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# Effect of Diet and Body Composition on Life Span in Aging Cats

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## Abstract

A longitudinal study found that a diet containing supplemental antioxidants, polyunsaturated fatty acids and a prebiotic increased longevity and improved the health of senior cats. Body weight and body composition data from the study were evaluated to assess possible associations of these parameters with longevity. Body weights along with all body composition parameters measured by DEXA were significantly related to survival, confirming the hypothesis that loss of body mass is a risk factor for mortality in aging cats. Cats eating the supplemented diet better maintained body weight and body composition over time. Nutrition can play a role in delaying age-related changes in body weight and body composition in senior cats.

### Glossary of Abbreviations

**BCS:** Body Condition Score
**BMC:** Bone Mineral Content
**BMD:** Bone Mineral Density
**BMI:** Body Mass Index
**BW:** Body Weight
**DEXA:** Dual-Energy X-Ray Absorptiometry
**LBM:** Lean Body Mass
**PUFAs:** Polyunsaturated Fatty Acids

## Introduction

In all mammals, aging is associated with changes in body composition, declining organ functions and other metabolic changes. Sarcopenia, an age-related loss of muscle and lean body mass, is common in aging humans, cats and other species. Nutrition may play an important role in delaying such changes or preventing their progression.[1,2]

Cross-sectional studies in cats[3] have documented that aging adult cats fall into two categories based on metabolic differences. In middle-aged cat populations (7 to 11 years of age), average energy requirements are reduced while the prevalence of obesity is increased. In geriatric cat populations (ages 12 years and above), the reverse is true in that average energy requirements increase while the prevalence of obesity greatly decreases. A limitation of cross-sectional studies is that they do not follow changes in individual cats over time. Thus, it is not known if the reduced prevalence of obesity is due to loss of weight and body condition in cats with time, or if it is due to attrition reflecting early mortality in obese cats.

Previously, we conducted a study to evaluate the effect of dietary management on life span in aging cats.[4,5] The study tested the hypothesis that supplemental antioxidants alone or combining antioxidants with added polyunsaturated fatty acids (PUFAs) and a prebiotic fiber could measurably benefit the health and longevity of aging cats. Among the three diets tested, the one containing a combination of supplemental antioxidants, a prebiotic and a blend of omega-3 and omega-6 fatty acids increased longevity and improved health in senior cats.

Data from that longitudinal study was evaluated to determine changes within individual cats in body composition over time. The objective was to determine if any of these changes in body composition may be associated with or predict morbidity or mortality in aging cats.

## Materials and Methods

The dataset evaluated for this paper was derived from a long-term feeding study initiated with 90 healthy mixed-breed cats, conducted at our Pet Center for nutritional studies. Healthy cats between the ages of 7 and 17 years were selected for the study. Cats were distributed equally among three dietary treatment groups, controlling for age, body condition score (based on 5-point scale), and gender. Groups of cats were assigned to one of three diets: Diet 1 Control (basal diet of nutritionally complete and balanced adult cat food); Diet 2 (basal diet with added antioxidant vitamins E and β-carotene); and Diet 3 (basal diet with added antioxidants, dried whole chicory root as a source of prebiotic, and a blend of supplemental n-6 and n-3 fatty acids). The diets were fed *ad libitum* as the exclusive source of nutrition for the remaining natural lifetime of each cat. Typical nutrient comparisons were previously reported.[4]

### *Clinical Observations*

Health monitoring and medical treatments of all cats were carried out according to established colony veterinary standards throughout the trial, and veterinary personnel were blinded to dietary treatment groups. In addition to physical examinations and routine blood sampling (serum biochemistry and hematology), measures of body weight and body composition by dual-energy X-ray absorptiometry (DEXA) were taken for all cats at study initiation and regular intervals throughout the study. Food consumption was measured daily during the study, and body weights were assessed weekly.

