referral weight management clinic. Dogs were studied during their period of weight loss, and cases classified according to outcome as "completed" (reached target weight), "euthanized" (was euthanized before reaching target weight), or "stopped prematurely" (program stopped early for other reasons). Factors associated with successful completion were assessed using simple and multiple logistic regression.

Results: 87/143 dogs (61%) completed their weight loss program, 11 [8%] died or were euthanized, and the remaining 45 [32%] stopped prematurely. Reasons for dogs stopping prematurely included inability to contact owner, refusal to comply with weight management advice, or development of another illness. Successful weight loss was positively associated with a faster rate ($P<0.001$), a longer duration ($P<0.001$), and feeding a dried weight management diet ($P=0.010$), but negatively associated with starting body fat ($P<0.001$), and use of dirlotapide ($P=0.0046$).

67 **Conclusions and Clinical Relevance:** Just over half of all obese dogs on a controlled weight
68 loss program reach their target weight. Future studies should better clarify reasons for
69 success in individual cases, and also the role of factors such as activity and behavioral
70 modification.
71

ABBREVIATIONS

AAFCO	Association of American Feed Control Officials
AF	as fed
BMD	Bernese mountain dog
CKCS	Cavalier King Charles spaniel
CI	confidence intervals
DEXA	dual-energy X-ray absorptiometry
DM	dry matter
EBT	English bull terrier
F	female
FCR	Flat coated retriever
FOS	fructo-oligo saccharides
GR	Golden retriever
GSD	German shepherd dog
HPHF	high protein high fiber
HPMF	high protein medium fiber
M	male
ME	metabolizable energy
MER	maintenance energy requirement
NF	neutered female
NM	neutered male
OR	odds ratio
SBT	Staffordshire bull terrier
STROBE	Strengthening and reporting of observational studies in epidemiology
TDF	total dietary fiber

97 YT Yorkshire terrier

98

Background

The medical profession classifies human obesity as a disease,[1] and it is arguably the most important medical disease in dogs.[2] Recent studies have suggested that approximately half of all pet dogs are overweight[3,4] and that the prevalence has been steadily increasing.[5] Obesity is associated with many diseases, including orthopedic disease, diabetes mellitus, respiratory disease, and certain types of neoplasia.[2,3] Dogs that are overweight might also develop metabolic derangements,[6,7] altered renal function,[8] and respiratory dysfunction causing poorer oxygenation.[9] Obese dogs have a reduced quality of life,[10] and a shorter lifespan.[11] Given the large at-risk population, and the effects on health and quality of life, obesity is a major welfare concern. Management usually involves controlled weight loss through energy restriction using a purpose-formulated weight loss diet coupled with increased activity,[12-15] but licensed drug therapies are also available.[16,17]

The benefits of controlled weight loss in obese dogs are well established, with evidence of improvement in disease status,[18] reversal of metabolic derangements,[6,7] and improved quality of life.[10] However, studies are often of short duration, only assessing the initial phase of weight loss (e.g. first 2-3 months), and often use colony dogs with experimentally-induced obesity rather than client owned-dogs with naturally occurring disease.[16-18] As a result, simple outcomes are studied such as rate of weight loss, percentage weight loss and energy intake required to achieve weight loss.[13,14] Arguably, studies that assess the whole of the weight loss period and beyond are more desirable, and also focus outcomes such as success of reaching and maintaining target weight.[19] Human studies suggest that weight loss usually plateaus at 6 months on diet-based weight loss program, with most people never reaching their target weight,[20] or subsequently regaining a substantial amount within one year.[21] To the

124 authors' knowledge, only one previous study of dogs has reported success of a weight loss
125 program,[15] although the weight loss period was short (6 months), and it was not clear whether
126 all dogs had reached their target weight. In light of the limited information, the aims of the
127 current study were, first, to determine the proportion of obese dogs commencing a diet-based
128 weight loss program that successfully reached target weight and, second, to identify factors
129 associated with success.
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Methods

Study design

This was a cohort study of obese client-owned dogs designed to determine the outcome of controlled weight loss programs and the factors associated with successful completion. It has been reported according to the Strengthening and Reporting of Observational Studies in Epidemiology (STROBE) statement guidelines.[22]

Animals

The dogs in the cohort studied were all referred to the Royal Canin Weight Management Clinic, University of Liverpool UK, for investigation and management of obesity. Eligible cases were: originally seen between November 2004 and July 2012, started a weight management program, and reached a known end-point for their weight loss (i.e. completed, stopped prematurely, or died [see below]) by February 2013. Additional eligibility criteria included having data available from the preliminary investigations undertaken prior to weight loss (see below), and having had body composition analysis conducted by dual-energy X-ray absorptiometry (DEXA).[23] Given the study timeframe and broad eligibility criteria, dogs used in previous studies assessing weight loss in selected cases that successfully lost weight only,[13,14] and also in a study examining subsequent rebound after successful weight loss.[19] However, none of these studies examined the proportion of cases starting a weight loss program that successfully reached target weight. The study protocol adhered to the University of Liverpool Animal Ethics Guidelines, and was approved by the University of Liverpool Research Ethics committee, the Royal Canin ethical review committee, and the WALTHAM ethical review committee. Owners of all participating animals gave informed consent in writing.

