Effects of Weight Loss on Heart Rate Normalization and Increase in Spontaneous Activity in Moderately Exercised Overweight Dogs

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ABSTRACT

The objective of this study was to evaluate the impact of weight loss on heart rate normalization at rest and during moderate exercise in overweight dogs. Spontaneous physical activity level evolution in relation with weight loss was also assessed.

A group of 15 overweight dogs (average body condition score, BCS=7 on a 9-point scale) were enrolled in a 3-month energy restriction protocol to help them reach an ideal body condition. Weight loss rate was fixed at 1 to 1.5% of body weight loss per week for a steady and healthy weight loss. Dogs were fed a weight management diet enriched in key nutrients to support heart function (i.e., omega-3 fatty acids from fish oil, taurine and L-carnitine) and assigned to a daily walk of moderate intensity (5 km/h) for the 12-week study.

At the completion of the study dogs recovered an ideal body condition (BCS=4.3). DEXA measurement showed maintenance of lean tissue and a 60% decrease in initial body fat mass. A normalization of lipid metabolism was observed with a significant decrease in blood triglycerides and an increase in circulating free fatty acids. Normalization of heart rate was also observed: heart rate decreased by 17% both at rest and during the walk after only 6 weeks on study, demonstrating a beneficial impact of both weight loss and exercise on heart function. Compared to initial levels, voluntary physical activity increased by 1.5 hours per day following weight loss.

In conclusion, coupling a weight loss program together with daily standardized activity helped dogs recover an ideal body condition characterized by a better body composition with maintenance of lean tissues at the expense of fat. Blood parameters improved, while heart rate also normalized. This study highlights the fact that normalizing heart rate is a key parameter to take into consideration when treating overweight dogs in a weight loss program. Helping increase voluntary physical activity and promoting a better balance between energy input and energy expenditure will also be useful in preventing weight rebound.

INTRODUCTION

Overweight and obesity are a growing problem in the canine population, just like that observed in the human population. The incidence of dogs being considered overweight is increasing, affecting an estimated 20-40% of the canine population.[1-3] The most typical risk factors associated with weight gain in dogs are: 1) uncontrolled food intake that leads to excess calorie intake and storage of energy as fat, 2) lack of activity and exercise due to living conditions (indoor or urban lifestyle), 3) spaying/neutering where the hormonal changes lead to a decrease in daily energy expenditure, and 4) breed predilections.[4] Any one, or a combination, of these risk factors can lead to overweight and obesity, which increases the dog's risk of several health conditions. A life-long study in Labrador retrievers shows moderately overweight dogs were at greater risk for earlier morbidity and shortened life spans compared to their lean-fed littermates.[5,6] Overweight and/or obese dogs are also at increased risk of diabetes, hypertension, pulmonary and cardiovascular disease, and degenerative joint disease.[3,6,7]

Pet food companies have addressed the first risk factor mentioned above by providing veterinarians and consumers with weight management products with adapted nutrient profiles and feeding recommendations for weight loss, as well as maintenance. The second risk factor (e.g., lack of activity) is still a factor that veterinarians have difficulties to correct. Despite recommendations to the owner to increase daily activity, the compliance is generally very low, even though the combination of diet and exercise increases the efficacy of the weight management program. But very often, as it can be painful for the overweight/obese dog to move, owners prefer not to add another constraint to their calorie-restricted dog. Although the development of overweight-associated osteoarthritis can largely explain the decrease in spontaneous physical activity in this population of dogs, cardiac function may also contribute to low activity level.

Cardiac muscle workload changes together with body condition. Obesity has adverse effects on cardiac function, increasing heart rate and blood pressure. It has been suggested that abnormal left ventricular function may occur early in the development of canine obesity, in association with high caloric diets.[8] The increase in heart rate observed in obese dogs has been elsewhere explained by a transient increase in sympathetic activity and a long-lasting decrease in parasympathetic activity.[9,10] These modifications of the sympathetic/parasympathetic regulation of the heart, lead overweight dogs to exhibit higher heart rates at rest and during activity compared to lean dogs.[11]

