Integration of a physical training program in a weight loss plan for overweight pet dogs

Anne D. Vitger DVM
Bente M. Stallknecht MD, PhD, DMSc
Dorte H. Nielsen DVM, PhD
Charlotte R. Bjornvad DVM, PhD
From the Departments of Veterinary Clinical and Animal Sciences (Vitger, Nielsen, Bjornvad) and Biomedical Sciences (Stallknecht), Faculty of Health and Medical Sciences, University of Copenhagen, 2200 Copenhagen, Denmark.
Address correspondence to Dr. Vitger (anvi@sund.ku.dk).

OBJECTIVE
To investigate whether a controlled physical training plan for overweight dogs during a weight loss program would improve cardiorespiratory fitness and better preserve lean body mass, compared with results for dogs undergoing a weight loss program based on caloric restriction alone.

DESIGN
Prospective, nonrandomized clinical study.

ANIMALS
19 client-owned overweight or obese dogs.

PROCEDURES
All dogs were fed the same calorie-restricted diet rationed to achieve a weight loss rate of 1% to 2%/wk for 12 weeks. The fitness-and-diet (FD) group participated in a training program that included underwater and land-based treadmill exercise 3 times/wk. The diet-only (DO) group had no change in exercise routines. Daily activity before and during the intervention was recorded by accelerometry. Before and after intervention, heart rate during exercise was recorded to assess cardiovascular fitness, and body composition was analyzed by dual-energy x-ray absorptiometry. Differences between groups were evaluated with t tests and multiple regression analysis.

RESULTS
Mean weight loss was 13.9% and 12.9% for the FD and DO groups, respectively (n = 8 dogs/group that completed the study). Mean accelerometer counts during intervention were 13% higher than baseline counts for the FD group. Heart rate during exercise declined after intervention in both groups. Lean body mass was preserved in the FD group and lost in the DO group during intervention.

CONCLUSIONS AND CLINICAL RELEVANCE
The controlled exercise plan used with a dietary weight loss program prevented loss of lean body mass in dogs. This finding supports inclusion of controlled physical training for obesity management in dogs. (J Am Vet Med Assoc 2016;248:174–182)

Excess body weight is a frequently observed problem in the canine population.1,2 Overweight and obese dogs have a shorter life span, reduced quality of life, and increased risk of diseases such as degenerative joint disease and neoplasia, compared with nonoverweight dogs.3 Similar to findings reported for people, adiposity in dogs results in numerous metabolic changes, such as insulin resistance, hyperlipidemia, and chronic low-grade inflammation.4,5 Obesity research in human patients emphasizes the health-promoting effects of physical activity,6 but to date, the value of physical activity has received little attention in canine obesity research. Increased physical activity is often recommended as an adjunct to restricted energy intake in weight loss programs for dogs,4,7 but scientific studies evaluating the effects of such a regimen are scarce and lack documentation of the successful accomplishment of increased physical activity during the programs.

During the last decade, pedometers and triaxial accelerometers have been validated for use in dogs as reliable ways to record the number of steps taken (pedometers) or movement (accelerometers), making it possible to monitor a dog’s activity level in its home environment8–10 and during treadmill activity.11 These tools are useful for quantifying physical activity in canine obesity and fitness research. Studies have reported fewer steps12 and less vigorous physical activity13 by overweight dogs, compared with normal-weight dogs; however, in 1 study,14 overweight dogs did not spontaneously increase their physical activity during a 6-month weight loss program, despite successful weight loss.

For physical activity to have optimal health benefits in people, it should be linked to improved car-
Materials and Methods