Weight loss regimen

Complete details regarding the weight loss protocol used at the clinic have been described.[13,14] Briefly, dogs were determined to be systemically well, and without abnormalities that would make controlled weight loss inappropriate by complete blood count, serum biochemical analysis and urinalysis. Serum free thyroxine concentration was measured by equilibrium dialysis at an accredited external laboratory[a] to determine thyroid status. Throughout weight loss, dogs were weighed on electronic scales,[b] which were regularly calibrated using certified test weights.[c] Body composition was analyzed before and after the weight loss regime in all dogs, using fan-beam DEXA.[d] Body composition results from before weight loss were used to estimate ideal weight.[10,19] Briefly, the body composition data were entered into a computer spreadsheet,[e] containing a purpose-created mathematical formula to predict expected body composition after weight loss at different weights. The predictive equation was based upon typical body composition results from previous weight clinic studies.[13,14] This enabled an appropriate ideal body weight to be set, for the individual dog, to be used in energy intake calculations.

One of three purpose-formulated weight management diets was used for the weight loss protocol (Table 1), namely a high protein high fiber dry diet (HPHF dry),[f] a high protein medium fiber dry diet (HPMF dry),[g] and a high protein medium fiber wet diet (HPMF wet).[h] The choice of whether to feed dry food, wet food or a mix of the two depended upon what the owner had fed the dog prior to the weight loss period. Owner and dog preference was also used when choosing between the HPMF and HPHF dry diets (e.g. whether high fiber diets had been tolerated in the past). However, diet choice also depended upon availability and whether any reformulations had occurred. In this respect, both HPMF diets (dry and wet) were available for the whole of the study period, and the formulation did not change.

However, the HPHF diet first became available in June 2006, and was then reformulated in 2010 with a slight increase in moisture content, without major changes in the nutrient profile (Table 1), with 22 dogs of the 88 dogs fed this diet receiving the reformulated version. The ME content of both formulations was marginally different (before reformulation: 2900 Kcal/kg; after reformulation: 2865 Kcal/kg).

The initial food allocation for weight loss was determined by first estimating maintenance energy requirement (MER=440kJ [105Kcal] × body weight [kg]$^{0.75}$/day) [24] using the ideal weight of the dog, as determined by DEXA. The degree of restriction for each dog was then individualized based upon gender and other factors (i.e. presence of associated diseases), and was typically between 50-60% of MER at target weight.[13] Owners also received tailored advice on lifestyle and activity alterations to assist in weight loss. Further, five dogs whose weight loss had been slow also received oral dirlotapide[i] to aid weight loss, whilst four additional dogs had concurrent hypothyroidism (two diagnosed at the referring veterinarian, and two diagnosed at the time of initial referral) and also received levothyroxine.

Dogs were reweighed every 7-28 days and changes made to the weight loss plan if necessary.[13,14] Throughout the weight loss period, owners maintained a diary in which they recorded feeding of the purpose-formulated diet (amount offered and consumed), and any additional food that had been consumed (either given as treats or stolen). At each re-evaluation, progress was assessed and changes were made to the weight loss plan, as necessary. Where progress was good (e.g. weight loss of 0.5-2.0% per week in the first 6 months, and >0.3%/week thereafter), the weight loss protocol was not adjusted, except that the owner was always encouraged to increase activity whenever possible. If weight loss was deemed to have stalled (defined as either no change [0%] in weight or a gain of weight

between two appointments that were at least 14 days apart) or was deemed to be slow (<0.5%/week in the first 6 months, and <0.3% week thereafter), the potential causes were investigated based upon the information provided by the owner in diary records and discussions during the consultation. If poor compliance to the weight loss protocol was thought to be the cause, (i.e. additional food had been consumed) the amount of food fed was not altered, and advice was given to restore compliance; if the dog's activity levels had been less, then advice regarding activity was reiterated; however, where no obvious reason for poor progress could be identified, the amount of food fed was reduced by a readily-calculated amount (e.g. 5g dry food for small dog or 10g for large dog; ¼ sachet of wet food for a small dog or ¼ x 400g can for large dog) on each occasion. When weight loss was deemed to be too quick (>2%/week) the amount of diet was increased in similar increments. In addition to the official reweighs, contact was maintained at other times either by phone or email.

