Effectiveness of a New Dietetic Food to Achieve Weight Loss and to Improve Mobility in Client-Owned Obese Dogs with Osteoarthritis

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ABSTRACT

Objective

Evaluate weight loss parameters and to assess clinical signs related to osteoarthritis in dogs fed a new dietetic food (NDF).

Design

Prospective, uncontrolled/unmasked clinical trial.

Animals

Thirty-eight overweight/obese, client-owned dogs with osteoarthritis.

Methods

Initial and follow-up evaluations (monthly for 6 months) included determination of body weight, body condition score (BCS), body fat index (BFI), and evaluation of osteoarthritis-related parameters as assessed by the veterinarian (lameness, weight bearing, pain on joint palpation) and the owner (difficulty rising, aggression, reluctance to walk and to play, inactivity). Begging behavior, fecal score, and acceptance of food were also evaluated. Initial veterinary consultation consisted of physical examination, nutritional assessment, determination of ideal body weight (IBW), development of weight-loss feeding guidelines (DER = 70 x $IBWkg^{0.75}$), and explanation of the assessments performed. Statistical analysis comprised

scatterplots, regression analysis, summary statistics, Friedman's chi-square test, and a mixed model ANOVA to assess changes over time (statistical significance was set to < 0.05).

Results

Ninety percent of the dogs lost weight (n=34) with an average weight loss of 12.6% (SEM, 1.3%) over 6 months, and an average weekly weight-loss rate of 0.5% (SEM, 0.04%) of starting body weight. The mean duration of weight loss was 174 days (SEM, 6 days), with an average of 33 days (SEM, 1 day) between rechecks. BCS and BFI in the dogs that lost weight were significantly lower compared with baseline in months 2-6 of the study. Difficulty rising and reluctance to play improved significantly compared with baseline starting at month 2 of the study, whereas reluctance to walk and inactivity improved significantly compared with baseline starting at month 3 of the study. Similarly, lameness, weight bearing, and pain on palpation improved significantly compared with baseline starting in month 3 of the study. Fecal scores were unaffected, and begging was significantly lower in months 3 and 4 compared with baseline.

Conclusions and Clinical Relevance

This clinical study confirmed the effectiveness of the NDF* in achieving weight loss and improvement of clinical signs related to osteoarthritis in overweight/obese client-owned dogs. Owners and veterinarians reported significant improvements in dog's weight and mobility without negative side effects.

* Hill's™ Prescription Diet™ Metabolic + Mobility Canine, dry (caloric distribution: protein=27%, fat=37%, carbohydrate=36%)

ABBREVIATIONS

BCS Body condition score

BFI Body fat index

BW Body weight

CI Confidence interval

DER Daily energy requirement for weight loss calculated as 1x (70 x $IBWkg^{0.75}$)

IBW Ideal body weight

LSM Least square mean

MCS Muscle condition score

NDF New dietetic food

NSAID Non-steroidal anti-inflammatory drugs

OA Osteoarthritis

RER Resting energy requirement

SD Standard deviation

SEM Standard error of the mean

INTRODUCTION

Osteoarthritis (OA) is a common degenerative joint disease that affects an estimated 20% of the canine population (Aragon et al. 2007; Johnston 1997). Dogs with OA exhibit variable degrees of pain, inflammation, lameness, and reduced mobility (Henrotin et al. 2005). Management of OA includes pharmacological and non-pharmacological treatments. Pharmacological treatments consist of non-steroidal anti-inflammatory (NSAID) drugs, analgesic medication, and other medications. Non-pharmacological treatments encompasses activity control, nutritional support, and physical therapy, and weight management for overweight animals (Aragon et al. 2007).

An estimated 50-60% of dogs are considered overweight or obese according to recent publications and surveys (Brooks et al. 2014; Lund et al. 2006).[a] Excessive body weight is believed to exacerbate the severity of clinical signs in dogs with OA (Kealy et al. 2002; Smith et al. 1995).[b] This has been demonstrated in clinical studies and is thought to be caused by an increased mechanical burden on joints in obese animals (Brady et al. 2013; Smith et al. 2006). Weight loss decreases the severity of lameness, as was recently shown in a study by Marshall et al. where a decrease in lameness related parameters was observed once animals had lost 6.1-8.8% of their starting body weight (Marshall et al. 2010). Obesity is also an inflammatory condition characterized by an increased amount of inflammatory mediators and oxidative stress, which further contribute to OA (Laflamme 2012).

