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**Early-life risk factors identified for owner-reported feline overweight and obesity at
around two years of age**

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Abstract:

Obesity is considered the second most common health problem in pet cats in developed
countries. This study used prospective data from a longitudinal study of pet cats
(‘C.L.A.W.S.’, www.bristol.ac.uk/vetscience/claws) to identify early-life risk factors for feline
overweight/obesity occurring at around two years of age. Data were collected via five
owner-completed questionnaires (for cats aged two – six months, six months, 12 months, 18
months and two years respectively) completed between May 2011 and April 2015. Owner-
reported body condition scores (BCS) of cats at age two years, assessed using images from

the 9-point BCS system (Laflamme, 1997), were categorised into a dichotomous variable: overweight/obese (BCS 6 – 9) and not overweight (BCS 1 – 5) and used as the dependent variable. Of the 375 cats with owner-reported BCS, 25.3% were overweight or obese at two years of age. Multivariable logistic regression models were built using stepwise forward-selection. To account for potential hierarchical clustering due to multi-cat households two-level random intercept models were considered but clustering had no impact on the analysis. Models were compared using Wald tests.. Six factors were significantly associated with overweight/obesity at two years of age: being overweight or obese at one year of age (OR=10.6, 95%CI 4.4 – 25.3); owner belief that BCS 7 was the ideal weight (OR=33.2, 95%CI 8.5 – 129.4), or that BCS represented overweight cats but they would not be concerned if their cat were classified in this category (OR=2.7, 95%CI 1.2 – 6.2), at questionnaire five completion; vets advising owners that the cat should lose weight, or making no comment on their weight, between one and two years of age (OR=12.1, 95%CI 3.2 – 44.9 and OR=3.9, 95%CI 1.5 – 10.3 respectively); owners giving their cat treats when they “felt happy” with them at 18 months of age (OR=2.7, 95%CI 1.0 - 7.3); feeding ≥ 250 g wet food daily between two and six months of age (OR=2.7, 95%CI 1.2 – 5.9), and feeding dry food as the only or major part (> 50%) of the diet at two years of age (OR=2.1, 95%CI 1.0 – 4.2). These findings have the potential to reduce the current high prevalence of a widespread problem by informing preventive advice, and as such improve the health and welfare of pet cats.

Introduction

Feline obesity has become an extremely prevalent problem for pet cats, and indeed has been identified as the second most common health problem (after dental disease) in

domestic cats in developed countries studied to date (Cave et al., 2012). Obesity is detrimental to health, predisposing animals to a variety of diseases and conditions, with evidence that it also decreases quality of life and longevity (German et al., 2012; O'Neill et al., 2015). Evidence from previous studies indicates that the prevalence of overweight and obesity is already high by an early age (Kronfeld, Donoghue, & Glickman, 1994; Lund et al., 2005; Scarlett et al., 1994). This suggests that the factors which significantly increase a cat's risk of obesity occur early on in life, before adulthood is reached, which is supported by the human literature on the importance of the early-life environment in the development of childhood obesity an early-life critical period for the development of childhood obesity (eg, Reilly et al, 2005).

Although numerous studies have already identified a number of risk factors for feline obesity (see Rowe et al., 2015 for a summary), all of these studies bar two (Rowe et al., 2015; Serisier et al., 2013) have been cross-sectional in design, where reverse causality cannot be ruled out. Studies utilising prospective data are needed in order to provide evidence for a predictive relationship between putative risk factors and obesity, if successful preventive strategies are to be developed.

The aim of this study was to investigate early-life risk factors for feline obesity using prospective data. The age period chosen to be investigated was from two months of age, when most kittens are fully weaned and independent from their mothers, to two years, the age at which obesity prevalence has been found to increase sharply (Scarlett et al., 1994). A large number of potential risk factors were investigated, including feeding method, where clear definitions were used to distinguish free choice and *ad libitum* feeding. Identifying risk factors for feline obesity which occur early in life using prospective data from a large cohort

of owned pet cats will enable more effective preventive strategies to be developed, which are needed in order to reduce the prevalence of this serious health and welfare problem.

Materials and methods

Subjects

Data used in this analysis were from the ‘Cat Longitudinal Analysis of Welfare Study’ (‘C.L.A.W.S.’), a longitudinal UK-wide questionnaire-based feline health and welfare study. The inclusion criteria for ‘C.L.A.W.S.’ were that owners must live in the UK, be aged 18 years and over and own a cat aged approximately two to six months old in order to participate. Owners were recruited between May 2012 and May 2013 from rehoming organisations - mainly Cats Protection, the UK’s largest feline welfare charity. By the end of the recruitment process, owners of 628 cats had completed the first questionnaire. These cats formed the study cohort for the ‘C.L.A.W.S.’ study.

Data collection

Data were collected via owner-completed questionnaires. Owners were requested to complete a questionnaire when they first adopted their kitten aged between two and six months old (Q1), followed by questionnaire two (Q2) when their cats reached 6.5 months of age, questionnaire three (Q3) at 12.5 months of age, questionnaire four at 18.5 months of age and questionnaire five (Q5) at 24.5 months of age. Most questions were ‘closed questions’ with multiple choice answers and questionnaires took 10–15 minutes to

complete. The majority of owners completed electronic questionnaires, although some elected to complete paper questionnaires. Copies of the questionnaires can be obtained from the corresponding author.

Dependent variable

Dual energy X-ray Absorptiometry (DEXA) is often used as the 'gold standard' for measurement of body fat (German et al, 2006). The use of this was however beyond the scope of the current study.

Instead the dependent variable used was owner-reported body condition score (BCS) at two years of age (Q5) derived from owner-selected images from a choice of 5 images taken from the 9-point body condition score (BCS) system, as only five images are included on the 9-point system (Laflamme, 1997), thereby essentially becoming a 5-point system. The use of a standard body condition scoring system combining images and text was avoided. This was in an attempt to reduce reporting bias by owners, as previous research suggests that owners tend to underestimate their cat's body condition (Allan et al., 2000; Kienzle and Bergler, 2006; Colliard et al., 2009; Cave et al., 2012) or normalise their judgement, underestimating BCS of overweight cats and overestimating thin cats (Courcier et al., 2010). One potential reason for this could be that the text descriptors used in body condition scoring systems could be considered judgmental and emotionally loaded, such as discussion of fat layers, and terms such as 'overweight', 'extremely overweight' and 'obese'. Furthermore, unpublished work by the authors supported the use of images as the dependent variable, as owners were found to be more accurate (i.e. showed better agreement with the 'gold

standard' of vet-assessed BCS) using images to assign a BCS to their cat rather than text descriptions.

In questionnaires 3 (12 month old cats) and 5 (two year old cats), owners were asked to select one of five images, depicting the view of a short-haired adult cat from the side and above, which best represented their cat. These images corresponded to scores of 1, 3, 5, 7 and 9 on the 9 point scale. Images were not labelled with their corresponding score and the order of the images was randomised using a random number sequence generator (Random.org, 2015) so that the images were presented to all owners in the following order in the questionnaire: score 5, 7, 9, 1, 3. This was in order to reduce the likelihood that owners would choose the middle image solely because they inferred that this represented the 'ideal' cat. As the outcome of interest in the current study was overweight and obesity, scores were dichotomised into 'not overweight' (scores 1, 3 and 5) and 'overweight/obese' (scores 7 and 9) for analysis.

