Investigation of relationships between body weight and age among domestic cats stratified by breed and sex

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OBJECTIVE
To evaluate mean body weight (BW) over the lifespan of domestic cats stratified by breed and sex (including reproductive status [neutered vs sexually intact]).

ANIMALS
19,015,888 cats.

PROCEDURES
Electronic medical records from veterinary clinics in the United States and Canada from 1981 to 2016 were collected through links to practice management software programs and anonymized. Age, breed, sex and reproductive status, and BW measurements and measurement dates were recorded. Data were cleaned, and descriptive statistics were determined. Linear regression models were created with data for 8-year-old domestic shorthair, medium hair, and longhair (SML) cats to explore changes in BW over 3 decades (represented by the years 1995, 2005, and 2015).

RESULTS
9,886,899 of 19,015,888 (52%) cats had only 1 BW on record. Mean BW for cats of the 4 most common recognized breeds (Siamese, Persian, Himalayan, and Maine Coon Cat) peaked between 6 and 10 years of age and then declined. Mean BW of SML cats peaked at 8 years and was subjectively higher for neutered than for sexually intact cats. Mean BW of neutered 8-year-old SML cats increased between 1995 and 2005 but was steady between 2005 and 2015.

CONCLUSIONS AND CLINICAL RELEVANCE
The large dataset for this study yielded useful information on mean BW over the lifespan of domestic cats. This could be a basis for BW management discussions during veterinary visits. A low frequency of repeated BW measurements suggested a low frequency of repeated veterinary visits, especially after 1 year of age, making engagement of cat owners in the health of their animals particularly relevant. (*J Am Vet Med Assoc* 2019;255:205–212)

Little information is available in the scientific literature regarding the changes in BW of cats over their lifetimes and the relationship of BW with breed and sex.[1] Obesity is a growing concern in the human population as well as in many nonhuman animal species in contact with people, including domestic cats.[2] In people, weight gain during early adulthood was associated with decreased odds of healthy aging, with an increase of ≥ 2.3 to < 10 kg (5 to 22 lb) associated with an increased risk of developing chronic diseases such as diabetes, hypertension, and cardiovascular disease.[3]

ABBREVIATIONS

BCS	Body condition score
BW	Body weight
CI	Confidence interval
SML	Shorthair, medium hair, and longhair

Although ideal BWs for cats of different breeds and sexes have not been established, short-term studies[4–6] that involved 118 to 14,270 cats have estimated the prevalence of obesity in cats in the United States to range from 27% to 39%. Obesity has been associated with arthritis, diabetes mellitus, cardiac disease, respiratory illness, and other diseases in cats.[7] Research has shown that cats have a decreased ability to digest proteins, fats, and starches as they age,[8] and weight loss, particularly in older cats,[9] has been observed with diseases such as hyperthyroidism, renal disease, and neoplasia.[10–12] Currently, veterinarians have limited resources available to determine an appropriate target BW for different cat breeds. The objective of the study reported here was to characterize BW changes over the lifespan of domestic cats and in-

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vestigate associations of BW in adult cats with breed, sex, and reproductive status.

Materials and Methods

Case selection and data review

Data collected and entered into electronic medical records by veterinarians and clinic staff as part of the routine health care of patients between January 1, 1981, and June 11, 2016, were used in the study. The information was collected by Idexx Laboratories Inc[a] through links to 4 practice management software programs[b–e] used by veterinary clinics in the United States and Canada and was provided to the researchers as anonymized data.

Data of interest were initially extracted for all animals categorized as feline and having ≥ 1 BW measurement on record. The information collected included breed, sex, year of birth, BWs, units and dates of BW measurements, and anonymized animal identification number. The data were transferred from Idexx Laboratories Inc to the researchers who used an open-source format for storing structured data[f] for subsequent processing 1 record at a time. Data from nonfelid species (eg, dogs or skunks) and nondomestic felids (eg, lynx, lions, or tigers) were excluded. Records that contained abbreviations and spellings that were not recognized were also excluded.