In exercise physiology, it is well-known that heart rate is lower at submaximal workloads and even at rest in trained versus untrained subjects.[12] This lower resting heart rate enables athletes to slow down and delay the increase in heart rate during exercise so that they can exercise for longer at higher intensities compared to sedentary people. The authors observed the same differences in another study examining the resting and exercising heart rates of 14 trained Alaskan huskies.[13] Heart rate at rest (lowest heart rate during inactivity period) and average heart rate during mild (45 minutes of walking on a leash at 5km/h), moderate (2h of trotting at 12km/h), and intense exercise (6 minutes of free running at 35 km/h) ranged from 46$\pm$2, 159$\pm$5, 179$\pm$5 and 190$\pm$3 beats per minute (bpm), respectively. In another study (unpublished), we observed that lean, sedentary kennel dogs from various breeds (Brittany Spaniel, Labrador retriever) exhibited resting heart rates of 70-80 bpm and an average heart rate between 140 and 160 bpm during walking, while obese kennel dogs from the same breeds exhibited resting heart rates of 90-110 bpm and average walking heart rates between 170 and 200 bpm. This difference in heart rates in relation to being overweight has also been reported by Kuruvilla.[11] Kuruvilla observed a difference of 20 bpm at rest between lean and overweight dogs, and a faster recovery in resting heart rate after exercise in lean

dogs. [11] The authors concluded that heart function of pet dogs can be affected by body condition and exercise. This illustrates that being overweight increases the work load on the heart. To our knowledge, there are no published studies that address the question of the reversibility of cardiac function with weight loss. In other words, can an overweight dog recover a normal heart rate if he loses the extra weight and regains an ideal body condition/weight and, if so, what is the impact on the dog's spontaneous physical activity?

In the present study, we examined whether reducing excess weight in dogs using an adapted nutritional strategy that included a tailored weight management product, adapted feeding guidelines, and activity plans, could normalize heart function and help the dogs lower their heart rates and increase their spontaneous physical activity level.

Nutritional strategy: decrease of energy input

A strategy to help an overweight dog lose excess body weight generally includes the choice of an appropriate food (i.e., a low calorie, high protein, low fat diet with moderate to high fiber) coupled with adapted feeding guidelines to decrease the energy intake. For the current study, the weight loss diet contained higher levels of dietary protein and reduced levels of fat. Because these overweight dogs had elevated resting heart rates, the diet also contained key nutrients (omega-3 fatty acids, taurine, and L-carnitine) involved in heart function metabolism to help normalize the heart rate to that of a lean dog's level. Omega-3 fatty acids, EPA and DHA, from fish oil have anti-inflammatory, hypotensive, anti-arrhythmic, and antivasopressor activities. By binding directly to the protein of the sodium channels in the cell membrane, omega-3 fatty acids stabilize the electrical activity of monocytes, resulting in a reduction in left ventricular systolic pressure and a slower resting pulse rate.[14] Taurine is one of the most abundant free amino acids and is found in relatively high amounts in heart tissue. Several cardioprotective benefits are attributed to taurine, such as being an effective cardiotonic compound, regulator of natriuresis and diuresis, exhibiting positive effects on myocytes, and minimizing the adverse effects of angiotensin II. L-Carnitine is a molecule which transports long-chain fatty acids into the mitochondria for the beta-oxidation pathway and to supply energy to the cell. L-carnitine can improve heart rate and exercise tolerance, thus further helping the animal to return to normal cardiac function.

Physical activity strategy: increase in energy output

As already mentioned, one key parameter that is not taken into consideration very often or is poorly applied by owners of overweight dogs is the increase in energy output (i.e., 24 hour energy expenditure linked to physical activity). As in humans, increasing the level of activity during the day is a very efficient and quantifiable way to impact energy balance. It has been shown that lean body mass maintenance during weight loss is a key parameter for long-term weight maintenance success.[15] Exercise has been identified as an efficient way to positively modulate body composition changes during weight loss programs.[16] Exercise stimulates muscle mass and prevents the catabolism of endogenous proteins during periods of energy restriction faced during weight loss programs.[17,18] Exercise stimulates muscle protein synthesis and helps maintain lean body mass, while losing body weight. The authors believe that in dogs, an increase in daily spontaneous activity should also be a part of any weight loss program. Walking has been described in humans as the perfect exercise with regards to improving health[19], principally because it is an exercise of low intensity and one that is relatively easy to perform, even in overweight people. Nevertheless, exercising overweight/obese dogs is not an easy task and should not exceed mild to moderate intensity (walking, not running). Since the main goal of the study was to make the dogs lose weight in a healthy

manner, we included a daily walk to help the dogs preferentially lose fat while maintaining lean body mass, resulting in maintenance of basal metabolic rate and avoidance of weight rebound following the weight loss.

