Research

Development of behavior in adopted shelter kittens after gonadectomy performed at an early age or at a traditional age

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ABSTRACT

Prepubertal gonadectomy (PPG) is promoted for population control in cats, but concerns related to health and behavior still exist. From a behavioral point of view, in order for PPG to be an acceptable alternative for traditional-age gonadectomy (TAG), the occurrence of undesirable behavior should be unaffected by age at gonadectomy. The aims of this study were to investigate (1) whether the average number of (potentially) undesirable behaviors in shelter kittens during 24 months after adoption was associated with the age at gonadectomy and (2) whether social or environmental factors were related to the occurrence of commonly reported undesirable behaviors (inappropriate elimination, fearfulness, aggression, and destruction). Eight hundred healthy kittens between the estimated age of 8 and 12 weeks (0.7 and 1.4 kg) were recruited from animal shelters in Flanders, Belgium. Before adoption, kittens were randomly assigned to a PPG group (gonadectomy on assignment) and a TAG group (gonadectomy between 6 and 8 months of age). Online short- and long-term follow-ups were conducted using a 30-day diary immediately after adoption and surveys at 2, 6, 12, 18, and 24 months after adoption. Mean number of potentially undesirable behaviors per day during the first month after adoption was not significantly different between PPG (1.48 ± 0.957) and TAG (1.39 ± 0.899) kittens ($P = 0.32$) and neither was the evolution of the mean number of potentially undesirable behaviors and undesirable behaviors during the long-term follow-up ($P = 0.0946$ and $P = 0.10$, respectively). The occurrence of inappropriate elimination, fearful behavior, non−play-related aggression, and destruction was associated with other social and environmental variables (e.g., the use of punishment by the owner and friendliness toward a stranger). In conclusion, this study in shelter cats did not demonstrate an effect of age at the time of gonadectomy on the mean number of (potentially) undesirable behaviors during 24 months after adoption. Other factors seem to play a more dominating role in the development of such behaviors.

Introduction

To date, surgical gonadectomy in cats is the most reliable and permanent method of contraception (Looney et al., 2008; Reichler 2009; ACC&D 2013). Traditionally, gonadectomy is performed around the age of 6 months or later (Stubbs et al., 1995; Olson et al., 2001; Root Kustritz 2007), but at that age, some cats will have already entered puberty and are able to produce litters (Jemmett and Evans 1977; Jackson 1984). Consequently, to ensure that adopted cats from shelters will not reproduce, prepubertal gonadectomy (PPG) has been promoted (Stubbs et al., 1995; Howe, 1997; Bushby and Griffin, 2011; Joyce and Yates, 2011; Root Kustritz, 2012; Polson et al., 2012; Root Kustritz, 2013).

Concerns about PPG, defined as gonadectomy between 6 and 16 weeks of age (Root Kustritz, 2013), have been voiced in the past, particularly by practicing veterinarians (Spain et al., 2002; Murray et al., 2008). Especially, the risks related to anesthesia and surgery and the possible development of certain medical conditions (e.g., obesity, feline urinary tract diseases, delayed physeal closure time, and so forth) were debated. To date, however, several studies have established safe anesthetic and surgical protocols for PPG

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(Porters et al., 2014; Porters et al., manuscript in revision; Aronsohn and Faggella 1993; Faggella and Aronsohn, 1993; Howe, 1997; Robertson et al., 2003; Robertson, 2007; Joyce and Yates, 2011; Bushby, 2013). Furthermore, a number of studies have investigated physical development (e.g., diameter of the urethra, body weight, physeal closure time) after early-age neutering in cats without significant differences between cats neutered at 7 weeks or 7 months (Root et al., 1996; Stubbs et al., 1996; Root et al., 1997). Finally, there have also been concerns about the behavioral development after PPG in cats. Because PPG is performed during the sensitive socialization period, which lasts until 9-10 weeks of age (McCune, 1995; Adamelli et al., 2005; Overall et al., 2005), this intervention might affect the behavioral development, resulting in behavior problems.

Commonly reported behavior problems in cats are inappropriate elimination, fearful behavior, aggression to other cats or people, and destructive behavior (Heidenberger, 1997; Fatjo et al., 2006; Shore et al., 2008; Amat et al., 2009). Behavior problems may be caused by or result in fear and anxiety, thereby affecting animal welfare (Landsberg, 1996; Levine, 2008). Furthermore, many feline behavior problems can be a burden for the owner, affecting the owner–cat bond (Overall et al., 2005). Consequently, the risk for relinquishment or even euthanasia increases (Patronek et al., 1996; Salman et al., 1998; Shore et al., 2003; Casey et al., 2009). In order for PPG to be considered an acceptable alternative for traditional-age gonadectomy (TAG), it should have at least the same advantages without any additional disadvantages compared with TAG.

The link between age at the time of gonadectomy and behavioral development in cats has been scarcely investigated (Stubbs et al., 1996; Howe et al., 2000; Spain et al., 2004; Wright and Amoss 2004). In the experimental study by Stubbs (1996) investigating the physical manifestations after (prepubertal) gonadectomy, behavioral manifestations were also assessed at 12 months of age: sexually intact cats displayed greater intraspecies aggression and less affection toward humans than did cats neutered at 7 weeks or 7 months. In one long-term follow-up study, no differences were detected in two age groups (gonadectomy at <24 and ≥24 weeks of age) for overall behavior problems, destructive behavior, inappropriate elimination, and other miscellaneous behavior problems (Howe et al., 2000). Spain et al. (2004), on the other hand, reported that early-age neutering was associated with a decreased occurrence of hyperactivity and increased shyness in the presence of strangers in both sexes and increased hiding in male cats, but significance disappeared when analysis was restricted to cats whose owners considered the behavior "serious." Unfortunately, the reported studies have one or more methodological limitations. In some cases, a study design relying on an extensive recall ability by the owners of more than 1 year was used (Spain et al., 2004; Howe et al., 2000). Furthermore, the sample size could be quite small (Stubbs et al., 1996). Finally, early-age gonadectomy was sometimes defined as neutering cats up until 22-24 weeks of age (Howe et al., 2000; Spain et al., 2004), and therefore, there is a good chance that some cats would not have been prepubertal. In a more recent study, investigating the prevalence of house soiling and aggression in shelter kittens during the first year after adoption, no significant association between age at the time of gonadectomy (between 6 and 13 weeks or between 5 and 7 months of age) and the behaviors of interest was found (Wright and Amoss, 2004). Data collection occurred prospectively and at several time points but, unfortunately, ended at 52 weeks after adoption. Therefore, a prospective long-term study in cats, with randomized PPG and TAG groups, spanning the postadoption developmental stages into social maturity, is currently lacking.

The present study is part of a larger project on early-age gonadectomy in cats, supported by the Belgian government. The use of the term "behavior problem" was avoided as this is commonly used to refer to a clinical problem, which is difficult to establish without a detailed behavioral history. Instead, the behaviors as reported by the owner were examined, including the "undesirability" thereof, as it is the personal perceptual element which defines the concept of an "undesirable" or "problematic" behavior (Blackwell et al., 2008; Ramos and Mills 2009). Consequently, the term potentially undesirable behavior will be used to describe behavior that is reported by the owner and that might potentially become troublesome to the owner (Blackwell et al., 2008). The term undesirable behavior, on the other hand, refers to behavior that has been indicated by the owner to be truly troublesome or problematic and thus considered to be unacceptable to the owner (Blackwell et al., 2008; Amat et al., 2009). The main aim of the present study was to investigate the effect of age at gonadectomy in both sexes on the mean number of potentially undesirable and undesirable behaviors in shelter cats during the first month after adoption (short term, potentially undesirable behavior only) and during 24 months after adoption (long term, both potentially undesirable behavior and undesirable behavior). Furthermore, the present study also aims to investigate the association of age at gonadectomy and other selected social and environmental factors on the most common (potentially) undesirable behaviors in cats as reported in literature: inappropriate elimination, fearfulness, (non)play-related aggression toward people or animals, and destruction (Heidenberger 1997; Fatjo et al., 2006; Shore et al., 2008; Amat et al., 2009).

Materials and methods

The study protocol was approved by the local Ethical Committee (Faculty of Veterinary Medicine, Ghent University, Belgium) (licence numbers EC 2010/019 and EC 2011/077) and the Deontological Committee (Federal Public Service Health, Food Chain Safety and Environment, Brussels, Belgium).

Animals

Between May 2010 and August 2012, healthy, dewormed, and vaccinated kittens were recruited from animal shelters in Flanders (Belgium). Based on their body weight (between 0.7 and 1.4 kg), kittens were enrolled between the estimated age of 8 and 12 weeks (Lawler 2008). A thorough physical examination was performed to establish the good health of the kittens before they were transported with their littermates to the Faculty of Veterinary Medicine at Ghent University.

