Factors associated with house-soiling in Italian cats

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Abstract

Objectives The aim of the present study was to identify factors associated with house-soiling in Italian cats.
Methods A cross-sectional online survey collected information on respondents' and cats' details and litter management, and whether the cat showed house-soiling. Univariable and multivariable regression models were performed using house-soiling (present/absent) and the type of house-soiling (ie, urinary, faecal, concurrent urinary and faecal) as dummy variables.
Results Data from 3106 cats were obtained. The number of dogs and other cats in the household, the cat's age, the number, type and location of the litter boxes, the type of litter, and the frequency of litter scooping and full replacement were retained in the final multivariable regression model for house-soiling (model $P < 0.001$, Akaike information criterion [AIC] = 2454.30). Urinary tract diseases, the type and number of litter boxes and the number of dogs in the household were associated with urinary house-soiling (model $P < 0.001$, AIC = 534.08), and gastroenteric/musculoskeletal diseases, number of litter boxes and litter box location were associated with faecal house-soiling (model $P < 0.001$, AIC = 448.52). Healthy cats, the number of dogs in the household, the type of litter and litter full replacement frequency were retained in the final multivariable regression model for the concurrent expression of urinary and faecal house-soiling (model $P < 0.001$, AIC = 411.47).
Conclusions and relevance Meeting cats' preferences for litter and litter box type, location, behavioural needs and strict litter hygienic conditions is recommended. Cat owners need to be educated to prevent and manage house-soiling in their cats.

Keywords: Behaviour; litter; management; health; welfare

Introduction

House-soiling is a common behavioural problem in cats, prompting owners to complain and seek professional consultation.[1–3] It consists of the deposition of urine (periuria), faeces (perichezia) or both outside the litter box.[4,5] It is frequently a cause of behavioural veterinary visits, with a reported prevalence in the range of 51.2–79%.[6–11] House-soiling is considered to impair the cat–owner relationship, so much so that it is one of the main reasons for cat relinquishment[2,12,13] and the second main owner complaint (39%) after aggression (47%).[9] Despite owners' concerns, the solution to house-soiling often relies on simply understanding the factors behind it, whether medical or management related, and handling them.[14]

House-soiling can be manifested through different types of elimination.[4,5] If it involves urine, it can be either

in urine-marking behaviour (ie, spraying) or voiding.[15,16] Spraying usually occurs with the cat in a standing position, depositing a small amount of urine on vertical

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objects/surfaces, and is elicited for territorial, competitive or sexual reasons.[4,15,17] Conversely, voiding is usually performed in a squatting position, depositing a large amount of urine on horizontal surfaces, and is elicited by the necessity to relieve pressure on the bladder.[4,15–17] Spraying and voiding are considered behavioural problems by owners.[14] As there are many reasons why a cat voids its bladder (or bowels, in the case of faecal house-soiling) outside the litter box, house-soiling is considered a multifactorial problem.[18]

Studies conducted mainly in the USA, the UK and Australia postulated many risk factors for house-soiling in cats. The characteristics of litter (eg, individual preference, granule size, new litter, cleaning frequency) and the litter box (eg, covered vs open, location, number),[5,19,20] cats' characteristics (eg, breed and age),[10,21] anxiety related to significant social or environmental challenges (eg, multi-cat household, presence of other animals),[2,4,22–24] negative associations with the litter box (eg, pain during its use)[4] and a wide range of medical conditions, including age-related conditions (eg, arthritis, cognitive dysfunction, urinary tract or kidney diseases, neurological diseases and general weakness),[2,4,19] have all been associated with this behavioural problem.

In particular, several studies agree that various medical conditions could predispose cats to house-soiling.[15–18] Medical conditions causing discomfort at the urinary or gastrointestinal level (ie, cystitis, diarrhoea) have been considered to be risk factors for its occurrence, as they increase the urgency to evacuate.[17] Moreover, it seems that the type of medical condition may lead to a specific type of house-soiling: a history of urinary tract disease could predispose to urinary house-soiling, while osteoarticular, pelvic or gastroenteric diseases could predispose to faecal house-soiling.[2,19,22]

Although house-soiling is a widespread problem, there is still no clear information regarding the possible risk factors for its occurrence.[2] In particular, the studies to date were performed mainly in countries outside Europe, on a limited number of cats presented to veterinary consultations for behavioural problems (ie, with a risk of overestimating the prevalence of house-soiling in the population) or without considering multivariable regression models. Therefore, scientific evidence on house-soiling and its risk factors is still scant.

We hypothesised that respondents' details, the cats' intrinsic details, and litter and litter box details would be associated with house-soiling in pet cats. This research aimed to detect the possible factors that may increase or decrease the likelihood of house-soiling, to fill the current gap of knowledge and enhance both cat–human relationships and cat welfare.

Materials and methods

Survey

Detail of the design and distribution of the survey and the description of the study population's demographic characteristics and house-soiling prevalence have been reported previously.[25] Briefly, the survey was developed through a process of iterative review by the researchers, piloted by the authors with 20 cat owners and adjusted in response to feedback. The study design considered key design features that Dean[26] and Christley[27] suggested to develop a valid questionnaire in veterinary medicine. The survey was digitised using Qualtrics Software (Qualtrics; www.qualtrics.com) and it was open between March and May 2022. Italians owning one or more domestic cats and having a litter box for them were invited to take part in the survey. Invitation letters in Italian and the link to the survey were disseminated through social media, associations and veterinary institutions. The anonymous survey comprised 18 closed and three open-ended questions asking for the respondents' housing, family and pet details, cats' details, litter details and whether the cat showed elimination outside the litter box (see Table S1 in the supplementary material). If the respondent replied 'Yes' to question 17 (ie, 'Does your cat eliminate outside the litter box?'), a further set of four questions was asked, regarding elimination type, locations of the eliminations, the cat's posture and whether the cat had health problems (see Table S1 in supplementary material).