### *Statistical Analysis*

Analysis of variance was used to compare initial parameters across groups to confirm that randomization was effective in producing balance at baseline ($t_0$) in the three study groups.[5]

Survival analyses were performed to compare the three diets for the age at which the cats died of natural causes (Age at Death) and the number of days the cats were alive (Days on Trial). For Age at Death, a Kaplan-Meier nonparametric analysis was performed.[6] For Days on Trial, a Cox's proportional hazard model was used to compare the survival rates of the three diets (pair-wise comparison).[6] Hazard ratios along with their 95% confidence intervals were estimated. Because there was a wide range of ages of the cats at trial initiation, the initial age of the cat was used as a covariate in the model.

Analysis of measured health parameters was performed by a longitudinal analysis.[7] The longitudinal model allowed for each animal's trend to be considered over time and an average trend or slope predicted for each group. Where appropriate, a quadratic effect was included in the longitudinal model.

To determine if any of the measured parameters were related to survival, a Cox's proportional hazard model was performed using the measured parameter as a time-varying covariate. The Cox's model evaluates whether an increase or decrease of the parameter is associated with an increased or decreased rate of survival. The hazard ratio indicates what percent increase or decrease in "hazard of dying" is associated with each unit of measure for that parameter. Using the formula, (1.00 – Hazard Ratio) x 100, gives the correlation with survival.

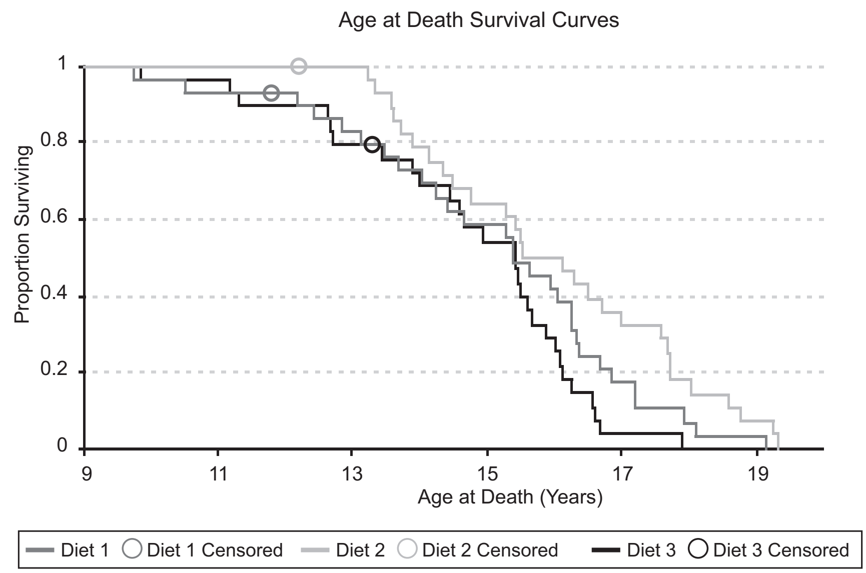
Longitudinal DEXA data for lean body mass (LBM) and fat mass in grams also were evaluated retrospectively from the time of death for the entire population of cats to determine how changes in these measures might be predictive of death. For fat mass, a segmented regression model was used, where the best fit for the period closest to death was a quadratic model. For LBM, the best fit for the data was found to be a longitudinal linear regression model.

All statistical calculations were performed using SAS.[8] Statistical significance is at the $P < 0.05$ level unless otherwise stated.

**Table 1. Age at Death (Nonparametric)**

| Diet | Mean Age at Death (Years) | P Value | |
|---|---|---|---|
| 1 | 14.72 | Diet 1 vs Diet 2 | 0.1429 |
| 2 | 15.09 | Diet 1 vs Diet 3 | 0.0074 |
| 3 | 16.00 | Diet 2 vs Diet 3 | 0.1121 |

**Figure 1: Age at Death**




## Results

### *Longevity*

For the survival analysis, two cats were removed from trial within the first six months for poor food consumption and were not included. There were 88 total cats in the final data set — 85 that died, and 3 that were removed for poor food consumption before they died (but after they had been on trial for over six months). These last three cats that did not complete the trial were considered censored in the statistical analysis.