Dogs

Overweight, sedentary dogs were recruited by advertisement in local newspapers, by distribution of pamphlets at the University Hospital for Companion Animals at the University of Copenhagen, and by referral from local veterinary clinics. Dogs eligible for inclusion were medium- to large-breed dogs (body weight, 15 to 55 kg [33 to 121 lb]) and 2 to 13 years of age with a BCS ≥ 6 on a 9-point scale.26,27 Dogs were also required to have a sedentary lifestyle, defined as not engaging in any habitual high-intensity activities, with daily walks being short or of mainly light intensity. The lifestyle criteria were evaluated by discussion with the owners during patient evaluation. A low degree of fitness was subjectively confirmed by gait evaluation, clinical examination, and a trial run on a land-based treadmill. Dogs were evaluated as being too fit and excluded from the study if they were able to run comfortably at a speed of > 8 km/h with a 5% incline. All dogs were evaluated as healthy (other than being overweight or obese) on the basis of physical examination findings and were deemed able to perform light to moderate exercise. Further inclusion criteria included no clinically important abnormalities on CBC, serum biochemical analysis (including free thyroxine and thyroid stimulating hormone concentrations), and urine analysis. Dogs routinely receiving medications (other than prophylaxis against internal parasites and fleas or ticks) were not eligible for inclusion. Following telephone interviews with the owners, 30 dogs were accepted for initial examination, and 19 of these were included in the study. Reasons for exclusion were musculoskeletal pain (n = 7), active lifestyle (2), and biochemical abnormalities (1). One owner chose to withdraw the dog prior to the start of the study for personal reasons. A signed owner consent form was obtained for each dog before initiation of the study. The protocol was approved by the Ethical Committee at the Department of Veterinary Clinical and Animal Sciences, University of Copenhagen, and by the Danish Animal Experimentation Inspectorate (approval No. 2011_561-80). Five dogs enrolled in the study also participated in a study evaluating the 13C-bicarbonate technique for measurements of energy expenditure during the same intervention.25 The measurements were non-invasive and had no effect on the dogs.

Study design

The study was designed as a prospective, non-randomized clinical trial. Following enrollment in the 12-week weight loss program, dogs were assigned to the FD group or the DO group solely on the basis of owner preference. Dogs in the FD group were exercised 3 times/wk at the university hospital, and owners were encouraged to increase each dog’s daily activity level at home. Owners of dogs in the DO group were instructed not to change their dog’s daily exercise routines during the study period, but that any spontaneous increase in the dog’s activity should not be restricted.

Prestudy evaluation

Prior to initiation of the study, all dogs wore an accelerometer in a collar around the neck for 1 week to obtain a baseline value for their habitual daily activity level. Dogs were weighed, and BCS was determined by 2 evaluators (ADV and CRB). Treatment group was known to the evaluators at the time of assessment. Body composition was assessed by dual-energy x-ray absorptiometry under general anesthesia. After anesthesia, the dogs were allowed ≥ 7 days to recover and gradually habituate to the study diet before commencement of the 12-week intervention period.

Diet

During the study period, all dogs were fed a commercial low-fat, high-protein, dry diet.4 Mean initial food allocation was 62 ± 2 kcal/U of metabolic target body weight (kg0.75), calculated by use of a purpose-designed software program5 as 55% of the estimated maintenance energy requirement (according to the

dioresporacle fitness.15 Heart rate during exercise has been used to assess fitness in several canine exercise studies, but research has so far focused on fit dogs under strenuous exercise.16-18 The effect of weight loss and exercise on heart rate in overweight pet dogs has only been sparingly studied.19

Weight loss usually results in loss of both fat and lean body mass. Factors affecting lean body mass loss during canine weight loss programs include protein content in the diet and weight loss rate. A high-protein diet has been reported to reduce the loss of lean body mass in dogs to a ratio of 15% to 20% of the total loss,20,21 compared with 30% when a moderate-protein diet was fed.21 Results of studies22,23 in people have shown that loss of lean body mass can be prevented or minimized, if weight loss is obtained by use of a low-calorie, high-protein diet in combination with physical exercise. Preservation of lean body mass is preferable because it preserves energy requirements and physical strength, and thereby the achieved weight loss is easier to maintain than that achieved by dietary changes alone.24,25
calculation, 132 kcal/kg target weight\(^{0.73}\) (60 kcal/lb target weight\(^{0.73}\)). The target weight was estimated on the basis of BCS, where each unit of BCS above ideal (5/9) was regarded as equivalent to 10% overweight.\(^{21,26}\) Manufacturer-reported nutritional contents of the commercial diet are provided (Appendix). Owners were advised to divide the daily allowance into 2 feedings and a portion to be used for treats. The aim was to achieve a weight loss rate of approximately 1.5%/wk. The dogs were weighed every other week, at which time compliance with the feeding plan was discussed with the owner; and if weight loss was < 1% or > 2%, the dog’s daily feeding allowance was adjusted (increased or decreased) by 10%.