In order to assess the accuracy of owner-reported BCS at two years of age, owner-selected images were compared to the 'gold standard' of vet-reported BCS. This was done for cats whose owners had returned a completed, clinic-stamped BCS card from their vet at approximately 27 months of age, and where vet-reported scores corresponded with the scores represented by the images (i.e. 1, 3, 5, 7 and 9), in order to enable a direct comparison. A comparison was also made between dichotomised (not overweight vs. overweight/obese) owner-reported and vet-reported BCS, which therefore enabled the inclusion of vet-reported scores other than 1, 3, 5, 7 and 9. Cohen's Kappa score was used to assess agreement, and interpreted based on suggestions by Viera and Garrett (2005). The

135 best way of comparing owner-reported BCS to true body condition would be to use DEXA,
136 but this was beyond the scope of the current study.

137

138

139 **Potential explanatory variables**

140 The 376 variables which were extracted from data collected from Questionnaires 1-5 and
141 analysed as potential risk factors for feline overweight/obesity are available as
142 supplementary material. For variables with multiple categories, categories were combined if
143 numbers in individual categories were small or when univariable analysis results suggested
144 that this was appropriate, and if the combined categories were biologically plausible. Owner
145 attachment was investigated in the third questionnaire using the 'Lexington Attachment to
146 Pets Scale' (LAPS), developed and validated by Johnson, Garrity and Stallones (1992).

147

148 **Descriptive statistics**

149 Characteristics of the final cat cohort for which there was an outcome measure available are
150 summarised: number of cats and owners, sex of cat, pedigree status (pedigree / non-
151 pedigree), age of neutering, age at time of questionnaires one to five completion, diet type,
152 feeding method and outdoor access. Number and percentage of cats which were
153 overweight and obese at approximately two years of age (questionnaire five completion)
154 according to both owner- and vet-reported BCS, and age at time of vet-reported BCS are
155 given. Dichotomised owner-reported BCS at questionnaire five completion and vet-reported
156 BCS at approximately 27 months of age were compared to assess agreement. Owner-

reported BCS at questionnaire three and five completion were compared to assess changes in BCS over time.

Missing data

There were 396 cats whose owners had completed the fifth questionnaires. Of these, 21 had missing data for the owner-selected BCS image used as the outcome measure, resulting in 375 cats forming the final study sample for analysis. However, some missing data for these cats existed for the potential explanatory variables, as not all owners had completed all questions and/or questionnaires. In addition, if owners selected 'don't know' for a question, these cats were excluded from the analysis for the variable derived from that question. This resulted in a different sample size for each potential explanatory variable in the univariable analysis.

In the first stage of multivariable analysis (the "grouped by questionnaire" multivariable models, see below), for each model, only cats for which there were no missing data for any of the variables were included. Because not all owners had completed all questions and/or questionnaires, and if owners selected 'don't know' for a question, these cats were excluded from the analysis, this resulted in a relatively large amount of missing data for this stage of the analysis. Sample sizes ranging from $n = 162$ to $n = 224$ (see Table 10).

Of the 375 cats, those with missing data for any of the variables eligible for inclusion in the multivariable analysis ($n = 127$) were excluded from the dataset used for multivariable analysis, in order to enable comparison of models. This resulted in 248 cats included in the final stage of the multivariable analysis. When two variables which were significant in a

previous study by the authors (Rowe et al., 2015) were added to the final model (see below for details), there were missing data for 79 of the 375 cats on the variables to be tested, resulting in a model with 296 cats.

Statistical analysis

Univariable analysis was first conducted using logistic regression models to screen all 376 potential explanatory variables for an association with the outcome of owner-reported overweight/obesity at two years of age. Variables with a Wald test p-value <0.10 were considered for inclusion in the multivariable analysis. Collinearity between variables which were significant in the univariable analysis was assessed by calculating a Spearman Rank correlation matrix. Variables which were found to be highly correlated ($|r| > 0.9$) were not included in the same multivariable model.

The first stage of the multivariable analysis involved analysing these variables in separate multivariable logistic regression models for a binary response for predictors for each of the five questionnaires. A similar “grouping” stage of the multivariable analysis has been reported in previous risk-factor analyses for feline obesity (Allan et al., 2000; Cave et al., 2012), although in these studies, variables were grouped according to “biologically sensible groupings” (Cave et al., 2012). In the current study it was decided to group variables according to questionnaire, as this would reduce the amount of missing data within groups and all cats without missing data for the group of variables were included in the analysis (as owners who completed one questionnaire may not have completed all subsequent or previous questionnaires). The final stage of the analysis was then to build a combined multivariable logistic regression model for a binary response using the significant variables

202 identified from the five questionnaire multivariable models. For both stages of the
203 multivariable analysis ("grouped by questionnaire" models and combined models),
204 multivariable logistic regression models were built using stepwise forward-selection i.e.
205 potential explanatory variables were added to the model in order of significance according
206 to the univariable analysis and Wald tests were used to test whether variables added to the
207 model significantly improved the model, using a critical value of 0.05. Significant variables
208 were retained in the model until no more significant predictors could be found, and this was
209 deemed the final model. In the final model, first order interaction terms between significant
210 variables which were biologically plausible were added and whether they significantly
211 improved the model was assessed using Wald tests. In order to take into account potential
212 hierarchical clustering of data due to some participants owning more than one study cat,
213 the model was extended to a two-level random intercept model, with level two
214 representing owner identification (level one represented cat identification), and compared
215 to the single-level logistic regression model using Wald test p-values. This enabled differing
216 owner-level effects on the probability of cats being overweight/obese to be tested. A
217 second combined multivariable logistic regression model was built using only 'management'
218 variables (i.e. diet and environmental variables, rather than cat characteristics and
219 behaviour and owner and vet variables). This was in order to investigate risk factors for
220 feline obesity which could be modified by owners in order to reduce the risk of obesity
221 developing. Finally, although they had not been retained in the analysis model up to this
222 point, two variables which had been found to be significantly associated with feline obesity
223 in a previous study by the authors (Rowe et al., 2015) were added to the final stage of the
224 model building process, in order to confirm whether or not they were still associated with
225 the outcome. These were diet type and outdoor access at the time of outcome measure

(questionnaire five). All analyses were conducted using MLwiN version 2.33 (Rasbash et al., 2009).

Results

Dependent variable

According to owner-reported BCS at Questionnaire 5 completion, 25.3% (95/375) of cats were overweight or obese at approximately two years of age (see Table 3 for median and range of age of cats at Questionnaire 5 completion).

Reliability of dependent variable

There were 144 cats with both an owner-selected BCS image at questionnaire five completion and a vet-reported BCS at around two years and three months of age. When owner-selected BCS image and vet-assessed BCS were dichotomised into 'not overweight' and 'overweight/obese' i.e. the outcome measure of interest in this study, the agreement between owners and vets was rated as 'fair' and significant ($n = 144$, $\kappa = 0.299$, $p < 0.0005$); Table 1 illustrates this comparison and also shows how owner's generally underestimate BCS. The age at time of BCS assessment by vets for these cats ranged from 24.3 to 31.8 months, with a median (interquartile range) of 26.7 (26.1 – 27.5) months.

According to vet-reported BCS, 36.8% of cats were overweight or obese (53/144), while only 37/144 (25.7%) were classified as overweight or obese by owners.