The selected kittens were randomly assigned to one of two treatment groups, by a stratified randomization scheme using unequal group sizes (2/3 PPG and 1/3 TAG). Kittens belonging to the PPG group were gonadectomized on assignment and received a microchip for identification at the end of the surgery. In the TAG group, kittens also received a microchip for identification, but gonadectomy was postponed until the age of 6-8 months.

Before preanesthetic examination (PPG) or placing the microchip (TAG), the reaction of the kittens toward a stranger (N.P.) at the Faculty was noted. For this purpose, kittens were first observed and approached while N.P. talked to the kittens. Afterward, kittens were handled and petted. Friendly kittens did not hide, were playful, and easy to manipulate. Shy kittens hid but could be handled and petted without signs of aggression, whereas frightened kittens also hid but when handled tried to escape or showed aggressive behavior. Following the stay of the kittens (PPG and TAG) at the Faculty, the litter was returned to the shelter, and the kittens were offered for adoption.

The length of time that the kittens (PPG and TAG) stayed at the Faculty was 5 days from May 2010 to April 2011 and 1 day only from

April 2011 until August 2012. The reduction in time spent at the Faculty resulted from the fact that, given the observed limited surgical and anesthetic complications, there was no obvious clinical benefit for the long postoperative follow-up period at the Faculty. The stress caused by the environmental changes during transport and temporary housing at the Faculty, however, was deemed to be responsible for the observed increase in the incidence of anorexia and upper respiratory tract diseases compared with the pre-Faculty entry.

The anesthetic and surgical protocols and complication rates in PPG and TAG cats were described in detail elsewhere (Porters et al., manuscript in revision; Porters et al., 2014).

Postadoption survey instrument

Individuals interested in adopting a kitten included in the project received a brochure from the shelter staff containing information about the study, its goals, and the effort required by the new owners. Adopters were asked to sign an informed consent form and provide their contact information. Next, over the course of the following 24 months, the owners received e-mail invitations (and, if necessary, automatic reminders) to complete several Web-based surveys created on a dedicated Microsoft Dynamics CRM platform (ESC, De Pinte, Belgium). Paper copies were available to owners without Internet access.

The surveys were partly based on existing surveys (BSAVA, 2009; Corridan, 2010) and consisted of open-ended or closed questions, the latter mostly being multiple-choice items. The original surveys (in Dutch) are available from the corresponding author.

General information

Immediately after adoption, participants were asked to complete a 17-item survey to obtain general information about the adopter's household (e.g., contact details, family composition, presence of other pets, and the availability of food, toys, litter boxes, scratching posts, and so forth to the kitten). Individuals who adopted more than 1 kitten from the project need to complete this survey only once.

Short-term follow-up

Evidence in literature suggests that kittens are at the highest risk for developing certain behavioral issues (house soiling and aggression toward people or animals) during the first month after adoption (Wright and Amoss, 2004). Consequently, participants were requested to keep a diary for 30 days, starting the day after adoption. Each day, the same 34-item questionnaire was presented, requesting information about the kitten's general activity (feeding and drinking, (solitary) play, litter box use, and outdoor access), reciprocal interaction with other animals (if applicable) and with the owner (affiliative and agonistic interactions, including use of punishment by the owner, proximity to owner or other family members, and the time spent home alone by the kitten), and the occurrence of potentially undesirable behavior (inappropriate urination, defecation, and urine marking; (non)social fearful behavior; (non)play-related aggression toward people or animals; destruction; excessive vocalization; pica; and sucking on fabric). In addition, owners were asked to rate on a 10-point Likert scale how satisfied they were with their kitten (Corridan, 2010).

Long-term follow up

At 2, 6, 12, 18, and 24 months after adoption, owners were asked to fill out an identical survey containing 75 questions to obtain information about the behavior and medical condition of the kitten, the attitude of the owner, and living conditions. Except for pica, sucking on fabric, and play-related aggression to animals, the occurrence of the same list of potentially undesirable behaviors as mentioned in the diary was investigated. In addition, the following behaviors were inquired: negative interaction with other animals, excessive activity, the tendency to keep to itself, attention seeking, disobedience, stealing food, excessive or inadequate coat care, hunting, and sexual behavior. When owners indicated one of these potentially undesirable behaviors, they were asked to state whether the behavior bothered them, in which case it was also counted as an undesirable behavior. Owners were asked whether their cat had shown the following behaviors during the past month or during the past 4 or 6 months for the survey at 2, 6, and 12, 18, and/or 24 months after adoption, respectively. Other aspects that were covered in the survey were as previously mentioned for the diary, with the addition of certain cat-related factors (medical condition, adapted to the household, and solely entertainment), owner-related factors (using advice about cat's behavior), and environment-related factors (number, type and cleaning frequency of litter box, distance between litter box and feeding bowl, (un)limited feeding regimen, feeding enrichment, use of scratching posts, and changes in daily routine).

Statistical analysis

The inclusion criteria for the kittens in the data analysis were: kittens were adopted within 30 days after their stay at the Faculty (variation in age of kittens limited to 8 weeks), kittens in foster families were not adopted by those families, at least 3 days of the diary had been filled out by the owners (short-term follow-up), surveys (long-term follow up) were filled out within a specific period after the invitation (60 days for the survey at 2 months and 90 days for the survey at 6, 12, 18, and 24 months after adoption), and cats had not been rehomed after adoption and had not been seen by a behavior consultant.

Effect of group and gender on the mean number of (potentially) undesirable behavior

Before analysis, data were tested for normality and equal distribution of male and female cats in the PPG and TAG groups using a χ^2 test. If data were not normally distributed, a $\log_{10}$ transformation of the data was performed for analysis, and results were reported as back transformed means ± standard deviation.

Short-term follow-up. The mean number of potentially undesirable behavior was calculated as the sum of the reported behaviors per kitten divided by the number of days the diary was completed by the owner. To examine the effects of age at gonadectomy and gender, a linear model was fitted with group, gender, and the interaction between group × gender as fixed effects. If gender and/or group × gender were not significant, they were removed from the model.

Long-term follow-up. A similar model as for the short-term follow-up was developed to assess the evolution of the mean number of potentially undesirable and undesirable behaviors over time with group, gender, and time (2, 6, 12, 18 and 24 months after adoption) and interactions among these as fixed effects.

Identification of social and environmental factors associated with common (potentially) undesirable behaviors
Short-term follow-up. Responses of the diary were transformed to binary responses for each of the selected potentially undesirable behaviors reported: a score of 0 was assigned if the behavior was reported less than 3 times, to exclude accidentally performed behaviors in the analysis. A logistic regression model was fitted for each behavioral outcome and investigated the effect of the

Table 1
Selection and ranking of 10 social and nonsocial environmental factors according to expected biological relevance for 5 undesirable behaviors

	Inappropriate elimination	Fearful behavior	Non−play-related aggression (people)	Play-related aggression (people)	Destruction
1.	Maintenance litter boxes	Reaction as kitten to stranger	Reaction as kitten to stranger	Outdoor access	Outdoor access
2.	Number of litter boxes compared with the number of cats in household	Punishment	Punishment	Positive interaction	Positive interaction
3.	Type of litter box (open and closed)	Outdoor	Adaptation to household	Punishment	Feeding enrichment
4.	Distance between litter box and food bowl	Adaptation to household	Changes in daily routine	Play	Solely entertainment
5.	Outdoor access	Changes in daily routine	Medical condition	Proximity	Feeding regimen
6.	Medical condition	Proximity	Outdoor access	Feeding regimen	Play
7.	Adaptation to household	Play	Feeding regimen	Reaction as kitten to stranger	Use of scratch post as a resting place
8.	Changes in daily routine	Positive interaction	Play	Adaptation to household	Proximity
9.	Reaction as kitten to stranger	Solely entertainment	Positive interaction	Changes in daily routine	Reaction as kitten to stranger
10.	Punishment	Other cat in household	Proximity	Other cat in household	Other cat in household

previously mentioned social and environmental factors on the response. Retention of those factors was verified by means of backward elimination technique.

Long-term follow-up. A longitudinal logistic regression model was fitted for each undesirable behavior of interest, with as fixed effects group, time, group × time, and 10 social and/or environmental covariates, selected based on their expected biological relevance for the particular behavioral outcome (Table 1). During the model-building process, insignificant variables were removed one at a time, starting with the least biologically relevant one.

For the short-term and the long-term follow-ups, group and the interaction group × time, respectively, were always retained in the model, irrespective of their significance. Cutoff for retention of social and environmental factors in the models was set at $P = 0.10$, given the large number of covariates. Thereby, statistical trends ($0.05 \leq P < 0.10$) were also reported. For the variables retained in the models, odds ratios (OR) and 95% confidence intervals were calculated.

Continuous variables were expressed as mean (± standard deviation) and categorical variables as the proportion of kittens (number or percentage) belonging to a specific category.

All data were exported from the CRM platform to excel 2010. The analysis was performed in SAS version 9.2 (SAS Institute Inc). Significance was set at 0.05.