### Accelerometry

Each dog had a waterproof triaxial accelerometer\(^{c}\) attached to the ventral aspect of the neck collar as described by Hansen et al\(^{10}\). Data were collected at a frequency of 30 Hz and stored in a raw format. Data were collected for 1 full week prior to the study and continuously throughout the 12-week intervention period. Data were downloaded from the accelerometer in epochs of 10 seconds with appropriate software\(^d\) approximately every 2 weeks. Only full weeks were used for comparison of activity level over time. It was anticipated that some collection time would be lost when changing the devices and if the battery ran out of charge. Therefore, to obtain the most consistently available data sets, only data from days 2 to 8 in each collection period were included for analysis. In the event that the owner had removed the collar during this period, data were replaced by the next full day of the same kind (weekday or weekend). Activity levels of each dog were analyzed on the basis of total counts per week. To counteract the effect of a possible seasonal bias, starting time for both groups was evenly distributed between progression to warmer and lighter days (starting time January to April) and to colder and darker days (starting time August to October).

### Exercise

Dogs in the FD group received training supervised by one of the authors (ADV) at the University Hospital for Companion Animals 3 times/wk in conjunction with the described dietary management during the 12-week intervention period. The general exercise protocol consisted of 30 minutes on the underwater treadmill\(^{f}\) and 30 minutes on the land-based treadmill.\(^{f}\) This combination of modalities was chosen in an attempt to provide optimal functional and cardiorespiratory training while minimizing the risk of strain injuries and complacency from repetitive training. For the same reasons, all exercise sessions were individually tailored with variations in speed, inclination angle (for the land-based treadmill), and water level (for the underwater treadmill). Water at the level of the stifle joint and a water temperature of 25°C were the most commonly used settings. Speed on the underwater treadmill was primarily walking (35 to 65 m/min) with intervals of trotting or fast walking (up to 115 m/min) in the second half of the intervention. On the land-based treadmill, the dogs exercised primarily in a steady trot at a 5% incline, mixed with faster and slower intervals. During the first 2 weeks, exercise on the underwater treadmill was gradually increased from approximately 10 minutes to 30 minutes. Intensity of exercise was gradually and continuously increased throughout the study depending on the dog’s ability and willingness to exercise. Owners of dogs in the FD group were repeatedly encouraged to increase the duration and intensity of the dog’s daily exercise at home. Exercise was limited or temporarily cancelled if the dog was lame or had other signs of illness. Medical management for signs of pain was prescribed at the discretion of one of the authors (ADV). Data were discarded for a dog if medication was needed for ≥ 14 days.

### Heart rate

Heart rate recordings for each group were obtained during an incremental exercise test on the land-based treadmill at the start and at the end of the study. For the incremental exercise test, the treadmill was set at a 5% incline, and the dog was exercised for 5 minutes at each of 3 increments (4 km/h [level 1], 6 km/h [level 2], and 8 km/h [level 3]) or until the dog showed signs of fatigue (eg, straining against the collar or movement becoming less coordinated). For the recordings, a heart rate monitor\(^{g}\) was attached to the shaved ventral midline aspect of the dog’s thorax with an elastic belt. Prior to the first test, the dogs were habituated to running on the treadmill 2 or 3 times (depending on the dog’s adaptiveness). To have a comparable degree of habituation between groups, treadmill running for 10 to 15 minutes was included in the fortnightly checkups of the dogs in the DO group.

### Body weight and body composition

Dogs were weighed before, approximately every 2 weeks during, and after the intervention on the same electronic weight scale.\(^{13}\) Before and after the intervention, the dogs’ BCS was determined by 2 experienced examiners (ADV and CRB), and dogs were scanned by fan-beam dual-energy x-ray absorptiometry\(^{i}\) for body composition analysis. After food was withheld overnight (approx 10 to 12 hours) and prior to scanning, dogs were premedicated with methadone hydrochloride (0.3 mg/kg [0.14 mg/lb], IM) and acepromazine maleate (0.015 mg/kg [0.007 mg/lb], IM) or diazepam (0.25 mg/kg [0.11 mg/lb], IV), and anesthesia was induced with propofol (4.0 mg/kg [1.8 mg/lb], IV) and maintained with isoflurane in oxygen delivered via a circle system. For the scanning (performed by one of the authors [DHN]), dogs were positioned in ventral recumbency with the thoracic limbs extended cranially and pelvic limbs extended caudally. Body composition was analyzed for lean body mass, fat mass, and bone mineral content by use of purpose-designed computer software.\(^{13}\) The heads of the dogs were not included in body composition analyses to eliminate bias attributable to anesthesia equipment.
Statistical analysis

