



Research

Owner's perception of changes in behaviors associated with dieting in fat cats

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ARTICLE INFO

Article history:

Received 24 March 2015

Received in revised form

8 November 2015

Accepted 24 November 2015

Available online 30 November 2015

Keywords:

cat

appetitive behavior

weight loss

diet

dietary fiber

ABSTRACT

Fifty-eight obese cats were fed 1 of 3 equicaloric diets for 8 weeks: a high-fiber (HiFi) diet, a control diet formulated to maintain weight in adult cats, or a low-carbohydrate and high-protein diet. The cats' changes in weight at 4 and 8 weeks were compared with baseline weights. Behaviors at 4 weeks were compared between diet groups. Whether the cats differed in behaviors compared with baseline was compared at 4 and 8 weeks without regard to diet. The behaviors were recorded by the owners and analyzed for direction of the change (if change occurred). The behaviors were prefeeding begging, following, meowing, and pacing. Those recorded postfeeding and similarly analyzed were jump in lap, purr, rest, sleep, and use litter box. The owners were also asked whether the cat's affection toward them had changed since the diet was fed. Most of the cats (38 of 47; 81% of those with data for that time) lost weight during the first 4 weeks, irrespective of the diet; there was no difference in percentage of original body weight lost at 4 weeks between the diets ($P = 0.36$). However, the HiFi group lost relatively more weight across the entire 8 weeks than did the low-carbohydrate and high-protein diet group ($P = 0.0075$). Overall, 38 of 50 (76% of cats with data for that time) of all cats had weight losses at 8 weeks.

Irrespective of the diet, many cats reacted to caloric restriction by intensifying their appetitive behaviors. Of the cats that had changed the frequency of the particular behavior at 4 weeks, most increased the frequency: begging (32 of 41 increased), following (35 of 37), meowing (34 of 38), and pacing (30 of 31) before the meal (all $P \leq 0.0001$); however, the cats did not begin to beg earlier during food restriction ($P = 0.47$). The cats also increased the 4-week postmeal (satiated) behavior for jump in the owners lap (14 of 15 increased) and use the litter box (12 of 13) (both $P \leq 0.005$). Affectionate behavior increased in most cats (30 of 32 with change at 4 weeks; $P \leq 0.001$). The changes in behaviors at 8 weeks generally followed the same patterns except that purr became significant, and both beg and use of litter lost significance.

A HiFi diet led to more weight loss at 8 weeks than an equicaloric and high-protein diet, but the type of diet did not affect appetitive and satiated behaviors. Of the cats that changed behaviors, the appetitive behaviors typically increased, and the owners felt that their cats displayed more affection.

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Introduction

Obesity in cats has been defined as 25% or more over the cat's ideal body weight (Zoran, 2009). A study of 2000 cats from 31 veterinary hospitals in eastern United States found that 20% of the cats were overweight and 5% were obese (Scarlett et al., 1994). A

large study based on body condition scores indicated that more than half of the pet cats were above optimal body condition (Lund et al., 1999). A more recent study indicated that 35% of the feline population is obese (Zoran, 2009). Overweight or obese cats are more likely to develop health problems. These health problems include lameness, diabetes mellitus, and nonallergic skin conditions (Buffington, 2002; Michel and Scherk, 2012), although there are few studies proving that obesity causes these problems rather than being associated with them. In addition, the ability to perform a thorough and adequate physical examination on an obese cat can be hindered because of the cat's size. Overall welfare is decreased if

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the cat is obese because of the myriad health problems. Factors that have been associated with feline obesity are living in an apartment, being a single cat, male, mixed-breed neutered or inactive, and being fed a specialty or prescription diet (Scarlett et al., 1994). Cats that live in apartments cannot climb stairs or travel more than a few meters in any direction; therefore, they do not expend as many calories. Male cats seem to be more sedentary, and castration only intensifies their inactivity. Neutering decreases feline maintenance energy requirements (Mitsuhashi et al., 2011). Prescription diets are very palatable so the cats consume more calories. Single cats have no other cat with which to play—or fight—so are less active than cats in multicat households. Free-choice feeding in which the cat can eat *ad libitum* is another risk factor for obesity. Owners are often reluctant to impose a weight loss program on their cats because they think the cats will be less affectionate and will beg all the time. They fear that the cat will no longer like them and do not want the cat to exhibit annoying behaviors.