Results

Of a total of 800 recruited kittens, the general information survey was completed for 678 kittens (PPG, n = 465 and TAG, n = 213). For most of the kittens, the responding owner was a female (PPG, 65% and TAG, 62%), between 18 and 38 years of age (PPG, 60% and TAG, 65%), and without children (PPG, 56% and TAG, 62%). Most kittens lived in a house (PPG, 81% and TAG, 80%) and/or had access to a garden, a terrace, and/or a court (PPG, 91% and TAG, 91%). More than half of all PPG and TAG kittens (59%) lived together with at least one other cat in the household (mean, 1.5 ± 1.5; range, 1-15 cats). Ninety-five respondents had adopted more than 1 kitten: 45 owners adopted 1 PPG kitten and 1 TAG kitten; 39 owners adopted 2 PPG kittens; 7 owners adopted 2 TAG kittens; 2 owners adopted 3 PPG kittens; 1 owner adopted 2 PPG kittens and 1 TAG kitten; and 1 owner adopted 4 PPG kittens and 1 TAG kitten.

During the short-term follow-up, the diary was completed for 612 kittens. After the application of inclusion criteria, data on 480 kittens (PPG, n = 334 and TAG, n = 146) were retained for analysis. On average, compliant owners completed 22 ± 9.5 days of the diary. The gender distribution for kittens in the PPG (164 males

and 170 females) and TAG (68 males and 78 females) groups was not significantly different ($\chi^2 = 0.2597$; df = 1; $P = 0.61$).

During the long-term follow-up, 1456 of 2072 potential surveys were completed. According to the inclusion criteria, data of 1250 surveys of 495 kittens (PPG, n = 345 and TAG, n = 150) were retained for the longitudinal analysis (Table 2). Long-term data until 24 months after adoption could not be collected for every recruited kitten because of the end date of the project. There was also some dropout of kittens (91 of 465 PPG and 35 of 213 TAG) throughout the study, but the response rate per survey remained high. The gender distribution for kittens in the PPG (165 males and 180 females) and TAG (77 males and 73 females) groups was also not significantly different in the long-term follow-up ($\chi^2 = 0.5147$; df = 1; $P = 0.47$).

Table 2
Potentially undesirable behaviors included in the short-term follow-up and the number (%) of kittens in the early gonadectomy (PPG, n = 334) and traditional-age gonadectomy (TAG, n = 146) groups that displayed them

Potentially undesirable behavior	Group	Kittens[a], n (%)	Mean ± SD, per day
Inappropriate elimination	PPG	49 (14.7)	0.058 ± 0.13
	TAG	20 (13.7)	0.064 ± 0.14
Fearful behavior (people and animals)	PPG	83 (24.9)	0.12 ± 0.21
	TAG	32 (21.9)	0.10 ± 0.18
Fearful behavior (movement and noise)	PPG	160 (47.9)	0.21 ± 0.26
	TAG	61 (41.8)	0.17 ± 0.21
Non−play-related aggression (people)	PPG	45 (13.5)	0.056 ± 0.13
	TAG	14 (9.6)	0.047 ± 0.11
Non−play-related aggression (animals)	PPG	33 (9.9)	0.045 ± 0.13
	TAG	13 (8.9)	0.049 ± 0.14
Play-related aggression (people)	PPG	221 (66.2)	0.36 ± 0.33
	TAG	93 (63.7)	0.37 ± 0.33
Play-related aggression (animals)	PPG	29 (8.7)	0.044 ± 0.16
	TAG	9 (6.2)	0.032 ± 0.14
Destruction	PPG	193 (57.8)	0.30 ± 0.30
	TAG	88 (60.3)	0.30 ± 0.29
Excessive vocalization	PPG	25 (7.5)	0.028 ± 0.094
	TAG	9 (6.2)	0.026 ± 0.088
Pica	PPG	13 (3.9)	0.019 ± 0.063
	TAG	5 (3.4)	0.024 ± 0.080
Sucking on fabric	PPG	122 (36.5)	0.23 ± 0.32
	TAG	56 (38.4)	0.20 ± 0.27

PPG, prepubertal gonadectomy; SD, standard deviation.
The daily averages of each potentially undesirable behavior, calculated across the kittens within the PPG and TAG groups, are also shown.
[a] Kittens displayed a specific potentially undesirable behavior if this behavior was at least 3 days reported in the diary to exclude accidentally performed behaviors in the analysis.

Effect of group and gender on the mean number of (potentially) undesirable behaviors

Short-term follow-up

Of the 480 kittens included for analysis, only 10 kittens were reported by their owner not to show any of the potentially undesirable behaviors during the first month after adoption. The most frequently reported potentially undesirable behaviors in PPG and TAG kittens were play-related aggression toward people, destruction, sucking on fabric, and fearful behavior (toward noise and/or movement) (Table 3). The mean number of potentially undesirable behaviors per day did not differ significantly between PPG kittens (1.48 ± 0.957) and TAG kittens (1.39 ± 0.899) ($P = 0.32$). There was a tendency ($P = 0.055$) that male kittens, irrespective of the age at gonadectomy, exhibited on average more potentially undesirable behaviors per day during the first month after adoption compared with female kittens (1.50 ± 0.980 and 1.37 ± 0.893, respectively).

Long-term follow-up

At 2, 6, 12, 18, and 24 months after adoption, the percentage of kittens displaying at least one potentially undesirable behavior ranged between 89.5% (2 months) and 98.6% (24 months). In almost half of the cases, the behaviors were disturbing to the owner; hence, they were termed as undesirable behaviors (Table 1). In PPG and TAG cats, the most frequently reported potentially undesirable behaviors at each time point were hunting, destruction, sexual behavior, fearful behavior, and attention seeking. Common undesirable behaviors were destruction, stealing food, and (non)play-related aggression toward people (Table 4). As can be seen in Figures 1 and 2, evolution over time of the mean number of potentially undesirable behaviors and undesirable behaviors, respectively, was comparable for PPG and TAG cats. The mean number of potentially undesirable behaviors rose slightly, without statistical significance between PPG and TAG cats ($P = 0.095$). In PPG cats, the mean number of undesirable behaviors also slightly increased over time, whereas it decreased slightly for TAG cats, but this difference was not statistically significant ($P = 0.10$). There was also a numerical, but not statistically significant, decrease in mean number of (potentially) undesirable behaviors in PPG and TAG cats for the survey at 12 months after adoption.

Identification of social and environmental factors associated with common (potentially) undesirable behaviors

Short-term follow-up

Unlike age at gonadectomy, other variables were found to be significantly associated with the occurrence of the potentially undesirable behaviors of interest: inappropriate elimination, fearful behavior, (non)play-related aggression toward people or animals, and destruction (Table 5). The OR provided an indication of the effect (<1.0 represents a decrease and >1.0 an increase) of each class of a specific categorical variable compared with a predefined reference value (for the same categorical variable) on the response under investigation, when all other variables are fixed (average value for continuous variables and reference value for categorical variables). For example, use of physical punishment was associated with a 12-fold increase (OR = 12.242) in inappropriate elimination compared with no use of punishment. Summarizing Table 4, during the first month after adoption, cats whose owners used verbal and/or physical punishment, as opposed to no punishment, had a greater chance to show inappropriate elimination and to display fearful behavior in response to noises and/or movements, play-related aggression, or destructive behavior. Second, single cats were more likely to behave aggressively during play and be fearful in response to noises and/or movements than cats living in a multicat household. Third, compared with those reacting friendly to a stranger (N.P.) as kittens, kittens responding shy or frightened were more likely to be fearful and aggressive to family members in non–play-related contexts. Fourth, spending less time in the proximity of the owner or family members was associated with being more fearful in response to noises and/or movements and displaying more inappropriate elimination.

Long-term follow-up

Evolution over time of most undesirable behaviors of interest was not significantly different between PPG and TAG cats. Only for destruction, the interaction between group and time was significant ($P = 0.034$), implying that the evolution of the occurrence of destruction over time differs between PPG and TAG cats. More specifically, at 8.24 months after adoption (weighted mean based on the time points and observations at each time point), PPG cats were more likely to display undesired destructive behavior than TAG cats, but numerically, this increase was barely different from 1.0 (OR = 1.047; range, 0.721-1.520).