A number of dietary supplements

Table 1a. *List of ingredients contained in the new dietetic food (NDF; Hill's™ Prescription Diet™ Metabolic + Mobility Canine, dry):*

Wheat, maize gluten meal, pea bran meal, flaxseed, chicken and turkey meal, digest, tomato pomace, cellulose, dried beet pulp, fish oil, coconut oil, minerals, L-lysine, DL-methionine, dried carrots, pork cartilage, taurine, crustacean shell hydrolysate, trace elements and beta-carotene. With a natural antioxidant (mixed tocopherols).

have been suggested as having beneficial effects on OA through anti-inflammatory and chondroprotective effects. This is particularly interesting since these supplements have minor adverse effects and may decrease the need for medication. In dogs, the results from several studies provided evidence that diets supplemented with omega-3 fatty acids from fish oil improve OA related signs (Fritsch et al. 2010b; Roush et al. 2010a; Roush et al. 2010b; Vandeweerd et al. 2012). Comblain et al recently published a manuscript that reviews the dietary supplements used for the management of OA (Comblain et al. 2016). The authors concluded that dietary supplements may be considered as an option for the prevention and management of OA in the dog, but well-designed scientific studies are still needed in order to elucidate the mechanism of action and efficacy of these supplements (Comblain et al. 2016). Several dietetic foods exist on the pet food market

Table 1b. *Average nutrient content in the new dietetic food (NDF; Hill's™ Prescription Diet™ Metabolic + Mobility Canine, dry).*

Criterion	Dried ration		
	As fed	Dry matter	Per 100 kcal ME
Protein	24.9 %	27.2 %	7.8 g
Fat	13.7 %	15.0 %	4.3 g
Carbohydrate (NFE)	32.9 %	36 %	10.3 g
Fiber (crude)	14.4 %	15.7 %	4.5 g
Moisture	8.5 %	-	2.7 g
Calcium	0.78 %	0.85 %	245 mg
Phosphorus	0.53 %	0.58 %	166 mg
Sodium	0.32 %	0.35 %	100 mg
Potassium	0.87 %	0.95 %	273 mg
Magnesium	0.15 %	0.16 %	47 mg
Omega-3 fatty acids	3.22 %	3.52 %	1 g
Omega-6 fatty acids	1.96 %	2.14 %	614 mg
EPA	0.35 %	0.38 %	110 mg
L-carnitine	278 mg/kg	304 mg/kg	9 mg
Vitamin A	6,885 mg/kg	7,525 IU/kg	216 IU
Vitamin D	725 IU/kg	792 IU/kg	23 IU
Vitamin E	675 IU/kg	738 mg/kg	21 mg
Vitamin C	122 mg/kg	133 mg/kg	3.82 mg
Beta-carotene	2.0 mg/kg	2.2 mg/kg	0.06 mg
Metabolisable Energy			
Kcal/100g	319	349	
KJ/100g	1,335	1,459	

Table 2: *Osteoarthritis related parameters as assessed by owners and veterinarians at baseline and consequently at each monthly follow-up visit for the period of 6 months.*
N/A = not applicable