Statistical analyses were performed using commercial computer software. All continuous variables were first assessed for normal distribution with the Shapiro-Wilk test, and when appropriate, parametric statistical tests were performed. These included paired and unpaired t tests. A Welch t test was used for data of unequal variance. When variables were not normally distributed, a nonparametric test (Wilcoxon rank sum test) was used. A key outcome measure, change in lean body mass during weight loss, was also analyzed by multiple linear regression with the baseline and intervention measurements as dependent factors, and the parameter age was tested for interaction with intervention. Longitudinal data (accelerometer counts during the intervention) were analyzed for changes over time with random effects models, with value of P < 0.05 were accepted as significant. Data are expressed as mean ± SD or median and range as appropriate. Changes in tissue distribution are reported as differences in mass and as percentages of total mass loss.

Results

Study completion

Of 19 dogs initially enrolled (10 and 9 in the FD and DO groups, respectively), 16 dogs (8 in each group) completed the study. One dog from the FD group was excluded because of evidence of chronic disease (mammary tumor growth and reluctance to exercise on the treadmills). One dog from each group was excluded because pain management (for arthritis in one dog and signs of pain in the lumbar region in the other) was required during the study period for > 2 weeks. Furthermore, 1 dog in the FD group developed pruritic, acute dermatitis at the end of the study, and to avoid bias, accelerometer data from the last 2 weeks for that dog were excluded.

Dogs for which data were analyzed in the FD group included 3 Labrador Retrievers, 2 Australian Shepherds, 1 Bernese Mountain Dog, 1 Border Collie, and 1 mixed-breed dog (all female, 6 spayed). Mean ± SD age for dogs in this group was 7.6 ± 2.8 years. Dogs remaining in the DO group included 4 Labrador Retrievers and 1 each of the following breeds: Basset Griffon Vendeen, Bernese Mountain Dog, Nova Scotia Duck Tolling Retriever, and mixed breed. The mean ± SD age of these dogs was 6.0 ± 2.0 years; there were 3 males (2 neutered) and 5 females (3 spayed).

Diet

All dogs tolerated the diet well and consumed it willingly. At the fortnightly visits, compliance was discussed with the owners. Occasional deviations from the prescribed food allowances occurred in both groups as a result of dogs finding extra food or noncompliance by the owners. In these cases, plans were made to improve compliance before adjustments were made to the feeding plan.
rate during level 1 and 2 exercise tests were 27 ± 15 beats/min and 25 ± 10 beats/min, respectively, for the FD group and 18 ± 12 beats/min and 23 ± 15 beats/min, respectively, for the DO group. Differences between the groups for any given exercise level and time point were not significant (Figure 1).

Physical activity measurement
Accelerometer counts for baseline activity over 1 week were obtained for all dogs. The baseline activity did not differ significantly (P = 0.07) between the DO and FD groups. Accelerometer counts for alternating weeks during the study were obtained 6 times for 11 dogs, 5 times for 4 dogs, and 4 times for 1 dog. Reasons for missing data were breakdown of accelerometer (n = 2 one-week data collection periods), battery failure (1), lack of owner compliance (2), and dismissal from the study at the end of intervention owing to pruritic dermatitis (1). Mean accelerometer counts during the intervention increased in the FD group (P = 0.002) and decreased in the DO group (P = 0.01), compared with the respective baseline values. The percentage change from baseline in mean alternate week counts during the intervention period (weeks 1 to 11) for individual dogs is depicted (Figure 2). The mean ± SD percentage increase in the FD group was 13 ± 8%, and the mean percentage decrease in the DO group was 14 ± 10%. For the FD group, mean ± SD accelerometer reading for the baseline week was 6.3 ± 1.8 million counts, and readings per alternate week during the intervention period of the study were 7.4 ± 2.4 million counts, 7.0 ± 1.7 million counts, 6.9 ± 1.8 million counts, 7.0 ± 1.9 million counts, and 6.1 ± 2.0 million counts. For the DO group, the mean ± SD baseline reading was 8.0 ± 1.6 million counts, and readings per alternate week during the intervention period were 7.1 ± 1.7 million counts, 6.7 ± 2.1 million counts, 7.2 ± 1.7 million counts, 6.9 ± 1.5 million counts, 7.0 ± 1.5 million counts, and 7.1 ± 1.7 million counts. During the course of the intervention, activity remained stable in both groups and variation among weeks was not signifi-

