From the Purina Companion Animal Nutrition Summit: *Focus on Gerontology*; Clearwater Beach, FL; March 26-27, 2010.

Feline Decline in Key Physiological Reserves: Implications for Mortality

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Abstract

Adult cats undergo changes in body weight and tissue reserves during the course of their lives. These changes are predictable trends that form distinctive life stages: adulthood (1 to 7 years), mature (7 to 12 years) and geriatric (over 12 years). During adulthood cats gain body weight slowly, leading to a mature life stage with high risk of obesity. In the geriatric life stage, cats suffer progressive losses of weight, fat and lean tissue reserves. Data records show that cats associated with longer life had a mature life stage with lower body condition scores than the population mean. The strategy for longevity should target ideal body weight and provide nutrition that evolves to manage specific trends during different life stages.

Glossary of Abbreviations

ANOVA: Analysis of Variance
BCS: Body Condition Score
BW: Body Weight
CR: Caloric Restriction
CRF: Chronic Renal Failure
DEXA: Dual Energy X-Ray Absorption
MER: Maintenance Energy Requirements
VMDB: Veterinary Medical Database (Purdue University)

Introduction

In this presentation, we share data from Nestlé Purina studies collected over several years. Specifically, these data include body weight (BW), body condition scores (BCS), water balance, food intake, maintenance energy requirements (MER), and body composition measured by dual energy X-ray absorption (DEXA). The trends found in these data are used to substantiate the notion of distinctive physiological life stages of fully grown cats. The particularities found for each specific life stage are discussed, as well as the risks that might affect the health status of the aging cat. Finally, the information is used to propose life-stage specific nutrition to address the particular needs of each life stage and help promote ideal body weight in pets.

Cats

Data presented is from our colonies of cats. We care for cats in our colonies over their entire natural life, unless they are adopted as pets. Our aim is that our cats are true representatives of the general pet cat population. This is for scientific reasons, i.e., to ensure that our studies on nutrition and behavior are meaningful and in line with our company values and passion for pets. Our cat colonies represent the pet population in gender balance and age span. We also work to create a homelike, enriched environment in terms of space, temperature, access to windows and natural light, access to toys, and opportunities for interaction with other cats and pet care personnel.

The majority of our cats have a job: They decide which pet products they like better, and thus are offered choices of the majority of pet foods available in the market. Our veterinarians focus on preventive medicine (vaccinations, worming, periodic dental and health examinations) to ensure a healthy colony. Our cats enjoy at least the same standard of veterinary care available to most house pets.

Adult Cat Life Stages

Adult: 1 to 7 Years of Age
Mature: 7 to 12 Years of Age
Geratric: Over 12 Years of Age

This paper presents historical data from two unrelated cat colonies. There are probably a limited number of cat colonies in the world that maintain a pet-like environment and compile years of data on BW, BCS, body composition, clinical histories, and food intakes. Hence, these data can be of significant value to understand the life stages of the species. The data coming from the two different colonies are not combined, but compared with one another to see if observed trends in one data set are reproducible in the other.

Cat Life Stages

The first step to study cats' life stages was to look at BW records. A plot of cats' BW data from one colony (Figure 1) shows trends with age in fully grown cats (1 to 21 years). One way to look at the data is to fit a nonlinear regression model to two tendencies: Cats increased in BW steadily between 1 and 9 years following the equation BW (kg) = 3.5 + (0.1 x years), and then, after age 9 years, BW decreased following the equation BW (kg) = 6.6 - (0.2 x years).

Figure 1: Body Weight (g) of cats (n = 235) by age (1 to 21 years).

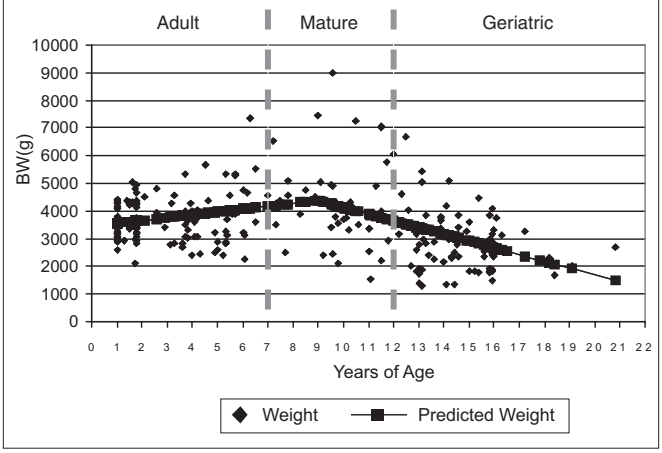


Table 1. Comparison of BW, obesity incidence (BW > 6 kg) and underweight incidence (BW < 2 kg) in different age groups.