Non–play-related aggression toward animals could not be analyzed because of the very low frequency of this behavior for both PPG and TAG cats, but various other variables were found to be associated with the occurrence of the undesirable behaviors of interest (Table 6). Being punished verbally and/or physically was associated with an increase in cats displaying (non)play-related aggression toward people and destructive behavior compared with cats that were not punished. On the other hand, cats that were punished verbally and/or physically were less likely to behave fearful compared with cats whose owners did not use punishment. Having positive interaction with the owner or other family members at least 2-3 times per day was associated with a greater chance of destruction, fearful behavior, and play-related aggression toward people but a lesser chance of showing non–play-related aggression toward the owner or other family members. Also, single cats were more likely to be destructive than cats living in a multicat

Table 3
Distribution of completed and analyzed surveys during the long-term follow-up and the number (%) of cats with at least one (potentially) undesirable behavior at 2, 6, 12, 18, and 24 months after adoption from a shelter

Time points of long-term follow-up surveys (months after adoption)	2	6	12	18	24
Cats available per survey[a]	649	616	402	275	130
Number of cats survey completed	497	402	284	173	79
Response rate (%)	76.6	65.3	70.6	62.9	60.8
Number of cats survey analyzed[b]	430	357	242	151	70
Number of cats with at least one potentially undesirable behavior, n (%)	385 (89.5)	333 (93.3)	234 (96.7)	144 (95.4)	69 (98.6)
Number of cats with at least one undesirable behavior, n (%)	195 (45.3)	172 (48.2)	96 (39.6)	65 (43.0)	33 (47.1)

[a] Number of cats available per survey decreases toward the end of project, ending date of the project did not permit a follow-up of every kitten until 24 months after adoption.

[b] Taking into account the inclusion criteria, kittens were adopted within 30 days after their stay at the Faculty, surveys were filled out within a specific period after the invitation (60 days for the survey at 2 months and 90 days for the survey at 6, 12, 18, and 24 months after adoption), cats had not been rehomed after adoption, and had not been seen by a behavior consultant.

Table 4
Potentially undesirable and undesirable behaviors included in the long-term follow-up and the number (%) of cats in the prepubertal gonadectomy group (PPG, n = 295, 240, 186, 114, and 55 at 2, 6, 12, 18, and 24 months after adoption, respectively) and traditional-age gonadectomy group (TAG, n = 135, 117, 56, 37, and 15 at 2, 6, 12, 18, and 24 months after adoption) that displayed them

| Behaviors	Group	Time points of long-term surveys (months after adoption)									
		2		6		12		18		24	
		Potentially undesirable	Undesirable	Potentially undesirable	Undesirable	Potentially undesirable	Undesirable	Potentially undesirable	Undesirable	Potentially undesirable	Undesirable
Inappropriate elimination	PPG	12 (4.1)	12 (4.1)	8 (3.3)	8 (3.3)	6 (3.2)	6 (3.2)	4 (3.5)	4 (3.5)	1 (1.8)	1 (1.8)
	TAG	1 (0.7)	1 (0.7)	2 (1.7)	2 (1.7)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Fearful behavior	PPG	39 (13.2)	3 (1.0)	76 (31.7)	6 (2.5)	6 (32.2)	1 (0.5)	49 (43.0)	2 (1.8)	21 (38.2)	1 (1.8)
	TAG	17 (12.6)	0 (0)	29 (24.8)	1 (0.9)	14 (25.0)	0 (0)	9 (24.3)	0 (0)	2 (13.3)	0 (0)
Non−play-related behavior (people)	PPG	19 (6.4)	11 (3.7)	28 (11.7)	11 (4.6)	9 (4.8)	2 (1.1)	10 (8.8)	6 (5.3)	6 (10.9)	5 (9.1)
	TAG	12 (8.9)	7 (5.2)	10 (8.5)	6 (5.2)	6 (10.7)	3 (5.4)	4 (10.8)	4 (10.8)	1 (6.7)	1 (6.7)
Non−play-related behavior (animals)	PPG	1 (0.3)	0 (0)	3 (1.3)	1 (0.4)	6 (3.2)	2 (1.1)	3 (2.6)	0 (0)	0 (0)	0 (0)
	TAG	1 (0.7)	1 (0.7)	2 (1.7)	0 (0)	1 (1.8)	0 (0)	1 (2.7)	1 (2.7)	1 (6.7)	0 (0)
Play-related behavior (people)	PPG	23 (7.8)	13 (4.4)	21 (8.8)	12 (5.0)	12 (6.5)	5 (2.7)	10 (8.8)	7 (6.1)	1 (1.8)	1 (1.8)
	TAG	15 (11.1)	12 (8.9)	15 (12.8)	9 (7.7)	5 (8.9)	2 (3.6)	5 (13.5)	3 (8.1)	5 (33.3)	2 (13.3)
Destruction	PPG	117 (39.7)	79 (26.8)	102 (42.5)	67 (27.9)	75 (40.3)	46 (24.7)	39 (34.2)	24 (21.1)	22 (40.0)	16 (29.1)
	TAG	64 (47.7)	45 (33.1)	55 (47.0)	33 (28.2)	23 (41.1)	12 (21.4)	14 (37.8)	8 (21.6)	5 (33.3)	1 (6.7)
Negative interaction with animals	PPG	3 (1.0)	2 (0.7)	6 (2.5)	2 (0.8)	3 (1.6)	1 (0.5)	7 (6.1)	2 (1.8)	3 (5.5)	3 (5.5)
	TAG	3 (2.2)	3 (2.2)	4 (3.4)	3 (2.6)	0 (0)	0 (0)	1 (2.7)	0 (0)	0 (0)	0 (0)
Excessive vocalization	PPG	38 (12.9)	13 (4.4)	34 (14.2)	12 (5.0)	29 (15.6)	5 (2.7)	16 (14.0)	2 (1.8)	9 (16.4)	1 (1.8)
	TAG	19 (14.1)	6 (4.4)	24 (20.5)	7 (6.0)	9 (16.1)	1 (1.8)	9 (24.3)	3 (8.1)	3 (20.0)	1 (6.7)
Excessive activity	PPG	40 (13.6)	10 (3.4)	27 (11.3)	5 (2.1)	15 (8.1)	4 (2.2)	12 (10.5)	3 (2.6)	3 (5.5)	1 (1.8)
	TAG	23 (17.0)	5 (3.7)	29 (24.8)	4 (3.4)	4 (7.1)	0 (0)	3 (8.1)	1 (2.7)	2 (13.3)	0 (0)
Tendency to keep to itself	PPG	5 (1.7)	0 (0)	10 (4.2)	1 (0.4)	9 (4.8)	0 (0)	8 (7.0)	0 (0)	3 (5.5)	0 (0)
	TAG	1 (0.7)	0 (0)	2 (1.7)	2 (1.7)	1 (1.8)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Attention seeking	PPG	80 (27.1)	5 (1.7)	74 (30.8)	4 (1.7)	54 (29.0)	1 (0.5)	25 (21.9)	2 (1.8)	16 (29.1)	3 (5.5)
	TAG	57 (42.2)	4 (3.0)	50 (42.7)	2 (1.7)	13 (23.2)	0 (0)	11 (29.7)	1 (2.7)	3 (20.0)	0 (0)
Disobedience	PPG	23 (7.8)	10 (3.4)	30 (12.5)	9 (3.8)	10 (5.4)	3 (1.6)	10 (8.8)	5 (4.4)	3 (5.5)	1 (1.8)
	TAG	15 (11.1)	6 (4.4)	11 (9.4)	5 (4.3)	5 (8.9)	0 (0)	2 (5.4)	2 (5.4)	1 (6.7)	0 (0)
Stealing food	PPG	71 (24.1)	58 (19.7)	66 (27.5)	50 (20.8)	45 (24.4)	25 (13.4)	25 (21.9)	15 (13.2)	112 (21.8)	10 (18.2)
	TAG	39 (28.9)	27 (20.0)	40 (34.2)	26 (22.2)	17 (30.4)	6 (10.7)	14 (37.8)	7 (18.9)	6 (40.0)	3 (20.0)
Excessive coat care	PPG	7 (2.4)	0 (0)	9 (3.8)	2 (0.8)	8 (4.3)	2 (1.1)	4 (3.5)	0 (0)	1 (1.8)	1 (1.8)
	TAG	3 (2.2)	0 (0)	3 (2.6)	0 (0)	5 (8.9)	1 (1.8)	2 (5.4)	0 (0)	0 (0)	0 (0)
Inadequate coat care	PPG	1 (0.3)	0 (0)	1 (0.4)	1 (0.4)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.8)	0 (0)
	TAG	1 (0.7)	0 (0)	0 (0)	0 (0)	1 (1.8)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hunting	PPG	123 (41.7)	2 (0.7)	138 (57.5)	1 (0.4)	150 (80.6)	6 (3.2)	82 (71.9)	2 (1.8)	47 (85.5)	3 (5.5)
	TAG	69 (51.1)	0 (0)	69 (59.0)	1 (0.9)	45 (80.4)	1 (1.8)	27 (72.9)	3 (8.1)	12 (80.0)	0 (0)
Sexual behavior	PPG	123 (41.7)	0 (0)	65 (27.1)	1 (0.4)	83 (44.6)	0 (0)	52 (45.6)	0 (0)	23 (41.8)	2 (3.6)
	TAG	63 (46.7)	0 (0)	46 (39.3)	0 (0)	23 (41.1)	0 (0)	14 (37.8)	0 (0)	5 (33.3)	0 (0)

household. Although cats being shy or frightened to a stranger (N.P.) as kittens were less likely to behave aggressively during play or to be destructive, they were more likely to show inappropriate elimination and fearful behavior compared with cats who behaved friendly as a kitten.