Classification of final outcome

Dogs were assigned to three groups, according to their outcome, as follows. Dogs that lost weight and reached their target were classified as 'completed'. Dogs that were euthanized before reaching target weight were classified as 'euthanized', and the reason was recorded where it was known. Finally, dogs that did not complete for other reasons were classified as 'stopped prematurely', and again the reason was recorded where it was known. This latter category included all dogs lost to follow up because their owners stopped attending the clinic. In such cases, owners were contacted at least 3 times by their preferred method of contact (telephone or email), and at least once by post.

Statistical Analysis

All data are expressed as median (range), except where indicated, and there were no missing data. Statistical analyses were performed with computer software,[j] with the level of significance set at $P<0.05$ for two-sided analyses. Given that this was an observational cohort study, and no such study had previously been conducted, a sample size calculation was not performed. Instead, the principle determinant of sample size was the number of dogs seen that met the eligibility criteria during the study timeframe. The Shapiro-Wilk test was used to determine whether or not datasets were normally distributed, and either parametric or non-parametric tests were then performed as appropriate. For continuous variables, differences amongst groups were assessed with the Kruskal-Wallis test, with *post hoc* comparisons made, where appropriate, using the Dwass-Steel-Critchlow-Fligner test.

The continuous variables analyzed by groups were age, body fat percentage before weight loss, percentage weight loss, duration of weight loss, rate of weight loss, metabolizable energy intake during weight loss, the number of times weight loss stalled (i.e. when there was no change in weight or weight gain between appointments), and the number of diet energy intake changes (i.e. when the weight management clinic staff adjusted down the daily food intake at the time of a recheck). Overall percentage weight loss and rate of weight loss were both expressed as a proportion of starting weight lost, and reported rates of weight loss are the average of the whole weight loss period. Duration of weight loss was calculated from the date of the first appointment to the date when target weight was reached (for those completing), or to the last available weight record (for those not completing). Where dogs were enrolled but then did not return for any reassessments, the duration was recorded as 0 days.

Categorical variables were compared, amongst dogs with different outcomes, using Fisher's exact test, and those assessed included breed, sex, neuter status, diet characteristics, concurrent hypothyroidism, and use of dirlotapide. The effect of breed was determined by first creating dummy variables for all breeds with more than 5 individuals (where 1 = dog of that breed; 0 = dog not of that breed). For sex comparisons, a dummy variable was created whereby male dogs were scored as 1 and female dogs as 0; a dummy variable was also created for neuter status whereby neutered dogs were scored as 1 and intact dogs as 0. The effect of diet was assessed in two ways: first, a dummy variable was created whereby comparing dogs fed dry food exclusively (including both those on HPHF and HPMF diets) were assigned a score of 1, to those fed either wet food exclusively, or a combination of dry and wet food were assigned a score of 2; second, where dogs were fed dry food exclusively, the type of dry food was also compared (1=HPHF diet; 0=HPMF).

In order to take account of possible confounding factors on the results obtained, logistic regression was performed. The outcome variable tested was success with weight loss, whereby dogs completing weight loss were assigned a score of 1, and those not completing were assigned a score of 0. Both 'intention-to-treat' (whereby dogs that were euthanized were included in the group not completing), and 'per-protocol' (whereby dogs that were euthanized were excluded) analyses were conducted. Initially, all variables listed above were tested separately with simple logistic regression. A multiple logistic model was then built, which initially included the variables identified as $P<0.2$ in simple regression. The model was then refined over multiple rounds using backwards-stepwise elimination, of the least significant variable each time, and variables were only retained in the final model if they were significant ($P<0.05$). Logistic regression results are reported as odds ratios (OR), 95% confidence intervals (95% CI) and the associated *P*-value.

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Results

Study animals and outcomes of weight loss

During the period of study, 160 dogs were referred to the clinic. Of these, 143 met the eligibility criterion of having a defined endpoint, and there were no missing data for any variable. The other 17 dogs were excluded because the weight loss period had not been completed at the time of data review. Of the 143 dogs, 87 (61%) completed, 11 (8%) were euthanized (by the referring veterinarian), and 45 (31%) stopped prematurely. Full details of all dogs finally included are given in Table 2. There were no differences in the proportions of the five most frequent breeds amongst groups (P>0.05 for all), and no differences for sex (P=0.57), starting weight (P=0.75) and body fat mass (P=0.16). However, age was different amongst groups (P=0.045), with dogs that were euthanized being older than those that completed the weight loss protocol. Three of the hypothyroid dogs completed the weight loss protocol, with the other dog stopping prematurely.

Outcomes of weight loss

Details of the outcomes of weight loss are reported in Table 3. For the whole cohort, percentage weight loss was 19.5 % (range -3.0 % to 43.9 %), median duration was 200 days (range 0-1149 days), and the corresponding rate of weight loss was 0.6 % per week (-0.3 to 2.2 % per week).