Age (yrs)	BW (kg)	Obesity Incidence	Underweight Incidence
1 to 7	3.7 ± 0.8[a]	1/114[a]	0/114[a]
7 to 12	4.4 ± 1.7[b]	6/39[b]	1/39[a]
Over 12	2.9 ± 1.0[c]	1/82[a]	19/82[b]

From these analyses it could be suggested that something changes around age 9, and hence, a cat's life stages could be defined as "pre-9" and "post-9." However, this segmentation creates two groups with great variability that actually do not differ in BW. The post-9 group contains some of the heaviest and some of the thinnest individuals in the colony. It would be impossible to formulate diets suitable for all cats in such a heterogeneous group. Age 9 is an inflexion point, rather than an actual limit between two life stages.

In order to better define groups with greater differences and less within-group variability, the data can be grouped according to the following age periods: 1 to 7 years (n=114), 7 to 12 years (n=39), and over 12 years (n=82). Table 1 shows results from analysis of variance (ANOVA) where BW (kg) of the three age groups are all significantly different.

The incidence of obesity and underweight of these age groups was compared, based on some arbitrary definitions: Cats were considered obese if their weight was greater than 50% over the mean BW and were underweight if less than 50% of the mean BW. As the mean BW of the cats was close to 4 kg, cats weighing over 6 kg (4 kg + 50% mean BW) were considered obese, and those weighing less than 2 kg (4 kg - 50% mean BW) were underweight. Fisher's exact test showed a higher ($P<0.001$) incidence of obesity in the group 7 to 12 years and a higher ($P<0.001$) incidence of underweight cats in the group over 12 years.

The BW records of an unrelated cat colony (Figure 2) show similar trends. Mean BW for this colony was 4.039 kg. BW increased with age up to an inflexion point around 9 years, and then decreased. The incidence of cats with a BW over 6 kg was higher in the 7- to 12-year group. The incidence of cats with a BW below 2 kg was highest in cats older than 12 years. Hence, we assume that these BW trends are a real reflection of the cat life changes.

Besides the BW records, we used BCS scores data available from one colony to look at the condition of each cat. BCS was assessed systematically by trained personnel according to charts, using a 9-point BCS system where 1 is severely underweight, 9 is morbidly obese, and 5 is ideal. The advantage of BCS is that it is independent of the size of the frame of the cat, and it is a better reflection of its real condition. Two cats of identical BW could have different body conditions, with one large frame cat having low BCS and the smaller frame cat having high BCS.

Figure 3 shows the average BCS of a cat colony plotted by cats' ages. A very similar pattern to BW can be observed: The population means plotted with age shows a tendency to obesity (BCS>7) in the 7- to 12-age period. The mean BCS shows a progressive decline for geriatric cats (over 12 years).

The increased risk for obesity at age 7 to 12 was investigated further using DEXA. Obesity, defined in this case as more than 25% body fat, was again highest (one-third of cats) during the 7- to 12-year period (Figure 4). These body composition data substantiate the need for nutritional management for mature cats (7 to 12 years of age) to address the risk of obesity.

Figure 2: BW data plot by age from another cat colony (n = 581).

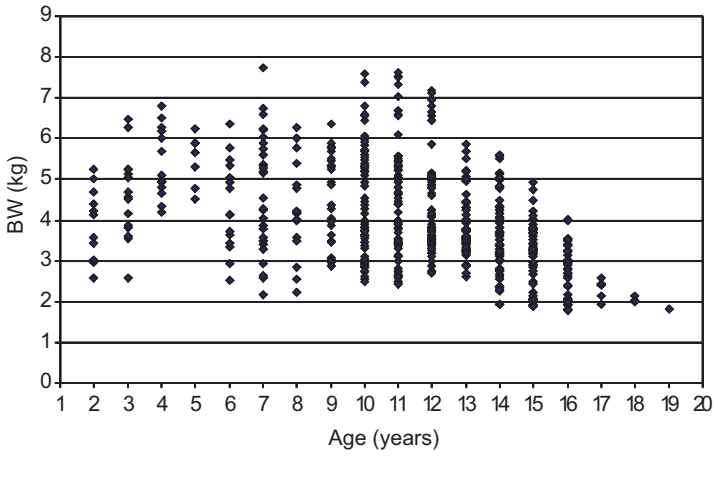


Figure 3: Mean BCS (range 1 to 9, ideal = 5, obese > 7) data plotted versus age (n = 631).