Owner		
Difficulty rising	1	No difficulty rising
	2	Mild difficulty rising
	3	Moderate difficulty rising
	4	Severe difficulty rising
	5	Very severe difficulty rising
	N/A	Unable to assess
Aggression	1	No aggression
	2	Mild aggression
	3	Moderate aggression
	4	Severe aggression
	5	Very severe aggression
	N/A	Unable to assess aggression
Reluctance to walk	1	No difficulty walking
	2	Mild difficulty walking
	3	Moderate difficulty walking
	4	Severe difficulty walking
	5	Very severe difficulty walking
	N/A	Unable to assess
Reluctance to play	1	No difficulty playing
	2	Mild difficulty playing
	3	Moderate difficulty playing
	4	Severe difficulty playing
	5	Very severe difficulty playing
	N/A	Unable to assess
Inactivity level	1	Extremely active
	2	Active
	3	Moderately active
	4	Inactive
	5	Extremely inactive
	N/A	Unable to assess
Veterinarian		
Lameness	1	No lameness
	2	Mild lameness
	3	Moderate lameness
	4	Severe lameness
	5	Very severe lameness
	N/A	Unable to assess
Reluctance to bear weight in the affected limb	1	No difficulty
	2	Mild difficulty
	3	Moderate difficulty
	4	Severe difficulty
	5	Very severe difficulty
	N/A	Unable to assess
Pain on palpation of affected joint	1	No pain on
	2	Mild
	3	Moderate
	4	Severe
	5	Very severe
	N/A	Unable to assess

that are targeted either to result in weight loss or to improve joint mobility and comfort.

Recently, a new dietetic food (NDF) was formulated (Tables 1a and 1b) with the goal to achieve both weight loss and to increase mobility in overweight or obese dogs, and therefore, to manage both of these common comorbidities at the same time.

The purpose of the study was to determine the effectiveness NDF to achieve weight loss and to improve mobility in obese/ overweight client-owned dogs with osteoarthritis. The objectives were:

- To evaluate weight loss parameters and
- To assess clinical signs related to osteoarthritis in dogs fed the NDF.

MATERIALS AND METHODS

Study Population

Dogs were recruited through private practice veterinarians from different European countries. Client owned dogs had to meet the following criteria to be eligible for inclusion in the study:

1. At least 1 year of age
2. Considered generally healthy
3. Overweight or obese with a body condition score (BCS) above 3 (on a 5 point scale), and
4. Diagnosed with osteoarthritis by clinical examination and at least one

diagnostic modality (i.e. radiography, CT scan, MRI, force plate analysis).

Dogs that were on pain medication (NSAIDs or other) were allowed for enrollment in the study in order to maintain a comfort level commensurate with the standard of care for each animal. Due to the duration of the study (6 months), it was recommended to limit enrollment to animals with a body fat index (BFI) of less than 50 (Witzel et al. 2014). Dog owners submitted their written consent to participate in the study and had to give their agreement to:

1. Feed the recommended amount of NDF dry food for the duration of the study
2. Return to the clinic for re-check evaluations at monthly intervals for 6 months
3. Report any relevant health issues during the study period.

Dogs were not eligible for the study if they:

1. Were pregnant or lactating or expected to become pregnant during the study
2. Had a history of adverse reactions to food
3. Required urinary acidifiers during the study
4. Needed another dietetic pet food
5. Were expected to undergo surgery during the study, or
6. Participated in another clinical study.

The study protocol was approved by the Hill's Global Animal Welfare Committee.

Study Design

The study was designed as a prospective, uncontrolled, unmasked clinical trial. Initial evaluation and follow-up evaluations (monthly for 6 months) of dogs included determination of body weight, body condition score (BCS), body fat index (BFI) (Witzel et al. 2014), and evaluation of OA-related parameters as assessed by the owner (difficulty rising, aggression, reluctance to walk and to play, inactivity) and the veterinarian (lameness, weight bearing, pain on joint palpation) (see Table 2) (Fritsch et al. 2010b; Roush et al. 2010b). Begging behavior, fecal score, and acceptance of food were also rated by the owner (see Table 3).

Initial veterinary consultation consisted of physical examination, nutritional assessment, determination of ideal body weight (IBW), development of weight-loss feeding guidelines (DER = 70 x $IBWkg^{0.75}$), and explanation of the assessments performed (Brooks et al. 2014; Freeman et al. 2011; Witzel et al. 2014).