Discussion

The present study was designed to provide short- and long-term information regarding behavioral characteristics in shelter cats undergoing PPG compared with TAG. To our knowledge, this is the only prospective study to date, with randomized PPG and TAG
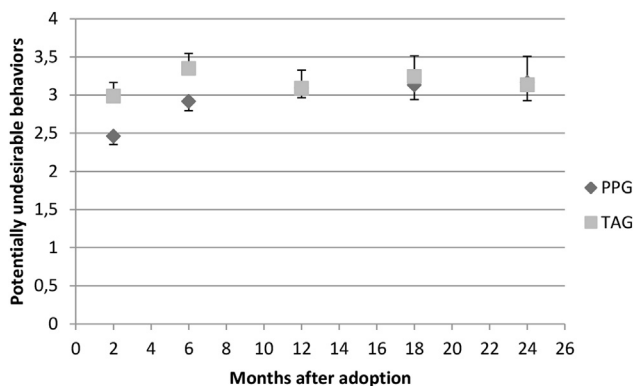
Figure 1. Evolution over time of the mean number ± SEM of potentially undesirable behaviors of prepubertal gonadectomy (PPG) and traditional-age gonadectomy (TAG) groups as reported by the owner in the long-term survey at 2, 6, 12, 18, and 24 months after adoption from a shelter.
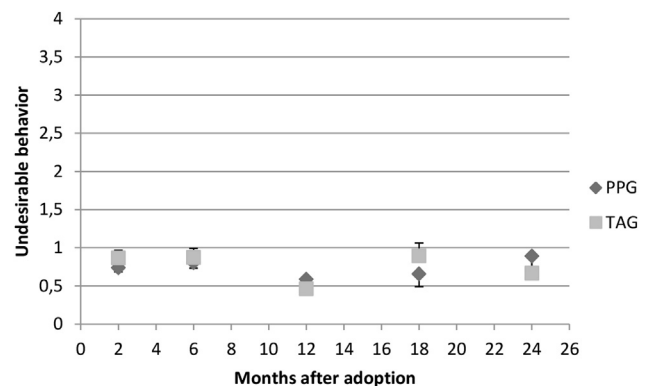
Figure 2. Evolution over time of the mean number ± SEM of undesirable behaviors of the prepubertal gonadectomy (PPG) and the traditional-age gonadectomy (TAG) groups as reported by the cat owner in the long-term survey at 2, 6, 12, 18, and 24 months after adoption from a shelter.

Table 5
Variables associated ($P < 0.05$ and $0.05 \leq P < 0.10$) with the occurrence of potentially undesirable behaviors in kittens during the first month after adoption from a shelter

Potentially undesirable behavior	Variable	P value	Variable values	OR (95% CL)
Inappropriate elimination	Proximity	0.0371	**At least half of the time that family members are home (≥50% D)**	—
			Less than half of the time that family members are home (<50% D)	1.894 (1.039-3.454)
	Negative interaction (animals)	0.0519	**No or occasionally (<20% D)**	—
			Frequently (at least once per d in ≥20% D)	1.824 (0.995-3.344)
	Punishment	0.0521	**No punishment**	—
			Verbal	5.002 (1.587-15.770)
			Physical	12.242 (1.481-101.200)
			Verbal and physical	3.485 (1.175-10.340)
	Duration interaction	0.0554	One min increase	0.997 (0.993-1.000)
Fearful behavior (people/animals)	Reaction of kitten to stranger	<0.0001	**Friendly**	—
			Shy	3.771 (1.995-7.128)
			Frightened	5.361 (2.383-12.057)
	Proximity	0.0008	**At least half of the time that family members are home (≥50% D)**	—
			Less than half of the time that family members are home (<50% D)	2.242 (1.400-3.591)
	Time spent alone	0.0010	**Less frequently 3 h per d (<70% D)**	—
			Frequently at least 3 h per d (≥70% D)	2.300 (1.401-3.776)
	Negative interaction (animals)	0.0065	**No or occasionally (<20% D)**	—
			Frequently (once per d in ≥20% D)	1.990 (1.212-3.265)
Fearful behavior (noises/movements)	Punishment	0.0001	**No punishment**	—
			Verbal	2.402 (1.294-4.461)
			Physical	1.851 (0.402-8.531)
			Verbal and physical	3.598 (2.089-6.197)
	Proximity	0.0121	**At least half of the time that family members are home (≥50% D)**	—
			Less than half of the time that family members are home (<50% D)	1.729 (1.127-2.652)
	Other cat in household	0.0141	**No other cat present**	—
			At least one other cat present	0.619 (0.421-0.908)
	Reaction as kitten to stranger	0.0322	**Friendly**	—
			Shy	2.553 (1.342-4.856)
			Frightened	1.312 (0.589-2.924)
Non–play-related aggression (people)	Reaction of kitten to stranger	0.0027	**Friendly**	—
			Shy	2.704 (1.266-5.775)
			Frightened	3.773 (1.597-8.910)
	Gender	0.0148	**Female**	—
			Male	2.045 (1.150-3.636)
Non–play-related aggression (animal)	Negative interaction (animals)	<0.0001	**No or occasionally (<20% D)**	—
			Frequently (once per d in ≥20% D)	9.226 (4.452-19.120)
	Other cat in household	0.0070	**No other cat present**	—
			At least one	3.107 (1.364-7.079)
Play-related aggression (people)	Punishment	<0.0001	**No punishment**	—
			Verbal	2.949 (1.509-5.763)
			Physical	2.706 (0.379-19.305)
			Verbal and physical	5.017 (2.798-8.997)
	Other cat in household	0.0005	**No other cat present**	—
			At least one other cat present	0.422 (0.259-0.688)
	Gender	0.00221	**Female**	—
			Male	1.718 (1.081-2.731)
	Time spent alone	0.0243	**Less frequently (<70% D at least 3 h per d)**	—
			Frequently (≥70% D at least 3 h per d)	0.554 (0.332-0.926)
	Duration interaction	0.0474	One min increase	1.003 (1.000-1.005)
	Negative interaction (animals)	0.0499	**No or occasionally (<20% D)**	—
			Frequently (once per d in ≥20% D)	1.736 (1.000-3.013)
Destruction	Punishment	<0.0001	**No punishment**	—
			Verbal	4.261 (2.351-7.721)
			Physical	2.625 (0.607-11.349)
			Verbal and physical	6.229 (3.689-10.520)
	Outdoor access	0.0410	**Outdoor access (≥25% D)**	—
			Rarely outdoor access (<25% D)	1.564 (1.018-2.401)

D = number of completed days in the diary (during the first month after adoption).
The effect of the different variable values compared with the variable reference value (bold) is shown by odds ratios (OR) and their respective 95% confidence limits (95% CL).

groups and short-term and long-term follow-ups, spanning the postadoption developmental stages into social maturity. In shelter cats, age at the time of gonadectomy (8-12 weeks vs. 6-8 months of age) did not affect the mean number of potentially undesirable behaviors during the first month after adoption nor the evolution over time of (potentially) undesirable behavior during 24 months after adoption. The nonsignificant numerical decrease in mean number of (potentially) undesirable behaviors in PPG and TAG cats around 12 months after adoption could be associated with a post-puberty phase (Beaver, 2003a; Beaver, 2003b). Also, no association

Table 6
Variables associated ($P < 0.05$ and $0.05 \leq P < 0.10$) with the occurrence of undesirable behaviors in cats during the long-term follow-up (surveys at 2, 6, 12, 18, and 24 months after adoption from a shelter)