247

248 **Table 1.** A comparison between dichotomous owner-reported and vet-reported body
249 condition score (BCS) based on data from the longitudinal questionnaire-based study
250 ‘C.L.A.W.S.’ (UK, 2011 – 2015).

Owner-reported body condition score ^c	Vet-reported body condition score ^a n = (%) ^b	
	Not overweight	Overweight or obese
Not overweight	77 (84.6)	30 (56.6)
Overweight or obese	14 (15.4)	23 (43.4)

251 ^aCats were scored by vets at around two years and three months of age using the 9-point
252 BCS system (Laflamme 1997)

253 ^bPercentages expressed are of column totals

254 ^cCats were scored by owners at around two years of age by selection of one of the 5 images
255 taken from the 9-point system.

256

257 **Descriptive statistics**

258 The 375 cats forming the final sample for analysis (i.e. which had an outcome measure)
259 were owned by 307 owners: 218 (71.0%) owners owned one study cat and 89 (29.0%)
260 owned two study cats. Male cats formed 51.4% (n = 187) of the study cohort and females
261 48.6% (n = 177; data were missing on sex for 11 cats). The majority of cats were non-
262 pedigree (92.0%, n = 333), with 8.0% pedigrees (n = 29, all of which were British Shorthairs;
263 data were missing on breed for 13 cats). Age at neutering is summarised in Table 2 (data
264 were missing on age at neutering for nine cats). Table 3 displays the age range and median
265 and interquartile range for age of cats at time of completion of questionnaires one to five.

266

267 **Table 2.** Age of neutering of cats based on owner-reported data from the longitudinal
268 questionnaire-based study ‘C.L.A.W.S.’ (UK, 2011 – 2015).

Age of neutering	Number (%) of cats ¹
2 months	59 (16.1)

3 months	80 (21.9)
4 months	70 (19.1)
5 months	43 (11.7)
6 months	89 (24.3)
7 months	11 (3.0)
8 months	9 (2.5)
9 months	4 (1.1)
20 months ²	1 (0.3)
Total	366

¹ Data on age were missing for 9 cats

²This cat was originally not neutered due to concerns reported by the owner about a heart murmur, a history of feline herpes virus, and the small size of the cat.

Table 3. The range, median and interquartile range of the age of cats at time of completion of questionnaires one to five in the longitudinal questionnaire-based study 'C.L.A.W.S.' (UK, 2011 – 2015).

Questionnaire	Age range in months	Median (interquartile range) age in months	n ¹
One (2 – 6 month old cats)	2.0 – 8.1	3.7 (3.2 – 4.6)	373
Two (6 month old cats)	5.0 – 9.3	6.7 (6.4 – 7.2)	354
Three (12 month old cats)	11.6 – 16.3	12.7 (12.5 – 13.2)	348
Four (18 month old cats)	17.5 – 22.9	18.8 (18.5 – 19.1)	355
Five (2 year old cats)	23.7 – 31.5	24.9 (24.5 – 25.5)	373

¹Of the 375 cats forming the final sample for analysis (i.e. which had an outcome measure), there was missing data on age as not all owners completed every questionnaire

Table 4 and Table 5 illustrate the number and percentage of cats at the five questionnaire time-points fed different diet types and fed dry and wet food with different feeding methods, respectively. As cats increased in age, an increasing proportion were fed a dry diet. The majority of cats fed wet food were fed in meals, and a greater proportion of cats fed dry food were fed by free choice or ad libitum feeding compared to those fed wet food, over all five questionnaires.

Table 4. Number and percentage of cats fed different diet types at the five questionnaire time-points, based on owner-reported data from the longitudinal questionnaire-based study 'C.L.A.W.S.' (UK, 2011 – 2015).

Food Type	Number (%) of cats fed different diet types at questionnaire time-points				
Single food type diet ^a	Q1 (2-6 months)	Q2 (6 months)	Q3 (12 months)	Q4 (18 months)	Q5 (two years)
Dry ^b	80 (22.0)	96 (27.7)	128 (36.8)	132 (38.2)	152 (40.9)
Wet ^c	157 (43.3)	120 (34.7)	100 (28.7)	110 (31.8)	108 (29.0)
Fresh ^d	2 (0.6)	1 (0.3)	2 (0.6)	1 (0.3)	0 (0.0)
Mixed food type diet ^e					
Wet and dry	121 (33.3)	123 (35.5)	115 (33.0)	100 (28.9)	109 (29.3)
Dry and fresh	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.3)	1 (0.3)
Wet and fresh	1 (0.3)	1 (0.3)	3 (0.9)	2 (0.6)	2 (0.5)
Wet, dry and fresh	2 (0.6)	5 (1.4)	0 (0.0)	1 (0.3)	0 (0.0)
Total	363	346	348	347	372
Missing data	12	29	27	28	3

^aFood type is major part (≥50%) or only food in diet.

^bDry kibble.

^cFood in tins or foil pouches.

^dRaw or cooked meat/fish.

^eEach food type listed contributes equally to diet.

Table 5. Number and percentage of cats fed dry and wet food with different feeding methods at each of the five questionnaire time-points, based on owner-reported data from the longitudinal questionnaire-based study 'C.L.A.W.S.' (UK, 2011 – 2015).

	Q1 (2-6 months)	Q2 (6 months)	Q3 (12 months)	Q4 (18 months)	Q5 (two years)
Dry^a food n = (%)					
Meals ^b	137 (41.3)	140 (56.5)	131 (42.0)	142 (45.2)	138 (41.6)
Free choice ^c	93 (28.0)	82 (33.1)	81 (26.0)	79 (25.2)	75 (22.6)
On request ^d	5 (1.5)	8 (3.2)	9 (2.9)	8 (2.5)	12 (3.6)
<i>Ad libitum</i> ^e	97 (29.2)	18 (7.3)	91 (29.2)	85 (27.1)	107 (32.2)
Total	332	248	312	314	332
Missing data	43	127	63	61	43
Wet^f food n = (%)					
Meals	290 (89.8)	245 (87.8)	250 (90.3)	247 (88.2)	247 (86.4)
Free choice	14 (4.3)	11 (3.9)	8 (2.9)	12 (4.3)	15 (5.2)
On request	7 (2.2)	7 (2.5)	9 (3.2)	12 (4.3)	17 (5.9)
<i>Ad libitum</i>	12 (3.7)	16 (5.7)	10 (3.6)	9 (3.2)	7 (2.4)
Total	323	279	277	280	286

Missing data	52	96	98	95	89
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^aDry kibble.

^bDefined as feeding the cat portions of food two or more times a day.

^cDefined as putting a specific amount of food in a bowl and leaving the bowl down all day for the cat to feed from in his/her own time but not refilling it again until the next day once it is empty.

^dDefined as feeding every time he/she asks for food.

^eDefined as filling the cat's bowl up and leaving it down all day but refilling it every time it is empty, or topping it up over the course of the day.

^fFood in tins or foil pouches.

Table 6 compares vet-reported BCS at approximately 27 months of age with whether or not a vet commented on the cat's weight between one and two years of age.

Table 6. Vet-reported body condition score (BCS) at approximately 27 months of age and whether or not the owner reported that a vet had commented on the cat's weight from one – two years of age (asked in questionnaire five) based on owner-reported data from the longitudinal study 'C.L.A.W.S.' (UK, 2011 – 2015). BCS based on the 9-point system (Laflamme 1997). Percentages expressed are of row totals.