IBW was estimated using the Hill's BFI risk chart or an on-line Healthy Weight Protocol tool.[c] Daily energy recommendation (DER)

Table 3: *Additional parameters assessed by owners at baseline and consequently at each monthly follow-up visit for the period of 6 months*

Begging behavior	1	No begging
	2	Occasional begging
	3	Normal
	4	Frequent begging
	5	Constant begging
	N/A	
Fecal scores (Jergens et al. 2003)	1	Watery
	2	Has texture but no shape
	3	Very moist but retains shape
	4	Firm but not hard
	5	Hard and dry
Acceptance of food	1	Poor
	2	Fair
	3	Average
	4	Very good
	5	Excellent
	N/A	

Table 4: *Weight loss characteristics for the dogs that lost weight presented by month.*

		Visit						
		Initial	1	2	3	4	5	6
Body weight	LSM	34.7[a]	33.4[b]	32.4[b]	31.6[b]	30.6[b]	30.7[b]	30.3[b]
	SE	2.1	2.1	2.1	2.1	2.1	2.1	2.1
	n	34	34	34	34	30	26	20
Percentage weight lost†	Mean	0	3.7	6.4	9.0	11.1	11.4	12.6
	SE	0	0.5	0.6	0.7	1.1	0.9	1.3
	n	34	34	34	34	30	26	20
BCS‡	Median	4[a]	4	4[b]	4[b]	4[b]	4[b]	3[b]
	IQR	4-5	4-5	4-4	3.5-4	3-4	3-4	3-4
	n	34	33	33	33	30	26	20
BFI	LSM	39.9[a]	39.2	35.3[b]	33.6[b]	31.6[b]	29.7[b]	28.7[b]
	SE	1.2	1.2	1.2	1.2	1.2	1.3	1.4
	n	33	32	31	31	29	25	20

Data is presented as least square mean (LSM) and standard error (SE), mean and standard error of the mean (SEM), or median and interquartile range (IQR). The number of data points for each evaluation is indicated (n). Significant differences are denoted by different superscript letters (a denotes baseline as well as follow up visits that were not significantly different from baseline. b Shows that a visit was significantly different from baseline). † Statistical analysis was not performed for this value but for body weight. ‡ For visits that are significantly different from baseline but whose medians are same as the baseline value, the interquartile range should be inspected for evidence of change in the outcome. Statistically significant differences may not always be evident for data that are skewed but the test compares the entire spectrum of measurements.

for weight loss was calculated as DER = 1 x Resting Energy Requirements (RER) = 1 x (70 x IBWkg $^{0.75}$). The importance of a healthy weight and the health risks for an overweight/obese dog were discussed with owners. Feeding guidelines to achieve IBW and maintain the newly acquired healthy weight were developed and explained to the owner. The owners were instructed to feed the NDF and to avoid other pet foods, people foods, or excess of treats. However, specific recommendations or restrictions about the amount and type of additional foods were not given. The expected rate of weight loss and target date for reaching IBW were reviewed with the owner. NDF was dispensed with feeding instructions, including the recommended amount of the dry food to be fed in grams per day, and how to gradually introduce the new food during a one-week period.

Statistical Analysis

At each follow-up time point, percent weight loss was computed as ((baseline body weight – current body weight)/baseline body weight) x100. For each animal, a scatter plot of percent weight loss or weight gain vs. weeks of follow-up was inspected to verify that the relationship was linear followed by regression analysis. Animals with a positive slope were considered to have lost weight; those with a negative slope were considered to have gained weight, while those with a slope of 0 were classified as dogs with no change in weight. Slopes were collated and summarized as mean ± standard error of the mean.

Other weight related continuous outcomes including actual body weight, percent of body weight loss, duration of weight loss, average time between visits, time to achieve ideal body weight, body weight at start and end of study, and body fat index (BFI) were summarized as mean ± standard error. Body condition score (BCS) and time to ideal bodyweight were skewed and, therefore,

summarized as median (range). Weight related categorical outcomes including dogs that achieved ideal bodyweight (IBW) (IBW was defined as weight within IBW ± 9.9% * IBW -this formula was chosen because this is the smallest increment/decrement in weight that is known to be clinically noticeable) and dogs that still lost weight despite eating more than the daily energy requirement were summarized as binomial proportions with a 95% confidence interval. The percentage of calories consumed over the daily energy requirements was skewed and summarized as median (range).

Osteoarthritis related parameters including lameness, weight bearing, pain on palpation, rising, aggression, reluctance to walk, reluctance to play, and activity were assessed on a 5-point scale and, therefore, summarized as medians (interquartile range). Begging behavior, fecal score and acceptance of food were also evaluated on a 5-point scale and summarized as median (interquartile range).