Undesirable behavior	Variable	P value	Variable values	OR (95% CL)
Inappropriate elimination	Reaction as kitten to stranger	0.0013	**Friendly**	—
			Shy	0.204 (0.028-1.465)
			Frightened	4.099 (1.784-9.417)
	Number of litter boxes compared with number of cats in household	0.0342	**Greater number**	—
			No litter box	0.229 (0.052-1.014)
			Equal number	0.548 (0.155-1.946)
			Smaller number	1.121 (0.316-3.973)
Fearful behavior	Reaction as kitten to stranger	<0.0001	**Friendly**	—
			Shy	2.055 (0.544-7.754)
			Frightened	1.724 (0.133-22.409)
	Punishment	<0.0001	**No punishment**	—
			Verbal	0.813 (0.076-8.738)
			Physical	<0.001 (<0.001-0.023)
			Verbal and physical	0.550 (0.032-9.565)
	Proximity	<0.0001	**≥2 to 3 times per d (active and passive)**	—
			<2 to 3 times/d	0.005 (0.001-0.023)
			≥2 to 3 times/d (active)	2.192 (0.809-5.936)
			≥2 to 3 times/d (passive)	2.480 (0.345-17.837)
	Positive interaction	<0.0001	**≥2 to 3 times/d**	—
			<2 to 3 times/d	0.006 (<0.001-0.046)
			≥2 to 3 times/workday	0.015 (0.005-0.047)
			≥2 to 3 times/holiday or weekend day	1.763 (0.373-8.325)
	Solely entertainment	<0.0001	**Regularly**	—
			Rare	6.541 (2.456-17.426)
	Medical condition	<0.0001	**No medical condition**	-
			At least one	1.144 [0.200-6.549]
	Adaptation to household	0.0104	**Adapted**	—
			Not adapted	20.000 (2.299-166.667)
Non–play-related aggression (people)	Positive interaction	<0.0001	**≥2 to 3 times/d**	—
			<2 to 3 times/d	1.221 (0.286-5.207)
			≥2 to 3 times/workday	<0.001 (<0.001-<0.001)
			≥2 to 3 times/holiday or weekend day	1.034 (0.387-2.764)
	Adaptation to household	0.0014	**Adapted**	—
			Not adapted	10.000 (2.915-34.483)
	Punishment	0.0052	No punishment	—
			Verbal	5.719 (0.715-45.727)
			Physical	6.184 (0.662-57.767)
			Verbal and physical	12.337 (1.592-95.613)
	Play	0.0938	**≥1 h/d**	—
			<1 h/d	2.503 (1.059-5.914)
Play-related aggression (people)	Punishment	<0.0001	No punishment	—
			Verbal	73.935 (39.412-138.700)
			Physical	94.666 (34.536-259.488)
			Verbal and physical	257.322 (159.670-414.698)
	Positive interaction	<0.0001	**≥2 to 3 times/d**	—
			<2 to 3 times/d	0.651 (0.203-2.093)
			≥2 to 3 times/workday	0.174 (0.091-0.335)
			≥2 to 3 times/holiday or weekend day	0.995 (0.534-1.854)
	Adaptation to household	0.0002	**Adapted**	—
			Not adapted	13.333 (4.348-40.000)
	Medical condition	0.0002	**No medical condition**	—
			At least one	1.003 (0.510-1.974)
	Changes in daily routine	0.0006	**No changes**	—
			At least one	0.0928 (0.464-1.859)
	Reaction as kitten to stranger	0.0011	**Friendly**	—
			Shy	0.196 (0.053-0.727)
			Frightened	0.613 (0.159-2.353)
Destruction	Punishment	<0.0001	No punishment	—
			Verbal	10.116 (4.048-25.279)
			Physical	10.771 (3.858-30.075)
			Verbal and physical	14.118 (5.503-36.216)
	Positive interaction	<0.0001	**≥2 to 3 times/d**	—
			<2 to 3 times/d	0.743 (0.299-1.847)
			≥2 to 3 times/workday	<0.001 (<0.001-<0.001)
			≥2 to 3 times/holiday or weekend day	0.993 (0.615-1.604)
	Outdoor access	0.0022	**Cat's choice**	—
			Owner's decision	1.745 (1.228-2.477)
			No outdoor access	1.770 (1.214-2.580)
	Feeding enrichment	0.0060	**No feeding enrichment**	—
			At least one	0.459 (0.267-0.790)
	Other cat in household	0.0293	**No other cat present**	—
			At least one other cat present	0.667 (0.494-0.963)
	Group × time	0.0335	**TAG (at 8.24 mo after adoption)**	—
			PPG (at 8.24 mo after adoption)	1.047 (0.721-1.520)
	Reaction as kitten to stranger	0.0673	**Friendly**	—
			Shy	0.620 (0.363-1.059)
			Frightened	0.996 (0.450-2.207)

PPG, prepubertal gonadectomy; TAG, traditional-age gonadectomy.
The effect of the different variable values compared with the variable reference value (bold) is shown by odds ratios (OR) and their respective 95% confidence limits (95% CL).

was found between age at gonadectomy and the frequency of commonly reported (potentially) undesirable behaviors in literature during the short- and long-term follow-ups (Heidenberger, 1997; Fatjo et al., 2006; Shore et al., 2008; Amat et al., 2009).

Notwithstanding the methodological optimization we have attempted in this study, our findings are in agreement with other previously published studies about early-age gonadectomy (Stubbs et al., 1996; Howe et al., 2000; Spain et al., 2004; Wright and Amoss, 2004). In one study, PPG (before 22 weeks of age) compared with TAG was significantly associated with less hyperactivity and more shyness toward strangers when it concerned potentially undesirable behaviors, but the association did not hold for undesirable behaviors (Spain et al., 2004). Most of the potentially undesirable behaviors (e.g., predatory and sexual behavior, scratching, and so forth) that were frequently reported both in the short- and long-term surveys belong to the normal behavioral repertoire of the cat (Landsberg, 1996; Heath, 2007; Radosta, 2011). Destruction was the most commonly reported potentially undesirable behavior during the first month after adoption. A thorough behavior history would be required to discover the underlying causes and motivation, but one could be the lively and inquisitive nature of kittens, resulting in exploration using eyes, paws, and mouth (Landsberg, 1996; Seksel, 2008). Another behavior, play-related aggression, may be because of lack of restraint training by conspecifics during the socialization period and beyond (Crowell-Davis, 2002; Ramos and Mills, 2009; Radosta, 2011) but can also be related to the type of play the owner instigates. Play by the owner using hand and feet is said to trigger aggression directed to these body parts, and the use of rods and other string toys is advised (Heath, 2002; Radosta, 2011). Inappropriate elimination and fearful behavior occurred more frequently during the first month after adoption, suggesting that some kittens had difficulties adapting to their new environment (Wright and Amoss, 2004).

With regard to the long-term follow-up, inappropriate elimination was always indicated as undesirable. Non–play-related aggression toward people, destruction, and stealing food were also often reported as undesirable. These findings are in agreement with other studies indicating that inappropriate elimination and aggression were regarded as serious problems for which people would be motivated to seek behavioral advice (Shore et al., 2008) or consulted a veterinarian and/or behaviorist (Fatjo et al., 2006; Amat et al., 2009). Moreover, destruction is frequently considered an undesirable behavior by cat owners (Morgan and Houpt, 1990; Heidenberger, 1997; Neidhart and Boyd, 2002). Stealing food was only mentioned as an undesirable behavior problem in one other publication (Heidenberger, 1997), possibly because this behavior is more easily managed (by not leaving food out) compared with aggression, elimination, and destruction issues, which often have complex underlying motivations. Aggression involving people was more often reported as being undesirable than aggression toward animals. The latter might affect owners less because they are not the target or they perceive agonistic interactions between animals as normal and, as such, something that should be tolerated (Fatjo et al., 2006).

Our study indicated that factors other than age at the time of gonadectomy were associated with the selected (potentially) undesirable behaviors. Clearly, punishment was associated with a number of (potentially) undesirable behaviors: inappropriate elimination (short-term follow-up), fearful behavior, destruction, play-related aggression to people (short- and long-term follow-ups), and non–play-related aggression toward people (long-term follow-up). A similar result has been found in dogs: the use of punishment was positively correlated with the incidence of problematic behaviors (Hiby et al., 2004) and associated with a higher number of undesirable behaviors (Blackwell et al., 2008). However,

it is important to note that an association does not necessarily also demonstrate causality. In agreement with the reasoning by Blackwell et al. (2008) for dogs, it is possible that, in the present study, cats showing many undesirable behaviors were more likely to be punished compared with cats rarely showing undesirable behaviors. Additionally, it is likely that undesirable behavior occurred more in cats associating punishment with the person punishing or with the context in which punishment occurred rather than with their own behavior. Furthermore, the remarkable finding that cats being punished verbally and physically were less likely to behave fearful than cats whose owners did not use punishment or only used verbal punishment could be explained by the possibility that owners of fearful cats might be inclined to use less severe methods. Another factor that was associated with certain behavioral outcomes during the short-term (fearful behavior and non–play-related aggression to people) and the long-term (inappropriate elimination, fearful behavior, and play-related aggression to people) follow-ups was the response of kittens to a stranger (N.P.) while at the Faculty of Veterinary Medicine. This response is assumed to be reflective of the degree of socialization of a kitten at the time of recruitment. Similarly, other studies indicated that lack of socialization of kittens was associated with an increased risk for showing fearful behaviors later in life (Heidenberger, 1997; Heath, 2007; Casey and Bradshaw, 2008) and for not being friendly toward people (McCune 1995). According to our results and those of a previous study (Amat et al., 2009), housing a single cat was associated with a greater chance for play-related aggression toward people, fearful behavior in response to noises and/or movements (short term), and destruction (long term). Single cats may experience stress associated with living in a more boring social environment (Kendall and Ley 2006) or may not have learned from other cats to moderate their responses in play (Beaver, 2004; Overall et al., 2005). According to the short-term follow-up, cats living in a multicat household were not at a higher risk for one of the most common symptoms of social stress, that is, inappropriate elimination, unlike reported elsewhere (Kendall and Ley, 2006). However, an increase in inappropriate elimination was associated during the long-term follow-up with having less litter boxes than the number of cats in the house, which may be indicative of a risk for social stress at a later stage during development.