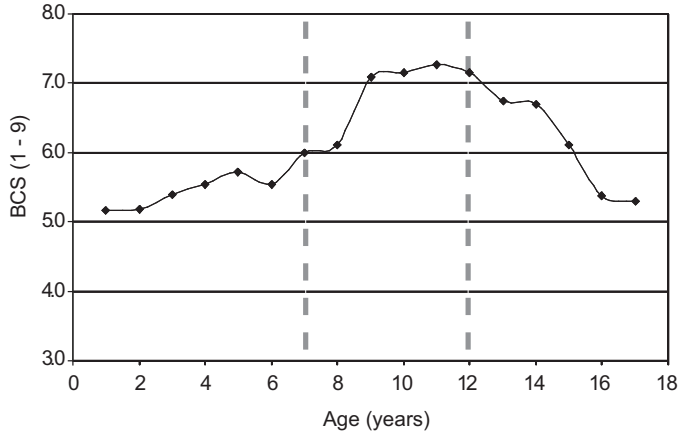
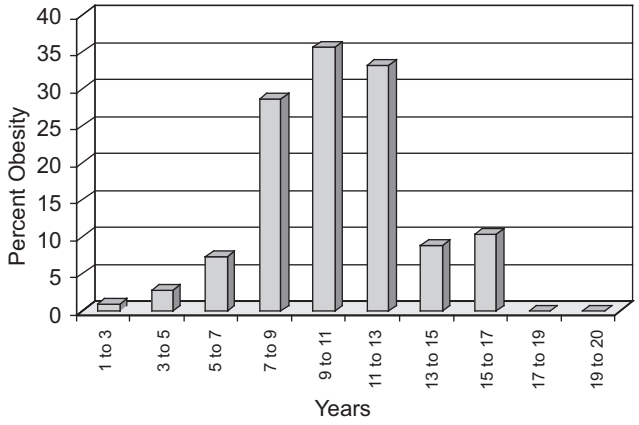


Figure 4: Incidence (%) of Obesity in cats (n = 256) by age (from 1 to 20 years). Obesity defined as more than 25% body fat.



Similarities found between the two unrelated cat colonies, and using different techniques like BW, BCS and DEXA, are unlikely to be a coincidence. The available data indicates that cats over 1 year of age undergo three distinctive life stages: adulthood, 1 to 7 years, during which cats are more likely to show ideal BCS but with a tendency to progressive BW increase with age; mature, 7 to 12 years, with a high risk of obesity; and geriatric, over 12 years, when BW and BCS tend to decrease progressively. These life stages allow diet products and recommendations to be tailored to the specific tendencies of the cats' age groups.

There could be some parallels drawn between the life stages of the cat and humans: 7 years of age in the cat is equivalent to 45 years in humans, and 12 years in the cat is equivalent to 65 years in humans.[1] The definition of mature cat as equivalent to 45 to 65 in human years, and geriatric cat defined as equivalent to over 65 in human years, could be used to make these life stage concepts more anthropomorphic. In general terms, humans have a tendency toward higher BW during maturity (45 to 65 years) than they had during early adulthood (i.e., at 25 years), and very elderly people tend to become progressively thinner or even frail, consistent with what is seen in cats.

Changes Along Life Stages and Decline in Physiological Reserves

DEXA measurements provide a valuable noninvasive tool to study changes in body composition. Percent fat and percent lean data from 256 adult cats, grouped in two-year age intervals, are shown in Figure 5, with scales on the left and right sides respectively. The overlapping of percent fat and lean tissue shows how the trends in both tissues mirror each other. Important shifts in body composition occur around the ages of 7 and 12 years, which are indicative of differences between life stages.