An objective and systematic screening of the data (ie, data cleaning) was performed in an effort to minimize the impact of potential data errors on the results.[13] The data were manually curated by 2 research assistants independently, with a final review performed by one of the study authors (AJC). Further exclusions were applied on the basis of possibility and plausibility of data entry error for recorded BW, age, and breed. The BW data from patients with results recorded as ≤ 0 kg (0 lb) or > 15 kg (33 lb) were excluded first. Next, BW data for cats with recorded ages of ≤ 0 days or ≥ 21 years (147,622 records) were excluded; these limits were chosen on the basis of histograms of recorded data in the age categories to determine when available data began to become limited, as well as by practical knowledge of cat BW and lifespans. Other data points for these same cats were retained in the analyses. The data field for breed in the practice management software systems was an open text field; thus, variations in spelling and syntax had to be accounted for when grouping cats into breed categories. For example, cats that were categorized as domestic shorthair had over 100 different inputs, including "DSH," "dom sh," "shorthair, domestic," "Domestique poil court," and other variations. Both registered and hybrid breeds were recorded.

Statistical analysis

Patient record information was analyzed with open-source statistical packages.[g] Data were viewed graphically, which confirmed a normal distribution. Summary statistics including the mean ± SD and median values were calculated for age and BW. The BW measurements for cats ≤ 1 year (≤ 365 days) of age were included only in analyses of the number of BW measurements per cat and the number of BW measurements per year of age. Only BW measurements obtained for cats > 1 year (> 365 days) of age were included in the overall analysis of BW changes (assessment of peak BW by age for commonly represented breeds and changes in mean BW over selected decades) because we were most interested in changes after cats reached maturity.

To assess changes in BW over selected decades, domestic shorthair, domestic medium hair, and domestic longhair cats were grouped together as domestic SML cats and evaluated on the basis of sex and reproductive status. The age at which the mean BW of > 1-year-old domestic SML cats peaked was determined and used to assess for changes in the mean BW for cats of that age in different decades. As the size of the dataset prevented use of the complete dataset in building regression models, the mean BWs of cats in the selected age category were determined for a single year during each of 3 decades (January 1, 1995, to December 31, 1995 [1995]; January 1, 2005, to December 31, 2005 [2005]; and January 1, 2015, to December 31, 2015 [2015]) and used to create models, thereby reducing the input size and creating independence of measurements. The years 1995, 2005, and 2015 were selected to represent decades beginning in 1990, 2000, and 2010, respectively. Four separate linear regression models were created (1 for each sex and reproductive status category: sexually intact males, castrated males, sexually intact females, and spayed females) for cats of the chosen age category. Body weight (measured in kilograms) was the dependent variable, and year of measurement (1995, 2005, or 2015) was the independent variable. Because a cat could be included in the regression only once (only the first BW measurement for the selected age year was used), measurements were assumed to be independent. By using the anonymized animal identification number, we could ensure that each animal would have at most 1 value used in building the model. Values of $P \leq 0.05$ were considered significant for all analyses.

Results

Of 19,416,753 animals categorized as feline in the database, 4,116 had no BW measurement recorded. Following exclusion of these records, those for nondomestic cat species, and those with abbreviations and spellings that were not recognized, the dataset included 19,015,888 cats **(Figure 1)**. This dataset included 54,380,004 BW measurements; after data from domestic cats with BW recorded as ≤ 0 or > 15 kg or with age recorded as ≤ 0 days or ≥ 21 years were excluded, 52,945,410 BW measurements for 19,015,888 animals remained **(Figure 2)**. These final exclusion criteria resulted in a loss of 1,434,594 of 54,380,004

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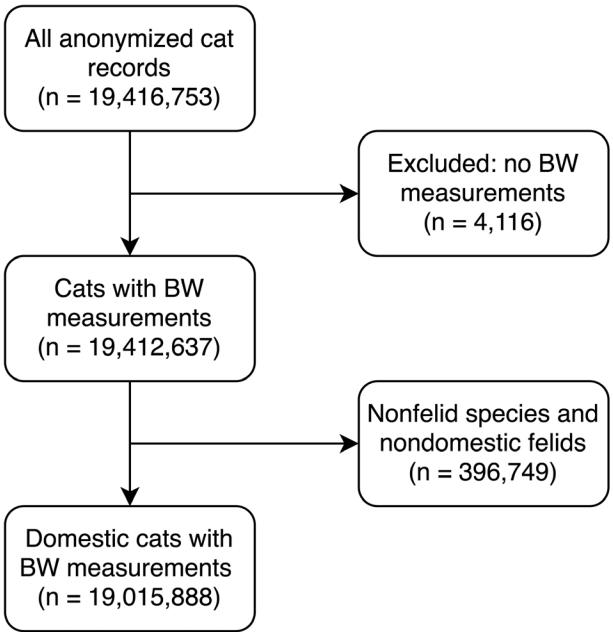