As previously reported, cats fed Diet 3 lived significantly longer than cats fed Diet 1.[4,5] Using nonparametric analysis for Age at Death, cats fed Diet 3 lived approximately 1.3 years longer, on average, than cats on Diet 1 (Table 1). Figure 1 shows the Kaplan-Meier curves for Age at Death.

The Cox's proportional hazard regression analysis using initial age as a covariate also showed a significant difference between Diets 1 and 3 for Days on Trial (Table 2). The hazard ratio of Diet 1 versus Diet 3 was 0.418, meaning that the hazard of dying for the cats on Diet 3 was only 42% of the hazard of dying for the cats on Diet 1. There were no significant differences between Diets 1 and 2 or between Diets 2 and 3.

### *Body Weight*

All three diet groups lost weight over time, but cats fed

**Table 2. Days on Trial, Cox Regression (Initial Age as Covariate)**

| Variabe | df | P Value | Hazard Ratio | 95% CI for Hazard Ratio |
|---|---|---|---|---|
| Diet 1 vs Diet 2 | 1 | 0.3487 | 0.763 | 0.433-1.344 |
| Diet 1 vs Diet 3 | 1 | 0.0038 | 0.418 | 0.231-0.754 |
| Diet 2 vs Diet 3 | 1 | 0.2722 | 0.741 | 0.433-1.266 |

Diet 3 lost less than cats on Diets 1 and 2 (Figure 2). The Cox's proportional hazard model for Diets 1 and 3, using body weight (BW) as a time-varying covariate, showed a significant relationship between BW and survival (Table 3). Using the hazard ratios in Table 3, for every 1 kg increase in BW, there was a 64% increased chance of survival, or decreased "hazard of dying."

*Body Composition*

Consistent with body weight, body condition score (BCS) decreased significantly over time for all dietary groups. Although there were no statistical differences among diets, there was a significant relationship between BCS and survival (Table 3). For every 1 point increase in BCS, there was an 88% increased chance of survival.

Both grams and percentage of body fat, as well as grams of LBM, bone mineral density (BMD) and bone mineral content (BMC), showed significant decreases over time for all dietary treatment groups, while percent of LBM and percent of bone increased over time. In general, cats fed Diet 3 showed less change over time than the other diets in the longitudinal analysis of these parameters. There was a trend for differences between Diets 1 and 3 over time for percent of LBM ($P < 0.10$; Figure 3), percent of fat ($P < 0.10$; Figure 4), BMD, BMC, and percent of bone ($P < 0.10$).

**Table 3. Survival Analysis with Time-Varying Covariate, Diet 1 Versus Diet 3**

| Parameter | Hazard Ratio | P Value | Survival Correlation |
|---|---|---|---|
| Body Weight | 0.364 | <0.0001 | 64% increase/kg |
| Body Condition Score | 0.117 | <0.0001 | 88% increase/BCS unit |
| DEXA Lean g | 0.998 | <0.0001 | 0.2% increase/gram |
| DEXA Fat g | 0.996 | <0.0001 | 0.4% increase/gram |
| DEXA BMD | 0.00002 | 0.0045 | 100% increase/g/cm2 |
| DEXA BMC | 0.985 | 0.0161 | 1% increase/gram |
| DEXA % Lean | 1.118 | 0.0002 | 12% decrease/% |
| DEXA % Fat | 0.876 | <0.0001 | 12% increase/% |
| DEXA % Bone | 2.35 | <0.0001 | 135% decrease/% |
| Vitamin E | 0.946 | 0.0357 | 5% increase/mg/L |