Comparison of baseline variables amongst groups

Comparisons were made amongst the three outcome groups (e.g. completed, euthanized, and stopped prematurely) for all baseline variables (Table 2). There were no differences in the proportions of the five most frequent breeds amongst groups (P>0.05 for all), and no differences for sex (P=0.57), starting weight (P=0.75) and body fat mass (P=0.16). However,

age was different amongst groups (P=0.045), with dogs that were euthanized being older than those that completed the weight program.

Comparison of weight loss outcomes amongst groups

Comparisons were made amongst the three outcome groups (e.g. completed, euthanized, and stopped prematurely) for all weight loss (Table 3). There were no differences in the median daily energy intake (per kg metabolic body weight) amongst groups (P=0.67), and also no differences for the number of times weight loss process stalled (P=0.37), the number of times food intake had to be reduced (P=0.16), and the use of dirlotapide (P=0.082). However, dogs that succeeded remained on their weight loss program longer (P<0.001), had faster overall rates of weight loss (P=0.001), and lost more weight overall (P<0.001). An effect of diet type was also seen, with more of the completing dogs having been fed dry food than either wet food or a mix of types (P=0.0077). However, there were no group differences in the type of dry food used (i.e. HPHF vs. HPMF diets, P=0.54).

Logistic regression analysis to determine factors associated with success

Given that a number of group differences were evident, logistic regression analysis was then used to determine factors associated with success, when taking account of any possible confounding. When assessed on an intention-to-treat basis, simple logistic regression (Table 4) identified that rate of weight loss (P=0.0092), duration of weight loss (P=0.014) and diet type (P=0.028) were positively associated with success, whilst starting body fat was negatively associated with success (P=0.029). Other factors were not significantly associated with weight loss, but qualified (at P<0.2) for inclusion in the initial multiple regression model including: age, breed (with Mixed Breed, Golden Retriever, and Yorkshire Terrier included independently), dirlotapide use, number of weight loss stalls, and number of changes to the

330 weight loss plan (Table 4). After the initial model was refined by backwards stepwise
331 elimination, the best-fit model was one that included six factors. Factors positively associated
332 with success included being of mixed breed (P=0.039), being fed a dry weight loss diet
333 (P=0.0095), rate of weight loss (a faster rate of weight loss in completing dogs, P<0.001), and
334 duration (a longer duration or weight loss in completing dogs, P<0.001), whilst factors
335 negatively associated with success included starting percentage body fat (P<0.001), and
336 dirlotapide use (P=0.0046). When data were instead analyzed on a per protocol basis by
337 excluding dogs that were euthanized, results were similar, except that the breed effect was no
338 longer evident (Table 4). Given that dogs fed wet food or a mix of food types were less
339 successful, there was a concern such a categorization might have inadvertently selected for
340 dogs with problematic feeding habits, since this category included those where diet type had
341 been changed. As a result, the analyses were repeated only to include dogs that had remained
342 on the same diet type for the whole of weight loss. Once again, a diet effect remained (simple
343 regression: OR 10.41, 95%-CI 1.22-89.00, P=0.032; multiple regression: OR 32.50, 95%-CI
344 2.02-458.68, P=0.016).

Discussion

This large study assesses the success of obese dogs at completing a controlled weight loss program and at reaching target body weight. The finding that 40% of dogs stopped prematurely is similar to a previously published study,[15] and suggests that controlled weight loss is challenging. However, whilst somewhat disappointing, this response rate is better than for humans who use diet-based strategies for losing weight where few individuals succeed with weight loss.[20] The weight loss period is only one aspect of the overall weight management process, which also includes maintaining weight long term and avoiding rebound. The fact that this aspect was not assessed in the current study is a limitation, although the population studied did include cases that also participated in a previous study that did specifically assess maintenance of weight in the post-weight-loss period.[19]

The large cohort size meant that we could also determine factors associated with success: associations were found with starting body fat percentage, overall rate of weight loss, duration of weight loss, and the type of food used. Given that the study was observational in nature, the reasons for such associations are not always clear and causality cannot necessarily be assumed, i.e. that the factors identify cause the dogs to complete or stop prematurely. Direct associations are more likely when associations are identified with factors present at the outset of the controlled weight loss program, such as body fat mass. Here, it is reasonable to speculate that the negative association between starting body fat mass and the outcome of weight loss might be causally related, and to suggest that the most overweight dogs might struggle to reach target weight. Indeed, this finding is similar to human studies where weight loss plateaus over time,[20] and is not surprising given the metabolic changes that occur upon caloric restriction.[21] In contrast, where the associations identified were with factors not present at the outset, conclusions should be more speculative. For instance, successful weight

loss was positively associated with the duration of the weight loss program, and this is most likely to be because the weight loss process was curtailed in cases that stopped prematurely or were euthanized. Therefore, a long duration is a characteristic of the successful case, rather than the cause of it. Nonetheless, whilst care should rightfully be taken when drawing any conclusions from these associations, these observations are still of interest since they might help to develop hypotheses to test in future studies.