The results of this study should be interpreted in view of its strengths and a few limitations. The size of the participating shelters might have caused a bias in the sample of adopters since small, usually privately owned animal shelters might have screened and as such selected adopters more than larger animal shelters. Moreover, owners were informed about the project before adoption of the kitten and the efforts required of them, which might have discouraged some owners. On the other hand, being well informed may have contributed to the response rate remaining high throughout the study in comparison with other longitudinal surveys (Clements et al., 2013).

The perspective adopted to assess behavior was that of the owner, as "undesirability" of behavior may lead to relinquishment of the perpetrating cat. Data were collected by surveys completed by the owner. Without a thorough behavioral history, however, the interpretation of the behavior of the owner, especially regarding underlying motivation, may not always be correct. We have attempted to minimize such errors by asking questions of descriptive nature. Furthermore, the long-term follow-up relied on recall ability as used previously in behavioral studies with cats (Wright and Amoss, 2004; Kendall and Ley, 2006; Kendall and Ley, 2008; Ramos and Mills, 2009) and dogs (Blackwell et al., 2008). To optimize accuracy of the owner's memory, a daily diary was designed for the first month after adoption, and data were gathered at different time points until 24 months after adoption with recall

periods ranging between 1 and 6 months. Finally, the study ended at 24 months after adoption, which does not represent the entire life span of a cat. However, it does permit evaluation of behavioral development into social maturity (Horwitz, 2001; Overall et al., 2005). The fact that not all cats could be monitored until that time, affected the power of the longitudinal follow-up analysis in that no interactions between variables associated with undesirable behaviors could be investigated. In the present study, no highly detailed measures of intensity (e.g., asking owners to classify potentially undesirable and undesirable behaviors as mild, moderate, or severe) or quantity (e.g., daily frequency of behaviors) were included. Instead and for the purpose of not overburdening the respondents, measures of quantity in the short-term follow-up study were based on daily 1-0 data (occurring or not), and intensity was measured in the long-term follow-up by asking owners if behaviors were undesirable.

As mentioned by Scarlett et al. (2002) and as suggested during a discussion on early neutering at the WSAVA/FECAVA/BSAVA Congress (Clark, 2012), neutering cats is not enough to reduce the number of relinquishments. Educating owners and informing them about the normal behavior of cats, their husbandry needs, and the benefits of giving environmental enrichment are very important to prevent unwanted behavior (Overall et al., 2005; Seksel, 2008; Ellis, 2009) and essential to ensure a successful adoption (Patronek et al., 1996; Neidhart and Boyd, 2002; Wright and Amoss, 2004; Shore, 2005). The number and variety of significant social and environmental factors identified during short-term and long-term follow-ups in our study confirm that the ontogeny of behavioral problems can be the result of a complex process, and prevention is definitely better than cure (Hunthausen and Seksel 2002; Scarlett et al., 2002). Veterinarians should routinely inquire owners about animal behavior during health checkups to prevent and allow early detection and timely management of behavioral problems. If indicated, they should refer owners to a behavior specialist (Patronek and Dodman, 1999; Scarlett et al., 2002; Overall et al., 2005; Fatjo et al., 2006; Lord et al., 2008; Seibert and Landsberg, 2008; Seksel, 2008; Roshier and McBride, 2013).

Conclusion

This study found no evidence that age at the time of gonadectomy (PPG vs. TAG) in cats has an effect on the mean number of (potentially) undesirable behaviors or on the occurrence of commonly reported behaviors (inappropriate elimination, non–play-related aggression, fearful behavior, or destruction) in literature during 24 months after adoption from a shelter. Consequently, also from a behavioral point of view, PPG can be recommended for shelter cats. In addition, various social and environmental factors (use of punishment by the owner, single cats, positive interaction with owner or family members, and so forth) associated with the most important (potentially) undesirable behaviors were identified.

Acknowledgments

Conflict of interest

The authors declare that there is no conflict of interest.

References

ACC&D, 2013. Contraception and Fertility Control in Dogs and Cats. Alliance for Contraception in Cats & Dogs. Available at: http://www.stray-afp.org/nl/wp-content/uploads/2013/06/Contraception-and-Fertility-Control-in-Dogs-and-Cats-van-Acc-d-febr-2013.pdf. Accessed June 24, 2013.

Adamelli, S., Marinelli, L., Normando, S., Bono, G., 2005. Owner and cat features influence the quality of life of the cat. Appl. Anim. Behav. Sci. 94, 89–98.

Amat, M., de la Torre, J.L.R., Fatjo, J., Mariotti, V.M., Van Wijk, S., Manteca, X., 2009. Potential risk factors associated with feline behaviour problems. Appl. Anim. Behav. Sci. 121, 134–139.

Aronsohn, M.G., Faggella, A.M., 1993. Surgical techniques for neutering 6- to 14-week-old kittens. J. Am. Vet. Med. Assoc. 202, 53–55.

Beaver, B.V., 2003a. Chapter 5—male feline sexual behavior. In: Feline Behavior, Second Edition. W.B. Saunders, Saint Louis, pp. 164–181.

Beaver, B.V., 2003b. Chapter 6—female feline sexual behavior. In: Feline Behavior, Second Edition. W.B. Saunders, Saint Louis, pp. 182–211.

Beaver, B.V., 2004. Fractious cats and feline aggression. J. Feline Med. Surg. 6, 13–18.

Blackwell, E.J., Twells, C., Seawright, A., Casey, R.A., 2008. The relationship between training methods and the occurrence of behavior problems, as reported by owners, in a population of domestic dogs. J. Vet. Behav. 3, 207–217.

BSAVA, 2009. BSAVA client questionnaire: behaviour series. In: Horwitz, D.F., Mills, D.S. (Eds.), British Small Animal Veterinary Association: Manual of Canine and Feline Behavioural Medicine.

Bushby, P.A. 2013. Efficient Spay/Neuter Techniques. Proceedings of 85th Annual Western Veterinary Conference, Las Vegas, Nevada. February 14-18, 2010.

Bushby, P.A., Griffin, B., 2011. An overview of pediatric spay and neuter benefits and techniques. Vet. Med-US 106, 83–89.

Casey, R.A., Bradshaw, J.W.S., 2008. The effects of additional socialisation for kittens in a rescue centre on their behaviour and suitability as a pet. Appl. Anim. Behav. Sci. 114, 196–205.

Casey, R.A., Vandenbussche, S., Bradshaw, J.W.S., Roberts, M.A., 2009. Reasons for relinquishment and return of domestic cats (Felis silvestris catus) to rescue shelters in the UK. Anthrozoös 22, 347–358.

Clark, K., 2012. Neutering: how early is too early? Vet.Rec. 170, 432–433.

Clements, D.N., Handel, I.G., Rose, E., Querry, D., Pugh, C.A., Ollier, W.E., Morgan, K.L., Kennedy, L.J., Sampson, J., Summers, K.M., de Bronsvoort, B.M., 2013. Dogslife: a web-based longitudinal study of Labrador Retriever health in the UK. BMC Vet. Res. 9, 13.

Corridan, C. 2010. Doggy Diaries. Personal communication, May 19, 2010.

Crowell-Davis, S., 2002. Social behaviour, communication and development of behaviour in the cat. In: Horwitz, D.F., Mills, D.S., Heath, S. (Eds.), BSAVA Manual of Canine and Feline Behavioural Medicine. British Small Animal Veterinary Association, Gloucester, UK, pp. 21–29.

Ellis, S.L., 2009. Environmental enrichment: practical strategies for improving feline welfare. J. Feline. Med. Surg. 11, 901–912.

Faggella, A.M., Aronsohn, M.G., 1993. Anesthetic techniques for neutering 6- to 14-week-old kittens. J. Am. Vet. Med. Assoc. 202, 56–62.

Fatjo, J., Ruiz-de-la-Torre, J.L., Manteca, X., 2006. The epidemiology of behavioural problems in dogs and cats: a survey of veterinary practitioners. Anim. Welfare 15, 179–185.

Heath, S., 2002. Feline aggression. In: Horwitz, D.F., Mills, D.S., Heath, S. (Eds.), BSAVA Manual of Canine and Feline Behavioural Medicine, 1st edition. British Small Animal Veterinary Association, Gloucester (UK), pp. 216–228.

Heath, S.E., 2007. Behaviour problems and welfare. In: Rochlitz, I. (Ed.), The Welfare of Cats. Springer, pp. 91–119.

Heidenberger, E., 1997. Housing conditions and behavioural problems of indoor cats as assessed by their owners. Appl. Anim. Behav. Sci 52, 345–364.

Hiby, E.F., Rooney, N.J., Bradshaw, J.W.S., 2004. Dog training methods: their use, effectiveness and interaction with behaviour and welfare. Anim. Welfare 13, 63–69.