Figure 1—Flow diagram depicting the selection, inclusion, and exclusion of electronic records in a retrospective study to evaluate mean BW over the lifespan of domestic cats stratified by breed, sex, and reproductive status (neutered vs sexually intact) and examined between January 1, 1981, and June 11, 2016. The initial dataset was collected by Idexx Laboratories Inc through links to 4 practice management software programs used by veterinary clinics in the United States and Canada and provided to the researchers after anonymization of the data.

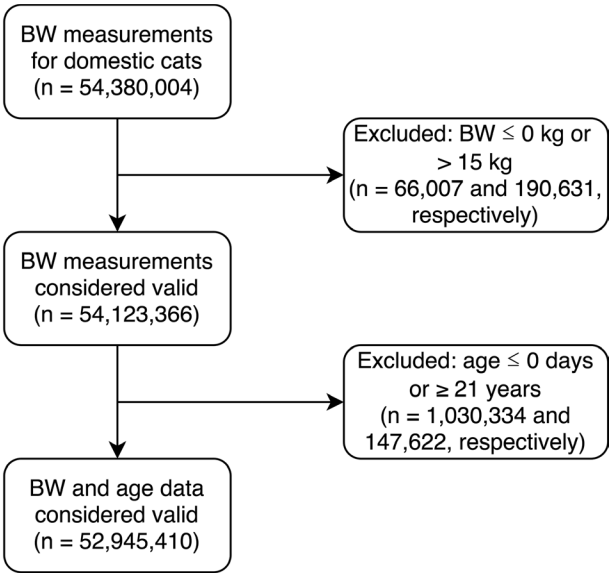

Figure 2—Flow diagram depicting inclusion and exclusion of BW measurements during data cleaning for the final dataset of 19,015,888 cats in Figure 1.

(2.6%) BW measurements from the dataset. The BW measurements made during the first year of life (n = 11,968,832) were only included in analyses of the number of BW measurements per cat and the number of BW measurements per year of age; this resulted in a dataset of 40,976,578 BW measurements from 13,715,510 cats at 3,971 clinics for the remaining evaluations.

The dataset of 19,015,888 domestic cats with BW data included 8,223,516 (43.2%) castrated males, 1,161,118 (6.1%) sexually intact males, 8,186,631 (43.1%) spayed females, and 1,444,623 (7.6%) sexually intact females. Prior to data cleaning, the 54,380,004 BW measurements comprised 24,389,251 (44.8%) measurements from castrated males, 2,740,669 (5.04%) measurements from sexually intact males, 23,965,444 (44.1%) measurements from spayed females, and 3,284,640 (6.04%) measurements from sexually intact females.

The number of BW measurements for each year of age was determined after data cleaning **(Figure 3)**. In total, 9,886,899 of 19,015,888 (52%) cats in the database, including those ≤ 1 year of age, had BW recorded only once; 3,405,103 (17.9%) had 2 BW measurements on record; and 1,063,016 (5.6%) had ≥ 10 BW measurements on record. A substantial proportion of all BW measurements (11,968,832/52,945,410 [22.6%]) were recorded during the first year of life **(Figure 4)**. After this point, there was a precipitous decline in the proportion of BW measurements recorded for cats 1 to < 2 years of age (4,847,713 [9.2%]) and a more gradual decline thereafter. The lowest proportion of BWs (136,363 [2.6%]) was recorded at 20 to < 21 years of age.

Most (9,118,267/19,015,888 [48%]) cats in the database were domestic shorthair, followed by domestic longhair (1,816,477 [9.6%]) and domestic medium hair (1,103,770 [5.8%]) cats. Domestic SML cats represented 63.3% of the total cat population in the study. Purebred cats included Siamese (335,371 [1.8%]), Persians (201,129 [1.1%]), Himalayans (150,496 [0.8%]), Maine Coon Cats (143,949 [0.8%]), and other breeds (5,868,751 [30.9%]); 277,678 were described as crossbred or mixed-breed cats.