A power calculation[28] determined that 2736 survey responses would be representative of the Italian cat population, which was estimated at 10.1 million in 2022,[29] with a 3%[30] absolute precision and 99.9% confidence interval (CI). The survey received 2839 responses. Of the total responses, 2794 met the inclusion criteria (respondents owning one or more domestic cats and providing a litter box for them). Data for 3106 cats were retained, reaching a significant sample size.

Data handling and definition of the variables

The full description of data handling has been published previously.[25] The categories with an insufficient number of answers (ie, <5% of answers) were combined to avoid unbalanced data in regression.[31] The complete list of the names, descriptions and categories of the variables analysed in this study was reported previously[25] and is also reported in the supplementary material (Table S2).

Statistical analysis

Descriptive statistics of all the numeric, categorical and dichotomous variables for the entire data set have been previously published.[25] Of the subset including respondents who had at least two litter boxes, descriptive statistics of the number of cats, number of litter boxes and total number of locations with at least one litter box (ie,

the total number of rooms that were ticked as locations with at least one litter box, inferred by question 13 of the survey) and number of litter boxes per location (see Table S3 in the supplementary material) were performed.

The variables 'Number of cats' and 'Number of litter boxes' were initially considered numeric to calculate the number of litter boxes per cat (ie, the ratio between the number of cats and the number of litter boxes). Then, the number of cats and the number of litter boxes were transformed into categorical variables, and the descriptive statistics of categorical and dichotomous variables referring to the subset of cats showing house-soiling were performed for this study.[28] In order to identify the association between the expression of house-soiling and household characteristics, living environment features and litter box/litter characteristics/ management, two-step regression models were performed on the entire data set, with univariable and then multivariable regression models for the dichotomous outcome variable 'Eliminates outside the litter boxes' (absence/presence). Moreover, to investigate whether multiple litter boxes located in the same room would increase the likelihood of house-soiling, a new categorical variable (named 'Litter boxes in the same location') was created for a subset of respondents having at least two litter boxes (1: all litter boxes in the same room; 0: litter boxes placed in different rooms) (see Table S3 in the supplementary material). This new variable was used as an independent variable in a univariable logistic regression model with house-soiling as the outcome. Then, to identify the factors associated with the different types of house-soiling (ie, urinary, faecal, and concurrent expression of urinary and faecal), a subset of data containing information for only the cats showing house-soiling was used to perform further regression models. Following what had been done previously, two-step regression models (first univariable and then multivariable) were performed for the dichotomous outcome variables (ie, yes/no) of 'Urinary house-soiling', 'Faecal house-soiling' and 'Concurrent expression of urinary and faecal house-soiling'. In both the regression analyses, to avoid over- or underestimations for the effects of explanatory variables due to collinearity, a first step to exclude multicollinear independent variables was conducted. Multicollinearity was tested by calculating variance inflation factors (VIFs) for models containing the independent variables. The calculation of VIFs was performed using the *vif* function in the *car* package in the R environment.[32] Variables that had a VIF value exceeding 5 were considered collinear.[33] Within the group of collinear variables, only the most representative variable was kept (eg, the size of the housing is also representative of the type of housing). The variables 'Housing type', 'Housing size' and 'Garden' were collinear, and thus only 'Housing size' was retained among the independent variables to be tested for

association with house-soiling in the subsequent regression models. Similarly, high multicollinearity values were noticed among the variables 'Other animals', 'Animals, other than cats', 'Animals, other than cats and dogs' and 'Dogs'; therefore, the variable that was kept was 'Other animals'. Moreover, in the regression analysis for the subset of data referring to the cats showing house-soiling, the association between the variables 'Presence of cat health problems' and 'Cat's age' was tested with a binomial model in which the presence of a feline health problem was the outcome and the cat's age was the independent variable. Cats aged >5 years were 1.7 times more likely to have health problems than younger cats (P <0.001). Since we aimed to investigate the possible risk factors that could determine the occurrence of a specific type of house-soiling, the variable 'Cat's age' was not further considered in these subsequent models, while 'Cat health status' was kept among the independent variables tested for the outcomes 'Urinary house-soiling', 'Faecal house-soiling' and 'Concurrent expression of urinary and faecal house-soiling'. After excluding the collinear variables, the associations between the independent variables and the dichotomous outcomes were tested. As a first step, univariable binary logistic regression models were carried out to test the pairwise associations between each independent variable and each outcome. The P values of each independent variable tested in a univariable binary logistic regression were calculated using the Wald test, and for each outcome, the variables that showed a P value <0.10 were considered for inclusion in the backward stepwise selection for multivariable logistic regression models. The backward elimination was run manually. Observations with missing values were automatically excluded from the analyses. Predictive variables were removed until all variables in the final model had a P value ≤0.10 and the lowest Akaike information criterion (AIC) value for the model was attained.

