



Overweight adult cats have significantly lower voluntary physical activity than adult lean cats

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Abstract

Objectives The objectives of the current pilot study were to evaluate whether body condition score (BCS) and body weight are significantly related to physical activity counts, and to evaluate potential interaction between BCS and voluntary physical activity measured over a 14 day period.

Methods Ten (five lean, five overweight), neutered, adult American Shorthair cats were selected for this study (median age 4 ± 0.5 years). Cats with a BCS of ≤ 3.0 were considered lean, whereas cats with a BCS > 3.0 were considered overweight, using a 5-point scale. Cats were housed in a free-living environment with indoor/outdoor access and were individually fed once daily a commercially available dry extruded diet and allowed 1 h to eat. Voluntary physical activity was measured consecutively for 14 days using the Actical Activity Monitors that were worn parallel to the ribs and attached via a harness.

Results Lean cats had a greater mean total daily voluntary physical activity ($P = 0.0059$), and a greater voluntary physical activity during light ($P = 0.0023$) and dark ($P = 0.0446$) periods, with overweight cats having 60% of the physical activity of lean cats. Lean cats were more active before feeding and during animal care procedures. These data suggest that lean cats have a greater anticipatory physical activity prior to feeding and are more eager to have social interaction with humans than overweight cats. A significant interaction was observed between day of physical activity measurement and BCS for total daily voluntary physical activity ($P = 0.0133$) and activity during the light period ($P = 0.0016$) where lean cats were consistently more active than overweight cats. In general, cats were more active during weekdays vs weekends.

Conclusions and relevance The results of this study suggest that overweight cats are less active than lean cats and that voluntary physical activity level appears to be influenced by social interaction with humans.

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Introduction

Maintenance of a healthy body weight (BW) and body composition through the life cycle is well accepted to reduce the risks associated with morbidity and mortality in mammals.¹ Despite this, being overweight and obesity are two of the most common health conditions in cats.² The prevalence of obesity in the US adult human population steadily increased in the past few decades,^{3,4} and more recently has been found to be leveling off.⁵ Similarly, in a follow-up survey of New Zealand cat owners, no increase in the prevalence of obesity was found from 1993–2007, suggesting that similar variables have contributed to the prevalence of obesity in both populations.⁶ The prevalence of human obesity is, in part, owing to people in industrialized countries expending less energy in physical activity in every facet of their life,^{7,8} and this

inactivity is correlated throughout life with obesity and subsequent morbidity and mortality in the human population.⁹ The similarity in frequency of obesity in both the human and pet population has not been lost on

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researchers. Sandoe et al discussed the importance of the relationship between human and companion animal obesity,¹⁰ and pointed out that the problem is more complex than previously thought and should be treated as a 'one health' problem. Indeed, German discussed the similarity in parenting and pet ownership and how these styles of pet ownership may contribute to pet obesity.¹¹ In addition, weight gain is often underappreciated by pet owners and underreported by veterinarians.^{12,13}

In spayed female cats, weight gain and related metabolic indices were related to diminished physical activity, mainly in daylight hours.¹⁴ Similarly, obese cats have lower energy expenditure than lean cats,¹⁵ but the relationship between physical activity and energy expenditure has not been studied simultaneously. Increased feeding frequency and dietary water content have been found to promote physical activity in adult lean male cats,¹⁶ and increased feeding frequency but not dietary water content have been shown to promote physical activity in adult lean female cats.¹⁷ In addition, indoor confinement and low physical activity were found to be correlated with the development of diabetes in cats.¹⁸ This is further supported by owner survey data of Burmese cats, which found that when owners of diabetic and non-diabetic cats were queried, risk factors for diabetes included dental disease, repeated corticosteroid use, indoor confinement and lower physical activity.¹⁹

The objectives of the current study were to evaluate whether body condition score (BCS) and BW significantly affect physical activity counts, and to evaluate the potential interaction between BCS and 14 days of voluntary physical activity measurement. Because care and management are standardized in this group of cats, this design allowed the evaluation of the effects of daily routine and the effect of day (weekday vs weekend) on physical activity in both lean and overweight cats.

Methods

All procedures were reviewed and approved by the Institutional Animal Care and Use Committee at The Iams Company, Procter and Gamble Pet Care, and in accordance with the Iams International Animal Welfare Advisory Board standards.