A faster rate of weight loss was also positively associated with success. At first, this observation seems counterintuitive, since faster rates of weight loss should make the weight loss program shorter yet, as stated above, duration was longer in cases that successfully completed. However, the findings can readily be explained by the fact that these associations with duration and rate of weight loss were independent of one another in the final multiple regression model. The faster weight loss rate could be a characteristic of the cases that successfully lose weight, but a causal relationship might exist. In this respect, those owners whose dogs lost weight more rapidly could be motivated to persist with the program for longer, thus improving the likelihood of successfully reaching target weight. Conversely, slow weight-loss progress could cause owner frustration making them more likely to stop prematurely. Of course, whilst such a hypothesis is intriguing, it does not explain why the dogs that stopped prematurely had a slower rate of weight loss in the first place. Possible causes might include lack of compliance with the weight loss program, difference in activity levels, or might be related to the speed of weight gain and development of obesity. A further limitation of the current study was that physical activity was not objectively assessed. Moreover, while owners were always questioned at the first consultation about the speed and duration of weight gain, most were unable to provide any detailed insight into this (for instance because weight had been infrequently recorded). Further work is required to

395 determine their respective roles of exercise and speed of weight gain on the success of a
396 subsequent weight loss program.
397
398 The study also identified an association between food type and successful weight loss, with a
399 greater proportion of cases fed dry food completing than those on wet food or a mix of wet a
400 dry food. However, the finding should be interpreted cautiously, in light of the fact that only
401 9 dogs were fed wet food or a mixture. One possible explanation for the effect would be
402 differences in macronutrient content of the various diets. Indeed, previous work has indicated
403 that voluntary food intake is less when dogs are fed diets with increased protein and fiber
404 content,[25] and such diets also promote greater fat loss during the weight loss period.[14]
405 However, in the current study, the fact that there was no difference in success for dogs on the
406 HPHF and HPMF foods suggests that differences in fiber content were not responsible. Thus,
407 other reasons are likely to account for the positive association between feeding dry food and
408 completing a controlled weight loss program. An alternative possibility would be the fact that
409 some of the dogs on a mixed feeding combination had switched rations during their program,
410 i.e. from dry to wet (or a mix) and vice versa. Whilst the reason for switching strategies was
411 not recorded, it was often because of problems with progress, so that we might have
412 inadvertently selected for less successful dogs. In light of this, we repeated the multiple
413 regression analysis excluding dogs that had switched food type, and the effect of dry food on
414 weight loss outcome remained. Thus, such a selection bias cannot account for effect of food
415 type. A third possibility might be that feeding dry food affords greater control than wet food;
416 the amount of food can be measured out precisely on weigh scales, small adjustments to the
417 amount fed can easily be made, and the food readily lends itself to methods of feeding that
418 promote environmental enrichment, such as the use of puzzle feeders. Such feeders have
419 been shown to slow food intake in dogs,[k] thereby improving satiety with the resulting effect

of decreased food-seeking behavior. Finally, owner factors might also explain this association, whereby the ease of using dry food might have increased compliance, thereby indirectly improving outcome. The added cost of wet food might have been an additional disincentive for owners using this format to continue with the weight loss program. Given the multiple possibilities, further studies are now required both to confirm and to determine reason for the association between diet type and successful weight loss.

Another factor that was negatively associated with the completing the weight loss program was use of the microsomal transfer protein inhibitor dirlotapide. Conclusions should be made cautiously because only a small number of dogs received the drug, and it was administered in conjunction with the current weight loss diet, which is not specifically recommended. Although all foods used had 10% fat content (on an as fed basis), and previous studies have suggested a good response to dirlotapide in dogs fed food with an equivalent fat content, dogs were not fed *ad libitum*.[16] This might account for the negative association between dirlotapide use and successful weight loss. Alternatively, selection bias could have been responsible, since the drug was used when cases were struggling with a conventional program using dietary caloric restriction. Nonetheless, the finding suggests that drug therapy does not always provide an additional advantage over dietary energy restriction alone in cases struggling to lose weight. Further work is required to understand better the reasons for failure of dirlotapide in the cases in which it was used.