Actual body weight and BFI at each month of follow were compared to baseline (one outcome at a time) using mixed-model repeated-measures analysis of variance followed by Dunnett's procedure for multiple comparisons. The linear model specified month of follow-up as a fixed effect with the Kenward-Roger approximation as the denominator degrees of freedom. G-side variation in the data was modeled by specifying dog identification as a random effect while the R-side variation in the data was modeled by specifying a first order autoregressive covariance matrix.

BCS, lameness, weight bearing, pain on palpation, rising, aggression, reluctance to walk, reluctance to play, activity, begging behavior, fecal score, and acceptance of food at each month of follow-up were compared to baseline (one outcome at a time) using Friedman's chi-square test with dog identification as a blocking factor. P-values were adjusted for multiple comparisons using Bonferroni's procedure. Statistical significance was set at $\alpha=0.05$. All analyses were performed using statistical software.d

RESULTS

Dogs

Forty-six dogs were enrolled in the study, and 38 dogs were used for data analysis. Eight dogs were excluded from the data analysis because only baseline data was accessible. Thirteen different breeds of dogs were represented in the study, and accounted for 32 dogs. Six of the dogs were mixed breeds. Labrador retrievers were the most frequent dog breed in the study (n=11). Twenty-one dogs were female (of which 15 were neutered) and 17 dogs were male (of which 11 were neutered). The median age was 7 years (range, 1-14 years). There was a decrease in the number of dogs participating in the study over time. The number of dogs for which data was collected at each visit is presented as part of Table 4.

Dietary Information Before the Study Started

Dog owners reported that they exclusively fed dry dog food to 29 dogs, whereas only two dogs received a food exclusively composed of wet food. Seven dogs were fed a mixture of dry and wet food. Eight dogs were on a dietetic or wellness weight management food, dogs were fed a dietetic food formulated to improve mobility, and 26 dogs were fed a variety of other dog foods. Eighty two percent of dogs were reported to be fed additional treats, foods or supplements. Due to the variety of information that was indicated in regard to food brands used and measurements used to determine the amounts of food fed, it was not possible to obtain a reliable estimate in regard to the caloric intake that was fed before the current study was started.

Pain Medication

Thirteen of the dogs (34%) received some form of pain medication over the duration of the study. Three dogs were given more than one drug as part of their pain medication. Twelve dogs (32%) were receiving pain medication at the beginning of the study. In seven dogs this medication was stopped

during the study, whereas medication was started in two dogs during the study. Pain medication dosages were not consistently reported and, therefore, could not be assessed for dosage adjustments potentially made over the course of the study. The most frequent class of drug administered were NSAIDs (11 dogs). Meloxicam was administered to four dogs and Robenacoxib (n=3), Firocoxib (n=3), and Cimicoxib (n=1) were given to the remaining dogs receiving NSAIDs. Tramadol, an opiate-like agonist, was dispensed to three dogs, and an Acetaminophen type drug was given to two dogs.

Weight Loss

Table 5: *Osteoarthritis related parameters as perceived by the owner and assessed by the veterinarian at the initial exam and at each check-up visit.*