Figure 1—Mean and SD heart rate of dogs at the start (solid bars) and end (crosshatched bars) of a 12-week study to determine whether a controlled physical training plan for overweight dogs during a weight loss program would improve measures of cardiorespiratory fitness and better preserve lean body mass, compared with results for dogs undergoing a weight loss program based on caloric restriction alone. Measurements were determined by use of a heart rate monitor during 5 minutes of exercise on a land-based treadmill set to a 5% incline at speeds of 4 km/h (level 1) and 6 km/h (level 2). At the start of the study, level 1 measurements were obtained for 8 dogs in the FD group and 7 dogs in the DO group, and level 2 measurements were obtained for 7 dogs/group. At the end of the study, measurements at both exercise levels were obtained for 15 dogs (8 in the FD and DO groups, respectively). *Within a group and test level, mean heart rate during exercise differed significantly (P < 0.01) between the beginning and end of the study.

Figure 2—Percentage change in physical activity (as determined by mean accelerometer counts) for alternate weeks during the 12-week intervention period, compared with the baseline value (counts for 1 week prior to the start of the intervention period), for individual dogs of the FD group (black bars; n = 8) and DO group (gray bars; 8). Data were collected by means of a triaxial accelerometer attached to each dog’s collar and were downloaded in epochs of 10 seconds approximately every 2 weeks during the intervention period. Data from days 2 through 8 were compared between time periods (except that for a few dogs, missing data were replaced with data from the next full day of the same kind [weekday or weekend]).

Figure 3—Mean accelerometer counts (data obtained for a 7-day period at 2-week intervals) for dogs in the FD group (black squares; n = 8) and DO group (white circles; 8) at baseline (week 0) and during the 12-week intervention period. Counts for week 11 were omitted because data were missing from 3 dogs in the FD group. Vertical lines represent SEM. *Significant difference from baseline (P < 0.05), depicted above symbols for the FD group and below symbols for the DO group.
Table 1—Dual-energy x-ray body absorptiometry composition measurements (mean ± SD) for 16 dogs that completed a 12-week study to assess effects of a controlled physical training plan on variables of interest for overweight dogs during a weight loss program, compared with results for dogs undergoing a weight loss program based on caloric restriction alone.

<table>
<thead>
<tr>
<th>Variable</th>
<th>FD (n = 8)</th>
<th>DO (n = 8)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat mass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before intervention (kg)</td>
<td>16.81 ± 5.80</td>
<td>17.97 ± 5.85</td>
<td>—</td>
</tr>
<tr>
<td>After intervention (kg)</td>
<td>12.14 ± 3.66</td>
<td>13.77 ± 5.01</td>
<td>—</td>
</tr>
<tr>
<td>Change (kg)</td>
<td>-4.67 ± 2.27</td>
<td>-4.20 ± 1.63</td>
<td>0.64</td>
</tr>
<tr>
<td>Change as % of TL</td>
<td>-110.7 ± 20.3</td>
<td>-90.60 ± 8.77</td>
<td>0.03</td>
</tr>
<tr>
<td>Lean mass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before intervention (kg)</td>
<td>13.72 ± 3.25</td>
<td>18.63 ± 6.58</td>
<td>—</td>
</tr>
<tr>
<td>After intervention (kg)</td>
<td>14.35 ± 3.86</td>
<td>18.17 ± 6.31</td>
<td>—</td>
</tr>
<tr>
<td>Change (kg)</td>
<td>0.63 ± 1.12</td>
<td>-0.46 ± 0.53</td>
<td>0.01</td>
</tr>
<tr>
<td>Change as % of TL</td>
<td>12.10 ± 21.10</td>
<td>-8.60 ± 9.40</td>
<td>0.03</td>
</tr>
<tr>
<td>Bone mineral content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before intervention (kg)</td>
<td>0.90 ± 0.32</td>
<td>1.00 ± 0.30</td>
<td>—</td>
</tr>
<tr>
<td>After intervention (kg)</td>
<td>0.04 ± 0.27</td>
<td>0.95 ± 0.27</td>
<td>—</td>
</tr>
<tr>
<td>Change (kg)</td>
<td>-0.06 ± 0.07</td>
<td>-0.05 ± 0.05</td>
<td>0.6</td>
</tr>
<tr>
<td>Change as % of TL</td>
<td>-1.50 ± 1.00</td>
<td>-0.90 ± 1.00</td>
<td>0.3</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before intervention</td>
<td>53.1 ± 5.90</td>
<td>48.5 ± 7.20</td>
<td>—</td>
</tr>
<tr>
<td>After intervention</td>
<td>44.5 ± 6.00</td>
<td>42.4 ± 7.90</td>
<td>—</td>
</tr>
</tbody>
</table>