All the univariable and multivariable models were performed using functions belonging to the packages *lme4*, *lmtest*, *nlme*, *lsmeans* and *car* in the R environment.[32] The results were reported as odds ratios (ORs), CIs and P values. The significance threshold was set at P ≤0.05, and P values >0.05 and <0.10 were set as trends towards significance.

Results

The description of the demographic population characteristics, cats' living environment, litter box/litter management and prevalence of house-soiling in Italian pet cats for the entire data set (3106 cats) have been published previously.[25] In the case of respondents having at least two litter boxes (n = 1636 cats), the median number of litter boxes was 3 (interquartile range [IQR] 2–4; range 2–30), the median number of cats was 3 (IQR 2–5; range 1–30), the median number of the total number of locations

with at least one litter box was 1 (IQR 1–2; range 1–7) and the median number of litter boxes per location was 2 (IQR 1.5–3; range 0.4–18).

House-soiling was shown by one-sixth of the total study population of cats, with a reported prevalence of 16.74%. Most cats eliminating outside the litter box showed urinary house-soiling (54.60%), with faecal house-soiling (24.90%) or concurrent urinary and faecal house-soiling (20.50%) being less frequent. The cats performing house-soiling eliminated mainly in the same spot (64.64%), precisely on objects (31.66%) or near the litter (28.25%), assuming a squatting posture (35.24%). However, almost one-third of the respondents reported not knowing the posture, since the cats were never observed while eliminating. Most cats that were house-soiling were healthy (80.18%); among those with pathologies, the main ones were gastrointestinal/musculoskeletal (10.91%) or urinary tract diseases (8.91%) (for further details, see Tateo et al[25]). In cats that were provided with ≥2 litter boxes, house-soiling reached a prevalence of 22.2% (364/1636).

In the case of cats showing house-soiling, the median number of cats owned by the respondents was 2 (IQR 2–5; range 1–20), and the median number of litter boxes provided to the cats was 2 (IQR 1–3; range 1–18). The median number of litter boxes per cat was 1 (IQR 0.50–1; range 0.08–4). Cats showing house-soiling were mainly kept in apartments (57.88%), of 71–100 m² (35.69%), without a garden (57.12%). The households often consisted of two adults (45.93%) without children (aged under 7 years: 89.42%; aged 7–12 years: 88.85%) and were mainly multi-animal households (85%), with dogs (32.73%) and multiple cats living in small groups (n = 2–3; 45.77%). Most cats that were house-soiling were aged >5 years (50.30%) and had mainly 2 (31.73%) open-type (44.42%) litter boxes at their disposal, with a median of 1 litter box per cat (IQR 0.5–1; range 0.08–4). The litter boxes were often located in the bathroom (53.91%) or in the bedroom (35.55%), filled with clumping substrates (45%) and scooped once a day (37.88%). The litter full replacement frequency was mainly once a week (55.19%). The complete description of the data for the subset of cats showing house-soiling is reported in Table S4 in the supplementary material.

Risk factors for house-soiling

In univariable models, house-soiling was associated with housing size (*P* = 0.038), number of children aged under 7 years (*P* = 0.027), presence of other animals (*P* <0.001), number of dogs (*P* <0.001), number of cats (*P* <0.001), square metres per cat (*P* <0.001), cat's breed (*P* = 0.030), cat's age (*P* <0.001), number of litter boxes (*P* <0.001), type of litter box (*P* <0.001), litter box location in the living room (*P* = 0.002), litter box location in the bedroom (*P* = 0.012), litter box location under the stairs (*P* = 0.017), type of litter (*P* <0.001), litter

scooping frequency (*P* = 0.004) and litter full replacement frequency (*P* = 0.007). The full list of Wald test *P* values for the predictive variables associated with the manifestation of house-soiling is reported in the supplementary material (Table S5).

In the univariable model, considering only the respondents with at least two litter boxes, whether multiple litter boxes were placed in the same or different locations was not associated with the occurrence of house-soiling (*P* = 0.218).

The variables retained in the final multivariable regression model for the expression of house-soiling behaviour (model *P* value <0.001, AIC = 2454.30) are shown in Table 1. The presence of dogs or other cats living in the family was strongly associated with an increased probability of cats showing house-soiling, with cats living with 1 dog or ≥3 dogs being 1.5–2 times more likely to show this behavioural problem than cats living in a family with no dogs (*P* <0.001). Similarly, cats living in large groups, with ≥4 cats, were almost twice as likely to show house-soiling as cats living alone (*P* = 0.018). Among the cats' intrinsic characteristics, older age was a risk factor for house-soiling, with cats having >1.5-fold higher odds of showing this behavioural problem if they were aged >2 years compared with younger cats (*P* <0.001). The number and type of litter boxes were also risk factors associated with house-soiling; cats living in an environment with more than one litter box were almost twice as likely to show this behaviour (*P* <0.001), and the odds of having cats showing house-soiling increased by 1.4 times if the litter box was open compared with a covered box (*P* = 0.021). The litter scooping frequency was also retained in the final model, as scooping frequencies lower than once a day significantly increased the odds of house-soiling (*P* <0.001) compared with a litter scooping frequency of twice a day. The litter type was also associated with the expression of house-soiling, with cats being more likely to show this behavioural problem if the litter was biodegradable or 'other' types (ie, papers, lentils) compared with the clumping type (*P* = 0.019). The variables of litter full replacement frequency and litter box location under the stairs were retained in the model as the AIC obtained including these variables in the multiple regression model was smaller than the AIC of the model without these factors (AIC = 2493). Therefore, the likelihood of having cats expressing house-soiling seems to increase when full litter replacement happened rarely (ie, 'clean when needed', 'never cleaned') (*P* = 0.050). Litter box location under the stairs also seems to increase the probability of house-soiling (*P* = 0.087).