This study was aimed at helping overweight dogs recover an ideal body condition while normalizing their heart function using an adapted weight management formula enriched in key nutrients for heart health. We expected that by accomplishing this aim, we would encourage the dogs to continue to exercise spontaneously during the days following weight loss to help them maintain their ideal body condition, even while back to a normal feeding schedule.

MATERIALS AND METHODS

Dogs and housing

A 3-month feeding study was initiated in overweight dogs to enable them to recover their ideal body condition and normalize their heart rate, while being fed a weight management diet (described below).

Prior to initiation of the study, dogs were screened to ensure/confirm there was not any pre-existing clinical diseases or an exercise intolerance condition. The screening consisted of a complete health status check by the attending veterinarian.

While overweight dogs were used in the study, there were no obese dogs in it. The dogs had an average BCS of 7.0 $\pm$ 0.2, on a 9-point scale, and were 20.7 $\pm$ 1.9 % overweight compared to their estimated ideal body weight. Dogs, ages 1-9 years old, were composed of various breeds, gender and sterilized status: 1 Mini Schnauzer, 3 Fox Terriers, 3 Cairn Terriers, 7 Beagles, 1 Brittany Spaniel, and 1 Labrador retriever.

They were housed in compatible pairs (one male and one female together) in indoor kennels with continuous free access to a large external court. All inside housing was maintained at a room temperature of 18°C-24°C with controlled lighting to provide 12-hour light and dark periods. The dogs continued to be involved in normal kennel activity sessions like play in bigger outdoor parks, so as to not decrease the normal daily activity level and socialization program they normally have in the colony.

Diets

All the dogs were fed the same weight control diet formulated as a complete and balanced adult dry dog food enriched in fish oil as a source of omega-3 fatty acids EPA and DHA, taurine and L-carnitine. The diet was produced in the Nestlé PURINA R&D Centre (Amiens, France) and was formulated to meet or exceed the minimum requirements for adult dog maintenance as established by FEDIAF (European Pet Food Industry Federation, Brussel, BELGIUM). Typical analysis is shown in Table 1.

The test diet was the sole source of nutrition the dogs received throughout the 3-month of study. Fresh, clean water was always available.

Dog Care and Health

Health monitoring and/or treatment of all dogs were carried out according to established colony veterinary procedures. All dogs were observed several times every day by the veterinary and caretaker staff. Any dog exhibiting sign of illness was immediately examined. If needed, medical treatments were administered.

Table 1. *Composition of the test diet. Metabolizable Energy (ME) calculated using Atwater factors.*

	Test Diet
Protein (g/100 g)	26.8
Fat (g/100 g)	8.2
Carbohydrates (g/100 g)	48.1
Crude Fiber (g/100 g)	3.0
Ash (g/100 g)	5.3
Taurine (mg/100 g)	159
EPA+DHA (g/100 g)	0.3
L-carnitine, added (mg/100 g)	20
ME (Kcal/g)	3.3

The protocol was approved by the Nestlé PURINA R&D Centre, Amiens Animal Care and Use Ethical Committee. The dogs in the study were considered healthy based on the results of physical examination and clinical laboratory tests.

Trial Protocol

Dogs were fed to lose 1 – 1.5% of their body weight per week depending on the severity of their overweight condition, using the following calculation for daily energy requirements (DER) determination:

DER = MER (Kcal/day) – [(Wt (kg) * Rate of loss/wk)/ 7days/week] * 7900Kcal/kg

Where MER = (Allometric factor)*Wt(kg)0.75

The allometric factor was determined for each dog before starting the protocol. If a dog reached ideal body condition before the end of the study, the dog was fed the same diet, but on a maintenance feeding protocol.