All dogs were fed a dry commercial weight loss diet throughout the study. Owners of dogs in the DO group were instructed not to change their dog’s daily exercise routines during the study, but that any spontaneous increase in the dog’s activity should not be restricted. Dogs in the FD group underwent an exercise program that included use of land-based and underwater treadmills 3 times/wk; exercise sessions were tailored for each dog with variations in speed, inclination angle (for the land-based treadmill), and water level (for the underwater treadmill); and intensity was gradually increased over the study period, depending on the dog’s ability and willingness to exercise. Owners of FD group dogs were also encouraged to increase each dog’s daily activity level at home.

— = Not applicable. TL = Total loss (sum of fat mass + lean mass + bone mineral content lost).

Change of fat in excess of –100% of TL and positive change in lean body mass occurred when lean mass was gained during weight loss.

Discussion

To the authors’ knowledge, the present study was the first to evaluate the combined effects of physical activity and caloric restriction on preservation of lean body mass in overweight dogs during weight loss. The observed loss of lean body mass in the DO group was in line with a study in pet dogs where mean loss of lean body mass was 15%. In that study, diet, mean percentage weight loss (18%), and mean rate of weight loss (0.85%/wk) were comparable to those in the present study. Percentage weight loss for the FD group did not differ from that for the DO group, but lean body mass was preserved in the FD group. Preservation of lean body mass during weight loss programs has not previously been described in dogs, and it seems likely that the increased physical activity was the determining factor for this result in our study.

This is in accordance with studies in humans, where the inclusion...
of aerobic training or resistance training in weight loss programs has been shown to preserve lean body mass.

An age-related reduction in muscle mass (sarcopenia) is a phenomenon that has been extensively researched in human medicine. Sarcopenia has also been described in a few studies of dogs, although the clinical implications have not been evaluated. In humans, physical activity can effectively delay the onset of sarcopenia, but once it is present, regeneration of muscle fiber is slower and less pronounced. Although the present study had a small sample size, our results suggested that this may also be the case in dogs, where lean mass was lost to some degree in some older dogs despite physical activity. The role of sarcopenia in weight management of senior dogs should be further studied in the future.

More active dogs can consume additional calories while achieving a weight loss similar to that of less active dogs. However, little is known about the amount of exercise necessary for dogs to achieve a detectable increase in energy expenditure. In our study, no difference in mean daily energy intake was detected between groups. This does not rule out that there was increased energy expenditure in the FD group as a result of exercise. Compared with the DO group, the baseline energy requirements of these dogs may have been lower. Although apparent differences were nonsignificant on the basis of baseline accelerometer count analysis. Measurement of resting metabolic rate before the intervention would have been a valuable tool for estimating the effect of physical activity on energy expenditure. In this study, the 2 groups had similar energy intake and similar accelerometer counts during the intervention. This is in alignment with studies that have found a positive correlation between energy requirements and physical activity of dogs measured by pedometers or accelerometers. However, accelerometer counts are only a crude estimate of physical activity, and data on energy intake in client-owned dogs are subject to inaccuracy. Noncompliance, attributable to actions of the owner or the dog, is likely inevitable, and in the present study, the dogs would likely have been hungry owing to energy restriction and would likely have tried to gain access to extra food. To limit noncompliance, this issue was continually addressed with the owners at the fortnightly visits, and the successful weight loss suggested that noncompliance was effectively limited.