Hypothyroidism is associated with obesity in dogs,[3] and 4 cases in the current series were diagnosed with this disease. We chose to include these dogs so as to ensure that our cases were as representative as possible of the obese pet dog population from which they were drawn. Including such cases in the study is a limitation because it introduces a possible

445 confounder, for example if response to a controlled weight loss program differs from that of
446 euthyroid obese dogs. Therefore, we would recommend further work examining the response
447 of hypothyroid dogs to controlled weight loss.
448
449 Breed was associated with outcome of weight loss in the intention-to-treat analysis, with a
450 greater proportion of mixed breed dogs completed compared with pedigree dogs. If genuine,
451 it might either suggest potential genetic influences on the success of weight loss programs, or
452 be related to owner factors (for instance, if the characteristics of a mixed breed dog owner
453 differed from those of a pedigree dog owner). This breed effect was the weakest of all
454 associations identified, and was no longer evident when data were analyzed on a per-protocol
455 basis. Conclusions should be even more cautious because of the limited range of breeds
456 included, as well as the limited numbers of each breed. Therefore, further work is needed to
457 confirm this observation before investigating the possible reasons for it further.
458
459 A number of limitations should be considered in addition to those discussed above. First, the
460 use of a cohort design means that the basis for our findings are not clear. Thus, further studies
461 are now needed to confirm these findings and to examine possible mechanisms. Second, the
462 dogs studied were referred to a weight management clinic and, as a result, the findings might
463 not be fully representative of dogs in primary care practice. Third, the use of client-owned,
464 rather than colony, dogs introduced a number of possible confounding variables, both dog and
465 owner related. Dog-specific factors increasing population variability include signalment
466 factors, tendency to scavenge, ability to exercise, and the presence of concurrent disease;
467 owner-specific factors include compliance with the weight management advice on feeding
468 and exercise. In human weight loss studies, non-compliance is common and is a major cause
469 of treatment failure.[26] Whilst the use of client-owned dogs could have affected the reliability

of the results, the findings are arguably more representative of the target population, such that they are more generalizable than findings from studies in colony dogs.

Finally, although numerous factors were considered, the roles lifestyle and activity alterations (including exercise) or behavioral manipulation were not examined. Advice on activity and behavior was given to all clients, which was specific to the circumstances of the owner and the dog. Unfortunately, the nature of the advice made it impossible to assign meaningful categories for analysis. As a result of this limitation, future studies should now be considered to assess the role of both activity and behavioral modifications on the outcomes of controlled weight loss.

Conclusions

In summary, the current study demonstrates approximately one half of all obese dogs on a controlled weight loss program reach their target weight. Associated with success was starting body fat percentage, with the most obese dogs less likely to reach their target weight. Since activity and behavioral modification were not specifically assessed in the current study, future studies should also be considered specifically to examine their role.

Footnotes

[a] Axiom Veterinary Laboratories Ltd, Newton Abbott, Devon, UK

[b] Soehnle Professional, Backnang, Baden-Württemberg, Germany.

[c] Blake and Boughton Ltd, Thetford, Norfolk, UK.

[d] Lunar Prodigy Advance; GE Lunar, Madison, Wisc, USA.

[e] Excel®, various versions; Microsoft Corporation. Redmond, WA, USA.

[f] Canine Veterinary Diet Satiety Dry, Royal Canin, Aimargues, France.

[g] Canine Veterinary Diet Obesity Management Dry, Royal Canin, Aimargues, France.

[h] Canine Veterinary Diet Obesity Management Wet, Royal Canin, Aimargues, France.

[i] Slentrol, Zoetis UK, London, UK.

[j] Stats Direct version 2.6.8, Stats Direct Ltd.

[k] German AJ, Towlson E, Holden SL, et al. Long-term follow-up after weight management in obese cats. Proceedings of the 55th British Small Animal Veterinary Association Congress, Birmingham, UK; April 2012

Conflicts of interest

The following conflicts of interest apply: AJG's Readership is funded by Royal Canin; AJG has also received financial remuneration and gifts for providing educational material, speaking at conferences, and consultancy work; SLH's post at the University of Liverpool is also funded by Royal Canin; the diet used in this study is manufactured by Royal Canin; YQ and VB are employed by Royal Canin; PM is an employee of Mars Petcare.

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581 **Table 1**. Average composition of diets for weight loss
582

Criterion	**High protein high fiber dry**[1]		**High protein medium fiber dry**		**High protein medium fiber wet**	
ME content	2900 / 2865 Kcal/kg		3275 Kcal/kg		548 Kcal/kg	
	Per 100g AF	g/1000 Kcal (ME)	Per 100g AF	g/1000 Kcal (ME)	Per 100g AF	g/1000 Kcal (ME)
Moisture	8 / 10	28 / 33	8	27	86	1569
Crude protein	30 / 30	103 / 105	34	104	7.0	128
Crude fat	10 / 10	33 / 33	10	30	2.0	36
Starch	19 / 18	66 / 61	22	66	2.1	38
NFE	30 / 29	102 / 100	32	97	2.5	46
Crude fiber	18 / 16	60 / 58	8	25	1.0	18
Total dietary fiber	28 / 28	97 / 97	18	56	1.4	26
Ash	5.3 / 5.7	18 / 20	8.1	25	1.5	27
Fiber sources	Cellulose, beet pulp, FOS, psyllium husk, diet cereals		Cellulose, beet pulp, diet cereals		Beet pulp, cassia gum, carrageenan	

583
584 High protein high fiber (Satiety Support Canine, Royal Canin). High protein medium fiber (Obesity Management Canine, Royal Canin). ME=
585 Metabolizable energy content, as measured by animal trials according to the American Association of Feed Control Officials protocol (AAFCO,
586 2010); AF= as fed; DM= dry matter; FOS= fructo-oligo-saccharides; NFE= nitrogen-free extract. [1] Diet formulation changed in 2010; figures in
587 column refer to diets used before and after 2010, respectively.