27 month vet-reported BCS	Q5 Vet comment on cat's weight n = (%) ^a			
	Yes, cat should lose weight	Yes, cat ideal weight	Yes, cat should gain weight	No
3	0 (0.0)	2 (100.0)	0 (0.0)	0 (0.0)
4	1 ^b (14.3)	5 (71.4)	0 (0.0)	1 (14.3)
5	0 (0.0)	36 (46.8)	2 (2.6)	39 (50.6)
6	5 (12.2)	18 (43.9)	0 (0.0)	18 (43.9)
7	3 (33.3)	0 (0.0)	0 (0.0)	6 (66.7)
8	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)
9	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)
Total	10	62	2	64

^aPercentages expressed are of row totals.

^bThis cat had a vet-reported BCS 6 at approximately 15 months of age so had lost weight since the vet recommended that the cat should lose weight.

Table 7 illustrates the number and percentage of owners who selected the image corresponding to BCS 3, 5 and 7 (no owners chose images of BCS 1 or 9) as representing an adult, short-haired cat with a “healthy optimal body size” at questionnaire one completion, therefore representing their perception of an ideal feline body condition at questionnaire one, when they first obtained their kitten. Table 8 displays the number and percentage of owners who selected statements they felt best applied to images corresponding to BCS 3, 5 and 7 at questionnaire five completion, therefore representing their perception of feline body condition later in cat ownership, when their cats were adults. The image owners selected to depict a cat with an ideal weight can be considered their perception of an ideal feline body condition at questionnaire five completion.

Table 7. Number and percentage of owners who selected the image corresponding to BCS 3, 5 and 7 (no owners chose the images of BCS 1 or 9) as representing an adult, short-haired cat with healthy, ideal weight at questionnaire one completion.

Q1 owner perception of ideal feline body condition ^a	Number (%) owners
BCS 3	15 (4.2)
BCS 5	318 (88.8)
BCS 7	25 (7.0)

^aThe body condition score (BCS) corresponding to the image reported by owners to represent an adult cat with a healthy optimal body size; BCS based on the 9-point system, where a score of 5 represents ideal body condition (Laflamme 1997)

Table 8. Number and percentage of owners who selected statements they felt best applied to images corresponding to BCS 3, 5 and 7 at questionnaire five completion

	Q5 owner perception of feline body condition		
	BCS ^a 3 n = (%)	BCS 5 n = (%)	BCS 7 n = (%)
Underweight and would concern me	187 (51.5)	7 (1.9)	0 (0.0)
Underweight and would not concern me	138 (38.0)	13 (3.5)	6 (1.6)
Ideal weight	30 (8.3)	344 (92.5)	41 (11.1)

Overweight and would concern me	5 (1.4)	2 (0.5)	171 (46.1)
Overweight and would not concern me	3 (0.8)	6 (1.6)	153 (41.2)
Total	363	372	371

^aBCS = body condition score based on the 9-point system, where a score of 5 represents an ideal body condition (Laflamme, 1997)

Univariable results

Forty-seven variables were significantly associated with owner-reported overweight/obesity at approximately two years of age, based on a critical value of $p = 0.10$. These variables are available as supplementary material and were taken forward to the first stage of the multivariable analysis.

Multivariable analysis

There were no correlations where $|r| > 0.9$ between any of the 46 variables which were significant ($p < 0.1$) in the univariable analysis, indicating that any of these variables could be reasonably included together in the same model. Results of the first stage of the multivariable analysis, where significant variables were grouped according to questionnaire number and multivariable logistic regression models run for each questionnaire group separately, are displayed in Table 9. Eight variables were significant ($p < 0.05$) and taken forward to the second stage of the multivariable analysis, where a combined multivariable logistic regression model was run.

Table 9. Questionnaire group multivariable logistic regression models for risk factors for feline overweight/obesity at two years of age, based on owner-reported data from the longitudinal study 'C.L.A.W.S.' (UK, 2011 – 2015).

Variable name	Category	Odds Ratio (95% Confidence Interval)	p-value for variable	Overweight or obese n (%)	Not overweight n (%)
Questionnaire one for 2 – 6 month old cats (n = 172) ^a					
Q1 Reward with treat	Other response	1.00	0.040	30 (33.3)	104 (40.9)
	Give treat	2.27 (1.04 – 4.97)		15 (16.7)	23 (9.1)
Q1 Weight of wet food	< 250g	1.00	0.047	33 (36.7)	108 (42.5)
	250g or more	3.30 (1.25 – 8.75)		10 (11.1)	10 (3.9)
	It varies according to how hungry the cat is	0.75 (0.15 – 3.70)		2 (2.2)	9 (3.5)
Questionnaire two for 6 month old cats (n = 162)					
Q2 Reward with treat	Other response	1.00	0.004	29 (65.9)	102 (86.4)
	Give treat	3.30 (1.46 – 7.45)		15 (34.1)	16 (13.6)
Questionnaire three for 12 month old cats (n = 200)					
Q3 Dichotomous owner-reported BCS	Not overweight	1.00	<0.0005	25 (55.6)	140 (90.3)
	Overweight	7.46 (3.37 – 16.51)		20 (44.4)	15 (9.7)
Questionnaire four for 18 month old cats (n = 224)					
Q4 Reward with treat	Other response	1.00	0.041	32 (69.6)	150 (84.3)
	Give treat	2.27 (1.03 – 4.96)		14 (30.4)	28 (15.7)
Q4 How regularly go beyond garden	Every day	1.00	0.049	26 (56.5)	133 (74.7)
	N/A no outdoor access	0.49 (0.06 – 4.21)		1 (2.2)	8 (4.5)
	Several times a week	3.51 (1.55 – 7.99)		14 (30.4)	19 (10.7)
	1-2 times a week to less than monthly	1.01 (0.27 – 3.80)		3 (6.5)	15 (8.4)
	Never	3.37 (0.52 – 21.71)		2 (4.3)	3 (1.7)
Questionnaire five for 2 year old cats (n = 244)					
Q5 Belief of BCS 7 image	Overweight and would be concerned	1.00	<0.0005	10 (16.1)	104 (57.1)
	Ideal weight	50.30 (14.69 – 172.23)		19 (30.6)	5 (2.7)

	Overweight and would not be concerned	3.84 (1.72 – 8.56)		33 (53.2)	73 (40.1)
Q5 Vet commented on cat weight	Yes advised that cat was ideal weight	1.00	<0.0005	13 (21.0)	78 (42.9)
	Yes advised that cat should lose weight	15.06 (4.11 – 55.23)		10 (16.1)	6 (3.3)
	No comment made on cat's weight	2.46 (1.07 – 5.67)		39 (62.9)	98 (53.8)

^aIn this first stage of multivariable analysis, for each model, only cats for which there were no missing data for any of the variables were included. Because not all owners had completed all questions and/or questionnaires, and if owners selected 'don't know' for a question, these cats were excluded from the analysis, this resulted in a relatively large amount of missing data for this stage of the analysis.