The Cox's proportional hazard model for Diets 1 and 3, using LBM (in grams and percent), fat (in grams and percent), BMD, BMC, and BCS as time varying covariates, showed significant relationships between these parameters and survival (Table 3). LBM in grams, fat in grams and percent, BMD, BMC, and BCS were all positively correlated with survival with hazard ratios less than 1, indicating that higher levels of these parameters are associated with a decreased hazard of dying. For example, for every 1 gram increase in LBM, there was a 0.2% increased chance of survival, and for every 1% increase in percent of body fat, there was a 12% increased chance of survival. Percent of LBM and percent of bone were negatively correlated with survival with hazard ratios greater than 1, indicating that higher levels of these parameters are associated with an increased hazard of dying. For example, for every 1% increase in percent of lean, there was a 12% decreased chance of survival.

Mean predicted LBM (gm) and fat mass are shown for all cats by months prior to death in Figures 5 and 6. A longitudinal linear regression model best fit the LBM data, and the prediction line shows a general progressive decrease in average LBM as the cat nears the end of its life span (Figure 5).

The fat mass in grams was transformed into natural logarithms to account for extreme observations. A segmented regression model was used, with a quadratic model best fitting the period closest to death, as shown by the predicted average line (Figure 6). This analysis estimated that cats start losing fat around 37 months prior to death, and that the decline showed an increasing amount of fat loss toward the end of life. The overall longi-