Animals and experimental design

Ten (four females, six males) neutered, adult American Shorthair cats were selected for this study (median \pm SD age 4 ± 0.5 years) from the Pet Health and Nutrition Center (Lewisburg, OH, USA). All cats had been raised in this animal facility with the same management (nutrition, socialization) and healthcare since birth. Cats were assigned to either a lean ($n = 5$) or an overweight ($n = 5$) group according to their BW and BCS, using a 5-point scale.²⁰ Cats with a BCS of ≤ 3.0 were considered lean, whereas cats with a BCS > 3.0 were considered

Table 1 Guaranteed analyses of chemical composition of commercial diet fed to lean and overweight cats*

Nutrient analysis	Concentration on as-is basis
Crude protein, minimum	32.0%
Crude fat, minimum	15.0%
Crude fiber, maximum	3.0%
Moisture, maximum	10.0%
Ash, maximum	7.0%
Magnesium, maximum	0.1%
Taurine, minimum	0.15%
L-carnitine, minimum	80 mg/kg
Omega-6 fatty acids, minimum	2.06%
Omega-3 fatty acids, minimum	0.21%
Metabolizable energy	3693 kcal/kg

*Commercial diet was Iams ProActive Health Original with Chicken

overweight. In this study, all lean cats had a BCS of 3.0. Physical examination, biochemical profile and complete blood count analyses were completed prior to the initiation of the study and all cats entering the study were healthy, other than five cats having a BCS < 3.0 .

Housing

Cats were housed together in a free-living environment with indoor/outdoor access during the day (08.00–15.00 h) and indoor-only access at night (15.00–08.00 h) and this was maintained on weekdays and weekends. The indoor room measured 5.6 m \times 4.7 m and the outdoor run (accessed through a cat friendly swinging door) measured 5.6 m \times 2.4 m. Room environment included perches, beds, toy houses, scratching posts, toys and climbing apparatus. All cats were socialized on weekdays for a minimum of 15 mins and the individual socialization and the length was recorded and marked on the data sets. Socialization did not occur at a standard time daily but always occurred between 09.00 and 15.00 h. On the weekends, cats did not have socialization beyond feeding and cleaning. Cats were maintained on a 12 h light schedule, with the lights being turned on at 06.30 h and turned off at 18.30 h, although the room was also exposed to natural light through the windows. The room temperature was maintained at 22°C and relative humidity was 50–60%. Room surfaces were cleaned daily and disinfected weekly with Nolvasan disinfectant (Pfizer). Water was provided ad libitum from automatic waterers.

Diets

Cats were fed a commercially available dry extruded diet (Iams ProActive Health Original with Chicken; Table 1). Each cat was fed to maintenance energy requirements as established based on historical records of the individual dietary energy required to maintain BW. Historically, cats' intakes were not adjusted if they maintained

Table 2 Mean and median age, daily food intake (FI), body weight (BW) and body condition score (BCS) of lean and overweight cats

Items	Means		Pooled SEM	Medians		Pooled SD	Minimum	Maximum	Pairwise <i>P</i> value
	Lean	Overweight		Lean	Overweight				
Age (years)	4.0	4.8	0.156	4.0	5.0	0.26	3.9	5.0	0.0068
Daily FI (g as-is basis)	48.2	66.2	4.851	46.0	68.0	10.847	41.0	79.0	0.9933
Daily FI (g/kg BW)	14.7	12.0	1.197	14.2	12.0	1.345	11.6	16.9	0.1792
BW (kg)	3.4	6.1	0.259	3.5	6.1	0.564	2.77	6.84	<0.0001
BCS	3.0	4.2	0.180	3.0	4.0	0.285	3.0	5.0	0.0015

between a BCS of 2.0–4.0. Cats were fed once daily, individually at 07.00 h and permitted 60 mins to eat during food offerings. Daily food intake was recorded and no food refusals were observed throughout the study.

Physical activity measurements

Voluntary physical activity was measured over 14 consecutive 24 h periods using the Actical Activity Monitors (Mini-Mitter) that were worn parallel to the ribs and attached via a harness for 24 h. Cats were acclimated to wearing the harness and monitors for 24 h. Sufficient acclimation to novel research practices reduces variability between and within animals,²¹ allowing us to minimize duration of exposure to the harnesses. The monitors contain omnidirectional sensors to measure intensity and duration of movements. Once the monitors were removed, the Actical software analyzed and converted the data into arbitrary numbers referred to as activity counts per designated time period (1 s).