		Visit						
		Initial	1	2	3	4	5	6
Owner perception								
Difficulty rising	Median	3[a]	2.5	2[b]	2[b]	2[b]	2[b]	1[b]
	IQR	2-4	2-4	2-3	1-3	1-3	1-2	1-2
	n	34	16	17	32	16	13	20
Reluctance to walk	Median	2[a]	2	1	1[b]	1[b]	1[b]	1[b]
	IQR	1-3	1-3	1-3	1-2	1-2.5	1-2	1-1
	n	34	16	17	32	16	13	20
Reluctance to play ‡	Median	2[a]	2	2[b]	1[b]	2[b]	1[b]	1[b]
	IQR	1-3	1-3	1-3	1-2	1-2.5	1-2	1-2
	n	34	16	17	32	16	13	20
Inactivity ‡	Median	3[a]	3	3	3[b]	3	2[b]	2[b]
	IQR	3-4	3-4	2-3	2-3	2-3.5	2-3	2-3
	n	34	15	17	32	16	13	20
Aggression	Median	1	1	1	1	1	1	1
	IQR	1-1	1-1.5	1-1	1-1	1-1	1-1	1-1
	n	33	16	17	32	16	13	20
Veterinary evaluation								
Lameness	Median	3[a]	2	2	2[b]	2[b]	1[b]	1[b]
	IQR	2-3	1.5-3	1-3	1-3	1-2	1-1.5	1-2
	n	33	16	17	31	15	12	19
Reluctance to bear weight ‡	Median	2[a]	2	2	1[b]	2[b]	1b	1[b]
	IQR	2-3	1-3	1-3	1-3	1-2	1-2	1-2
	n	33	15	16	31	15	11	19
Pain on palpation ‡	Median	2[a]	2	2	1[b]	2	2[b]	1[b]
	IQR	2-3	2-3	2-2	1-2	1-2	1-2	0-2
	n	31	13	14	29	14	10	19

Data is presented as median and interquartile range (IQR). Significant differences are indicated by different superscript letter (a denotes baseline as well as follow up visits that were not significantly different from baseline. b Shows that a visit was significantly different from baseline). ‡ For visits that are significantly different from baseline but whose medians are same as the baseline value, the interquartile range should be inspected for evidence of change in the outcome. Statistically significant differences may not always be evident for data that are skewed but the test compares the entire spectrum of measurements.

The dogs' weight ranged from 4.7 Kg in a Chihuahua dog to 58.5 Kg in a Rottweiler, and dogs were on average 25.6% above their IBW (range 6.5-66.7%). The mean duration of weight loss was 174 days (SEM, 6 days), with an average of 33 days between visits (SEM, 1 day). Ninety percent of the dogs lost weight (n = 34), and 10% of the dogs gained weight (n = 4). Because only a small number of dogs gained weight (n=4), these data were not analyzed statistically, and the data presented from here on forward will only be in regard to the dogs that lost weight. The average weight loss was 12.6% (SEM, 1.3%) over 6 months with an average weekly weight-loss rate of 0.5% (SEM, 0.04%) of starting body weight.

DER information was available from 30 dogs, and of these, 73% ate more than the recommended DER for weight loss, and 27% ate an amount equal or less than DER. The majority of the dogs that consumed above DER still lost weight (86.4%, CI 65.1 – 97.1%).

The average weight (LSM) of dogs was 34.7 kg at the beginning of the study and was 30.3 kg at the end of the study (Table 4). The weight achieved each month was significantly lower from the starting weight. The mean percentage of weight loss over time is indicated in Table 4. Body condition scores (BCS) of dogs were significantly lower in months 2 to 4 compared to baseline (see Table 4). The body fat index (BFI) decreased significantly in dogs from month 2-6 of the study compared to baseline (Table 4) and decreased by approximately 11% from the beginning to the end of the study.

Twenty-one dogs (56%, CI 39.5 – 72.9%) achieved their IBW during the study period. The average time to reach IBW was 81.3 days (range 11-238 days).

Osteoarthritis Related Parameters

A number of OA-related scores were evaluated and consisted in owner perceived parameters and parameters evaluated by veterinarians. Results are presented in Table 5. Difficulty rising was significantly lower in month 2 to 6 of the study compared to baseline. Reluctance to walk and play decreased significantly compared to baseline from month 3 to 6. Inactivity was significantly improved in months 3, 5, and 6 compared to baseline. No significant changes were seen in aggression scores over time. Scores for lameness were significantly lower compared to baseline from month 3 to 6 of the study. Similarly, reluctance to bear weight was significantly decreased compared to baseline from months 3 to 6 of the study. There was significantly less pain on palpation in months 3, 5, and 6 compared to baseline. Lameness improved in 82% of the dogs that lost weight (28/34) and 75% of the dogs that gained weight (3/4). Lameness improved significantly starting in month 3 of the study, which corresponded to a weight loss of 9 %.