**Figure 2: Body Weight Predicted Means**

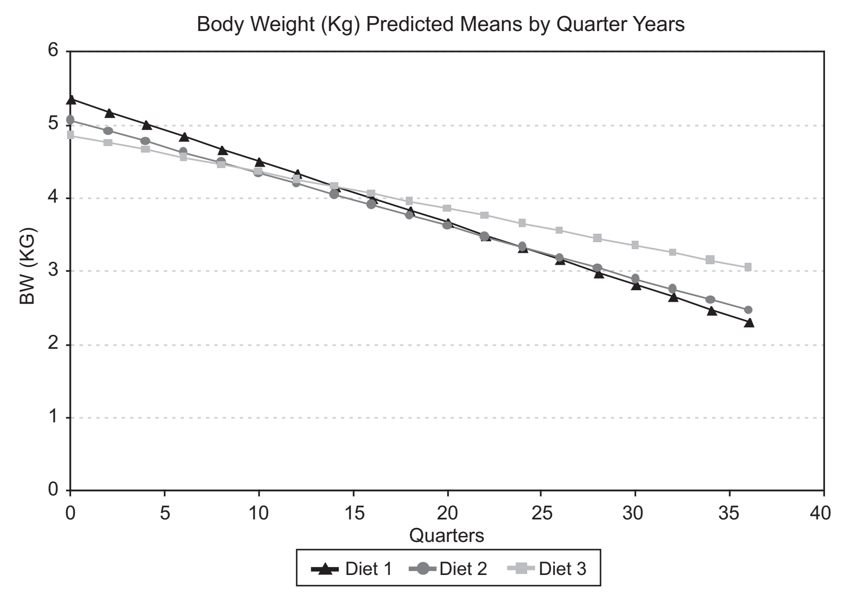


**Figure 3: Percent of LBM Predicted Means**

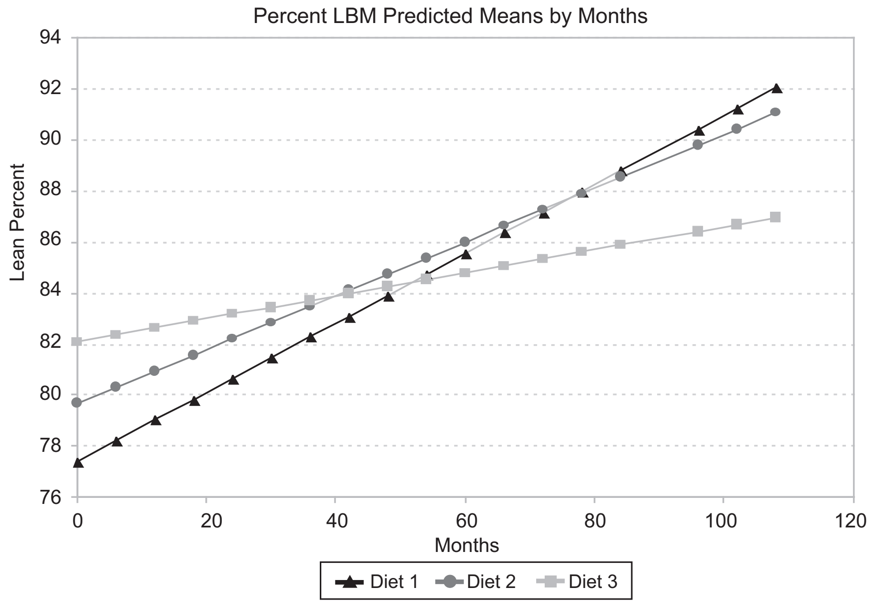
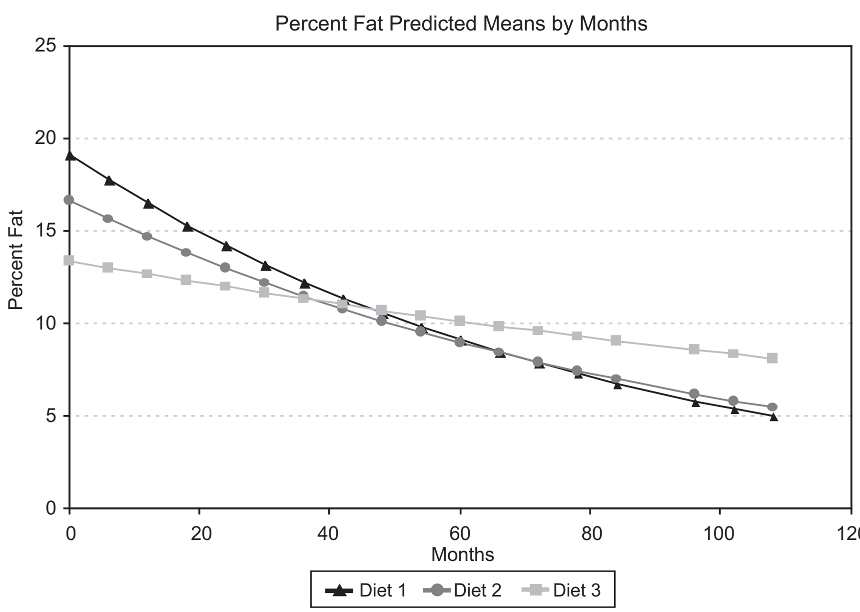



**Figure 4: Percent Fat Predicted Means**




tudinal patterns of mean predicted LBM (gm) and fat mass are shown together in Figure 7.

## Discussion

Prior cross-sectional studies evaluating populations of cats suggested that loss of body weight in aging cats was a risk factor for mortality,[3] and it was reported that extremely lean old cats had a significantly higher risk of death compared with cats in optimal body condition.[9] In the current study evaluating aging cats longitudinally, this observation was not only confirmed, but also the conclusions can now be expanded. According to this data, aging cats that lose excess body weight and body condition (fat or lean) have a significantly greater risk for earlier mortality.

Across most human age groups, a higher body mass index (BMI) is associated with increased morbidity and mortality.[10-12] Staying lean is widely recommended to decrease and delay disease incidence and extend longevity. In many species, including dogs,[13] maintaining a lean body condition through lifelong caloric restriction has been shown to increase longevity.