For cats of the 4 most common recognized breeds (Siamese, Persian, Himalayan, and Maine Coon Cat), changes in mean BW were examined in greater detail. For these breeds, the mean BW of neutered animals peaked between 6 and 10 years of age and then decreased after this time **(Figure 5)**. The mean BW for sexually intact animals followed similar patterns for all 4 breeds **(Figure 6)**. The mean BW peaked at an earlier age for cats of the largest of these 4 breeds (Maine Coon Cat; 6 years) than the mean BW for the smallest of these 4 breeds (Himalayan; 8 years).

Among domestic SML cats, castrated males, sexually intact males, spayed females, and sexually intact females all reached maximum mean BW at 8 years of age **(Figure 7)**. In this group of cats, maximum mean BW for castrated and sexually intact males was 6.1 ± 1.6 kg and 5.7 ± 1.8 kg (13.4 ± 3.5 lb and 12.5 ± 4.0 lb), respectively, and that for spayed and sexually intact

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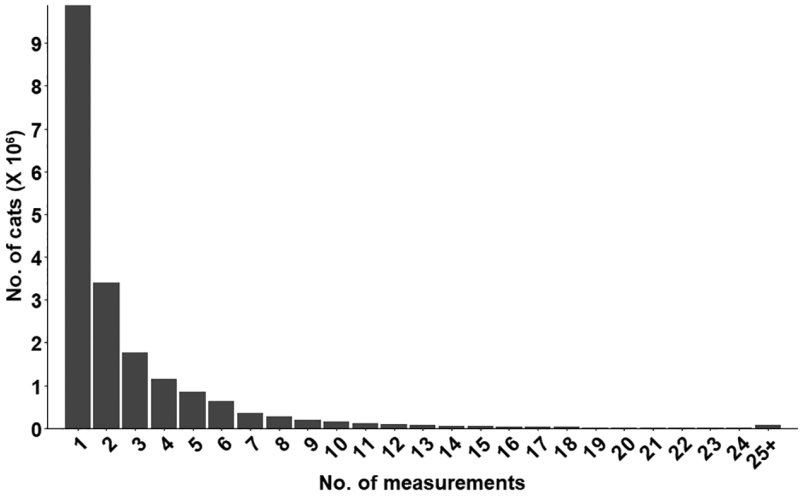

Figure 3—Frequencies of BW measurements recorded for the final dataset of 19,015,888 cats in Figure 1.

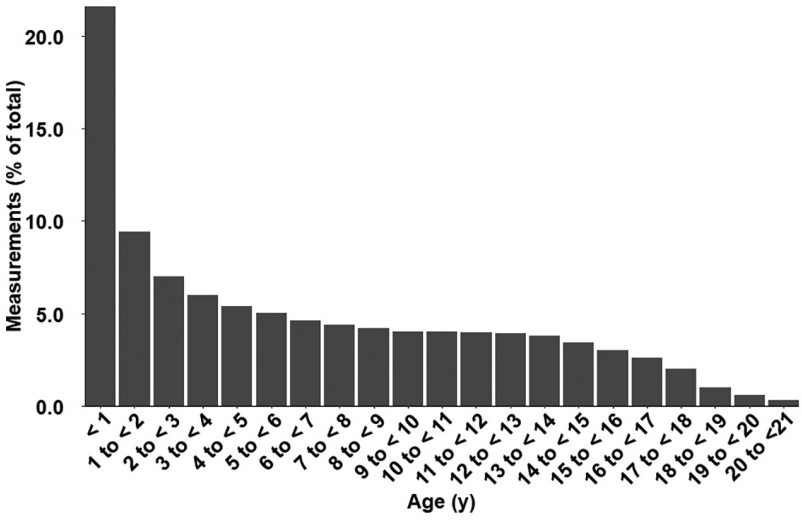

Figure 4—Percentage of BW measurements for the final dataset of 19,015,888 cats in Figure 1 grouped according to age (total, 52,945,410 BW measurements).