Osteoarthritis related parameters improved once dogs had lost between 6.4 and 9.0 % of their initial body weight (achieved in month 2 and 3 of the study). Scores for difficulty rising and reluctance to play were improved compared to baseline at the 2nd re-check exam. Whereas scores for reluctance to walk, inactivity, lameness, weight bearing, and pain on palpation only significantly improved compared to baseline at the 3rd re-check visit.

In addition, begging scores were significantly lower in months 3 and 4 compared to baseline (data not presented). No significant differences were noted over time in fecal scores or acceptance of the NDF (data not presented).

At least 58% of the dogs received some form of treat, food, or supplement over the course of the study. Twenty four received no additional food, and information was unavailable for 18% of the dogs. Veterinarians were either highly likely or probably likely to recommend food for managing overweight dogs with arthritis in the future. However, only 19 veterinarians provided a response to this question.

DISCUSSION

Ninety percent of client-owned obese/overweight dogs lost weight, and 82% of these dogs showed an improvement in OA-related

parameters. These findings support the effectiveness of NDF to achieve weight loss and to increase mobility in client-owned overweight/obese dogs. No negative effects were seen on the dog's begging behavior, stool, or acceptance of food. To our knowledge, this is the first study that evaluates the effect of a dietetic food, formulated with the goal to affect both weight loss and clinical signs of OA. In the discussion that follows here, we will compare the results of the present study to those reported in other studies that evaluated either the effect of foods or dietary supplements on OA in dogs or on weight loss in dogs.

An enhanced ability to rise from a resting position and a decrease in reluctance to play were noted from month 2 to 6 compared to baseline. Improvements in reluctance to walk, inactivity, lameness, weight bearing, and pain on joint palpation were significantly different from baseline for months 3 to 6 of the study. The median scores for difficulty rising and lameness improved by 2 points from the beginning to the end of the study, whereas all other significantly improved parameters only improved by 1 point from the beginning to the end of the study. These results are compared to those reported by other investigators (Fritsch et al. 2010a; Hielm-Bjorkman et al. 2012; Roush et al. 2010a; Roush et al. 2010b). Fritsch et al showed a modest improvement in clinical signs of OA in dogs receiving diets supplemented with fish oil (Fritsch et al. 2010a). The effect of omega-3 fatty acids on OA was previously assessed in a randomized, double blinded, controlled clinical trial (study 1) and in a multicenter study (study 2) (Roush et al. 2010a; Roush et al. 2010b).

Dogs in study 1 were reported to have significant improvements in lameness and weight bearing 3 months after the test food was started (Roush et al. 2010a). Dogs in study 2 showed an improvement in their ability to rise from a resting position 6 weeks after the beginning of the study, and in their ability to walk 12-24 weeks after the test food was started (Roush et al. 2010b).

Foods supplemented with fish oil were shown to lead to a decrease of inflammatory markers in the joints of dogs with inflammatory joint disease and in the serum of healthy dogs (Hansen et al. 2008; LeBlanc et al. 2008). These diets may, therefore, help reduce the inflammation and pain associated with OA and potentially decrease the dosage of NSAID needed keep affected pets comfortable. A study by Fritsch et al showed that feeding a diet supplemented with fish oil may allow for a reduction carprofen dosage in dogs with OA (Fritsch et al. 2010b). Our study did not include measurements of inflammatory mediators. Approximately one third of dogs in the study were on pain medication at the beginning of the study. During the course of the study, medication was discontinued in seven dogs, whereas, it was started in two dogs. Due to the variety of medications used and the lack of dosage information, it was not possible to draw any statistically meaningful conclusions on the effect of NDF on pain medication.

Obesity and OA not only frequently exist as comorbidities, but obesity likely also exacerbates clinical signs of OA. The effect of weight loss alone on clinical signs of OA can, therefore, not be discarded, and has in fact been evaluated in several studies (Impellizeri et al. 2000; Marshall et al. 2010; Mlacnik et al. 2006). Weight loss was shown to lead to decreased lameness and increased ground reactive force in dogs with OA (Burkholder & Hulse 2000; Impellizeri et al. 2000). Marshall et al evaluated the effect of weight loss on lameness in obese dogs with OA and showed that body weight reduction resulted in a significant decrease in lameness once a 6.1% in loss in BW was achieved (Marshall et al. 2010). Significant improvements in kinetic gait analysis were noted once a BW reduction of 8.8% was achieved. Subjective lameness parameters improved before a significant improvement in objective parameters was seen, which might be explained by the type of limb affected or the bilateral vs unilateral nature of OA. Similar to Marshall's findings, significant improvements in clinical parameters of OA were

seen in our study in dogs once 6.4 to 9.0% of their starting BW had been lost.