588 **Table 2**. Baseline variables of the study dogs
589

Variable	Completed (n=87)	Stopped prematurely (n=45)	Euthanized (n=11)	*P* value [4]
Breed [1]	Labrador 21 Mixed breed 14 CKCS 9 Golden retriever 7 Yorkshire terrier 7 OTHER: Alaskan Malamute, Akita, BMD, Border Collie 3, Cairn Terrier 2, Chihuahua, Cocker Spaniel 2, Corgi, Dachshund, Doberman 2, EBT, FCR, GSD, Irish Setter, JRT, Lhasa Apso, Miniature schnauzer, Pug 4, Samoyed, Schipperke, Shih Tzu	Labrador 14 Mixed breed 4 CKCS 2 Golden retriever 1 Yorkshire terrier 1 OTHER: Akita, Border Collie, Dachshund 3, Dalmatian 2, English Pointer, GSD, JRT 2, Labradoodle, Lancashire Heeler, Lhasa Apso 2, Patterdale terrier, Poodle, Pug, Rottweiler, Scottish terrier, Springer spaniel 2, Tibetan Terrier	Labrador 0 Mixed breed 1 CKCS 1 Golden retriever 0 Yorkshire terrier 0 OTHER: Bichon Frise, Boxer English Bulldog, EBT, Lhasa Apso, Newfoundland, SBT, Shih Tzu, Weimaraner	*Lab: 0.088* *Mix: 0.34* *CKCS: 0.49* *GR: 0.41* *YT: 0.41*
Reason for stopping or euthanasia	---	Personal reasons of owner 9, refused help shortly after enrolment 5, repeated failure to comply with program 3, owner chose to stop 7, dog developed another disease (pneumonia) 1, not recorded (could not contact owner) 20	Developed another disease 6 (severe orthopedic disease, metastatic mast cell tumor, splenic neoplasia, laryngeal neoplasia, and concurrent cardiac and renal disease), not recorded 5	
Sex [2]	M 2; NM 47, F 2, NF 36	M 1; NM 25; F 2; NF 17	M 1; NM 5; NF 5	*0.76*
Age (Mo)	72 (16-228)[a]	84 (24-156)[ab]	96 (55-144)[b]	*0.059*
Start Weight (kg)	32.0 (5.3-77.6)	33.9 (4.4 - 60.8)	27.1 (7.2-100.0)	*0.75*

Body fat (%) [3]	44.8 (27.3-55.0)	46.2 (27.9-60.8)	44.2 (35.3-55.5)	*0.10*

All data (except diet data) are expressed as median (range). [1] Breed acronyms are as follows: BMD, Bernese mountain dog; CKCS, Cavalier King Charles Spaniel; EBT, English bull terrier; FCR, Flat Coated Retriever; GSD, German Shepherd Dog; SBT, Staffordshire Bull Terrier. [2] Sex acronyms are as follows: M, male; NM, Neutered male; F, female; NF, neutered female. [3] Body fat percentage was determined before weight loss using dual-energy X-ray absorptiometry. [4] For breed and sex, *P* values are based upon Fisher's exact tests (Lab: Labrador, Mix: mixed breed, CKCS: Cavalier King Charles Spaniel; YT: Yorkshire terrier); for age, start weight and body fat, *P* values are based upon Kruskal Wallis tests. Groups with different letters are significantly different from one another, at $P<0.05$.

596 **Table 3**. Outcomes of weight loss

Variable	Completed (n=87)	Stopped (n=45)	Died (n=11)	*P* value [4]
Diet (number of dogs)[1]	HPHF dry 58[a] HPMF dry 27 HPMF wet 0 Mixed 2	HPHF dry 24[ab] HPMF dry 17 HPMF wet 2 Mixed 2	HPHF dry 6[b] HPMF dry 2 HPMF wet 2 Mixed 1	*HPMF v HPHF: 0.54* *Dry v Wet/mixed: 0.0077*
Weight loss (% start weight)	25.5 (5.5 to 43.9)[a]	8.8 (-3.0 to 33.0)[b]	16.7 (-2.3 to 39.5)[b]	*<0.001*
Rate of Weight loss (%/week)	0.7 (0.1 to 1.7)[a]	0.4 (-0.3 to 2.2)[b]	0.6 (-0.1 to 1.3)[ab]	*0.001*
Duration (days)	250 (84 to 796)[a]	139 (0 to 1149)[b]	141 (47 to 371)[b]	*<0.001*
Energy intake (Kcal/kg$^{0.75}$ ideal weight/day)	62.3 (44.0 to 92.9)	63.5 (42.3 to 87.1)	60.8 (51.8 to 75.2)	*0.67*
Weight loss stalls[3]	1 (0-6)	1 (0-18)	0 (0-6)	*0.37*
Diet energy intake changes[4]	2 (0-11)	2 (0-13)	2 (0-5)	*0.16*
Concurrent hypothyroidism	3	1	0	*0.78*
Dirlotapide	1	4	0	*0.082*