A previous study of weight loss in dogs incorporated physical activity in the form of treadmill exercise sessions and active client motivation. It was suggested that physical activity had a beneficial effect on the rate of weight loss, but the treadmill exercise sessions were few and because the dogs' physical activity in the home environment was not monitored, the effect of client motivation was unknown. The present study used accelerometry to measure changes in the dogs' physical activity. As intended, dogs in the FD group had increased physical activity (significantly increased mean accelerometer count) during the intervention period, compared with the baseline value. Owners of dogs in the DO group had been instructed not to change their dog's exercise routines. The mean accelerometer count for dogs in this group was significantly lower than the mean baseline count. A weight loss-induced reduction in physical activity is well recognized from research on human subjects, and it is considered to be a biologically meaningful adaptation to preserve energy. However, energy restriction may not induce a spontaneous reduction of physical activity in dogs. One study found no change in dogs' physical activity during a 6-month weight loss program, but in contrast to methods of the present study, no measurements of physical activity were taken before the dietary caloric restriction was implemented. Another study measured steps taken by dogs before and during a weight loss program and found that pedometer counts remained constant, although owners were repeatedly encouraged to take their dogs for longer walks. The authors assumed that lack of owner compliance, rather than decreased voluntary activity by the dogs, prevented increased physical activity. In the present study, the baseline values represent a possible bias between groups, as the groups were not randomized. Owners who chose to let their dog participate in the DO group may have felt less need for exercise intervention and may have been more likely to overestimate habitual activity; these individuals might (knowingly or unknowingly) have increased their dogs' physical activity level in the baseline period when data on normal routines were recorded. This speculation emphasizes the challenge of establishing a reliable baseline for activity studies. Dow et al evaluated activity counts for healthy, normal-weight dogs during 2 consecutive weeks. It was concluded that a 7-day sampling interval was reliable for activity monitoring. For longer intervention studies, a 7-day baseline may not be equally representative of habitual activity.

In the present study, within-group changes in mean alternate-week accelerometer counts were nonsignificant throughout the course of the 12-week intervention after the initial increase (FD group) or decrease (DO group) from baseline, despite gradually increased training intensity for the FD group. It is possible that increased voluntary activity by the dogs was counteracted by a gradual decrease in owner motivation. Another contributing factor could be that a change to a smoother gait pattern following weight loss might reduce accelerometer output for the same activity, as it has been shown in people that a greater mediolateral displacement of the body center of mass occurs in obese versus normal-weight individuals during walking. Additionally, the accelerometers in our study may not be sensitive enough to record minor differences in speed when placed in the neck collar. Preston et al compared counts from accelerometers in various positions on dogs walking at 5 km/h and trotting at 7 km/h on a land-based treadmill. No significant difference was found in counts unless the accelerometer was placed in a pouch between the
shoulders in a harness. It was also found that walking on an incline did not increase accelerometer counts. Consequently, assessment of energy expenditure from accelerometer counts is difficult. Although accelerometry is a practical and affordable tool for activity monitoring in dogs, interpretation of the data is subject to speculation, and more research in this field is warranted.

If physical training improved cardiorespiratory fitness in the FD group, it was not evidenced by the heart rate measurements because both the FD and DO groups had a significant decrease in heart rate from the first to the last test. This decrease in heart rate for both groups was not surprising, considering that weight loss results in less strain on the cardiovascular system. The lack of difference between groups could be partly due to the small sample size and interindividual variability, but the applied method of measuring heart rate during submaximal exertion also presents an obvious limitation. Measurement of maximal oxygen consumption (ie, VO2 max) is the gold standard for fitness assessment in humans and many experimental animals. However, dogs must be carefully trained for breathing through an airtight mask. In this setting, we found it neither practically possible nor ethically acceptable to measure maximal oxygen consumption. Assessment of cardiorespiratory fitness in pet dogs is a key element for investigations in health aspects relating to lifestyle, and more research is required to establish practical and reliable methods to make such determinations.