However, this relationship between leanness and longevity is not evident in older adults or those with chronic disease.[14] Instead, a low body mass index in very old humans is associated with an increased risk of morbidity and mortality.[10,15,16] With the highest mortality observed for the very obese and very thin, the result is a U-shaped curve for the relationship between BMI and risk of death or disease by age group.[15,16] Higher BMI and lean mass have been associated with increased longevity in these elderly age groups.[14,17,18] Higher fat mass was also associated with significantly lower mortality rates in human hemodialysis patients.[19] Based on the results presented here, an increase in longevity from higher levels of lean and fat tissue may be true for aging cats as well.

In this study, all parameters measured by DEXA, as well as body weights and BCS, showed a significant relationship with survival. LBM (in grams), fat mass (in grams and percent), bone mineral density and bone mineral content, as well as BCS, were all positively correlated with survival, indicating that higher levels of these parameters were associated with a decreased risk of dying.

The negative correlation between percent of LBM and survival and the positive correlation between body fat and survival observed in this study might be misleading if applied to the wrong population. These cats were in normal to lean body condition. The cats with the highest percent of LBM in this study had very low levels of body fat, and due to overall body weight loss, their percent of LBM was increased despite a significant reduction in total grams of lean. Substantially decreased absolute values of lean and fat tissue more clearly reflect the actual changes that are occurring in these elderly cats, with as much as one-third less lean tissue compared to what is measured during young adulthood.[25] A higher percent of LBM and bone relative to lower percent of fat mass previously has been described in our historical research colony data in cats toward the end of their life spans.[3] Slowing down this loss or change in relative amounts of these body tissues could theoretically help extend life expectancy.

**Figure 5: Mean Predicted LBM by Months Prior to Death**

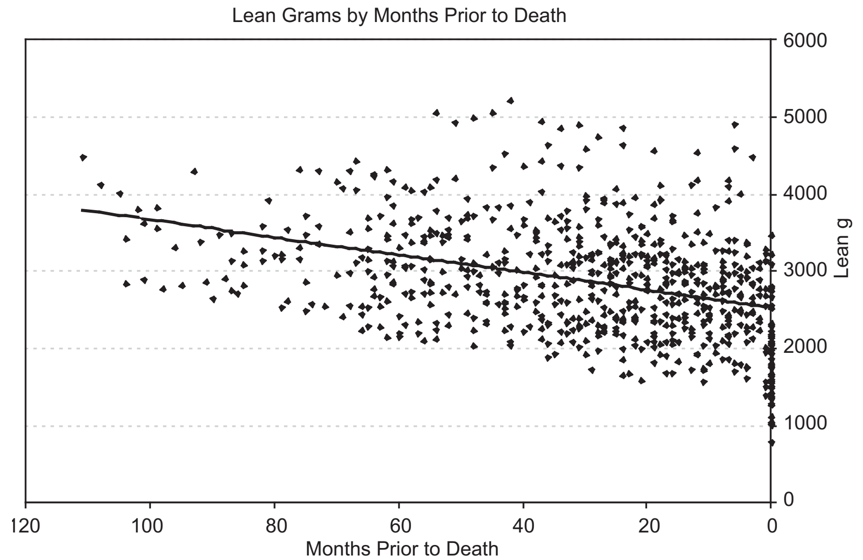
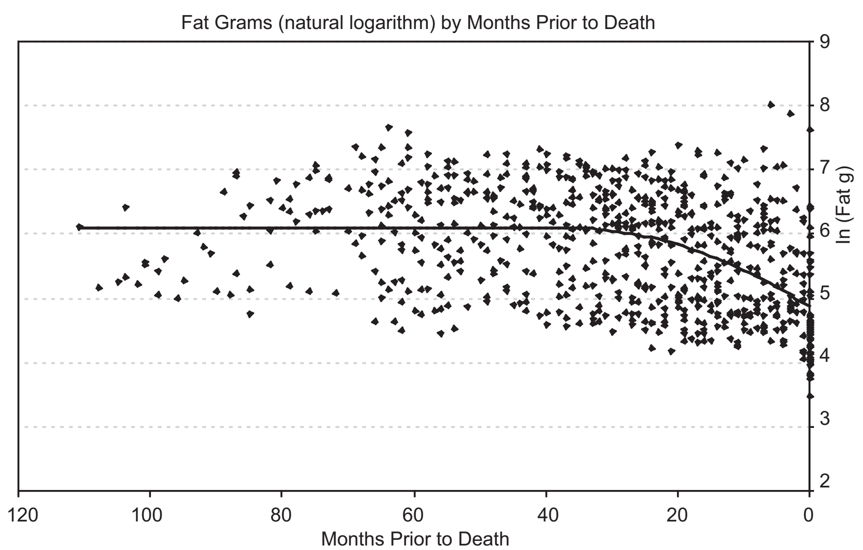