For the duration of the 3-month study, dogs were involved in a daily 30-minute leash walk (7 days per week at 8:00am). The intensity of the walk was mild to moderate and fixed at 5 km/h. Dogs were walked as couples to encourage them to complete the walk. Dogs were fed daily at 11:00 am. During the afternoon period, dogs continued to have access to usual outside free activity in wide yards, so as not to decrease their standard level of activity.

At t=0 and t=12 weeks, the following measurements were taken for all dogs: a complete blood count, serum chemistries, plasma total free fatty acids profile, triglycerides, total T4, glucose and insulin levels, fat and lean body mass by dual-energy x-ray absorptiometry (DEXA, GE Healthcare, Lunar, Velizy, FRANCE).

At t=0, t=6, and t=12 weeks, body condition scoring was done by the veterinary staff with the same scorers each time, using the PURINA 9-point scale.20 (Laflamme, 1997) Activity was measured using Actiwatches® devices and heart rate was assessed using Actihearts® (Mini Mitter / Philips Respironics, Oregon USA).

Actihearts® are considered a good tool to measure a wide range of heart rates in free living dogs both at rest and during exercise of various intensities.13 The procedure to put Actihearts® in place was adapted from the human procedure, as explained in the Actiheart® utilization manual. Briefly, small areas located on the chest around the heart were shaved to receive an electrocardiogram patch on which the Actiheart® was clipped. The device was then protected with an adapted bandage covering the ribs and surrounding front legs to prevent any unwanted slide during the walk and also to prevent the dog from removing it.

Actiwatches® were attached to the dog's collar. Devices were placed on the dogs 1 hour before the morning walk and removed just before feeding to allow collection of 3 hours of data during the recovery period following the walk. Actiwatches® were also attached to the dog's collar to allow for a 24-hour assessment of activity level and intensity (from morning until morning), as already described by Patil,21 where activity counts and intensity of activity are divided according to the following scale:

- Inactive (Intensity 0)
- Alert (Intensity 1-50)
- Mild Activity (e.g., slow walking) (Intensity 50-100)
- Moderate Activity (e.g., brisk walking) (Intensity 100-200)
- Intense Activity (Intensity 200-400)
- Very Intense Activity (Intensity >400)

Food consumption was measured daily and body weight assessed weekly.

Blood analysis

At the beginning and at the end of the protocol, six ml of blood was withdrawn from the jugular vein and divided into an EDTA- and heparinated-tube for haematology and biochemistry measurements, respectively. Glucose was immediately measured using an Abbot® Optium Xceed blood glucose meter (Superliving Ltd, Devon, UK). The DEXA scan was performed under anesthesia.

All blood analysis was performed by Vet Med Labor GmbH (Mörikestr, Germany). Free fatty acids were analyzed using the NEFA kit from Randox Laboratories Ltd (UK). Triglycerides were measured using the GPO-PAP kit from Cobas, Roche

Diagnostics GmbH (D-68298, Mannheim, GERMANY). Total T4 was measured using the DRI® Thyroxine (T4) Assay from Microgenics Corporation (Fremont, CA). Insulin was measured using the RIA IDSL 1600 from Diagnostic Systems Laboratories Inc (Webster, TX).

Statistical analysis

Analysis of variance was performed for comparing body weight and heart rate data evolution for t=0, 6 and 12 weeks. A paired t-test was performed for the comparison of body composition, blood and activity level data between t=0 and 12 weeks. All statistical calculations were performed using SAS 9.1.

RESULTS

One dog was removed from the study because of the identification of knee arthritis after the first week of walking. This dog stayed on the weight loss feeding program minus the daily walk. Data from this dog was not included in the averages calculations.

Body weight and body condition

Table 2 shows the evolution of body weight, overweight and body condition at t=0, t=6 and t=12weeks. Dogs lost weight at the expected rate (1-1.5% of body weight per week). After 12 weeks, the average body condition was considered ideal according to the PURINA BCS scale. The overweight condition was removed almost entirely.

Body Composition

Table 3 shows the evolution of body composition between t=0 and t=12 weeks. Dogs exhibited maintenance of their lean body mass while fat mass was reduced to levels in accordance with an ideal body condition.