There are many diets on the market to help cats lose weight. These diets vary in their nutritional content. Because cats are obligate carnivores and their natural diet consists of eating many (approximately 12 mice) rodents per day (Fitzgerald and Turner, 2000), one might hypothesize that a low-carbohydrate and high-protein (LoChoh) diet would reduce food-demanding behavior more than a high-fiber (HiFi) diet and would allow for a greater weight loss than a HiFi diet. This hypothesis is supported by studies in cats (Vasconcellos et al., 2009) indicating that weight loss is greater or sustained longer when a high-protein diet is consumed.

Feeding behavior can be divided into 3 phases, appetitive behavior, consummatory behavior, and satiety. Consummatory behavior is eating the food. Feline appetitive behaviors have not been well documented but could consist of biting or pouncing behavior because cats are predators or, if cats consider their caretakers as they do their mother, they may vocalize. Satiety behaviors could consist of playful behavior, because cats often play with their prey, but may also include rest and elimination behavior (Leyhausen, 1979).

Because owners have difficulty in reducing their cats' food intake, this study focuses on whether and how cats' behavior change when they are food restricted (Kienzle and Bergler, 2006). Our study had 2 primary objectives and 1 secondary objective. Our primary objectives were to quantify how a cat's behavior changes when its food intake is reduced and to determine which of these diets the owners believed made the cats feel more satiated.

A secondary objective was to determine whether percentage weight loss was greater with a high-protein diet than with a HiFi diet or a control diet after 4 and 8 weeks of consuming the assigned diet.

Methods

Recruitment, assignment, and eligibility criteria

Fifty-eight neutered cats (Table 1) were enrolled in a placebo-controlled study in which both the owners and the veterinarians

(who weighed the cats) arbitrarily were unaware of the formulation of the diets. The diets were coded LMN, PQR, and STU so that the owners and veterinarian did not know the composition of the diet. The owners were recruited via advertisements in local newspapers and on local radio and television stations. Each cat was assigned systematically (by household, if there were multiple cats) to 1 of 3 treatment groups: HiFi group, LoChoh group, or a control diet formulated to maintain weight in adult cats (Con) group (Table 1). The codes were not revealed to either the researchers or the owners until all the data were collected and entered into a statistical program; the statistician was blind as to the diet composition during the data analyses. The protocol was approved by the Cornell University Institutional Animal Care and Use Committee.

The cats had to be 25% or greater over their ideal body weight (defined as their weight at 1 year [larger breed cats, such as ragdolls and Maine coon cats may not reach adult size until 15–18 months, but these cats were not of those breeds] because any gain thereafter would not be because of growth) and could not have any other important abnormalities on the physical examination or blood tests. The blood tests included a complete blood count (hematocrit, hemoglobin, red blood cell number, and white blood cell number), chemistry panel (total protein, albumin, globulin, alkaline phosphatase, urea nitrogen, alanine transaminase, creatinine, and glucose), and a total tetraiodothyronine level. The complete blood count was made to determine if the cat was anemic or had an infection. The chemistry panel was done to assess liver, kidney, and muscle functions. The thyroxine levels were measured because hyperthyroidism is a common problem of middle-aged cats but usually causes weight loss. The cats had to be kept strictly indoors (to assure no caloric supplementation) so only normally indoor cats were enrolled. The owners needed to be able to monitor their cats' environment so that the cats had no access to human or other pets' food in the house. The owners had to return to Cornell to have their cats weighed at least every 4 weeks but were strongly encouraged to come every 2 weeks.