During the adulthood life stage (1 to 7 years), cats showed a mean of 10% body fat and 87% lean tissue. Toward the end of adulthood and during the mature life stage (7 to 12 years), cats have an increased percentage of fat, reaching a mean of approximately 18% by 9 years of age.

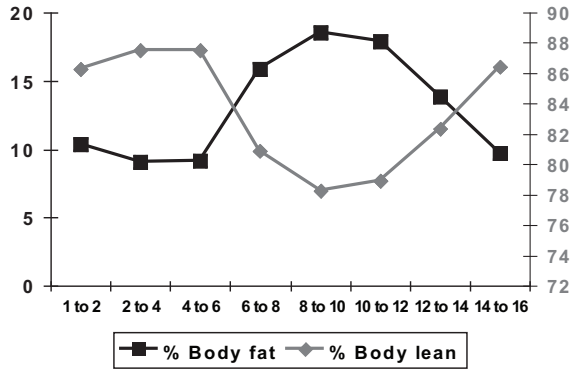
Mean percent body fat values in cats drop progressively after around 12 years of age (Figure 7). Percent lean tissue appears to increase in geriatric cats, but as they suffer progressive BW loss, the absolute values of lean tissue decrease (Figure 6). Lean tissue mean values drop dramatically after 12 years, and by age 15, geriatric cats have a mean lean tissue weight under 2 kg, one-third less than the mean during maturity (around 3 kg).

A longitudinal model analyses applied to data after 12 years of age estimated that geriatric cats lose in excess of 100 grams lean tissue per year. Lean tissue is an indication of muscle mass and is likely to affect the appearance and the capacity for activity of the cat. Reduced lean tissue and body fat can certainly contribute to the frail look of the geriatric cat.

Declining trends in the BW, BCS, fat reserves and lean tissue in the geriatric life stage seem consistent. We also know that the incidence of terminal diseases is most prevalent in this life stage. It is reasonable to question if there is an association between BW changes and disease.

To try to answer this question we used clinical histories from our colony archives to identify the primary causes of death in our colony cats. The data were grouped into those that died from cancer (n=26), chronic renal failure (CRF) (n=50), or hyperthyroidism (n=17). The remaining natural causes were combined into a fourth group (n=165). Then we tracked the BW records of each individual during the four years prior to their death. Figure 8 shows these historical BW data plotted by quarter (every three months) for a total of 16

Figure 5: Mean percentage body fat and lean tissue by age in cats (n = 256).



quarters. The BW from the last quarter prior to death was discarded as it was highly influenced by parenteral fluid treatments in the care of these cats.

In order to ensure that our colony data was representative of the pet population, the incidence of these diseases in the colony was compared to the general feline patient population using data from the Veterinary Medical Database (VMDB) at Purdue University collected over the same time period (1995 to 2001). No significant differences were found in the prevalence rates of cancer, CRF or hyperthyroidism between the Nestlé Purina colony and the U.S. pet cat population.

Two-stage nonlinear regression was used to fit the data, as shown in Figure 8. It was assumed the cats' BW remained constant and then at the point when BW losses start (inflection point), a quadratic model was fitted to allow for an increasing amount of BW loss as they approach death. The inflection point in BW for cats that died of cancer, renal failure and hyperthyroidism was at quarter 10 prior to death (equivalent to 2.5 years). The group of cats dying from other causes had an earlier inflection point at 15 quarters prior to death (equivalent to 3.75 years).

The decline in BW in the second year prior to death was over 6% for cancer, CRF and hyperthyroidism (Table 2). During the last year of life, the average percent of BW loss was over 10% for all four groups. The average age at death did not differ significantly among cancer (13.5 ± 2.3 years), CRF (13.0 ± 3.9 years) and hyperthyroidism (14.3 ± 1.9 years), but the cats from other causes of death died significantly earlier (12.4 ± 3.5 years) than the cats that died from hyperthyroidism. Over the four years prior to death, cats that died of renal failure lost significantly more body weight than the cats in the "other" diseases group.

All studied disease groups have a progressive decline in BW during a period of over two years prior to death. Hence, when it comes to decline in BW, the type of terminal disease of the cat does not seem to be a factor that makes the individual differ greatly from the main trend seen in the cat "other" population. We do not believe it is possible to single out any particular disease type as responsible for the body mass decline seen in the geriatric period. Data seems to indicate that weight loss in geriatric cats cannot be explained by one particular terminal disease.