Heart rate evolution

Figure 1 shows the evolution of heart rate during the walk and recovery. A decrease in heart rate was observed throughout the study as the dogs lost weight.

Table 4 shows the average heart rate during the walk and the measured resting values. Both resting and average walking heart rates were significantly lower after 6 and 12 weeks compared to the beginning of the study. The benefit of the daily walk can explain the huge decrease in heart rate observed after only 6 weeks (-17%), but the excess weight lost explains the results between 6 and 12 weeks in which resting and walking heart rates decreased further (-21% vs. t=0). This decrease can be explained by loss of the extra weight that still remained at 6 weeks: the reduction in resting heart rate was almost significant (P = 0.055).

Table 3. *Body composition evolution as measured by DEXA. The loss of lean and fat mass expressed as % after 12 weeks was calculated based on the absolute tissue weight values as measured by DEXA scans at t=0 and t=12 weeks ($a \neq b$, $P < 0.05$).*

	t=0	t=12 weeks
% Lean Mass	67.7 ± 1.9^a	81.1 ± 2.3^b
% Fat Mass	28.5 ± 2.0^a	14.5 ± 2.5^b
Evolution of lean mass, % of initial mass	-	0.8 ± 15.8
Evolution of fat mass, % of initial mass	-	-59.1 ± 5.2

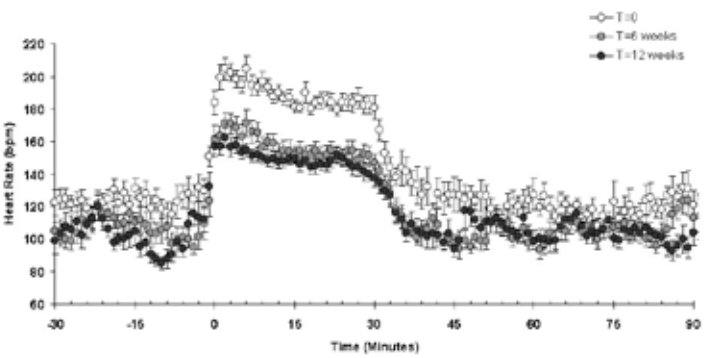
Spontaneous physical activity

Figure 2 shows the details of the activities recorded at t=0 when the dogs were overweight and at t=12 weeks following the weight loss. It appears that the inactive periods decreased significantly following weight loss (10.8 ± 0.5 hours at t=0 vs. 7.5 ± 1.3 hours at t=12 weeks, $P<0.05$). Both alert periods and mild to moderate activity periods increased significantly following weight loss. Time spent in intense and very in-

Table 2. *Evolution of weight lost, percentage above ideal body weight, and body condition score ($a \neq b$, $P < 0.05$).*

	t=0	t=6 weeks	t=12 weeks
Weight lost, % of initial weight	-	8.2 ± 0.9^a	15.9 ± 1.3^b
Overweight, % above ideal body weight	20.71 ± 1.9^a	10.87 ± 2.1^b	1.4 ± 1.6^c
Body Condition Score	7.0 ± 0.2^a	5.6 ± 0.3^b	4.3 ± 0.3^c

Figure 1. *Evolution of heart rate during the walk (from t=0 to t=30 minutes).*



tense activities was not different. However, weight loss over the 12 weeks promoted an increase in spontaneous physical activity (mild + moderate + intense + very intense) by 15% per 24 hours.

Blood analysis

Table 5 provides blood analysis values at t=0 and t=12 weeks of the study. Dogs were not exhibiting signs of hyperglycemia at the beginning of the study. They were in moderate hypoglycemia, which was expected as samples were taken prior to feeding time. After 12 weeks of study, the dogs were in a lean condition and appeared better able to support the fasted state as their glycemia was considered normal. A tendency for a decrease in the level of insulin was observed after 12 weeks, indicating a better management of glucose metabolism.