Results of the combined model are shown in Table 10. Model 1 is the final model where all eight variables from the grouped analysis were included. Of the 248 cats included in the final model, 24.2% (n = 60) were overweight according to owner report. Model 2 displays the model built using only 'management' variables which were significant from the grouped analysis, and Model 3 displays the model where the two variables which were significant in a previous analysis (Rowe et al., 2015) were added to Model 1. There were no significant interaction terms for biologically plausible interactions in any of the three models. None of the coefficients or standard errors in any of the models changed by more than 0.0005 when a two-level hierarchical structure was included in the model, and a Wald test revealed that there was no significant improvement when controlling for owner-level variation and so single level models are reported only.

380 **Table 10.** Final multivariable logistic regression models for risk factors for feline
381 overweight/obesity at two years of age, based on owner-reported data from the
382 longitudinal study 'C.L.A.W.S.' (UK, 2011 – 2015).

Variable name	Category	Odds Ratio (95% Confidence Interval)	p-value for variable	Overweight or obese (%)	Not overweight (%)
Model 1 (n = 248)					
Q3 Dichotomous owner-reported BCS ^a	Not overweight	1.00	<0.0005	30 (50.0)	173 (92.0)
	Overweight/obese	10.58 (4.43 – 25.26)		30 (50.0)	15 (8.0)
Q5 Belief of BCS 7 image	Overweight and would be concerned	1.00	<0.0005	14 (23.3)	109 (58.0)
	Underweight	4.37 (0.33 – 57.59)		1 (1.7)	2 (1.1)
	Ideal weight	33.15 (8.49 – 129.44)		15 (25.0)	4 (2.1)
	Overweight and would not be concerned	2.67 (1.15 – 6.16)		30 (50.0)	73 (38.9)
Q5 Vet commented on cat weight	Yes advised that cat was ideal weight	1.00	0.001	11 (18.3)	81 (43.1)
	Yes advised that cat should lose weight	12.06 (3.24 – 44.93)		13 (21.7)	9 (4.8)
	No comment made on cat's weight	3.89 (1.47 – 10.33)		36 (60.0)	98 (52.1)
Q4 Reward with treat	No	1.00	0.044	44 (73.3)	163 (89.4)
	Yes	2.74 (1.03 - 7.29)		16 (26.7)	25 (13.3)
Model 2 (n = 248)					
Q4 Reward with treat	No	1.00	0.026	44 (73.3)	163 (86.7)
	Yes	2.28 (1.11 – 4.70)		16 (26.7)	25 (13.3)

Q1 Weight of wet food fed daily	< 250g	1.00	0.027	45 (76.3)	161 (85.6)
	250g or more	2.71 (1.24 – 5.94)		13 (22.0)	18 (9.6)
	It varies according to how hungry the cat is	0.42 (0.05 – 3.39)		1 (1.7)	9 (4.8)
Model 3 (n = 296)				(n = 75)	(n = 221)
Q3 Dichotomous owner-reported BCS	Not overweight	1.00	<0.0005	38 (50.7)	202 (91.4)
	Overweight/obese	10.31 (4.68 – 22.71)		37 (49.3)	19 (8.6)
Q5 Belief of BCS 7 image	Overweight and would be concerned	1.00	<0.0005	15 (20.0)	124 (56.1)
	Underweight	4.46 (0.36 – 55.78)		1 (1.3)	2 (0.9)
	Ideal weight	29.46 (9.45 – 91.82)		23 (30.7)	7 (3.2)
	Overweight and would not be concerned	2.80 (1.30 – 5.99)		36 (48.0)	88 (39.8)
Q5 Vet commented on cat weight	Yes advised that cat was ideal weight	1.00	0.002	14 (18.7)	94 (42.5)
	Yes advised that cat should lose weight	7.28 (2.19 – 16.81)		13 (17.3)	11 (5.0)
	No comment made on cat's weight	3.30 (1.43 – 7.63)		48 (64.0)	116 (52.5)
Q5 Dry diet	Other ^b	1.00	0.041	39 (52.0)	135 (61.1)
	Dry	2.07 (1.03 – 4.17)		36 (48.0)	86 (38.9)

^aBCS = body condition score based on the 9-point system, where a score of 5 represents an ideal body condition (Laflamme 1997)

^bWet food (food in tins or foil pouches) fed as >50% of the cat's total diet, or a 50:50 mixture of wet and dry food

Discussion

Previous studies seeking to identify risk factors for feline obesity have been unable to rule out reverse causality for any associations identified due to their cross-sectional design. This study is the first (to the authors' knowledge) to utilise prospective data from a large-scale UK longitudinal study of owned pet cats in order to identify early-life risk factors for feline overweight/obesity at around two years of age.

Cohort characteristics

The majority of owners owned one study cat, resulting in only a small amount of clustering which may explain why the multivariable models were not changed by allowing for owner-level variation. The proportion of pedigree and non-pedigree cats in this cohort (8.0% and 92.0% respectively) were very similar to that reported by Murray and Gruffydd-Jones (2012): 7.6% and 92.4% respectively. As the population in the study by Murray and Gruffydd-Jones (2012) consisted of cats from a range of sources (pedigree breeders, non-pedigree breeders, bred by owner, rehoming organisations and bred by owners) and was randomly selected from a large UK-wide sampling frame, it could be considered to be a fair representation of the general UK cat-owning population in terms of pedigree status.

Overweight and obesity

According to owner-reported BCS, a quarter (25.3%, 95/375) of the study cohort were overweight or obese at approximately two years of age. According to vet-reported BCS, the proportion was even higher with over a third (36.8%, 53/144) being classified as overweight or obese. This study therefore adds to the evidence that the proportion of cats which are

overweight and obesity is already high by two years of age. The small difference in cat age between owner-reported scores (median age at Q5 completion 24.9 months, interquartile range 24.5 – 25.5 months) and vet-reported scores (median age 26.7 months, interquartile range 26.1 – 27.5 months) is unlikely to account for the difference between owner and vet scores, suggesting that the difference is due to incorrect owner perception of feline body condition compared to vets, who are more likely to be more objective and accurate when scoring cats due to lack of attachment and having more training and experience in scoring.

This study did not aim to estimate prevalence, due to the likely inaccuracy of owner-reported data based on their tendency to underestimate their cat's body condition (Allan et al., 2000; Cave et al., 2012; Colliard et al., 2009; Kienzle & Bergler, 2006), or normalise it (Courcier et al., 2010). The estimated proportion based on vet-reported BCS may be more reliable as these scores are considered to more accurately reflect true body condition than owner-estimated scores (Shoveller et al., 2014). Nonetheless care should still be taken when interpreting this estimate as there may still be biases in the study population, for example owners may be more motivated than the general UK cat owner population as they have voluntarily participated in a two-year long study. More motivated owners, for example, may more closely monitor a cat's BCS, resulting in a lower prevalence of obesity than within the general cat population. Conversely, more motivated owners may be more attached to their cats, which has previously been shown to be a risk factor for obesity (Kienzle and Bergler, 2006), resulting in a higher prevalence than within the general population (although pet attachment, as measured via the Lexington Attachment to Pets Scale, was not found to be associated with overweight and obesity in this study).

434 Over half the cats (56.6%, n = 30) reported to be overweight or obese by their vet were
435 regarded as not overweight by their owner. A smaller proportion (15.4%, n = 14) of cats
436 which were not overweight according to vet-reported BCS were regarded as overweight or
437 obese by their owners (Table 4). This tends to confirm the findings reported earlier that
438 owners will more commonly under- than over-estimate the body condition of their cats.
439 This suggests that owner training on body condition scoring is needed; however, this may
440 also be considered at least partly an inevitable consequence of attachment biasing the
441 objectiveness of an owner as scorer.