Study protocol

Weight-loss component

The length of time each cat was required to be on the study was 10 weeks. The first 2 weeks of the study was simply the time allotted for the owners to switch their cats gradually from their regular diet to the test diet. The owners did not have to limit their cat's food intake during these 2 weeks; therefore, no weigh in was required after these initial 2 weeks. Cats that rejected the diets were not included in the study. For the remaining 8 weeks, each owner was instructed to feed a specific amount of food to his or her cat over a 24-hour period. For example, a cat whose ideal weight is 4.5 kg would be given 1/3 cup (79 mL by volume) of the LoChoh or Con diet or 2/3 cup (158 mL) of the HiFi diet. The nutritional components of each diet are given in Table 2. To encourage compliance and avoid any errors, each owner was given a measuring cup with a line indicating the specified amount of food for their cat. If any cat refused to eat for a period of 48 hours, the owner was instructed to offer the cat's regular cat food and immediately to call the Cornell University Hospital for Animals.

Each cat received a physical examination at the Cornell University Hospital for Animals. At this time, the cat's weight was recorded, blood tests were performed, and an estimation of the cat's ideal body weight was made (Butterwick, 2000). If the owners knew the weight of the cat when it was 1 year old, that weight was used as the ideal target weight. If its weight at 1 year was not known, 2 measurements were made to estimate the ideal body weight. The measurement included the length from the cranial aspect of the scapula to the base of the tail and from the dorsal

Table 1
Characteristics of cats participating in dietary restriction

Diet	Sex (number of cats)		Age (y) Mean ± standard deviation	Cats on a restricted diet before the study began	
	Male	Female		%	Fraction
Con	10	8	8.4 ± 4.1	23	3/13
HiFi	10	9	6.1 ± 2.3	47	7/15
LoChoh	5	14	7.8 ± 3.4	27	4/15

Con, control diet formulated to maintain weight in adult cats; HiFi, high-fiber diet; LoChoh, low-carbohydrate and high-protein diet.

Table 2
Nutrient compositions of the 3 test diets

Nutrient	Diet		
	HiFi	LoChoh	Con
Protein, %	37.7	52.0	33.5
Fat, %	9.8	22.0	23.7
Crude fiber, %	13.7	5.5	0.9
Ash, %	6.2	4.9	5.4
Calcium, %	1.03	0.89	0.81
Phosphorus, %	0.85	0.76	0.74
Sodium, %	0.29	0.36	0.37
Potassium, %	0.77	0.73	0.66
Chloride, %	0.64	0.65	0.76
Magnesium, %	0.077	0.046	0.066
J/kg	13,861	17,610	18,091

HiFi, high-fiber diet; LoChoh, low-carbohydrate and high-protein diet; Con, control diet formulated to maintain weight in adult cats.

Numbers in bold are significantly different from Con.

aspect of the scapula to the dorsal aspect of the paw. These measurements can be used to determine lean body weight (Erat, 2011). All weight estimations and measurements were done by the first author. The smallest cat was 10 cm tall, and the largest cat was 16 cm tall.

All cats were weighed on the same scale throughout the study. Cats completing the study were given another physical examination, and a complete blood count and chemistry panel was repeated.

Before starting the study, the percentage of cats in each diet group that was receiving a restricted (amount of food) diet were 23% (3 of 13) of the cats in Con, 47% (7 of 15) of the cats in the HiFi, and 27% (4 of 15) of the cats in the LoChoh groups (Table 1).

Behavioral component

Before starting the study, each owner was required to complete a questionnaire (Supplemental Material) asking questions about various behaviors that their cat displayed when he or she was hungry (appetitive behaviors) and when he or she was satiated (Table 3 for the behaviors and Supplemental Material for the questionnaires.). The owners were required to answer a similar questionnaire (Supplemental Material) of 15 pages consisting of 31 questions about the cat's prefeeding behavior and 17 questions about its postfeeding behavior 4 and 8 weeks after the cat had been on the diet. Each question asked whether the behavior occurred more, the same, or less since feeding the new diet. The owners could also check not applicable for any question.