Water Turnover in Different Cat Life Stages

The decline in lean tissue in cats during their geriatric years needs further exploration in relation to their protein turnover and nitrogen balance. Another likely implication of the progressive loss of lean tissue is the reduction in the total amount of water in the body. This could make geriatric cats more prone to dehydration or less likely to recover from it.

We conducted studies comparing water balance between adult cats (1 to 7 years) and geriatric cats (> 12 years) fed the same canned diet. All cats in these studies had normal markers of renal function (BUN 11.7-33.3 mg/dl and creatinine 0.5-1.8 mg/dl). In the studies, water balance was defined as the relationship between water intake and water losses over a period of three weeks while maintaining BW. Water intake

Figure 6: Fat Content (grams) of cats (n = 631) plotted by age (years).

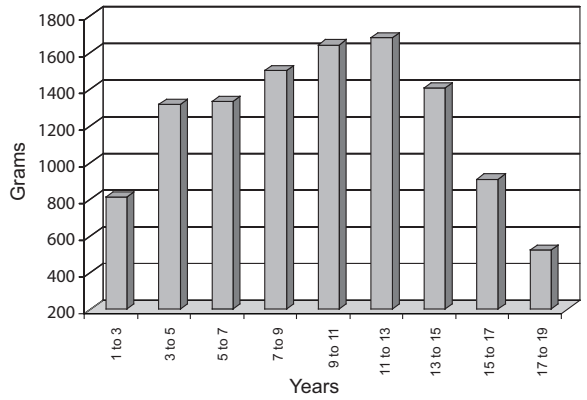


Figure 7: Lean Tissue Content (grams) of cats (n = 256) plotted by age (years).

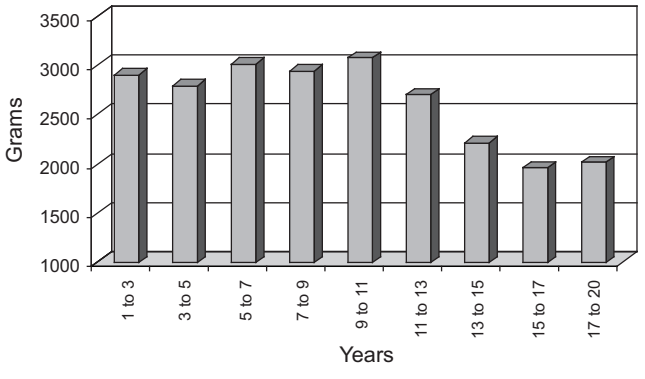


Figure 8: Mean BW (g) in the last four years prior to death by quarter (3 months) in colony cats (n = 258).

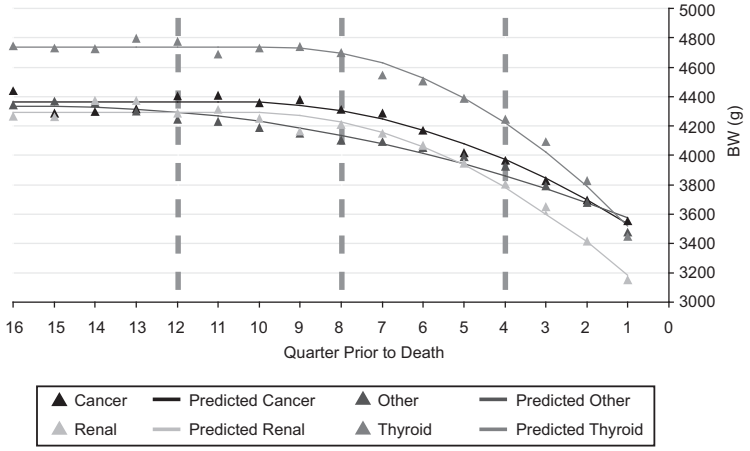


Table 2. Changes in % BW in the four years prior to death, by type of terminal disease.

Death Type	Percent BW change pre-death				Average Age at Death
	4th year	3rd year	2nd year	last year	
Cancer	-2,74	-0.59	-6.88	-10.34	13.5±2.3a,b
Others	-0.76	-2.28	-2.72	-11.38	12.4±3.5a
Thyroid	1.04	-0.77	-6.66	-18.85	14.3±1.9b
CRF	2.54	-2.82	-6.34	-17.35	13.0±3.9a,b

included both the moisture of the food ingested and the amount of drinking water consumed. Water losses were the sum of fecal moisture plus urinary volume. Some other water losses (salivation and respiration water losses) could not be accounted for, but it was assumed that there were no significant differences between adult and geriatric cats as they all shared the same colony environmental conditions (temperature and relative humidity).