442 It should be noted that owner inaccuracy when scoring cats using the visual system in this
443 study is unlikely to be due to the fur of cats obscuring the view of the cat's waist. This is
444 because the proportion of long-haired cats in the present study was small (9.1% of the total
445 original cohort, unpublished data).

446 Despite the evident scope for improvement in owner scoring-accuracy, the agreement
447 between owner- and vet-reported scores was significant and fair, according to
448 interpretation of the kappa statistic (Viera & Garrett 2005). This suggests that using
449 dichotomous owner-reported BCS as an outcome measure can be considered a fair
450 representation of vet scores, and therefore true body condition, if vet scores are taken to be
451 the 'gold standard'. Using owner-reported scores rather than vet-reported scores as the
452 outcome enabled a larger sample size to be used for analysis and so a robust power to
453 detect significant associations between potential risk factors and feline obesity. As evidence
454 from the current study and previous investigations suggest that owner-reported scores are
455 likely to be an underestimate, the associations found between explanatory factors and
456 outcome are likely to be conservative.

457

458 It should also be considered that vet scores may deviate from true BCS e.g. vets may not
459 want to upset owners so underestimate the score of an overweight cat; time pressures of
460 the consult may also result in inaccurate scoring by the vet, and vets may not necessarily be
461 trained to score accurately using the 9-point system than owners.

462

463 **Risk factor analysis**

464 This study identified six factors which were independently associated with an increased risk
465 of overweight or obesity being recorded at approximately two years of age in cats in the
466 final multivariable analysis (Table 10, Models 1 - 3): overweight or obese status at
467 approximately one year of age according to owner-reported BCS, owner belief that a cat
468 with BCS 7 was the “ideal weight” or was “overweight but they would not be concerned” at
469 questionnaire five completion; a vet advising that the cat should lose weight or making no
470 comment on their weight between approximately one and two years of age, giving cats a
471 treat when feeling happy with them at approximately 18 months of age, feeding 250g or
472 more wet food per day at approximately two – six months of age, and feeding a dry diet at
473 approximately two years of age. The multivariable model was not changed by allowing for
474 owner-level variation, suggesting that any clustering due to multi-cat households had no
475 impact on the conclusions. Each of the factors are discussed in turn below.

476

477 **BCS at approximately one year of age**

478 Cats which were reported by their owners to be overweight or obese at approximately one
479 year of age were over ten times more likely to be reported by their owners as being
480 overweight or obese at approximately two years of age, although the wide confidence
481 interval suggests a degree of uncertainty in this result (Table 10, Model 1). A higher body
482 weight at one year of age has previously been found to be associated with overweight and
483 obesity in cats later in adulthood (Serisier et al., 2013). This is also seen in dogs: female dogs
484 that were obese between nine and twelve months of age were 1.5 times more likely to
485 become obese as adults (Glickman et al., 1995). Therefore this study highlights the
486 importance of monitoring a cat's BCS very early in life, even before they reach one year of
487 age.

488

489 **Owner perception of feline body condition**

490 Owners who believed at questionnaire five completion that a picture of a cat of BCS 7 was
491 at an "ideal weight", were 33 times more likely to own overweight or obese cats at two
492 years of age compared to owners who believed that BCS 7 was overweight and it would
493 concern them if their cat had this body condition, although a very wide confidence interval
494 suggests further information is needed to confirm the magnitude of this association with
495 greater certainty (Table 10, Model 1). Owners who believed at questionnaire five
496 completion that a picture of a cat of BCS 7 was "overweight but they would not be
497 concerned" if this picture represented the body condition of their cat were almost three
498 times more likely to own overweight or obese cats at two years of age compared to owners
499 who believed that BCS 7 was overweight and it would concern them if their cat had this
500 body condition. Although previous studies have identified that owner underestimation (or

normalisation) of BCS is a risk factor for overweight and obesity (Allan et al., 2000; Cave et al., 2012; Colliard et al., 2009; Courcier et al., 2010; Kienzle & Bergler, 2006), this is the first study, to the author's knowledge, to investigate owner perception of feline body condition as a risk factor in more detail.

When cats were approximately 2 – 6 months of age (Q1), 7.0% of owners believed that the image of a cat with BCS 7 was ideal weight (Table 7), compared with 11.1% of owners at approximately two years of age (Q5, Table 8). This suggests that, over time, some owners' perception of body condition changes, so that more owners believe that an overweight cat is a normal weight cat. With the growing prevalence of obesity in companion animals, overweight could be becoming the new norm, as has been suggested for childhood obesity (Coombes, 2014). As owner perception of feline body condition at questionnaire five was associated with feline overweight and obesity at two years of age, this incorrect perception of what is a 'normal' (i.e. ideal) body condition could be a causal factor in the development of obesity in pets, and therefore contribute to the prevalence of the problem. However, further study is needed to confirm this, due to the cross-sectional nature of this data in the current study.

Furthermore, 41.2% (n = 153) of owners believed that a cat with BCS 7 was overweight, but that it would not concern them if it were their cat. This finding of a lack of concern about overweight cats from a large proportion of owners is supported by results from a previous survey conducted in the USA and Australia, in which almost a third (32%) of owners reported that their pet was overweight, but only 0.8% considered that this was a health

problem (Laflamme et al., 2008). These findings suggest a lack of awareness about the adverse health risks associated with being overweight.

These owners were 2.7 times (Table 10, Model 1) more likely to own an overweight study cat (according to owner-report). This suggests that a lack of concern may be contributing to the prevalence of the problem. If owners do not believe their cat's level of adiposity to be detrimental to health they may therefore take no measures to reduce their weight. Together the results outlined above suggest that owner education is needed on what constitutes a healthy feline body condition, as well as to explain the serious health consequences of obesity.

It should be noted that, as owner perception of feline body condition reported at questionnaire five, this data is cross-sectional (recorded at the same time as the outcome measure) rather than prospective. Therefore, this variable cannot necessarily be considered as a predictive risk factor for the development of obesity in cats. Nonetheless, it does add to the body of evidence highlighting the link between owner perception of feline body condition and feline overweight and obesity.

Vet comment on cat weight

A total of 124 cats had their weight commented on by their vet between one and two years of age (Table 6). Cats whose vet advised their owners that the cat should lose weight, between one and two years of age, were 12 times more likely to be overweight or obese at two years of age, compared to those whose vet advised they were ideal weight (Table 10

Model 1). This is logical as vets would be likely to only advise that overweight or obese cats need to lose weight, and this may make owners aware that their cat is overweight or obese and so be reflected in the owner-reported BCS in questionnaire five. However, perhaps more interestingly, cats whose vets made no comment on their weight were almost four times more likely to be overweight or obese at two years of age compared to those whose vet advised they were ideal weight. Although based on small numbers of cats, these data provide evidence that a large proportion of cats which are overweight were not reported by owners as having the weight discussed with their owners by their vets (Table 6), despite their vets performing a body condition assessment on the cat. Some caution should be taken in interpreting this result, as it is based on owner-report: therefore some vets may have discussed the cat's weight but owners did not report this, perhaps because they had forgotten the conversation. Incorrect reporting by owners is possible: for example the owner of a cat which was given a BCS of 9 by their vet reported that their vet advised that the cat was ideal weight, which may seem unlikely.