Table 4. *Resting heart rate (measured as the lowest heart rate during inactive periods) and average walking heart rate (average from 0 to 30-minute walk collected data) ($a \neq b$, $P < 0.05$).*

	t=0	t=6 weeks	t=12 weeks
Resting heart rate (bpm)	82.4 ± 1.8^a	68.7 ± 2.2^b	65.1 ± 2.2^b
Average heart rate during walk (bpm)	188.9 ± 4.5^a	156.7 ± 4.5^b	149.0 ± 3.5^b

Total thyroxin decreased significantly after weight loss, as reported in other weight loss program in dogs. Values stayed in the normal physiological range.

Triglycerides decreased significantly after weight loss. At the same time, a significant increase in free fatty acids was observed. These two results reflect an increase in lipid metabolism with a better mobilization of fat stores.

DISCUSSION

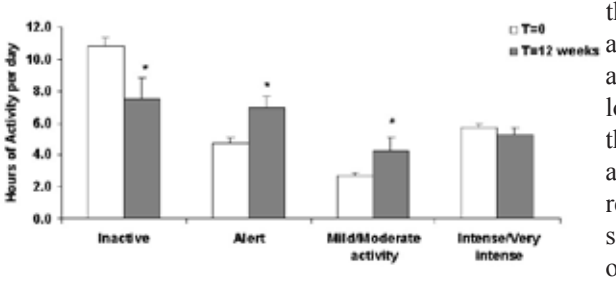
The main goal of this study, which was to help dogs recover a normal heart rate after a weight loss program, has been fully fulfilled after 3 months, with positive and significant results obtained after only 6 weeks into the study.

This study highlights the importance of including daily mild exercise during weight loss programs in dogs so that the energy restriction necessary to induce weight loss stays within an acceptable range (i.e., less than 1.5% of weight loss per week). In this study, this represented a 25% reduction of the daily dietary energy need calculated from the current body weight. This is in line with what is usually recommended in the feeding guidelines for overweight dogs for weight loss on pet food light products. This mild energy reduction, together with the nutrient profile of the product (high protein, low fat and moderate fiber levels), ensures the dog receives a quantity of food similar to what he should receive for maintenance with a non-light product, thus helping to fill the stomach and reduce hunger feelings. This helps guarantee a better compliance from the owner during the weight loss program.

Calorie restriction has been shown to increase median lifespan in dogs by 15% compared to full-fed littermates[5]. In humans, dietary modifications and lifestyle changes, such as increase in daily activity, have been reported as successful for increasing the quality of life during aging.[22] The present study emphasized the importance of increasing daily energy expenditure by an increase in daily activity to ensure the success of the

weight loss program. Exercise has been shown to positively influence body composition changes. The introduction of a daily walk during the study helped to maintain lean body mass. It has been described that diet or exercise alone cannot fully account for lean body mass maintenance. Association of both are keys to preserving body protein pools, maintain basal metabolic rate, and reducing risks of weight rebound after weight loss.[16]

Figure 2. Spontaneous physical activity during a 24 hour period.



Together with body composition modifications (i.e., fat mass loss and fat-free mass maintenance), one of the goals of this weight loss study was to normalize heart rate. Heart rate has been shown to be quickly impaired with weight gain, leading to an excess work-load which can contribute to the reduction in spontaneous physical activity. We confirmed that when overweight dogs recover their ideal body condition and exhibit a healthy heart rate, they increase their voluntary daily activity level, which can be considered as essential for the long-term maintenance of ideal body weight.

Weight loss and body composition

The rate of weight loss was in line with what was expected (16% weight loss in 12 weeks), which means dogs lost an average of 1.3% of body weight per week. It is well-documented that a healthy weight loss should be targeted at 1-1.5% body weight loss per week. The fact that the dogs were not obese and that a daily walk was introduced as a daily activity most likely induced a quick response to the weight loss program.

After 12 weeks, the modifications in body composition were in line with what is considered a "healthy" weight loss, with the majority of weight loss consisting of fat mass loss. Loss of lean body mass was not observed during the study; some dogs actually exhibited an increase in lean body tissues after 12 weeks compared to their initial lean body mass. This is a very positive result which is not always easy to achieve in weight loss programs.[4] Because the dogs in the current study were overweight and not obese, the degree of energy restriction required was not too severe (dogs received around 75% of their needs based on their current weight), therefore, limiting the risk of endogenous protein catabolism. Moreover, daily exercise helped stimulate muscle mass and increased protein synthesis, so that a high protein turnover was maintained. The protein level in the diet (much higher than the minimum required) worked in favor of supporting this protein turnover.