Statistical analysis

Age, sex, and weight-loss data

To determine whether there were any significant differences among treatment groups with regard to age or percentage weight loss (compared with the weight at entry into the study), Kruskal–Wallis nonparametric 1-way analyses of variance were used (Zar, 1996, pp. 198–202). If a difference was found, a Dunn's all-pairwise comparisons procedure was used to determine which diets differed. The test to determine whether feeding a restricted versus unrestricted diet before the study was associated with weight loss by week 8 was done with Wilcoxon rank sum test (Zar, 1996, p. 148). Sex was compared among the diets by chi-square test (Zar, 1996, pp. 485–488).

Behavioral data

To determine whether there were any significant behavioral differences among the cats in different diet groups at week 4, Kruskal–Wallis nonparametric 1-way analyses of variance were

Table 3
Behaviors of cats at meal time

Activity	Vocalization
Prefeeding	
Rub with head or body	Meow
Beg	Hiss
Groom	Growl
Lick	Chirp
Hide	
Ignore owner	
Turn back to owner	
Paw at cupboard	
Scratch carpet or owner	
Sprays urine	
Knock over objects	
Bite	
Spray	
Steal food	
Pace	
Follow	
Postfeeding	
Groom	Meow
Sleep	Purr
Play	
Litter	
Rub	
Scratch	
Rest	
Lap	
Bite	

Behaviors in bold were those analyzed for changes during the experiment.

used, followed (if significant) by Dunn's all-pairwise comparisons. Because we made so many comparisons, we tested only the week 4 data for association with test diet. To test whether the cat showed particular behaviors more often or less often after being on the assigned diet for 4 and 8 weeks (regardless of diet), we used the sign test (Zar, 1996, pp. 535–536, Appendix 132) which uses only the data from the cats that changed the behavior. The tests of whether the cat started begging for its meal at the same time before and after going onto the test diet used Wilcoxon signed rank tests.

General

Data were entered into an Excel spreadsheet and were then transferred into Statistix 9 (Tallahassee, FL) for analysis (some were confirmed recently with version 10). All tests were conducted 2-tailed, with a P value of 0.05 considered significant. However, Bonferroni-type adjustments were made within sets of related comparisons to lessen the risk of multiplicity (i.e., of excess risk of false-positive statistical conclusions arising from running multiple tests). Therefore, for comparisons between test diets for age, sex, previous restricted diet, and weight loss, the P for significance was dropped to 0.01. To compare behavior associations with test diet and for the tests of the direction of change in behavior, we lowered the threshold to $P \leq 0.005$ and $P \leq 0.0025$, respectively. We also used $P = 0.005$ to test the time at which the cat began begging for its meal.

Results

Of the 58 cats enrolled in the study, 47 returned for the weighing at 4 weeks and 50 returned for the weighing at 8 weeks. Not all owners answered all the questions concerning the cat's behavior.

Age, sex, and weight loss

There was no significant difference in age ($P = 0.16$) or sex ($P = 0.14$) among treatment groups (Table 1).

There was no significant difference ($P = 0.11$; Wilcoxon rank sum test) with respect to weight loss at 8 weeks and the feeding schedule (i.e., restricted vs. unrestricted amount of food) before the start of the study.

Most cats (87% [13 of 15] HiFi; 73% [11 of 15] LoChoh; and 82% [14 of 17] Con) lost weight during the first 4 weeks of the study (Table 4), but there was no significant difference among the different diets ($P = 0.36$). After being on the study for 8 weeks, there was a difference ($P = 0.0075$) among the treatment groups. Cats being fed the HiFi diet lost more weight than those being fed the LoChoh diet. Cats being fed the Con diet were not significantly different from the cats being fed HiFi or LoChoh diet at 8 weeks.