Statistical analyses

Data were analyzed using the Mixed procedure of a commercial software (SAS version 9.3; SAS Institute). Data normality was analyzed using PROC UNIVARIATE. Feline characteristics were compared using the Mixed procedure of SAS with the independent variable of BCS group and cat as the random effect. The experimental models included the effects of cat, day and BCS group, and the dependent variable was physical activity. The fixed effects of day (weekday and weekend day) and BCS group, and their interaction were also analyzed. When appropriate, hour and day were used as the repeated measurement, and Tukey adjustment was used to control for experiment-wise error. Results are presented as mean \pm SEM. A probability of $P < 0.05$ was considered significant and $P < 0.10$ for statistical trends.

Results

Age, daily food intake, BW and BCS

Overweight cats were significantly older than the lean cats ($P = 0.0068$; Table 2) with a difference of 0.8 years.

As both groups are considered young adult cats, we assumed that this was not a significant variable to physical activity. In addition, overweight cats had a greater BW (6.1 kg; $P < 0.001$) and BCS (4.2; $P = 0.0015$) when compared with the lean cats (BW 3.4 kg, BCS 3.0). Mean daily food intake (g/d as-is) did not differ between overweight and lean cats ($P = 0.9933$). Similarly, the daily food intake per kg BW did not differ between lean (14.7) and overweight cats (12.0; $P = 0.1792$). The lean group was comprised of three spayed female and two neutered males, whereas the overweight group was comprised of one spayed female and four neutered males.

Effect of BCS group on voluntary physical activity

The daily physical activity pattern (24 h) of lean cats differed from overweight cats (Figure 1). Lean cats were significantly more active from 06.00–13.00 h ($P < 0.05$) and tended to be more active between 14.00 and 15.00 h. The timing of increase in physical activity level coincided with the daily animal care management procedures. Lean cats had a greater mean total daily voluntary physical activity ($P = 0.0059$), and a greater voluntary physical activity during light ($P = 0.0023$) and dark ($P = 0.0446$) periods (Table 3). On average, overweight cats had a total daily voluntary physical activity of 47% of the total daily activity of the lean cats. Similarly, the voluntary physical activity of overweight cats during the light and dark periods corresponded to 42% and 58%, respectively, when compared with the lean cats.

Effect of day of collection and BCS on voluntary physical activity

A significant interaction was observed between day (within 14 d period of physical activity measurement) and BCS for total daily voluntary physical activity ($P = 0.0133$) and activity during the light period ($P = 0.0016$) but not the dark period ($P = 0.4715$; Table 4). Because of this finding of a significant interaction between day of collection and BCS, we broke the data into similar management days, mainly weekday and weekend days. In general, cats were more active during weekdays (days 1, 4–8, 11–13) vs

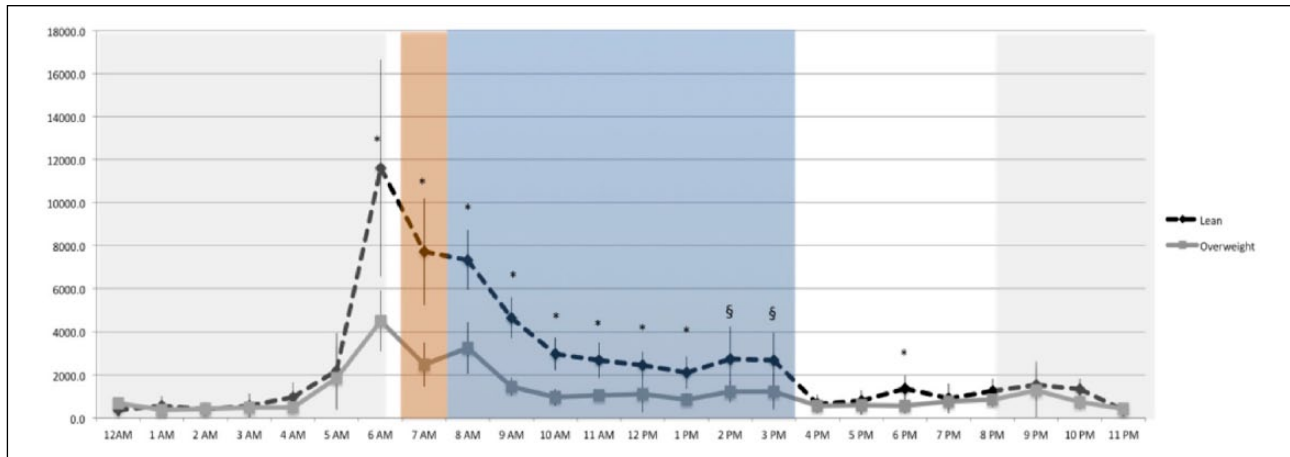


Figure 1 Mean voluntary physical activity pattern (mean activity counts/h \pm SD) of lean and overweight cats. The gray plot area in the graph represents the daily dark period, feeding time and daily animal care procedures (eg, cleaning room, brushing cats and cat socialization with care takers) are represented in the orange and blue plot areas, respectively. *Average activity differed between lean and overweight cats ($P < 0.05$). §Average activity tended to differ between lean and overweight cats ($P < 0.05$)