Dogs lost almost 60% of their initial fat mass going from 28.5% body fat mass down to 14.5%. This is considered as a healthy fat mass weight and is well-correlated with the ideal body condition scores on the 9-point BCS scale.20,23.

Heart Rate

The initial heart rates identified in these overweight dogs at initiation of the study were far beyond standard values for sedentary dogs. The at rest heart rates averaged 82 bpm, while standard value is generally considered to range between 60 and 70 bpm. During the walk, the overweight dogs showed an average heart rate of 189 bpm, representing about 80% of a dog's maximum

Table 5. Fasting blood parameters measured at t=0 and t=12 weeks ($a \neq b$, $P < 0.05$).

	t=0	t=12 weeks
Glucose (mmol/L)	3.6 ± 0.1^a	4.7 ± 0.1^b
Insulin (µU/mL)	14.2 ± 2.6	10.7 ± 1.5
Total T4 (nmol/L)	30.0 ± 2.4^a	22.6 ± 2.0^b
Triglycerides (mmol/L)	0.61 ± 0.07^a	0.45 ± 0.03^b
Free Fatty Acids (mmol/L)	0.70 ± 0.07^a	0.85 ± 0.08^b

heart rate (230-250 bpm for most of breeds). It is acceptable to observe an average of 140-150 bpm during exercise (representing only 60% of their maximum heart rate).

Heart rate has been largely proposed in human exercise physiology as a good indicator of exercise intensity. Indeed, heart rate represents a good tool to characterize aerobic/anaerobic metabolic pathways thresholds, while switching from moderate to intense activity types during exercise bouts. By measuring heart rate and blood lactate before, during and after exercise in Alaskan sled dogs, we recently demonstrated that heart rate can also be a good tool to classify exercise intensity and identify types of aerobic/anaerobic exercise in dogs.[13]

The heart rates observed during this weight loss study clearly show that even if the speed of the walk imposed on the dogs was mild to moderate (5 km/h, which represented a pace that was considered as below what we would qualify as a "brisk" walk), their average heart rate was around 80% of their maximum heart rate. We previously identified that the onset of blood lactate accumulation occurs in trained dogs at 76.5% of maximum heart rate, indicating large contributions from anaerobic metabolic pathways. Exercise-types with average heart rates beyond this value were considered as intense[13], but this, however, is not an intensity that a dog can sustain for a long time. One can easily understand that overweight dogs with impaired cardiac function are less keen to be involved in spontaneous physical activity because they feel exhausted very quickly. It emphasizes the importance of enabling these dogs to lose weight and involve them in daily activities to optimize the heart response to mild exercise. This is what we observed after only 6 weeks of study: dogs lost 1.5 points of body condition score, with a 17% decrease in heart rate both at rest and during exercise. After 12 weeks, ideal body condition was reached (4.3, on a 9-point BCS scale) and average heart rate during walking (considered to be in the mild range of exercise intensities) represented only 60% of their maximum heart rate.[13] With this average heart rate, aerobic metabolic pathways are thought to largely contribute to energy supply, allowing the dog to exercise for longer without feeling exhausted by relying mainly on fat stores as a source of energy substrate. The body will use the fat stores to create ATP from the oxidation of fatty acids in the muscles. By providing the dogs with an adapted food, energy restricting them, and introducing standardized daily activity, the metabolic response of the dog to mild/moderate activities was normalized. Dogs were effectively exercising using aerobic metabolic pathways, as reflected by their lower heart rate during exercise, showing a better mobilization of fat stores to fuel the 30 minutes of exercise.