Behavioral outcomes

The cats often showed changes in particular behaviors after being on the assigned diet for 4 and 8 weeks. More of the cats showed an increase than a decrease in begging (32 of 41), following (35 of 37), meowing (34 of 38), and pacing (30 of 31). The (categorized) median time at which the begging behavior began was 16–45 minutes before feeding for all 3 time points (both $P \geq 0.47$). When compared with their behavior before food restriction, the cats were significantly more likely to have increased purring, sitting in the owner's lap, resting, and using the litter after their meal at either 4, 8 weeks, or both (Table 5). The cats exhibited increased affection at both 4 and 8 weeks (both $P \leq 0.001$).

The only even near difference among the diets in the 10 tested behaviors at 4 weeks was for use of the litter box after the meal ($P = 0.013$; all others $P \leq 0.16$). Of the undesirable behaviors that might have accompanied food-restricted animals, aggression toward the owner was reported to increase in only 2 of 41 cats; no cats began to urine mark.

Discussion

The behavioral responses to food restrictions were similar across diets. Cats were most apt to increase vocalization (meowing and begging) before meals, follow their owners, and pace. There generally was no change in the types of behaviors exhibited by the cats—only a change in the frequency. One solution to the begging problem might be to feed the cats from devices that open at set times so that the food does not come from the owners. Although that might reduce the annoying begging behaviors, most owners seem to feel that the begging is affectionate behavior. None of the

Table 4
Weight changes (as % of original weight) in cats on reducing diets

Diet	Parameter	Week 4	Week 8
HiFi	N	15	20
	Minimum	−8.3	−16
	Median	−3.6	−6.5 ^a
	Maximum	2.0	2.0
LoChoh	N	15	15
	Minimum	−7.2	−8.3
	Median	−1.7	−2.5 ^b
	Maximum	4.0	7.5
Con	N	17	15
	Minimum	−9.3	−16
	Median	−2.9	−3.0 ^{a,b}
	Maximum	5.7	8.1
P value		0.36	0.0075

HiFi, high-fiber diet; LoChoh, low-carbohydrate and high-protein diet; Con, control diet formulated to maintain weight in adult cats.

^{a, b}Medians with a letter in common indicate distributions that are not significantly different.

Negative values indicate weight losses.

Table 5
Changes in behavior with dietary restriction

Behavior	Cats that changed behavior	Exhibited less	Exhibited more	P
Week 4				
Beg	41	9	32	≤ 0.001
Meow	38	4	34	≤ 0.001
Follow	37	2	35	≤ 0.001
Pace	31	1	30	≤ 0.001
Affection	32	2	30	≤ 0.001
Purr	15	2	13	≤ 0.01
Lap	15	1	14	≤ 0.001
Sleep	10	4	6	> 0.05
Litter	13	1	12	≤ 0.005
Rest	12	2	10	< 0.05
Week 8				
Beg	28	7	21	≤ 0.02
Meow	27	3	24	≤ 0.001
Follow	26	1	25	≤ 0.001
Pace	26	3	23	≤ 0.001
Affection	21	1	20	≤ 0.001
Purr	10	0	10	≤ 0.002
Lap	11	0	11	≤ 0.001
Sleep	6	0	6	≤ 0.05
Litter	9	2	7	> 0.05
Rest	9	0	9	≤ 0.005

The owners noted whether there had been a change in their cat's behavior in comparison to their behavior before dietary restriction was imposed. The total number of cats was 45 at 4 weeks and 48 at 8 weeks. Not all cats exhibited a change in each behavior.

truly undesirable behaviors such as urine spraying or aggression to the owner occurred with food restriction sufficiently often to warrant statistical testing, a fact that may encourage owners to restrict their obese cats' intake. Specifically, urine marking was not increased in any cats, and aggression was increased in very few.

Some of the cats were in multicat household, but the owners were not queried about aggression among the cats.

The cats became more affectionate, which owners should view as a positive side effect of restricting their cats' intake. Owners tend to anthropomorphize their cats and, therefore, are afraid to reduce the cat's food intake because they think the animal will become vindictive (German, 2006). It should be easier to convince owners to put their cats on a reducing diet, if the owners know that the cats will not snub them for it or exhibit undesirable behaviors.