Risk factors for urinary house-soiling

In univariable models, urinary house-soiling was associated with housing size (*P* = 0.048), number of dogs

Table 1 Multivariable regression model for the dummy dependent variable of house-soiling in Italian cats

Predictive variables	Estimate ± SE	OR (95% CI)	*P* value
Number of dogs			**<0.001**
0	Ref		
1	0.432 ± 0.139	1.54 (1.16–2.01)	0.001
2	0.367 ± 0.207	1.44 (0.95–2.15)	0.075
≥3	0.787 ± 0.244	2.19 (1.34–3.52)	0.001
Number of cats			**0.018**
Cat living alone (1)	Ref		
Small group (2–3)	0.246 ± 0.157	1.27 (0.94–1.74)	0.117
Large group (≥4)	0.582 ± 0.204	1.79 (1.19–2.67)	0.004
Cat's age (years)			**<0.001**
<2	Ref		
2–5	0.44 ± 0.155	1.55 (1.14–2.11)	0.004
>5	0.556 ± 0.147	1.74 (1.31–2.34)	<0.001
Number of litter boxes			**<0.001**
1	Ref		
2	0.573 ± 0.148	1.77 (1.32–2.37)	<0.001
3	0.657 ± 0.183	1.93 (1.34–2.76)	<0.001
≥4	0.517 ± 0.21	1.67 (1.1–2.53)	0.014
Type of litter box			**0.021**
Covered	Ref		
Open	0.342 ± 0.113	1.40 (1.12–1.75)	0.002
Open and covered	0.316 ± 0.176	1.37 (0.96–1.93)	0.073
Other	0.333 ± 0.857	1.39 (0.19–6.44)	0.697
Type of litter			**0.019**
Clumping	Ref		
Non-clumping	0.299 ± 0.158	1.34 (0.98–1.83)	0.059
Biodegradable	0.273 ± 0.136	1.31 (1–1.71)	0.044
Silica gel	0.12 ± 0.187	1.12 (0.77–1.61)	0.521
Other	0.693 ± 0.23	2.00 (1.26–3.11)	0.002
Litter box location: stairs			**0.087**
No	Ref		
Yes	0.626 ± 0.35	1.87 (0.91–3.65)	0.074
Litter scooping frequency			**<0.001**
Twice a day	Ref		
More than twice a day	0.176 ± 0.21	1.19 (0.78–1.78)	0.400
Once a day	0.292 ± 0.13	1.33 (1.03–1.73)	0.025
Three times a week	0.824 ± 0.215	2.28 (1.48–3.45)	<0.001
Twice a week	0.619 ± 0.204	1.85 (1.23–2.75)	0.002
Other	0.621 ± 0.218	1.86 (1.2–2.83)	0.004
Litter full replacement frequency			**0.050**
More than two/three times a week	Ref		
Once a week	0.415 ± 0.232	1.51 (0.97–2.43)	0.073
Every 10/20 days	0.333 ± 0.296	1.39 (0.78–2.51)	0.260
Once a month	0.289 ± 0.249	1.33 (0.82–2.21)	0.245
Other	0.876 ± 0.305	2.40 (1.32–4.4)	0.004

P values in bold refer to the statistical significance or trend towards the significance of the predictive variable in the model; the significance of a category against the reference is reported in regular font
CI = confidence interval; OR = odds ratio; Ref = reference category; SE = standard error

(*P* = 0.008), square metres per cat (*P* = 0.011), number of litter boxes (*P* = 0.029), type of litter box (*P* = 0.003) and cat health status (*P* <0.001). The full list of Wald test *P* values for the predictive variables associated with urinary house-soiling is reported in the supplementary material (Table S6).

The variables retained in the final multivariable regression model for the expression of urinary house-soiling

Table 2 Multivariable regression model for the dichotomous dependent variable of urinary house-soiling in Italian cats

Predictive variables	Estimate ± SE	OR (95% CI)	P value
Number of dogs			**0.002**
≥3	Ref		
0	1.291 ± 0.436	3.64 (1.57–8.83)	0.003
1	1.520 ± 0.486	4.57 (1.80–12.22)	0.002
2	0.331 ± 0.579	1.39 (0.45–4.37)	0.568
Number of litter boxes			<**0.001**
1	Ref		
2	0.148 ± 0.280	1.16 (0.67–2.01)	0.596
3	0.744 ± 0.322	2.10 (1.12–3.99)	0.021
≥4	1.352 ± 0.344	3.86 (1.99–7.70)	<0.001
Type of litter box			**0.002**
Open	Ref		
Covered	0.856 ± 0.237	2.35 (1.49–3.76)	0.003
Open and covered	0.074 ± 0.349	1.08 (0.54–2.14)	0.831
Other	12.533 ± 535.411	N/A	0.981
Cat health status			<**0.001**
Healthy	Ref		
Urinary tract disease	2.167 ± 0.526	8.73 (3.38–27.60)	<0.001
Other	−1.139 ± 0.360	0.32 (0.15–0.64)	0.001