Weight loss parameters (BW, BCS, and BFI) significantly improved over time compared to baseline. At the end of the study, dogs had lost on average, 12.6% of their initial BW, had improved their BCS by 1 point, and their BFI by a little over 10%. The average weekly weight loss rate in the present study was 0.5% of starting BW which is considered the minimum weight loss needed per week to keep an owner sufficiently interested and compliant to complete a weight loss program with his/her pet (Burkholder & Toll 2000). Our results for weekly weight loss rate were lower compared to previous clinical reports (Christmann et al. 2015; German et al. 2007; Markwell et al. 1994; Saker & Remillard 2005) and compared to the desired goal of 1-2% weekly weight-loss in experimental settings (Brooks et al. 2014). Our finding can be explained by the fact that

1. We used client-owned dogs of a variety of breeds and ages
2. Owners were allowed to feed additional treats, and
3. The activity level of dogs included in the study was variable and likely reduced compared to obese dogs not suffering from OA.

Dogs in our study achieved weight loss, even though a number of animals (n=22) were fed more than the recommended amount of food for weight loss, and despite them receiving additional treats. A little over 86% of the dogs fed more than the recommended DER for weight loss still lost weight. These findings are comparable to what we reported in a previous study that evaluated the effectiveness of a weight management food to achieve weigh loss in client-owned obese dogs (Christmann et al. 2015).

Nutritional formulations used in both foods were based on nutrigenomics technology. We speculate that these formulations might prevent the decrease in energy expenditure of dogs as a result of weight loss and thus maintain a weight loss rate despite an increased caloric intake. In preliminary canine studies, a nutritional formulation comparable to NDF not only resulted in weight loss and promoted maintenance of the new weight, but it also significantly changed expression of key metabolic genes (Hahn & Meyer 2013a; Hahn & Meyer 2013b).

In another study, obese dogs fed a nutritional formulation comparable to NDF for weight loss (4 months) and weight maintenance (4 months) consumed 25% and 33.7% more calories per kg IBW in months 7 and 8, respectively, compared to their adiposity matched controls fed a variety of foods for maintenance of obese weight (Jewell et al. 2014). It would be expected that caloric restriction decreases metabolic rate, which lowers amount of calories needed to maintain the new weight. However, results of this trial support that metabolic rate after the weight loss appeared to increase as evidenced by preservation of body weight despite increased caloric intake compared to a control group.

The present study had several limitations. This was an observational, uncontrolled, unmasked clinical trial, and bias in regard to the effectiveness of NDF can therefore not be excluded. However, the fact that our findings are comparable to those reported by other researchers strengthens their validity. We used subjective scores to evaluate changes in OA related parameters, which represents a limitation for result interpretation. The establishment of an accepted scoring system used to assess OA-related parameters is needed in order to corroborate results in future studies. Not all dogs included in the present study completed the study. This situation is reflective of conditions in clinical practice and may therefore be seen as part of the effectiveness rather than efficacy assessment of NDF.

CONCLUSION

In conclusion, results from this clinical trial indicate the effectiveness of NDF in achieving weight loss and improved mobility in client-owned obese dogs with OA. Owners and veterinarians reported significant

improvements in OA-related parameters without negative side effects and despite of a higher than recommended caloric intake.

FOOTNOTES

[a] http://www.petobesityprevention.org/pet-obesity-fact-risks/

[b] 2012 State of Pet Health Report issued by Banfield Pet Hospital

[c] http://www.hillsvet.co.uk/ (accessed August 31st, 2016)

[d] SAS version 9.3., SAS Institute Inc., Cary, NC, USA

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CONFLICT OF INTEREST STATEMENT

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