The results support previous findings that vets tend not to discuss a cat's weight with owners. McGreevy et al. (2008) revealed that vets completing a questionnaire on pet obesity where they were asked to assess the BCS of cats they saw only informed the owner of the cat's BCS in just under half the reported cases. Furthermore, vets may not just fail to discuss weight with owners but fail to document the overweight or obese status on the cat's medical record, suggesting that they may not consider the condition to warrant a formal diagnosis. Records from 52 veterinary practices in the USA revealed that, of cats identified as overweight(based on BCS assessed by the consulting vet for the purpose of the study),

only 3.2% had this diagnosis logged on their medical record, and of obese cats, only 21.5% (Lund et al., 2005). Even if a cat is not overweight or obese, a discussion about BCS with owners could be important so that owners can recognise an ideal body condition, in order to maintain their cats at a healthy body condition and identify if their cat is gaining or losing weight.

Rewarding with a treat

Owners who, when their cats were 18 months of age, reported that they gave their cat treats when they “felt happy” with them were almost three times more likely to have an overweight or obese cat at two years of age (Table 11, Model 1), compared to owners who rewarded their cat in other ways such as playing with them, stroking them or giving them a new toy. This reflects findings from Kienzle and Bergler (2006), who found that owners who used food as a treat (interpreted to mean a reward) were more likely to own an overweight cat compared to owners who used play as a treat. This association may be explained by the increased food intake from treats leading to a positive energy imbalance and so weight gain. In support of this, feeding treats several times a day was associated with a substantial increase in the risk of overweight and obesity at both questionnaire one and questionnaire two completion in the univariable analysis, compared to feeding treats less frequently or not at all.

Giving cats a treat when feeling happy with them may be viewed as a form of positive reinforcement, to reinforce a behaviour that the cat may have been performing to make the

owner feel happy with them (e.g. using the litter tray correctly, not scratching the furniture etc.). However, if this is the case, other forms of rewards may be just as effective, especially play. Play allows cats to exhibit their natural hunting behaviour which is thought to release endorphins, for example just as they are released in humans following exercise (e.g. Harte, Eifert, & Smith, 1995). This finding suggests that owner education on play as a better form of rewarding cats may be one important way to help diminish a major risk factor for feline overweight and obesity and so reduce the prevalence of this problem.

Weight of wet food

Cats which were fed 250g or more of wet food per day when aged between two and six months old were almost three times as likely to be overweight or obese at approximately two years of age compared to those which were fed less than 250g, when only 'management' variables were included in the final stage of the multivariable analysis (Table 10, Model 2). As discussed above, this early period before one year of age appears to be a sensitive time when kittens are susceptible to factors affecting energy balance and which contribute to obesity risk in adulthood. According to feeding guidelines and the energy requirement formula for cats outlined by WALTHAM (Alexander et al., 2010a), a 3kg cat has a daily energy requirement of approximately 170 kcals, and the average wet food contains between 75 – 100 kcal per 100g. Therefore feeding 250g of wet food would result in 188 – 250 kcal fed per day, a 10 – 47% excess in energy requirements. For two to six month old kittens which weigh less than 3kg this weight of food will be in even greater excess of their energy requirements. If a kitten eats all of their food and does not compensate with increased energy expenditure, this will result in weight gain. It is possible that kittens may

be prone to overeating as satiety mechanisms may not have fully developed yet. This result suggests that owners should take extra care not to overfeed kittens with wet food, and should follow the feeding guidelines.

Feeding dry food

Cats fed dry food as the only or major part of their diet at approximately two years of age were twice as likely to be obese at two years of age, compared to those fed a wet diet or a 50:50 mixture of wet and dry food (Table 10, Model 3). This replicates the finding from a previous study by the current authors (Rowe et al. 2015), with a different cohort of cats, that a dry diet was associated with increased risk of obesity at 12.5 – 13 months of age. Therefore, this strengthens the evidence suggesting that dry food is a risk factor for feline obesity. A potential reason for this may be its high energy density: for the same weight, dry food contains approximately four times the number of calories as wet food (Alexander et al., 2010b). Feeding dry food may therefore lead to an increased risk of feeding above a cat's energy requirements: over-feeding even a small additional amount may lead to a large increase in calorie intake over energy requirements, compared to wet food. For a full discussion of dry food as a risk factor for feline obesity, see Rowe et al. 2015.

At questionnaire five, 40.9% of cats were fed a dry diet, compared to 29.0% that were fed a wet diet and 29.3% a 50:50 mixture of wet and dry food. This suggests that a dry diet was the most popular type diet fed to adult cats in this cohort. A dry diet for domestic cats has been found to be popular in other developed countries (Laflamme et al., 2008; Robertson, 1999; Scarlett et al., 1994). This suggests that a large proportion of cats are at increased risk of overweight and obesity due to their diet.

637

638 **Conclusion**

639 This work has found that within this cohort a quarter (25.3%) of cats were overweight or
640 obese at approximately two years of age according to their owners, and over a third (36.8%)
641 according to their vets. This supports previous findings that overweight and obesity is
642 already high by a young age; however the study did not aim to estimate prevalence due to
643 potential biases in the study population. There was fair agreement between owner- and vet-
644 reported BCS, with owners tending to underestimate BCS, suggesting that owner education
645 on body condition scoring is needed. The majority of cats which became overweight or
646 obese at one year of age remained so at two years of age, and cats which were overweight
647 or obese at approximately one year of age were over ten times more likely to be overweight
648 or obese at approximately two years of age, highlighting the importance of preventative
649 strategies which need to be put in place from a young age. There was evidence that vets
650 tended not to discuss a cat's weight with the owner (according to owner report), even if the
651 cat was overweight. Six factors were found to be independently associated with an
652 increased risk of overweight or obesity at approximately two years of age according to
653 owner-reported BCS: being overweight or obese at one year of age; owner belief that BCS 7
654 represented an 'ideal weight' cat or 'an overweight cat but that this would not concern the
655 owner', at two years of age; vets advising owners that a cat should lose weight or making no
656 comment on cat weight between one and two years of age; owners feeding cats treats
657 when feeling happy with them at 18 months of age; feeding 250g or more of wet food per
658 day at two to six months of age, and feeding dry food as the only or major part of a cat's
659 diet at approximately two years of age.

660

661 The study highlights the importance of a cat's early environment in the risk of obesity
662 developing in early adulthood and suggests that preventative measures need to be taken
663 before a cat reaches one year of age. The results suggest that the following preventive
664 measures may help to reduce the risk of obesity developing in the domestic cat. Owner
665 education is needed on what is a healthy feline body condition and why they should be
666 concerned about overweight in cats due to the negative health and welfare impacts. Vet
667 education is needed on the importance of discussing a cat's weight with the owner. Owners
668 should be encouraged to use forms of reward for their cat other than feeding treats (e.g.
669 play), to feed their young kittens wet food according to their energy requirements, and to
670 potentially avoid a completely or mainly dry diet, or pay careful attention to the amount of
671 food fed, opportunities for exercise and BCS of cats fed a dry diet. These results can be used
672 to inform evidence-based preventive strategies for feline obesity, ie, preventive advice given
673 to kitten owners by veterinary and cat care professionals, and so potentially help to reduce
674 the prevalence of this widespread problem.