P values in bold refer to the statistical significance or trend towards the significance of the predictive variable in the model; the significance of a category against the reference is reported in regular font
CI = confidence interval; OR = odds ratio; N/A = not applicable due to high standard error estimates; Ref = reference category; SE = standard error

behaviour (model *P* value <0.001, AIC = 534.08) are shown in Table 2. The expression of urinary house-soiling behaviour in cats was strongly associated with the presence of urinary tract diseases, as cats with those health problems were about nine times more likely to urinate outside the litter box compared with healthy cats (*P* <0.001). The number and type of litter boxes were also associated with urinary house-soiling; cats with 3 and ≥4 litter boxes at their disposal were >2 and approximately 4 times more likely to show urinary house-soiling (*P* = 0.021 and *P* <0.001, respectively) compared with those living in houses with one litter box, and the odds of having cats showing urinary house-soiling increased by more than twice if the litter box was covered instead of open (*P* = 0.002). The expression of urinary house-soiling behaviour in cats was not proportionally related to the number of dogs living with them, since cats were four times more likely to show urinary house-soiling when they lived with no dogs or one dog compared with cats who lived with ≥3 dogs (*P* = 0.003 and *P* = 0.002, respectively).

Risk factors for faecal house-soiling
In univariable models, faecal house-soiling was associated with number of cats (*P* = 0.009), square metres per cat (*P* = 0.036), number of litter boxes (*P* = 0.016), litter box location on the balcony (*P* = 0.008) and the cat health status (*P* <0.001). The full list of Wald test *P* values for the predictive variables associated

with faecal house-soiling is reported in the supplementary material (Table S7).

The variables retained in the final multivariable regression model for the expression of faecal house-soiling behaviour (model *P* value <0.001, AIC = 448.52) are shown in Table 3. The expression of faecal house-soiling behaviour in cats was strongly associated with the presence of health problems belonging to the category 'other' (ie, gastrointestinal and musculoskeletal problems), as cats with those health problems were more than twice as likely to defecate outside the litter box compared with healthy cats (*P* <0.001). The number and location of litter boxes were also important cofactors for faecal house-soiling. Cats were less likely to defecate outside the litter box if they had ≥4 litter boxes at their disposal compared with cats living in houses with one litter box (*P* = 0.050), and less likely to perform faecal house-soiling when the litter boxes were located on the balcony or in the bathroom (*P* = 0.018 and *P* = 0.029, respectively).

Risk factors for concurrent urinary and faecal house-soiling
In univariable models, the concurrent expression of urinary and faecal house-soiling was associated with housing size (*P* = 0.010), number of dogs (*P* = 0.001), number of litter boxes per cat (*P* = 0.029), type of litter box (*P* = 0.006), type of litter (*P* = 0.003) and cat health status (*P* = 0.017). The full list of Wald test *P* values for the predictive variables associated with

Table 3 Multivariable regression model for the dummy dependent variable of faecal house-soiling in Italian cats

Predictive variables	Estimate ± SE	OR (95% CI)	*P* value
Number of litter boxes			**0.050**
1	Ref		
2	0.065 ± 0.278	1.07 (0.62–1.36)	0.816
3	−0.335 ± 0.338	0.71 (0.36–1.37)	0.320
≥4	−0.839 ± 0.368	0.43 (0.20–0.87)	0.022
Litter box location: balcony			**0.018**
Yes	Ref		
No	0.858 ± 0.378	2.36 (1.17–5.21)	0.023
Litter box location: bathroom			**0.029**
Yes	Ref		
No	0.507 ± 0.229	1.66 (1.06–2.61)	0.027
Cat health status			<**0.001**
Healthy	Ref		
Others	0.988 ± 0.324	2.69 (1.42–5.09)	0.002
Urinary tract disease	−1.518 ± 0.620	0.22 (0.05–0.64)	0.014

P values in bold refer to the statistical significance or trend towards the significance of the predictive variable in the model; the significance of a category against the reference is reported in regular font
CI = confidence interval; OR = odds ratio; Ref = reference category; SE = standard error

faecal house-soiling is reported in the supplementary material (Table S8).

The variables retained in the final multivariable regression model for the expression of concurrent urinary and faecal house-soiling behaviour (model *P* value <0.001, AIC = 411.47) are shown in Table 4. The number of dogs living with the cats was strongly related to the concurrent expression of urinary and faecal house-soiling, with respondents having 2 or ≥3 dogs being three times more likely to have a cat showing this behavioural problem compared with respondents who did not have dogs (*P* <0.001). Cats with urinary tract diseases were less likely to be reported to show the concurrent expression of urinary and faecal house-soiling behaviour in comparison with healthy cats (*P* = 0.004). The type of litter and the full litter replacement frequency were also associated with urinary and faecal house-soiling. In particular, the litter types belonging to the category 'other' (ie, papers, lentils) performed worse compared with silica gel litters, as they increased the likelihood of cats urinating and defecating outside the litter box eight-fold compared with silica gel (*P* = 0.027). Very frequent full litter replacement (more than two/three times a week, or weekly) increased the odds of cats urinating and defecating outside the litter box by >7 and 4 times (*P* = 0.035 and *P* = 0.050, respectively) compared with a litter full replacement frequency of every 10/20 days.