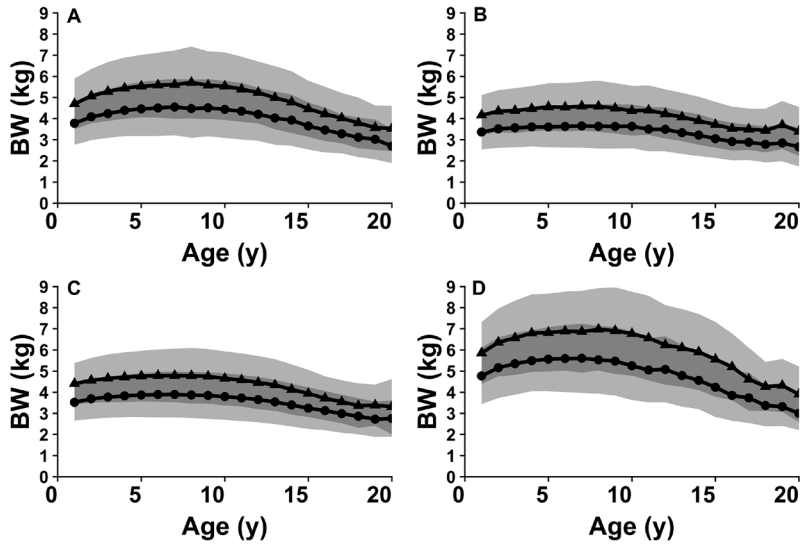

Figure 5—Results of descriptive analysis for the mean ± SD BW of castrated adult males (triangles) and spayed adult females (circles) of the 4 most common recognized breeds (Siamese, Persian, Himalayan, and Maine Coon Cat) in the study grouped according to age. A—Siamese cats included 150,934 males and 146,059 females. B—Persian cats included 88,853 males and 80,892 females. C—Himalayan cats included 67,530 males and 62,765 females. D—Maine Coon Cats included 83,263 males and 49,283 females. Standard deviation for each line is represented by shading; areas where SDs overlap appear darker. Cats ≤ 1 year of age were excluded from the analyses of weight over time.

females was 4.9 ± 1.4 kg and 4.6 ± 1.6 kg (10.8 ± 3.1 lb and 10.1 ± 3.5 lb), respectively.

The linear regression models were created with the referent category set to the year 2005. Because the mean BW of domestic SML cats peaked at 8 years of age, this age was chosen to examine changes in mean BW between 10-year intervals. The mean ± SD BW of 8-year-old spayed female domestic SML cats

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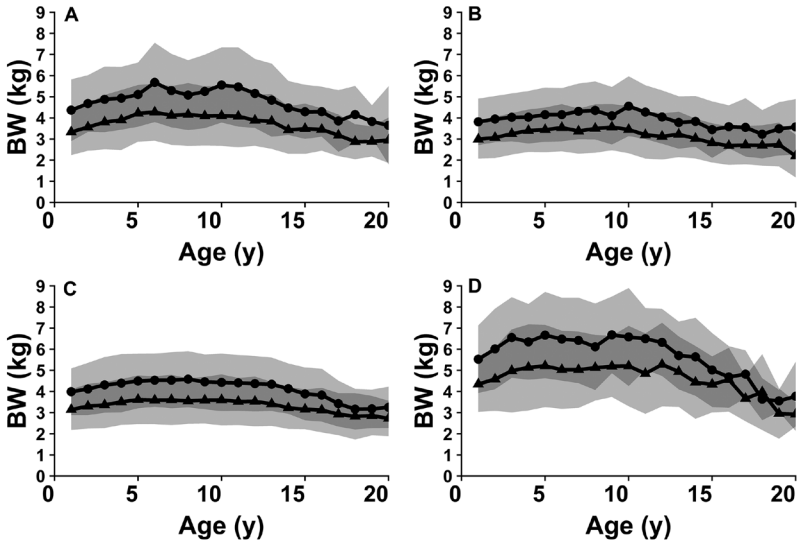

Figure 6—Results of descriptive analysis for mean ± SD BW of sexually intact adult males (triangles) and females (circles) of the 4 most common recognized breeds in the study grouped according to age. A—Siamese cats included 16,555 males and 21,823 females. B—Persian cats included 12,810 males and 18,555 females. C—Himalayan cats included 8,378 males and 11,823 females. D—Maine Coon Cats included 6,113 males and 5,290 females. ***See*** Figure 5 for remainder of key.