675

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680

681 **References**

682 Alexander, L., Buckley, C., Merrill, R., Morris, P., & Stevenson, A. (2010a). Feeding guides. In
683 A. J. German & R. Butterwick (Eds.), WALTHAM pocket book of healthy weight maintenance
684 for cats and dogs (p. 18). WALTHAM Centre for Pet Nutrition: Beyond Design Solutions Ltd.

685 Alexander, L., Buckley, C., Merrill, R., Morris, P., & Stevenson, A. (2010b). Food types. In A. J.
686 German & R. Butterwick (Eds.), WALTHAM pocket book of healthy weight maintenance for
687 cats and dogs (p. 19). WALTHAM Centre for Pet Nutrition: Beyond Design Solutions Ltd.

688 Allan, F. J., Pfeiffer, D. U., Jones, B. R., Esslemont, D. H. B., & Wiseman, M. S. (2000). A cross-
689 sectional study of risk factors for obesity in cats in New Zealand. *Preventive Veterinary*
690 *Medicine*, 46, 183–196.

691 Cave, N. J., Allan, F. J., Schokkenbroek, S. L., Metekohy, C. A. M., & Pfeiffer, D. U. (2012). A
692 cross-sectional study to compare changes in the prevalence and risk factors for feline
693 obesity between 1993 and 2007 in New Zealand. *Preventive Veterinary Medicine*, 107(1-2),
694 121–133.

695 Colliard, L., Paragon, B., Lemuet, B., Benet, J., & Blanchard, G. (2009). Prevalence and risk
696 factors of obesity in an urban population of healthy cats. *Journal of Feline Medicine and*
697 *Surgery*, 11(135-140).

698 Coombes, R. (2014). Overweight children could become the “new norm” for Europe, WHO
699 says. *BMJ (Clinical Research Ed.)*, 348(feb27_3), g1821. doi:10.1136/bmj.g1821

700 Courcier, E. A., O’Higgins, R., Mellor, D. J., & Yam, P. S. (2010). Prevalence and risk factors for
701 feline obesity in a first opinion practice in Glasgow, Scotland. *Journal of Feline Medicine and*
702 *Surgery*, 12, 746–753.

703 Glickman, L. T., Sonnenschein, E. G., Glickman, N. W., Donoghue, S., & Goldschmidt, M. H.
704 (1995). Pattern of diet and obesity in female adult pet dogs. *Veterinary Clinical Nutrition*,
705 2(1), 6–13.

706 Harte, J. L., Eifert, G. H., & Smith, R. (1995). The effects of running and meditation on beta-
707 endorphin, corticotropin-releasing hormone and cortisol in plasma, and on mood. *Biological*
708 *Psychology*, 40(3), 251–65.

709 Johnson, T. P., Garrity, T. F., & Stallones, L. (1992). Psychometric evaluation of the Lexington
710 Attachment to Pets Scale (LAPS). *Anthrozoos: A Multidisciplinary Journal of The Interactions*
711 *of People & Animals*, 5(3), 160–175.

712 Kienzle, E., & Bergler, R. (2006). Human-Animal Relationship of Owners of Normal and
713 Overweight Cats. *American Society for Nutritional Sciences Journal of Nutrition*, 136, 1947S–
714 1950S.

715 Laflamme, D. P. (1997). Development and validation of a body condition score system for
716 cats: a clinical tool. *Feline Practice*, 25(5-6), 13–18.

717 Laflamme, D. P., Abood, S. K., Fascetti, A. J., Fleeman, L. M., Freeman, L. M., Michel, K. E., ...
718 Willoughby, K. N. (2008). Pet feeding practices of dog and cat owners in the United States
719 and Australia. *Journal of the American Veterinary Medical Association*, 232(5), 687–694.

720 Lund, E. M., Armstrong, P. J., Kirk, C. A., & Klausner, J. S. (2005). Prevalence and Risk Factors
721 for Obesity in Adult Cats from Private US Veterinary Practices. *International Journal of*
722 *Applied Research in Veterinary Medicine*, 3(2), 88–96.

723 McGreevy, P., Thomson, P., Pride, C., Fawcett, A., Grassi, T., & Jones, B. (2008). Overweight
 724 or Obese Cats Presented to Australian Veterinary Practices, Risk Factors and Prevalence.
 725 Australian Veterinary Practitioner, 38(3), 98–107.

726 Murray, J. K., & Gruffydd-Jones, T. J. (2012). Proportion of pet cats registered with a
 727 veterinary practice and factors influencing registration in the UK. Veterinary Journal, 192(3),
 728 461–466.

729 O'Neill, D. G., Church, D. B., McGreevy, P. D., Thomson, P. C., & Brodbelt, D. C. (2014).
 730 Prevalence of disorders recorded in cats attending primary-care veterinary practices in
 731 England. Veterinary Journal (London, England : 1997), 202(2), 286–91.
 732 doi:10.1016/j.tvjl.2014.08.004

733 Rasbash, J., Charlton, C., Browne, W. J., M, H., & Cameron, B. (2009). MLwiN Version 2.1.
 734 Centre for Multilevel Modelling.

735 Reilly, J. J., Armstrong, J., Dorosty, A. R., Emmett, P. M., Ness, A., Rogers, I., Steer, C. &
 736 Sherriff, A. (2005). Early life risk factors for obesity in childhood: cohort
 737 study. *Bmj*, 330(7504), 1357.

738 Robertson, I. D. (1999). The influence of diet and other factors on owner-perceived obesity
 739 in privately owned cats from metropolitan Perth, West Australia . Preventive Veterinary
 740 Medicine, 40, 75–85.

741 Rowe, E., Browne, W., Casey, R., Gruffydd-Jones, T., & Murray, J. (2015). Risk factors
 742 identified for owner-reported feline obesity at around one year of age: Dry diet and indoor
 743 lifestyle. Preventive Veterinary Medicine. doi:10.1016/j.prevetmed.2015.07.011

744 Russell, K., Sabin, R., Holt, S., Bradley, R., & Harper, E. J. (2000). Influence of feeding regimen
745 on body condition in the cat. *Journal of Small Animal Practice*, 41, 12–17.

746 Scarlett, J. M., Donoghue, S., Saidla, J., & Wills, J. (1994). Overweight cats: prevalence and
747 risk factors. *International Journal of Obesity*, 18(Suppl.1), S22–S28.

748 Serisier, S., Feugier, A., Venet, C., Biourge, V., & German, A. J. (2013). Faster growth rate in
749 ad libitum-fed cats: a risk factor predicting the likelihood of becoming overweight during
750 adulthood. *Journal of Nutritional Science*, 2, e11.

751 Shoveller, A. K., DiGennaro, J., Lanman, C., & Spangler, D. (2014). Trained vs untrained
752 evaluator assessment of body condition score as a predictor of percent body fat in adult
753 cats. *Journal of Feline Medicine and Surgery*, 16(12), 957–65.

754 Stubbs, W. P., Bloomberg, M. S., Scruggs, S. L., Shille, V. M., & Lane, T. J. (1996). Effects of
755 prepubertal gonadectomy on physical and behavioral development in cats. *Journal of the*
756 *American Veterinary Medical Association*, 209(11), 1864–71.

757 Viera, A. J., & Garrett, J. M. (2005). Understanding Interobserver Agreement : The Kappa
758 Statistic, (May), 360–363.

759