Discussion

This study documents the prevalence of house-soiling in Italian cats and describes, for the first time, the possible factors associated with it. Surprisingly, our prevalence was lower than that reported in other studies.[2,4,8,11,23] This was probably because, in some of the studies, the prevalence was calculated in cats presented at veterinary consultations for behavioural problems, while our sample is representative of the Italian cat population, with and without health and behavioural problems. House-soiling was associated with cats' details, living environment characteristics, litter and litter box types and management, supporting our hypothesis. Our findings are useful in identifying the factors that may increase or decrease the risk of house-soiling, and consequently may be useful to enhance cat–human relationships and cat welfare. This study provides evidence that may help practitioners to educate owners about preventing the problem or managing it instead of considering cat abandonment, relinquishment to a shelter or euthanasia due to this behavioural problem.

Scientific evidence on the potential associations with, and causes of, house-soiling in cats is scant.[2] In the literature, the social environment has been judged critically for the manifestation of house-soiling.[2,4,16–18,34] In our multivariable model, the presence of dogs and the number of cats in the household were positively associated with the expression of house-soiling. This may be because, in the presence of dog(s) or other cats, cats may not have easy access to their litter box and/or a safe entry route that avoids an encounter with a potential enemy.[16,17,34] Moreover, a cat that has been ambushed by another household pet while using the litter box may be nervous about re-using it.[34] In the case of multi-cat households, cats may compete for the same resource, namely the litter box(es), and this may lead some cats to choose safer places to eliminate.[17,18] However, the relationship between cat welfare and social and environmental factors is complex. Finka and colleagues[24] reported that not only the

Table 4 Multivariable regression model for the dichotomous dependent variable of concurrent expression of urinary and faecal house-soiling in Italian cats

Predictive variables	Estimate ± SE	OR (95% CI)	*P* value
Number of dogs			<**0.001**
0	Ref		
1	−0.917 ± 0.407	0.40 (0.17–0.85)	0.024
2	1.153 ± 0.417	3.17 (1.38–7.17)	0.006
≥3	1.067 ± 0.446	2.91 (1.19–6.93)	0.017
Type of litter			**0.027**
Silica gel	Ref		
Other	2.091 ± 0.667	8.09 (2.29–32.41)	0.010
Non-clumping	0.945 ± 0.616	2.57 (0.80–9.39)	0.125
Clumping	1.017 ± 0.557	2.76 (1.00–9.21)	0.067
Biodegradable	0.824 ± 0.594	2.27 (0.75–8.03)	0.165
Litter full replacement frequency			**0.029**
Every 10/20 days	Ref		
More than two/three times a week	1.951 ± 0.928	7.04 (1.27–56.43)	0.035
Other	1.594 ± 0.848	4.92 (1.08–35.35)	0.060
Once a month	0.772 ± 0.808	2.16 (0.53–14.75)	0.339
Once a week	1.512 ± 0.774	4.53 (1.22–29.7)	0.050
Cat health status			**0.004**
Healthy	Ref		
Urinary tract disease	−1.929 ± 0.759	0.14 (0.02–0.52)	0.011
Others	0.257 ± 0.407	1.29 (0.56–2.80)	0.528

P values in bold refer to the statistical significance or trend towards the significance of the predictive variable in the model; the significance of a category against the reference is reported in regular font
CI = confidence interval; OR = odds ratio; Ref = reference category; SE = standard error

number of cats in the households per se could represent a stressor, but also the combination with other environmental (eg, outdoor access, indoor space availability, human density) and endogenous (eg, breed, sex, age, neuter status) factors.

More private litter box locations can be preferred if the litter box is located in busy areas of the house where the cat does not feel safe.[4,18] In our study, placing litter boxes near or under stairs seemed to increase the likelihood of house-soiling, most probably because stairs are a noisy place where many people, sometimes strangers, pass by.[15] This agrees with what was reported by Neilson,[34] namely that a cat that is uncomfortable with the presence of strangers/other animals can show litter box aversion due to social anxiety. In addition to placement, the distribution of multiple litter boxes in the house is also an important factor to consider. In fact, locating different litter boxes in the same area has been found to be associated with an increase in the manifestation of house-soiling.[23] In our study, distributing multiple litter boxes in the same room was not associated with an increased occurrence of house-soiling. However, from our survey, it was not possible to infer what the actual arrangement of litter boxes was within the room, such as whether they were close to each other or close to food and water sources. This is a limitation that should be taken into account

when interpreting the results, and the design of the survey should be improved in future studies. Some studies do not recommend placing multiple litter boxes within the same room,[16,18] especially if they are close together, as they could be considered by the cat as one big box[16] and the cat may similarly show aversion to all of them. Placing the different litter boxes in different locations is, therefore, encouraged in cats that are house-soiling.[4] In our subset considering only the respondents who had at least two litter boxes, the prevalence of house-soiling in cats was higher than in the total data set. This could be due to either the greater number of cats owned by those respondents with more litter boxes or a practice put in place to try to reduce the occurrence of house-soiling. Increasing the number of available litter boxes is certainly one way to manage house-soiling, but it should be complemented by other practices, such as offering litter boxes of different types, with different substrates and placed in different locations in the home.[4]