Table 3 Mean voluntary physical activity counts for total daily, and during light and dark periods in lean and overweight adult cats

Physical activity counts	Means		SEM	P value
	Lean	Overweight		
Total daily	59,483	28,097	5979.8	0.0059
Light period	38,999	16,204	3654.8	0.0023
Dark period	20,484	11,893	2553.9	0.0446

weekends (days 2–3, 9–10; Table 5). No significant interaction between weekday and BCS were observed for total daily physical activity and activity during the light and dark periods (Table 5; $P > 0.05$), suggesting that both groups had a similar response to the different management on weekdays and weekends. As such, significant effects of weekday and BCS were observed for total daily voluntary physical activity and activity during the light and dark periods in both lean and overweight cats. Similar to the data presented in Table 4, voluntary physical activity was greater during weekdays vs weekends, and in lean vs overweight cats. On weekdays, total daily voluntary physical activity, and activity during the light period and dark period were lower by 47%, 41% and 58% ($P < 0.05$), respectively, for overweight cats in contrast to lean cats. Similarly, differences were observed for voluntary physical activity of overweight vs lean cats during the weekends. Average voluntary physical activity for lean and overweight cats for total daily, activity during light and dark periods on the weekend corresponded to 83%, 81% and 87% ($P < 0.05$), respectively, of the average voluntary physical activity during weekday period for lean and overweight cats.

Discussion

This is the first study to demonstrate that when all other factors are similar, overweight cats have significantly lower physical activity than lean cats and that voluntary physical activity is stimulated in the presence or anticipation of human interaction. Overweight cats were 0.8 years older than lean cats. However, because both groups of animals were between 3 and 5 years of age, in practice this is a narrow age range, with both groups being considered within the ‘adult’ category. For this reason, age would be unlikely to result in differences in the voluntary physical activity in this study. Heuberger and Wakshlag noted an inverse correlation between age and reported feline activity by pet owners;²² however, the average age of the cats in that study was 6.9 years and no specific age range (or threshold) for the decline in physical activity was reported.

Overweight cats had numerically greater food intake than lean cats but numerically lower daily food intake:BW ratio (g/kg). On average, overweight cats ingested 67 calories more daily than lean cats. However, daily food intake when calculated per kg BW was 10 calories less for overweight vs lean cats but not

Table 4 Effect of day and body condition score grouping on voluntary physical activity counts (mean) of lean and overweight adult cats. Weekend days include days 2–3 and 9–10

Physical activity counts	BCS	Day										SEM	P values					
		1	2	3	4	5	6	7	8	9	10		11	12	13	BCS	D*BCS	
Total daily	Lean	59,269	48,202	50,965	61,873	62,027	45,510	59,888	74,152	62,390	47,549	74,385	72,720	54,353	7330.6	0.0003	0.0059	0.0133
	Over	33,754	27,193	20,507	34,047	27,180	27,190	34,310	29,298	24,185	26,697	28,396	28,403	24,099				
Light period	Lean	40,007	28,855	28,475	41,415	40,718	22,208	34,293	54,887	44,708	32,017	56,065	46,250	37,095	4999.3	<0.0001	0.0022	0.0016
	Over	16,946	16,123	10,531	20,563	16,382	13,226	18,213	20,624	15,051	14,409	17,097	16,445	15,039				
Dark period	Lean	19,262	19,347	22,490	20,459	21,309	23,303	25,596	19,264	17,682	15,532	18,320	26,471	17,258	3376.1	0.0186	0.0451	0.4715
	Over	16,807	11,070	9976	13,483	10,798	13,964	16,096	8673.8	9133.4	12,288	11,299	11,959	9060				

BCS = body condition score; over = overweight; D*BCS = interaction between day and BCS

different from each other. In this study all lean cats had an ideal BCS score of 3.0, on a 5-point scale,²⁰ whereas overweight cats ranged from 3.5–5.0. Pets with an ideal BCS have about 15–24% body fat, overweight between 25% and 34% and obese cats >35% body fat.²³ In the current study body composition was not determined; however, using data previously published establishing correlations among BCS, BW and body fat mass,^{20,23,24} it is reasonable to assume that overweight cats had, on average, 10% more body fat mass than lean cats. Furthermore, resting energy expenditure of skeletal muscle is 2.5 times greater than adipose tissue,²⁵ and there is a series of other systemic effects that result from the inflammation associated with adiposity. If we further transform the data using BW to the exponent 0.67, lean cats would continue to be numerically different, but no statistical differences would exist. Future research studies should investigate more cats with a greater spread in BCS and with the use of a method to quantify lean body mass.