597 All data (except diet data) are expressed as median (range). [1] Diet types were as follows: HPHF dry, high protein high fiber dry: HPMF dry, high protein medium fiber dry,
598 HPMF wet, high protein medium fiber wet; Mixed, mixed ration with more than one type (e.g. completed: HPHF dry with HPMF wet [n=2]; stopped prematurely: HPMF dry
599 and wet [n=2]; died: HPHF dry with HPMF wet [n=1]). Energy intake expressed in Kcal of metabolizable energy per kilogram of metabolic body weight of ideal weight
600 (kg$^{0.75}$). [2] For diet, *P* values are based upon Fisher's exact tests; for all other data, *P* values are based upon Kruskal Wallis tests. [3] Number of times the weight loss process
601 stalled. [4] Number of times food intake had to be reduced. Groups with different letters are significantly different from one another, at $P<0.05$.
602

603 **Table 4**. Results of the logistic regression analysis determining factors associated with success or failure
604

Logistic regression	Intention to treat			Per protocol		
	OR[a]	95% CI[b]	Probability	OR[a]	95% CI[b]	Probability
Simple regression						
Age (per month)	0.99	0.98-1.00	0.13	0.99	0.985-1.005	0.34
Target Body Weight (per kg)	1.00	0.98-1.03	0.78	1.00	0.98-1.03	0.79
Body Fat (per %)	0.94	0.89-0.99	0.029	0.94	0.89-1.00	0.047
Breed						
CKCS[c]	2.04	0.53-7.88	0.30	2.48	0.51-12.00	0.26
Labrador retriever	0.95	0.44-2.08	0.91	0.70	0.32-1.57	0.39
Mixed breed	2.49	0.78-8.00	0.12	2.79	0.73-9.89	0.12
Golden Retriever	4.81	0.58-40.22	0.15	3.85	0.46-32.31	0.21
Yorkshire Terrier	4.81	0.58-40.22	0.15	3.99	0.46-32.31	0.21
Sex (male vs. female)	0.97	0.49-1.90	0.92	0.94	0.46-1.95	0.87
Neuter Status (neutered vs. intact)	1.60	0.38-6.66	0.52	1.48	0.32-6.93	0.62
Diet						
HPHF v HPMF[d]	1.36	0.65-2.83	0.41	1.52	0.70-3.29	0.29
Dry v wet /mix	6.07	1.21-30.38	0.028	4.15	0.73-23.57	0.11
Concurrent hypothyroidism	1.96	0.20-19.37	0.56	1.57	0.16-15.55	0.70

Dirlotapide use	0.15	0.02-1.40	0.095	0.12	0.01-1.10	0.061
Rate of weight loss (per %/week)	3.35	1.35-8.30	0.0092	4.15	1.50-11.44	0.0061
Duration (per day)	1.003	1.000-1.004	0.014	1.002	1.000-1.004	0.046
Energy intake	0.99	0.95-1.03	0.49	0.98	0.94-1.02	0.37
Weight loss stalls (per stall)	0.90	0.78-1.05	0.17	0.87	0.74-1.02	0.092
Diet energy intake changes (per change)	1.11	0.95-1.29	0.19	1.08	0.93-1.27	0.31
Multiple regression						
Breed: Mixed breed	6.22	1.10-35.30	0.039	---	---	---
Body Fat (per %)	0.87	0.80-0.94	<0.001	0.88	0.81-0.96	0.0039
Diet: Dry v wet /mix	15.93	1.97-128.91	0.0095	15.37	1.57-150.71	0.019
Dirlotapide use	0.01	0.00-0.27	0.0031	0.02	0.00-0.43	0.011
Rate of weight loss (per %/week)	10.66	2.99-38.00	<0.001	9.52	2.58-35.16	<0.001
Duration (per day)	1.010	1.01-1.013	<0.001	1.009	1.005-1.013	<0.001

a: Odds Ratio, b: Confidence Interval, c: Cavalier King Charles Spaniel, d: High Protein Medium Fiber (Satiety) diet and High Protein High Fiber (Obesity dry diet).