In addition to litter box location, anxiety related to negative events (eg, pain) can also lead to aversion towards the litter box. For example, older cats may have trouble climbing over the edge of a litter box and may perceive pain during litter box entry or use.[16,34] In this way, a classically conditioned aversive association with litter box use may occur.[4,16] In our study, older cats were more

likely to show house-soiling than younger cats (aged <2 years). These results agreed with other studies[2,16,34] reporting age as a risk factor for house-soiling in cats, especially if the cat has arthritis or other musculoskeletal problems. In fact, older cats are considered more experienced cats that may have learned to associate certain litter and litter box characteristics with negative experiences.[22] The household pet group and the cat's behavioural needs and characteristics must be considered crucial factors in the prevention and management of house-soiling. Decreasing the pet population density in multi-pet households, allowing outdoor access or access to different parts of the house, and moving the litter box away from busy places are, therefore, recommended.[4]

Aversion to litter boxes was also reported in relation to litter box attributes.[4,9,15–17,19] However, whether litter box characteristics are a risk factor for house-soiling is still a matter of debate. While Barcelos et al[2] found no statistical association between litter box attributes and house-soiling, multiple litter box attributes were significantly associated with house-soiling in our study. Our results showed conflicting associations between the type of litter box and house-soiling in cats. This is in line with the literature, where a real preference for, or aversion to, open vs covered litter boxes has not been reported, as long as each type of litter box is clean and is appropriate for the size of the cat.[16,18,35] In our study, more than one-third of the respondents did not observe cats performing house-soiling and only found soiled materials near the litter box (see Tateo et al[25]). This suggests that the house-soiling, especially concerning faeces, could be related not to real house-soiling behaviour, but instead to an accidental drop of faeces as the cat left the litter box (eg, possibly as a result of faeces stuck to the fur and then dropped) or to the litter box characteristics precluding an old cat from comfortably entering or posturing to defecate. An open litter box could be more prone to material dispersion, especially if the cat performs a very marked burying behaviour. Moreover, the cat could perceive an open-type litter box as 'less protective' from external stressors, especially in multi-pet households,[16,17] and then choose elimination places where it feels safer. In this study, the number of litter boxes was positively associated with house-soiling expression, with a higher number of litter boxes increasing the likelihood of having cats that were house-soiling. This is contrary to what is generally reported as the rule of thumb, namely having at least one litter box per cat in the household plus one more.[4,16,18] However, as mentioned before, a higher number of litter boxes should not be considered as a possible cause of house-soiling but as a possible attempt to minimise the problem. Our study confirms the best practices already suggested, but not statistically validated, by Olm and Houpt,[4] namely increasing the number of litter boxes per cat and trying to use different sizes and types (covered and open)

of litter boxes to make them as attractive to the cat as possible and to re-establish their use in cats performing house-soiling.[4]

The type of litter and the litter box cleaning frequency have been identified as risk factors, since they can determine substrate aversion in cats.[16,17,34] Litter material should meet cats' needs instead of human preferences (eg, aromatic litter).[18] Fine, sand-like, non-scented, clumping materials are reported to be optimal and seem to be a possible solution to house-soiling in some cats.[17–19,36] Our findings confirm that biodegradable or other types of litter (ie, papers, lentils) increased the likelihood of cats showing house-soiling compared with the clumping type of litter. However, beyond the type of litter, an even more critical point is litter cleanliness. A study conducted by Ellis et al[20] stated that cats prefer clean litter boxes to dirty ones. In particular, it seems that it is the physical presence of urine and faeces in the litter that deters the cat from reusing the litter box.[20] Moreover, Lawson et al[23] found an association between less frequent cleaning of the litter box of both urine and faeces and the occurrence of house-soiling. In our study, we found that highly frequent scooping (ie, twice a day) decreased the likelihood of cats showing house-soiling. The same was true for the frequency of full litter replacement, with cats having their litter boxes cleaned rarely (eg, 'clean when needed', 'never clean') being more likely to develop house-soiling. Our results agree with many studies on the absolute necessity of providing cats with a clean litter box to avoid house-soiling problems.[4,17,18,23] Therefore, a suggested best practice to follow to guarantee high hygienic standards is to scoop and fully clean the litter box at least once a day and every 1–4 weeks, respectively.[4,17,18]

There are three types of house-soiling, namely urinary, faecal and both.[4,5] Urinary house-soiling was associated with the number of dogs in the household, litter box type and number, and health problems. In agreement with Barcelos et al,[2] the association with the number of dogs may be explained by the social dynamics established in a group of pets, rather than by the number of pets per se. Covered litter boxes were positively associated, probably because covered litter box dirtiness is less perceptible by cats' owners compared with open litter boxes.[18] Moreover, it has been reported that when the litter box is dirty, cats seem to prefer a litter box soiled with faeces rather than urine.[20] This may have motivated them, in the case of dirty litter, to perform urinary house-soiling. However, as mentioned before, our findings regarding the association between house-soiling and type of litter box need to be interpreted with caution. Instead, it is worth highlighting that, in agreement with the literature,[19,22] urinary house-soiling is strongly associated with the presence of urinary tract disease. Feline lower urinary tract disease (FLUTD) includes several pathologies affecting the urinary system, and house-soiling is

considered a typical clinical sign of FLUTD.[4,16,18] There are many reasons why a cat with FLUTD might eliminate outside the litter box. Cats may develop an aversion to using the litter box because of negative associations due to painful elimination,[4] may have a decreased ability to retain urine[4] or may prefer to urinate on cool surfaces (eg, sinks, bathtubs).[37] When managing urinary house-soiling, the cat's medical history should therefore be taken into account, with urinary tract diseases considered among the first possible causes of this behavioural problem and the possible presence of such disease excluded. Behavioural problems may, indeed, be the manifestation of an underlying health problem, and veterinary input becomes essential for the management of the disease, which automatically becomes the management of the behavioural problem.