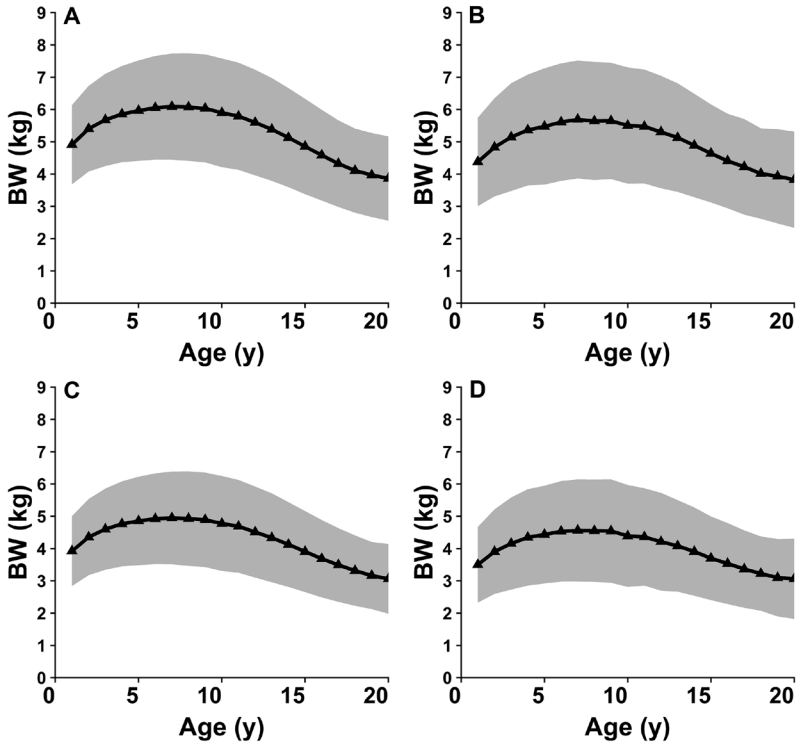

Figure 7—Results of descriptive analysis for the mean ± SD BW of adult male and female domestic SML cats grouped according to age. A—Castrated males (n = 5,281,788). B—Sexually intact males (n = 616,144). C—Spayed females (n = 5,395,341). D—Sexually intact females (n = 745,241). ***See*** Figure 5 for remainder of key.

was 4.93 ± 1.4 kg (10.85 ± 3.08 lb) in 2005 (95% CI, 4.92 to 4.95 kg [10.8 to 10.9 lb]; $P < 0.001$; **Table 1**). The mean BW for cats of this category in 1995 was significantly less than that in 2005, but the results did not differ between 2015 and 2005. The mean ± SD BW of 8-year-old sexually intact female domestic SML cats was 4.5 ± 1.6 kg (9.9 ± 3.5 lb; n = 2,594) in 2005 (95% CI, 4.44 to 4.56 kg [9.8 to 10.0 lb]; $P < 0.001$), and the results for cats of this category in 1995 and 2015 were not significantly different from those in the referent year.

The mean BW of 8-year-old castrated male domestic SML cats was 6.05 ± 1.7 kg (13.3 ± 3.7 lb) in the year 2005 (95% CI, 6.03 to 6.07 kg [13.3 to 13.4 lb], $P < 0.001$; Table 1). The mean BW for cats of this category in 1995 was significantly less than that for 2005, and no difference was detected for this variable between 2015 and 2005. The mean BW of 8-year-old sexually intact male domestic SML cats was 5.52 ± 2.0 kg (12.14 ± 4.4 lb) in 2005 (95% CI, 5.45 to 5.59 kg [12.0 to 12.3 lb], $P < 0.001$). The mean BW for cats of this category was significantly higher in 2015 but did not

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Table 1—Results of linear regression analysis of BW measurements for 8-year old domestic SML cats during the years 1995, 2005, and 2015 in a retrospective study to evaluate mean BW over the lifespan of domestic cats stratified by breed, sex, and reproductive status (neutered vs sexually intact) and examined between January 1, 1981, and June 11, 2016.