**Figure 6: Mean Predicted Fat Mass by Months Prior to Death**




It is interesting that the overall longitudinal data on LBM (in grams) showed a steady linear decline prior to death while fat mass (in grams) remained constant until approximately three years prior to death, then increasingly declined toward the end of life. This pattern closely follows that seen in body weights of our colony cats that were tracked in the four years preceding their death[20] and likely reflects the onset of chronic disease and more rapid utilization of body tissue reserves during disease states.

Sarcopenia is common in aging humans and is recognized as a significant contributor to disability and mortality in geriatric people.[2,21] There are many causes of sarcopenia, including age-related decreases in hormones, inefficiencies in protein synthesis, increased pro-inflammatory cytokines and oxidative stress.[2,21] In addition, dietary factors can contribute to sarcopenia. Inadequate intake of energy or protein can contribute to gradual loss of lean body mass.[2]

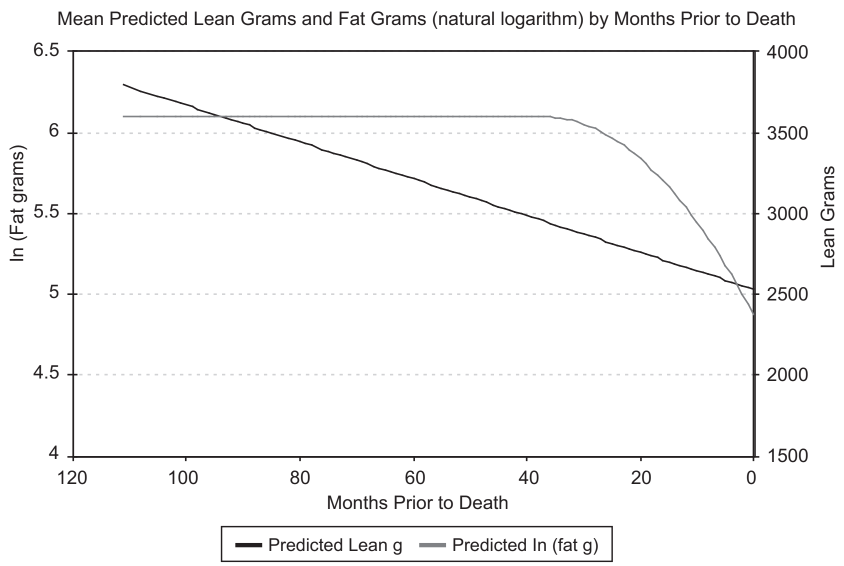
Increased dietary protein has been proposed as a means of preserving LBM in older dogs.[22] Old dogs require more protein to achieve better protein turnover, a process that decreases with increasing age.[23,24] Sufficient protein turnover is important for preserving immune competence in the older dog and will certainly have an effect on morbidity and mortality.[22,25]

Cats have high protein requirements to maintain their LBM, and we previously reported cross-sectional population data showing that body weight, LBM and fat mass all decline in cats over the age of 12 years, particularly in the last one to two years of life.[3,20] In this study, where differences in body composition and life span developed longitudinally among different dietary treatments, protein and caloric density of the diets were similar across all three diets. Food consumption, while initially similar, increased in those diet groups that lost the most body weight.[4] Hence, inadequate protein or calories does not explain the loss of lean and fat mass.