Faecal house-soiling was also associated with health problems, with cats with gastrointestinal and musculoskeletal problems being more likely to develop it. Diarrhoea and constipation are recognised in other studies as possible medical causes.[15,16,18] Pain or incontinence, as for urinary house-soiling, may be associated with faecal house-soiling. Moreover, a cat that has diarrhoea and gets its paws dirty by eliminating in the litter box may develop an aversion to eliminating in the same litter box again.[15] Musculoskeletal problems can elicit pain in cats.[16,34] For this reason, as already discussed for senior cats, cats with musculoskeletal problems may have difficulty reaching the litter box or associate a negative experience with using the litter box and therefore avoid it.[4,16] The locations of litter boxes seem to be more important for faecal than urinary house-soiling. Finally, from our results, concurrent urinary and faecal house-soiling seems to be more related to the cat's behavioural preference/aversions. Consequently, the appropriate locations and management of the litter boxes are strongly recommended to prevent and minimise concurrent urinary and faecal house-soiling, and a veterinary examination is suggested as the first step in case of either urinary and/or faecal house-soiling.

Our findings need to be interpreted with caution, since this study has several limitations. First, our findings are affected by the common limitations of every survey-based study,[27] and many associations must not be interpreted as causes but as practices already in place to manage house-soiling. Moreover, from the design of our survey, it is, unfortunately, impossible to differentiate between voiding and spraying. Similarly, from our questions, it was impossible to know whether some faeces were dropped accidentally by the cats outside the litter box (ie, stuck on their fur and then dropped) or voluntarily eliminated in different locations. There was also no question about the cats' hair length, and the variable of 'length of cat hair' was assigned to each cat based on the cat's breed. Consequently, there may be uncertainty about the findings related to this variable, and this limitation

should be addressed to improve the design of the survey. There were also no questions regarding the arrangement of the litter boxes when placed in the same room. This may have affected the lack of association found in our study between house-soiling occurrence and litter boxes placed in the same location. Moreover, there were no questions about inter-cat relationships in multi-cat households. Therefore, we do not know whether tensions between cats in the same household could have increased the risk of house-soiling compared with multi-cat households where there were no tensions. Finally, it should be acknowledged that the information related to the cats' health problems was obtained only from the owners claiming to have a cat that was house-soiling, so the presence of health problems could not be tested as a factor for all respondents. Future surveys should add specific questions to address these limitations, including a question related to hair length and open-ended questions where the respondents could provide more detail about the history of the cats. Notwithstanding these limitations, this is, to the authors' knowledge, the study with the largest population ever investigated to identify the factors associated with house-soiling in cats. Our findings provide evidence to prevent and manage this unhygienic behavioural problem and may enhance cat welfare and cat–owner relationships.

Conclusions

The occurrence of house-soiling in Italian cats was 16.74% and was associated with household composition, litter type and litter box management, and the cat's intrinsic characteristics, such as age and pre-existing health problems. In the case of urinary house-soiling, it seems crucial to double-check whether the cat has a urinary tract disease, which could be the cause of the behavioural problem and needs to be treated. Faecal house-soiling could also be related to gastroenteric and musculoskeletal disorders, while concurrent urinary and faecal house-soiling seem to be more linked to a cat's behavioural preference/aversions and litter box management. Meeting cats' preferences for litter type, litter box type and location are recommended, as well as strict cleanliness of the litter and litter boxes. Overall, cat owners need to be educated on this matter when they acquire a kitten or adopt an adult cat to prevent the development of this behavioural problem, or deal with it.

Supplementary material The following files are available online:

Supplementary Table 1 (S1): The online survey of cat owners in Italy used by Tateo et al.[25]

Supplementary Table 2 (S2): Description of numeric and categorical variables considered in the descriptive analysis.

Supplementary Table 3 (S3): Description of numeric and categorical variables considered in the descriptive analysis and univariable regression model for the subset of respondents who provided their cats with two or more litter boxes.

Supplementary Table 4 (S4): Breakdown of all respondents' answers.

Supplementary Table 5 (S5): Wald test P values of the univariable binary logistic regressions for the predictive variables associated with the expression of house-soiling reported in the responses (n = 3106) to a survey on house-soiling in Italian cats.

Supplementary Table 6 (S6). Wald test P values of the univariable binary logistic regressions for the predictive variables associated with the expression of urinary house-soiling reported in a subset of the responses (n = 520) to a survey on house-soiling in Italian cats.

Supplementary Table 7 (S7): Wald test P values of the univariable binary logistic regressions for the predictive variables associated with the expression of faecal house-soiling reported in a subset of the responses (n = 520) to a survey on house-soiling in Italian cats.

Supplementary Table 8 (S8): Wald test P values of the univariable binary logistic regressions for the predictive variables associated with the concurrent expression of urinary and faecal house-soiling reported in a subset of the responses (n = 520) to a survey on house-soiling in Italian cats.

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