			BW (kg)		
Category	**Year**	**No. of cats**	**Mean ± SD**	**Change from referent (95% CI)**	***P* value**
Spayed female	2005 (referent)	31,269	4.93 ± 1.4	—	—
	1995	3,839	4.70 ± 1.3	0.24 (0.19 to 0.29)	< 0.001
	2015	59,219	4.95 ± 1.4	0.01 (–0.002 to 0.04)	0.08
Sexually intact female	2005 (referent)	2,594	4.51 ± 1.6	—	—
	1995	608	4.51 ± 1.4	0 (–0.13 to 0.14)	0.9
	2015	3,578	4.52 ± 1.5	0.01 (–0.04 to 0.10)	0.35
Castrated male	2005 (referent)	32,168	6.05 ± 1.7	—	—
	1995	3,636	5.86 ± 1.6	0.19 (0.14 to 0.25)	< 0.001
	2015	64,630	6.07 ± 1.66	0.02 (–0.004 to 0.04)	0.11
Sexually intact male	2005 (referent)	2,287	5.54 ± 2.0	—	—
	1995	525	5.72 ± 1.64	0.18 (0 to 0.34)	0.051
	2015	2,776	5.66 ± 1.7	0.12 (0.04 to 0.21)	0.007

The years 1995, 2005, and 2015 (January 1 to December 31 of each year) were selected to represent decades beginning in 1990, 2000, and 2010, respectively. The age of 8 years was selected to examine changes in mean BW over decades because the mean BW of domestic SML cats peaked at this age. Within a category, *P* values are shown for comparisons of mean BW with that for the referent year in linear regression analysis. Values of $P < 0.05$ were considered significant.

— = Not applicable.

differ significantly in 1995, compared with that in the referent year.

Discussion

To the authors' knowledge, the present study provided information about BW for the largest population of domestic cats to date. A previous study by Lund et al[5] included BCSs of 14,270 cats,[5] and our study population included 19,015,888 cats (13,715,510 adult). Although the previous study[5] did not include multiple measurements per cat or examine the differences among cats of various breeds and sexes, access to diagnosis data allowed for the calculation of the prevalence of different diseases. However, associations of conditions such as dental calculus, heart murmur, or renal disease with BW were not determined. Results of the study by Lund et al[5] indicate that 22.2% of BW measurements for cats were recorded for animals ≤ 1 year of age,[5] the same percentage found in the present study. Commonly represented breeds were similar between the previous study[5] and the present study, with domestic shorthair being the most common, although the proportions of cats within these breeds varied.

In the present study, the ability to access millions of clinical data points from cats of various breeds and ages was feasible owing to consolidation of records from multiple practice management systems. Although 9,886,899 of 19,015,888 (52%) cats of this study had only 1 BW measurement on record, combining all values for each year of age allowed for gaps in these measurements to be filled by the large number of records. The large number of BW measurements for cats contributed to the external validity of the study, as our target population was pet cats in the United States and Canada.

The peak BW of cats occurred between 6 and 10 years of age, and BW declined in general after this point, with variations among the most commonly represented breeds and among sexes. To the authors' knowledge, this has not previously been reported, likely because changes over time have not been a primary area of feline BW investigations in earlier studies.[4–6,14–16] Knowing when weight gain and weight loss can typically be expected for domestic SML cats as well as commonly encountered purebred cats of different sexes and reproductive statuses can aid veterinarians and cat owners in monitoring the health of cats.

As previously mentioned, 22% of BW measurements in the present study were recorded for cats ≤ 1 year of age, and 52% of cats had only 1 BW measurement on record. The number of BW measurements dropped off quickly after this time. Although it could not be determined from the data whether cats with only 1 BW on record had subsequently been taken to a different veterinarian or whether apparently healthy cats were not routinely weighed during veterinary clinic visits, the relatively low proportion of cats with multiple measurements suggested a lack of routine veterinary visits, which has been noted previously.[17] Thus, the first visit may be the only opportunity for a veterinarian to engage owners regarding the importance of keeping their cats active and including BW measurements at home as part of overall health monitoring.