Neither inflammatory cytokines nor markers of oxidative stress were measured in this study. However, serum vitamin E levels were increased to a significantly greater extent in the Diet 3 cats,[5] and this is the group that maintained body weight and body composition to a greater extent.

There is a considerable body of research on the role vitamin E plays in protecting against oxidative stress in aging.[26,27] It has been hypothesized that vitamin E status may alter health and quality of life during aging through effects on immune function

**Figure 7: Mean Predicted LBM and Fat Mass Prior to Death**




and inflammatory pathways.[28] These authors reported that elderly humans with poorer physical and mental health status had lower circulating concentrations of alpha-tocopherol and increased concentrations of inflammatory markers. Inflammation does appear to be a fundamental characteristic of aging, and vitamin E has been shown to exert anti-inflammatory actions.[29,30] Low concentration of vitamin E also was found to be significantly associated with decline in physical function in elderly adults.[31]

It is possible that the sarcopenia and fat loss in the cats in this study were related to oxidative stress, and that the diet that maintained higher serum vitamin E levels helped maintain body tissue reserves and contributed to an overall increase in longevity.

## Conclusions

Data from this longitudinal study confirm observations from previous cross-sectional studies that weight loss is a risk factor for mortality in aging cats. Additionally, cats that lose body fat, lean and bone mass are at greater risk for earlier mortality. In this study, all body composition parameters measured as well as body weight were significantly related to survival. A retrospective longitudinal analysis of lean and fat mass indicated that, on average, LBM (in grams) declines at a steady rate for many years prior to death, while fat mass (in grams) is maintained until around three years before death, then increasingly declines.

The data also suggests that nutrition can play a role in delaying these age-related changes in body weight and body composition. Higher body weights and better maintenance of lean and fat mass may extend life by providing increased nutritional reserves in elderly cats. The diet containing supplemental antioxidants, a prebiotic and polyunsaturated fatty acids better maintained body weight and body composition in the senior cats in this long-term study, and this likely contributed significantly to their increased longevity.

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# Q&A Discussion

**Q: Dr. Joe Millward, University of Surrey:** One of my own pet hypotheses is that sarcopenia is a consequence of the shortening of the bones that accompanies demineralization. So you get some osteoporosis and the bones shorten a little bit and that takes tension off muscles, and muscles atrophy as a result of that. How good is your data on the interaction between loss of bone and loss of muscle, and have you looked at that?

**A: Dr. Cupp:** We haven't looked a lot at the bone data. Osteoporosis hasn't been as much of an issue in pets as it has in humans. And it's one of the things that DEXA obviously measures. We did see the correlation with survival, but we haven't looked at any great length at that data at this point.

**Q: Dr. Bill Milgram, CanCog:** I'd like some clarification on your cat study and the impact of the antioxidants. Since the cats were at different ages at the start of the study, was the effect different for cats that were on the study longer?

**A: Dr. Cupp:** The study used 90 cats ages 7 to 17 at the start. The cats were blocked by age into three groups aged 7 to 9, 10 to 12, and 13 and above, with 30 cats per group. These groups were then blocked by age, sex, body condition and hematology into groups of 10. So, each age group was equally represented among the three diets. Unfortunately, the groups were not large enough to provide statistical power to determine if the dietary effect differed among the different age groups within a dietary treatment.

**Q: Dr. Bill Milgram, CanCog:** My second question is if you followed individual animals with respect to weight loss as opposed to lumping the data together of all the animals at a given point in time. And I'll tell you what I'm thinking of. The population data suggests a nice linear relationship, but if you look at an individual cat, I wouldn't be surprised to see the weight relatively stable rather than a sharp drop.

**A: Dr. Cupp:** Yes, that's correct. The data showed that lean mass tended to decrease slowly over time, while body weight was fairly stable until near the end of life, in the last couple years of life.