As shown in Figure 9, there were neither significant differences in the water ingested with the food nor in the drinking water consumed between the two age groups. Likewise, no differences were observed in fecal moisture losses, but the urinary volumes were significantly higher ($P<0.05$) in the geriatric cats. As a consequence of the urinary volume differences, geriatric cats have higher total water losses ($P<0.05$) than adult cats, possibly due to decreased ability to concentrate urine even when there is no other evidence of renal insufficiency. Small but continuous water losses could predispose geriatric cats to a negative water balance. If we consider water as an essential nutrient, it would be advisable to encourage higher intake particularly in the geriatric cat.

Importance of the Mature Life Stage on Longevity

It is clear that BW, BCS, fat and lean tissue decline in cats during their last stage of life. The speed of the decline seems to be a predictor of time of death. In view of this, we wonder what would be the best strategy for a cat in the mature life stage to try to extend its life. Should the cat aim at starting the geriatric life stage at the highest BW possible to allow for a more prolonged decline over coming years? This approach would appear to contradict caloric restriction (CR). CR has been shown to extend life in mice, dogs and other species in a consistent manner, although data in cats is lacking.

Given the unavailability of data on CR in cats, we attempted to approach this question by evaluating the association between longevity and body composition during the cats' mature years. We identified a small number of cats that had lived longer than the colony average (around 14 years). With data records available during their mature years (n=2 at 8 years, n=4 at 9 years, n=5 at 10 years, n=3 at 11 years, and n=7 at 12 years), we compared (Figure 10) their BCS data records against the average of the colony at mature years. Cats that lived over 14 years (14 +) showed lower mean BCS than the colony average during the mature life stage (7 to 12 years). Regression analyses for BCS of 14+ survivors showed significantly different slopes ($P=0.0245$) from the rest of the colony. The 14+ group maintained a more constant BCS average (around 6.5) while the non-survivors increased average BCS during maturity (>7).

Limited DEXA data of 14+ survivors were available to compare body composition at maturity. Regression analyses comparing percentage fat of 14+ survivors versus colony during mature years showed no significant difference. However, averages of percentage fat were around 3% lower during maturity for 14+ survivors than for the colony (Figure 11). Likewise, the 14+ survivors were more likely to have a higher percentage of lean tissue (3% more) than the colony.

We have to be cautious as we do not know yet the longevity of all the cats contributing to the data in the colony. The database will continue to grow with time and as better data mining tools become available. However, we found significant indications that those cats that lived over 14 years had a lower BCS during their mature period, and preliminary indications that they also had lesser percentage of fat and leaner body composition than the colony average.

To answer the question regarding "which is the best strategy during the mature life stage for a cat to live longer," there seems to be some evidence to support that it is best to maintain BCS closer to ideal. "Piling up fat reserves" during maturity, prior to geriatric years, does not seem to be associated with longevity. An obese or overweight mature period may overload body organs and systems (e.g., cardiovascular, joints, hepatic, pan-

Figure 9: Water Balance (g/day/kg BW) differences between adult (1 to 7 years) and geriatric cats (> 12 years) fed canned food.

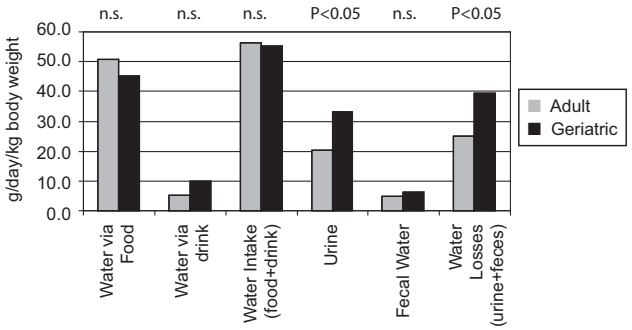
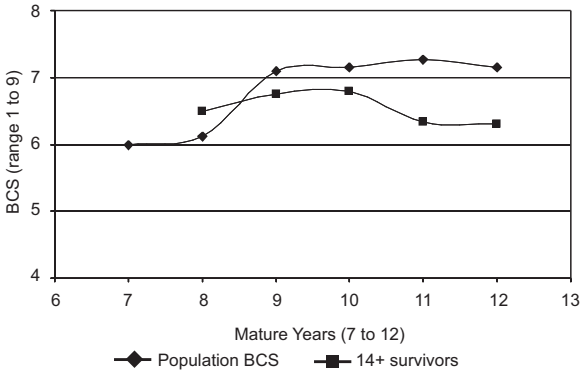