The presence and degree of obesity in dogs and cats are often assessed by use of BCS instead of BW. This is because BCS, when performed by experienced evaluators, is more closely correlated with percentage of body fat.[14] However, accuracy of BCS is influenced by the training and experience of the evaluator, and it is not easy to train an assessor to be accurate.[15] When dog owners were trained to use a BCS chart, their perceptions of their ability to assess BCS increased, but their ability to assess BCS was not demonstrably improved.[18] This indicated that the training required to provide a layperson with sufficient knowledge to

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perform a BCS assessment must be further explored before BCS can be used reliably by pet owners. Body weight is an objective measurement, and a significant association was found between percentage of body fat and BW.[14] We chose to focus on BW because of a larger number of available data points as well as the objectivity of the measure, and the present study did not investigate measures of body fat or BCS.

The finding that mean BW continued to increase after cats reached maturity merits further investigation of potential associations between BW and cat health. Importantly, the mean BW of cats in the present study is informative but is not sufficient to determine optimal BW. Further studies should investigate associations among BW, breed, and longevity of cats to provide a better understanding of ideal BW ranges for various breeds.

The veterinary community and popular media emphasize what has been described as an epidemic of obesity in pets.[2,4,5] Although the results of some studies[2,4] support these claims, they were limited by the availability of data. Whereas determination of obesity is often made on the basis of body fat assessment,[4–6,14–16] a study by Klimentidis et al[2] focused only on BW changes in 574 cats between the years 1989 and 2001 and found that female cats had a significant increase in BW, but male cats did not have a significant change in BW during the same period. Results of the present study may partially support the claim made by Klimentidis et al,[2] in that there was an increase in mean BW of 8-year-old neutered domestic SML cats of both sexes between the years 1995 and 2005. However, we also found that mean BW of sexually intact domestic SML cats did not increase during this same period, and between the years 2005 and 2015, we identified a small but significant increase in mean BW of sexually intact male domestic SML cats but not of spayed female, castrated male, or sexually intact female domestic SML cats. It must also be considered that without measures of body fat, BCS, and overall size and frame for the cohorts of cats in our study, no conclusions can be drawn about the prevalence of obesity. Possible reasons for the BW increase among neutered domestic SML cats between the years 1995 and 2005 included changes in habitat as cats moved from outdoor or indoor-and-outdoor lifestyles to an indoor-only lifestyle.[19] Improved palatability of cat foods and owners transitioning from feeding wet foods to providing free-access dry foods for their cats may have also led to increased BWs[19]; however, further research would need to be done to confirm this. The difference in changes in weight between the years for sexually intact cats, compared with neutered cats, may have been confounded by differences in lifestyle, health status at visits, or other unmeasured variables.

Limitations of the present study included variety and variability of individuals who recorded the data. Through the data-cleaning process, 1,434,594 of the 54,380,004 (2.6%) recorded data were found to represent an obvious error in input or were considered unreasonable. It was assumed that the remaining data were accurately recorded. Additionally, with such a large dataset, the impact of error attributable to large variations among clinicians and BW scales could not be known. Although it was not known whether the study population was representative of all cats or cats at all veterinary clinics in the United States and Canada, it was an accurate representation of cats examined by veterinarians at clinics where any of the 4 practice management systems were used, and these have been estimated to comprise approximately 65% to 77% of the veterinary practice market.[20,21] Health status of the cats was not evaluated as part of the present study; thus, underweight cats might have been overrepresented if most were being examined for conditions associated with weight loss, which is more common as cats age.[22] Conversely, overweight cats might have been overrepresented if many cats were weighed as part of a weight loss program or part of the evaluation for conditions associated with obesity, such as diabetes mellitus. Because the reasons for evaluations, diagnoses, and demographics of the patients were not available, whether systematic bias was present and the direction of such bias could not be assessed.

The results of the present study can provide a starting point for health discussions with cat owners related to the BW of their pets. Additional exploration of the associations between health status, BW, and longevity of cats may help to guide a more personalized approach to the care of feline patients.

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Footnotes

a. Idexx Laboratories Inc, Westbrook, Me.
b. Cornerstone software, Idexx Laboratories Inc, Westbrook, Me.
c. AVImark software, Henry Schein Veterinary Solutions, Piedmont, Mo.
d. ImproMed software, Henry Schein Veterinary Solutions, Oshkosh, Wis.
e. Intravet software, Patterson Veterinary Inc, Effingham, Ill.
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