This study had several strengths. An objectively measured increase in physical activity was achieved in dogs during a weight loss program. The study included a control group that was fed the same diet, had similar energy intake, and obtained a similar degree of weight loss. Consequently, the combined effects of energy restriction and physical activity in overweight dogs could be studied in more detail, compared with previous canine weight loss studies. Our study also had several limitations, most notably the small sample size, lack of randomization, and large degree of variability in regard to the age, breed, sex, and neuter status of the dogs. The 12-week intervention period may also have been a limiting factor. Although 12 weeks is a frequently used time span for studies relating to either weight loss or physical activity in dogs or people, it may be that, because a cautious approach is needed to prevent injury when training overweight dogs, 12 weeks is too short a time to identify significant changes in cardiorespiratory fitness, especially in older dogs. To ensure a sufficient number of participants, a wide age range was accepted in this study, but it may be advisable to provide a more extended program if geriatric dogs are included in future canine fitness studies.

Our findings suggested that adding physical training to a weight loss program for pet dogs can more effectively preserve lean body mass, compared with dietary energy restriction alone. It is worth noting that the results were obtained from a group of pet dogs, and a drastic change in the level of physical activity was not accomplished; this occurred partly because owners’ routines were not easily changed, but also, given that the dogs were overweight and unfit, many dogs were incapable of, or uncomfortable with, more than light physical activity. To avoid injuries, exercise training was gentle and the progression in intensity was slow. Even so, we obtained convincing data to indicate that increased physical activity during a weight loss program can have a marked, beneficial effect on lean body mass preservation.

Despite the high prevalence of canine obesity, this study was restricted in the number and uniformity of dogs that we could recruit within the available time frame. We consider it an important observation that pain and inability to exercise were major limiting factors in the recruitment of canine participants and for the completion of the exercise program. In the future, weight management in dogs may benefit from an increased focus not only on physical activity, but also on pain management and rehabilitative training, enabling dogs to become more physically active.

Acknowledgments
This research represents a portion of a thesis submitted by the first author to the University of Copenhagen Department of Veterinary Clinical and Animal Sciences as partial fulfillment of the requirements for a doctoral degree.

Supported in part by the University of Copenhagen UNIK Food, Fitness and Pharma Research Program and the University of Copenhagen Synergy in Human and Animal Research (SHARE) program. Royal Canin, Denmark, donated the diets used for dogs included in the study.

Presented in abstract form at the 8th International Symposium on Veterinary Rehabilitation/Physical Therapy and Sports Medicine, Corvallis, Ore, August 2014, and the 18th Congress of the European Society of Veterinary and Comparative Nutrition, Utrecht, The Netherlands, September 2014.

The authors thank Drs. James Miles, Helle Harding Poulsen, and Anna Cronin for technical assistance.

Footnotes
a. Royal Canin Satiety Support, Royal Canin, Aimargues, France.

b. Slimfit, Royal Canin, Aimargues, France.
c. Actigraph GT3X+, ActiGraph, Pensacola, Fla.
d. ActiLife Software, ActiGraph, Pensacola, Fla.
e. Hydro Physio HP200, Shor-Line, Kansas City, Kan.
g. Polar RS-400, Polar Electro, Kempele, Finland.
h. Veterinary Scale, Soehnle Professional GmbH, Backnang, Germany.
i. Lunar Prodigy, GE Healthcare, Munich, Germany.
j. encore, version 13.60, GE Healthcare, Munich, Germany.
l. GraphPad Prism, version 6.05, Prism Software, La Jolla, Calif.

References

Appendix

Composition of a dry commercial weight loss diet† (metabolizable energy content, 2.692 kcal/kg [1.224 kcal/lb]) fed to 19 dogs enrolled in a 12-week study to assess the influence of controlled physical training on variables of interest for obese and overweight dogs during a weight loss program.

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage (g/100 g diet)*</th>
<th>ME basis (g/1,000 kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>30</td>
<td>111</td>
</tr>
<tr>
<td>Crude fat</td>
<td>9.5</td>
<td>35</td>
</tr>
<tr>
<td>Starch</td>
<td>17.6</td>
<td>62</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>16.6</td>
<td>61</td>
</tr>
<tr>
<td>Total dietary fiber</td>
<td>28.1</td>
<td>104</td>
</tr>
<tr>
<td>Ash</td>
<td>5.3</td>
<td>20</td>
</tr>
</tbody>
</table>

†Three dogs were removed from the study because of unrelated illness (n = 1) or need for NSAID administration for > 2 weeks (2). Values shown are manufacturer-reported data.

*Determines an as-fed basis. ME = Metabolizable energy.