Figure 10: Comparison of BCS means during the mature life stage between the colony and cats that have lived over 14 years.



creatic) and predispose the body for a harder and steeper "fall" in the geriatric years, contributing to a shorter life. This is aligned with CR findings in other species.

The maintenance of ideal BCS and high percentage of lean tissue could help promote healthy activity levels, more interaction with the environment and the pet owner, and a better quality of life. Hence, particular attention must be paid to the mature life stage as this is the period when cats are more likely to have excess BW.

Matching Nutrition to Cat Life Stages

Over the years, we have conducted a number of studies evaluating the MER of adult cats. Generally, MER decreased in mature cats, compared to younger adult cats.[4] However, MER was found to increase in cats older than 10 to 12 years of age.[5,6] This increase was not linear, increasing more dramatically between 12 and 15 years of age, as shown in Figure 12.

It is not easy to identify the cause of the decreasing trends in BW, BCS, body fat and lean tissue in geriatric cats at a time when cats tend to eat more. An increase in energy requirements due to higher activity levels in geriatric years is unlikely. Perhaps metabolic efficiencies might be reduced in some organs. One organ that has been shown to decrease in efficiency is the digestive system.[7,8] Digestion data from several Nestlé Purina colonies were evaluated to test this theory and identified that one-third of geriatric cats have compromised fat digestibility. In some geriatric cats, fat digestibility was found to be as low as 30% with no apparent health problem.[9,10] As fat is the most energy-dense macronutrient, impaired ability to digest fat could contribute, at least in part, to the changes in BW and body composition observed in geriatric cats.

The ability to digest protein is also compromised in many geriatric cats. After the age of 14 years, one-fifth of geriatric cats have reduced ability to digest protein.[9,10] Reduced protein digestibility in geriatric cats seems to occur in parallel with reduction of lean tissue and it might predispose them to negative nitrogen balance.

Figure 11: Comparison of Percent fat between 14 + survivors versus the colony average during the mature years.

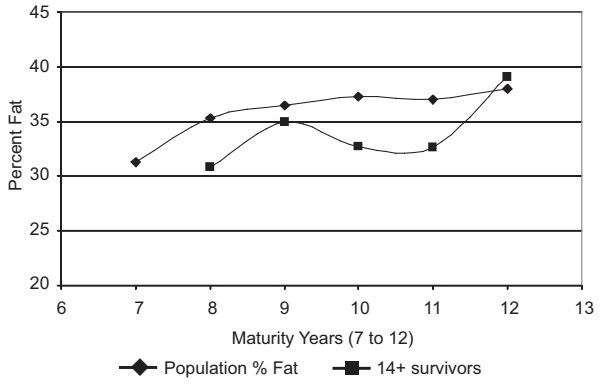
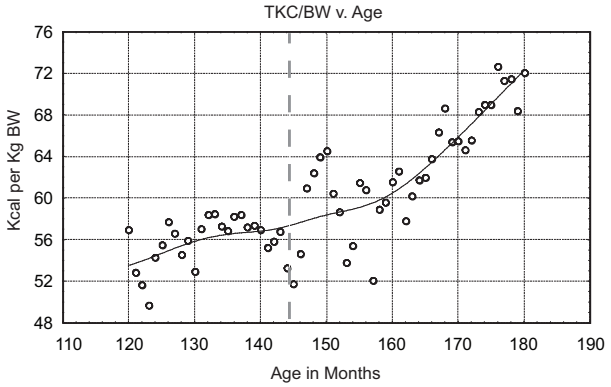


Figure 12: Daily energy requirements (kcal per kg BW) with age (months).