Blood metabolites

This proposed better ability to burn fat was confirmed by circulating levels of triglycerides and free fatty acids. We observed a decrease in circulating triglycerides and an increase in free fatty acids, indicating an improvement in lipid metabolism. Hyperlipidemia is well described in obese dogs and is defined by an increase in plasma concentrations of cholesterol and triglycerides. Dietary modifications have been shown to modulate and help normalize blood lipids,[24-26] and is in line with what we observed in the present study for triglyceride levels. The increase in circulating free fatty acids well reflects the improved mobilization of fat stores and has already been reported elsewhere.[26]

This increase in fasting circulating free fatty acids has to also be considered in parallel with fasting blood glucose. At the beginning of the study, dogs were in slight hypoglycemia at the time of the bleeding, while the glycemia was significantly higher and considered normal after 12 weeks. This reflects the success of the energy restriction strategy and the fact that the energy balance of the dogs was reached at the completion of the study. The higher fasting circulating free fatty acids levels indicate an improved management of energy substrates, even at rest.

Dogs relied less on glucose metabolism after weight loss because they were able to mobilize their fat stores, therefore, glycemia was better maintained in these lean dogs.

Hormones

Insulin levels were inside normal range values and not significantly different between the beginning and the end of the study, showing no signs of insulin resistance in the dogs at the beginning of the study. When calculating the HOMA index (Homeostatic model assessment) for insulin resistance (HOMA-IR = [fasting glucose (mmol/L) x fasting insulin (mU/L)]/22.5), no significant differences were observed (2.5$\pm$ 0.5 at t=0 vs. 2.1$\pm$0.3 at t=12 weeks). This is quite logical as none of the dogs was considered obese. Insulin resistance has been reported in severely obese dogs .[24] There was a trend in the present study, however, for higher insulin values at t=0 when dogs were overweight, which could also explain the higher plasma triglyceride levels observed (even though levels were still considered in the normal healthy range).

A significant decrease in total thyroxin after weight loss was also observed, which has been already reported in dogs. Values, however, were in the normal physiological range both times, which is consistent with other studies, reporting that obese dogs are euthyroidic with normal total T4 concentrations.[28,29]

Spontaneous activity

Voluntary physical activity significantly increased at the completion of the study. Dogs were 15% more involved in physical activities after weight loss. This is a very positive result which emphasizes the importance to maintain dogs in ideal body condition with a healthy heart function, so that heart rate and overweight are not contributing factors that decrease daily activity levels. This is particularly important for the long-term success of a weight loss and/or weight management program since dogs that are active will have a higher 24-hour energy expenditure and will be able to better maintain their body weight and their lean body mass.

Surprisingly, the level of intense activities was not significantly different before and after weight loss, only mild and moderate activities were increased. One explanation for this finding is due to the way the Actiwatches® are measuring activity. These devices contain an accelerometer that records activity bouts, with each movement of the actimeter being translated into an activity count. Given the fact that the actimeters were put in a collar around the neck of the dog, it is possible that part of the intense activities measured when the dogs were overweight were probably of less intensity compared with what was measured. Overweight dogs have less fluid mobility than lean dogs, with the impact of the feet on the ground being much heavier given the extra weight they carry. This can also cause unwanted head shaking. The accelerometer may have, therefore, recorded and considered activity peaks as very intense, when in fact they were the result of an activity that was only moderate. Regardless, the important result is that when pooled together, all the activity sessions were 15% longer during a 24-hour period following weight loss. It is also important to highlight the fact that the protocol started in September when temperatures where still cool (between 17 and 21°C) and finished in December with temperatures as low as 5°C. The cool temperatures could have contributed to the dogs having a tendency to stay in their heated kennels in order to be less exposed to the cold weather. A significant increase in activity level was observed despite the weather, however, and the dogs voluntarily exercised more with their recovered lean body condition.

CONCLUSION

In conclusion, we demonstrated that during this weight loss program that the adapted diet, containing high levels of protein, low levels of fat and supplementation with taurine, L-carnitine and omega-3 fatty acids from fish oil, together with the daily walking program were efficacious at making dogs lose weight and recover a healthy heart rate in only 3 months. The rate of weight loss

was not too excessive (between 1-1.5% per week) and allowed a healthy loss of body tissues. Dogs preferentially lost fat mass, while maintaining and even increasing their lean tissues. The decrease in heart rate observed together with the increase in spontaneous physical activity measured after 12 weeks emphasize the need to propose both an adapted weight management diet and a daily activity during a weight loss program. The combination of diet and exercise will ensure a successful and healthy weight loss is reached and lean body condition is maintained long-term.

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