The cats were subjected not only to caloric restriction but also to a feeding regime change from free choice to meals. It is surprising that there was no difference in the behaviors of cats that had been fed *ad libitum* and those that had already been on a restricted diet. An observational study of the cats directly, rather than a study of the owners' assessments of their behavior, might reveal more differences in the dieting cat's behaviors.

The cats lost the most weight (median, 6.5% of starting weight) on the HiFi diet—which was contrary to our expectation. In an earlier study, a high-protein diet was not associated with greater weight loss but caused greater loss of fat with consequent sparing of lean body mass (Lafamme and Hannah, 2005). Our study did demonstrate that cats could lose weight when enrolled in a program with restricted feeding prescribed by veterinarians (regardless of diet composition) and weigh ins under veterinary supervision (at least, across 8 weeks). Provision of a measuring cup was probably one of the most important factors in encouraging the owners to restrict the amount their cats received.

The minimum and maximum values listed in Table 4 allow readers to understand the wide variations in response seen across the test diets; some cats did very well in proportionate weight loss, and some cats actually gained weight despite the enrollment by their owners in the weight-loss trial. These cats may have adapted

to caloric restriction by lowering their activity and possibly even their metabolic rate. There are differences between owners of overweight and owners of normal weight cats. Fifty-three percent of owners of overweight cats watched them eat, whereas only 25% of owners of normal weight cats did so (Kienzle and Bergler, 2006). These owners rate obtaining food, rather than play or petting, as the cat's favorite interaction with them (Kienzle and Bergler, 2006).

The cats that were fed the HiFi (13.7% crude fiber) diet achieved the greatest weight loss. The cats were fed twice as much of this diet by volume, yet lost proportionally the most weight. The HiFi diet probably dilutes the nutrients and delays absorption, and it might delay gastric emptying (Zoran, 2009). The cellulose is indigestible, but the cats displayed no increase in hunger signs in comparison to the cats fed a low-volume (but isocaloric) diet as indicated by the similarity in signs of hunger among diets. The satiety might be a result of simple gastrointestinal fill. The only gastrointestinal appetite stimulant is the peptide ghrelin that is released when the stomach is empty (Ida et al., 2007). The HiFi diet would delay gastric emptying and, therefore, delay release of the peptide (and, thus, delay hunger). Cellulose (the fiber component of the HiFi diet) is not digested by cats.

Cats do not compensate for dilution of their diet with cellulose (Kanarek, 1975) or kaolin (Hirsch et al., 1978) by eating a greater volume. They can compensate for caloric dilution with water by increasing their volume of intake (Castonguay, 1991). The cats in this study had no opportunity to compensate for dilution by eating a greater volume but might not have done so even if food was available *ad libitum* (Kanarek, 1975). This is important because most owners of overweight cats feed dry food *ad libitum* (Scarlett et al., 1994). When weight loss occurs on a low-calorie diet, the cats lose weight, and most of that weight is fat rather than lean tissue (Butterwick and Markwell, 1996). A high-protein diet might promote an increased lean tissue mass in cats so that the lost weight is more likely to be fat rather than lean body mass (Nguyen et al., 2004; Laflamme and Hannah, 2005). Cats that were fed a high-protein diet *ad libitum* not only expended more energy but also ate more than cats on a moderate protein diet (Wei et al., 2011). Body composition was not determined in our study but should be determined in future investigation. In addition, a long-term study should be performed to determine whether weight loss is sustained. The effect of the low carbohydrate diet on maintenance of lean body mass in comparison to the other diets would be important.

Conclusion

Equicaloric food restriction led to weight loss in cats irrespective of the diet composition. A HiFi diet leads to a greater percentage weight loss than an equicaloric high-protein diet. No matter the composition of the diet, cats react behaviorally to feed restriction by intensifying their appetitive behaviors and showing increased affection to their owners.

Ethical considerations

The protocol was approved by the Cornell University Institutional Animal Care and Use Committee.

Conflict of interest

The authors declare no conflict of interest.

Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.jveb.2015.11.004>.

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