General Nutritional Recommendations for Cat Life Stages

The most sensible approach seems to be to try to maintain ideal body condition during all life stages. Obesity has been linked to increased risk of hepatic lipidosis, glucose intolerance and musculoskeletal problems in cats. It would seem logical to use diets of moderate energy density that could help reduce the risk of weight gain during the mature life stage.

Although moderation of calorie intake may be suitable for mature cats, it does not appear to match the needs of geriatric cats. On the contrary, it would seem more logical to use highly digestible, energy-dense food for geriatric cats in an attempt to slow down the decline in BW and lean body tissue. Protein reduction for geriatric life stage, at a time when lean tissue is lost, seems contraindicated. Geriatric cats seem to have nutritional requirements closer to kittens than to mature adult cats.

Of course, the "average" cat does not exist; it is just a statistical calculation. Dietary management must take into account the individual BCS and MER, and the presence of diseases. A diet must provide all required nutrients and the energy to maintain ideal BW. It must also be palatable to ensure intake. Fecal consistency plays a part in ensuring water balance, which can be compromised in geriatric cats. The diet could be used as a vehicle to aid water intake for the geriatric cat.

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Q&A Discussion

Q: Dr. Margarethe Hoenig, University of Illinois: I was wondering if you could elaborate on how these cats were fed throughout that time. Was it group feeding? Were they separated during feeding? What happened?

A: Dr. Pérez-Camargo: Thank you for the question. That's something that I forgot to mention, and it's very relevant. These cats live in social rooms with around 15 to 20 cats per group, and they are used in our palatability panels. So their job is basically to choose between "I like this today better than that," or the other way around. They have access to food most of the day, and they have access to a variety of products in the market, so they see nearly everything in the marketplace. They have personalized access to their own feeding boxes, gaining access via a chip in their collar. The computer recognizes that cat and allows the cat to enter into that feeder and access the feeder however many times a day as he or she wants. Cats tend to prefer feeding multiple times per day.

Q: Dr. Aulus Carciofi, Sao Paulo State University: When you measured energy data in cats and concluded that they have increased requirements, did you take into consideration that old cats have lower digestibility?

A: Dr. Pérez-Camargo: No, the data was based on actual energy intake, so part of the increased requirement may be related to decreased digestive function. The impact of age on digestion will be better explained by my colleague, Avi Patil, later in the conference, and how that will impact the energy requirements of the cat. But, I would dare to say that the impact of the decreasing digestibility can be so extreme that the cats do not manage to compensate by increasing their intake.

Q: Dr. Joe Millward, University of Surrey: Let me ask you about this phenomenon of weight loss in the geriatric period. I guess what interests me is to what extent it is a function of disease development. It wasn't clear whether you were saying that the weight loss was in cats that were developing chronic illness as opposed to a physiological decline that is, for example, comparable to sarcopenia in humans where you can have muscle wasting in perfectly healthy individuals. Are your geriatric cats basically sick cats or cats that are physiologically unable to maintain their lean body mass?

A: Dr. Pérez-Camargo: Your question is a very good one. For most of these cats we could detect illness probably around one year prior to death if they had chronic renal failure or hyperthyroidism. We monitor the cats regularly, particularly after the age of 7 to 9, in order to detect some of their diseases early, but the fact is that they began to lose body weight before we knew they were sick. And because there currently are no sensitive early markers, we don't actually know if cats have subclinical disease until they show some biochemical marker or clinical sign of disease.

Q: Geraldine Blanchard, Animal Nutrition, France: Your data showed that the energy requirements per kilogram body weight increases with age in cats. However, since that is based on actual body weight, which was already lower in these cats, their total calorie requirements may not be different, still 50 something calories per kilogram of ideal body weight. I wonder how many of these cats were neutered?

A: Dr. Pérez-Camargo: Most of them would have been spayed or neutered. We tend to keep males intact only for reproduction, and females are kept intact if they will be used in the breeding colony but only until they are around 4 to 6 years of age. Once they are no longer needed for breeding, they are spayed to reduce uterine problems. By the time they get to maturity around 9 years of age, they all are neutered.

Q: Dr. Stan Marks, University of California-Davis: You eloquently stated that cats that maintain the more optimal BCS at maturity, live longer, more than 14 years compared to cats that are obese at maturity. Did your data show any association between obesity and a terminal disease, like cancer for example, in those cats?

A: Dr. Pérez-Camargo: Unfortunately, our data does not provide an answer to that question.