In this study, daily food intake, and feeding and animal care procedures were kept constant throughout the study to avoid potential confounding factors on voluntary physical activity of the cats. The 24 h daily voluntary physical activity of overweight and lean cats followed a similar pattern, and both groups of cats were more active during periods that corresponded to the majority of the daily animal care procedures, including at minimum feeding (07.00–08.00 h), and socialization and cleaning (08.00–15.00 h). Despite the similar pattern between the two groups, lean cats were more active before feeding and during animal care procedures than the overweight cats. These data suggest that lean cats have a greater anticipatory physical activity prior to feeding and are more eager to have social interaction with humans than overweight cats. Similarly, when the data were analyzed as total daily physical activity, and voluntary physical activity during light and dark periods, lean cats were also more active than overweight cats in all three categories. The greater physical activity of lean cats during the dark period (20.30 h to 06.30 h) was driven mostly by the increased activity from 05.00 h to 06.30 h, which reinforces the concept of a greater food anticipatory behavior of lean cats vs overweight cats. Previous studies in domestic cats have also reported greater voluntary physical activity before a feeding period.^{16,17,26} In addition, lower voluntary physical activity was reported in cats transitioning from a lean to an obese phenotype.²⁷ In this study, the average daily activity counts were lower than reported ranges in previous studies.^{14,16,17,26} However, direct numerical comparisons across studies are not always valid as many factors differed in these studies, including age, sex, BCS, intact vs neutered, housing and animal care, and positioning of activity collar (neck vs thoracic area).

Table 5 Effect of weekday or weekend and body condition score (BCS) on voluntary physical activity counts of lean and overweight adult cats

Physical activity counts	BCS	Means		SEM	Weekday	P values	
		Weekday	Weekend			BCS	Weekday*BCS
Total daily	Lean	62,687	52,276	6327.3	0.0004	0.0071	0.2016
	Over	29,631	24,645				
Light period	Lean	41,437	33,514	4092.9	0.0039	0.0028	0.2064
	Over	17,171	14,029				
Dark period	Lean	21,249	18,763	2742.6	0.0474	0.0361	0.7534
	Over	12,460	10,617				

Over = overweight; weekday*BCS = interaction between weekday and BCS

A significant interaction between day and BCS was observed for total daily physical activity and activity level during the light period but not for the dark period. Overweight cats were consistently less active than lean cats during a 14 day period of voluntary physical activity measurement, and lean and overweight cats were, on average, 16% less active during weekends than on weekdays. We attribute the lower physical activity observed during the weekends to a more condensed animal care procedure and lower traffic of animal caretakers and research personnel on these days. These results emphasize the importance of having standard procedures during voluntary physical activity collection, and that voluntary physical activity measurement periods of less than 7 days may under- or overestimate the activity level of cats, depending on how many weekdays vs weekend days are included in the voluntary physical activity measurement period. We also hypothesize that an opposite voluntary physical activity pattern maybe observed in client-owned pet cats, as it would be expected that these animals would have a greater social interaction during the evenings and weekends with their owners. Further evaluation of the impact of human interaction on the voluntary physical activity of pet cats is also warranted, as this study was performed in a colony setting. However, this requires further investigation.

Conclusions

Despite the small number of animals in this study, our design was effective in detecting that overweight cats had lower voluntary physical activity than lean cats. Furthermore, voluntary physical activity level appears to be influenced by social interaction with humans. Future studies should further validate these findings using larger populations of cats, investigate the directional effect between BCS and physical activity, and also evaluate the impact of environmental modifications, social interaction opportunities with humans and other pets (eg, single-pet vs multiple-pet household/setting), as well as assess nutritional and feeding interventions as

potential strategies to increase physical activity or energy expenditure in domestic cats.

Conflict of interest AK Shoveller had financial and personal interest in The Procter and Gamble Company and was an employee of The Iams Company, Mars Pet Care North America.

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