Horwitz, D.F. 2001. Feline Aggression. Periodical. Feline Aggression. Available at: http://www.ivis.org/advances/Behavior_Houpt/horwitz/chapter.asp?LA=1. Accessed, May 2010.

Howe, L.M., 1997. Short-term results and complications of prepubertal gonadectomy in cats and dogs. J. Am. Vet. Med. Assoc. 211, 56–62.

Howe, L.M., Slater, M.R., Boothe, H.W., Hobson, H.P., Fossum, T.W., Spann, A.C., Wilkie, W.S., 2000. Long-term outcome of gonadectomy performed at an early age or traditional age in cats. J. Am. Vet. Med. Assoc. 217, 1661–1665.

Hunthausen, W., Seksel, K., 2002. Preventive behavioural medicine. In: Horwitz, D.F., Mills, D.S., Heath, S. (Eds.), BSAVA Manual of Canine and Feline Behavioural Medicine. British Small Animal Veterinary Association, Gloucester (UK), pp. 49–60.

Jackson, E.K., 1984. Contraception in the dog and cat. Br. Vet. J. 140, 132–137.

Jemmett, J.E., Evans, J.M., 1977. A survey of sexual behaviour and reproduction of female cats. J. Small Anim. Pract. 18, 31–37.

Joyce, A., Yates, D., 2011. Help stop teenage pregnancy! Early age neutering in cats. J. Feline Med. Surg. 13, 3–10.

Kendall, K., Ley, J., 2006. Cat ownership in Australia: barriers to ownership and behavior. J. Vet. Behav.: Clin. Appl. Res. 1, 5–16.

Kendall, K., Ley, J.Q., 2008. Owner observations can provide data for constructive behavior analysis in normal pet cats in Australia. J. Vet. Behav.: Clin. Appl. Res. 3, 244–247.

Landsberg, G., 1996. Feline behavior and welfare. J. Am. Vet. Med. Assoc. 208, 502–505.

Lawler, D.F., 2008. Neonatal and pediatric care of the puppy and kitten. Theriogenology 70, 384–392.

Levine, E.D., 2008. Feline fear and anxiety. Vet. Clin. North Am. Small Anim. Pract. 38, 1065–1079. vii.

Looney, A.L., Bohling, M.W., Bushby, P.A., Howe, L.M., Griffin, B., Levy, J.K., Eddlestone, S.M., Weedon, J.R., Appel, L.D., Rigdon-Brestle, Y.K., Ferguson, N.J., Sweeney, D.J., Tyson, K.A., Voors, A.H., White, S.C., Wilford, C.L., Farrell, K.A., Jefferson, E.P., Moyer, M.R., Newbury, S.P., Saxton, M.A., Scarlett, J.M., 2008. The Association of Shelter Veterinarians veterinary medical care guidelines for spay-neuter programs. J. Am. Vet. Med. Assoc. 233, 74–86.

Lord, L.K., Reider, L., Herron, M.E., Graszak, K., 2008. Health and behavior problems in dogs and cats one week and one month after adoption from animal shelters. J. Am. Vet. Med. Assoc. 233, 1715–1722.

McCune, S., 1995. The impact of paternity and early socialisation on the development of cats' behaviour to people and novel objects. Appl. Anim. Behav. Sci. 45, 109–124.

Morgan, M., Houpt, K.A., 1990. Feline behaviour problems: the influence of declawing. Anthrozoös 3, 50–53.

Murray, J.K., Skillings, E., Gruffydd-Jones, T.J., 2008. Opinions of veterinarians about the age at which kittens should be neutered. Vet. Rec. 163, 381–385.

Neidhart, L., Boyd, R., 2002. Companion animal adoption study. J Appl Anim. Welf. Sci. 5, 175–192.

Olson, P.N., Kustritz, M.V., Johnston, S.D., 2001. Early age neutering of dogs and cats in the United States (a review). J. Reprod. Fertil. Suppl. 57, 223–232.

Overall, K.L., Rodan, I., Beaver, B.V., Carney, H., Crowell-Davis, S., Hird, N., Kudrak, S., Wexler-Mitchel, E., 2005. Feline behavior guidelines from the American Association of Feline Practitioners. J. Am. Vet. Med. Assoc. 227, 70–84.

Patronek, G.J., Dodman, N.H., 1999. Attitudes, procedures, and delivery of behavior services by veterinarians in small animal practice. J. Am. Vet. Med. Assoc. 215, 1606–1611.

Patronek, G.J., Glickman, L.T., Beck, A.M., McCabe, G.P., Ecker, C., 1996. Risk factors for relinquishment of cats to an animal shelter. J. Am. Vet. Med. Assoc. 209, 582–588.

Polson, S., Taylor, P.M., Yates, D., 2012. Analgesia after feline ovariohysterectomy under midazolam-medetomidine-ketamine anaesthesia with buprenorphine or butorphanol, and caroprofen or meloxicam: a prospective, randomised clinical trial. J. Feline Med. Surg. http://dx.doi.org/10.1177/1098612X12444743.

Porters, N., de Rooster, H., Moons, C.P.H., Duchateau, L., Goethals, K., Bosmans, T., Polis, I. Prepubertal gonadectomy in cats: different injectable anaesthetic combinations and comparison with gonadectomy at traditional age. Manuscript in revision.

Porters, N., Polis, I., Moons, C.P.H., Duchateau, L., Goethals, K., Huyghe, S., de Rooster, H., 2014. Prepubertal gonadectomy in cats: different surgical techniques and comparison with gonadectomy at traditional age. Vet. Rec. http://dx.doi.org/10.1136/vr.102337.

Radosta, L., 2011. Chapter 12-Feline behavioral development. In: Peterson, M.R., Kutzler, M.A. (Eds.), Small Animal Pediatrics. W.B. Saunders, Saint Louis, pp. 88–96.

Ramos, D., Mills, D.S., 2009. Human directed aggression in Brazilian domestic cats: owner reported prevalence, contexts and risk factors. J. Feline Med. Surg. 11, 835–841.

Reichler, I.M., 2009. Gonadectomy in cats and dogs: a review of risks and benefits. Reprod. Domest. Anim. 44 (Suppl 2), 29–35.

Robertson, S.A. 2007. Anaesthesia and Analgesia for Kittens and Puppies. Proceedings: Voorjaarsdagen, Amsterdam, Netherlands. pp. 46–47.

Robertson, S.A., Levy, J., Gunkel, C., Taylor, P.M. 2003. Comparison of isoflurane and butorphanol with medetomidine, ketamine and buprenoprhine for anesthesia of 7-12 week old kittens for surgical sterilization. In Proceedings: Association of Veterinary Anaesthetists, Spring Meeting: Pain Assessement and Pain Control. Doorwerth, Netherlands. May 28-30, 2003.

Root Kustritz, M., 2007. Determining the optimal age for gonadectomy of dogs and cats. J. Am. Vet. Med. Assoc. 231, 1665–1675.

Root Kustritz, M., 2012. Effects of surgical sterilization on canine and feline health and on society. Reprod. Domest. Anim. 47 (Suppl 4), 214–222.

Root Kustritz, M., 2014. Pros, cons, and techniques of pediatric neutering. Vet. Clin. North Am. Small Anim. Pract. 44, 221–233.

Root, M.V., Johnston, S.D., Johnston, G.R., Olson, P.N., 1996. The effect of prepuberal and postpuberal gonadectomy on penile extrusion and urethral diameter in the domestic cat. Vet. Radiol. Ultrasound 37, 363–366.

Root, M.V., Johnston, S.D., Olson, P.N., 1997. The effect of prepuberal and postpuberal gonadectomy on radial physeal closure in male and female domestic cats. Vet. Radiol. Ultrasound 38, 42–47.

Roshier, A.L., McBride, E.A., 2013. Canine behaviour problems: discussions between veterinarians and dog owners during annual booster consultations. Vet. Rec. 172, 235.

Salman, M.D., New Jr., J.G., Scarlett, J.M., Kass, P.H., Ruch-Gallie, R., Hetts, S., 1998. Human and animal factors related to relinquishment of dogs and cats in 12 selected animal shelters in the United States. J. Appl. Anim. Welf. Sci. 1, 207–226.

Scarlett, J.M., Salman, M.D., New, J.G., Kass, P.H., 2002. The role of veterinary practitioners in reducing dog and cat relinquishments and euthanasias. J. Am. Vet. Med. Assoc. 220, 306–311.

Seibert, L.M., Landsberg, G.M., 2008. Diagnosis and management of patients presenting with behavior problems. Vet. Clin. North Am. Small Anim. Pract. 38, 937–950.

Seksel, K., 2008. Preventing behavior problems in puppies and kittens. Vet. Clin. North Am. Small Anim. Pract. 38, 971–982. v-vi.

Shore, E.R., 2005. Returning a recently adopted companion animal: adopters' reasons for and reactions to the failed adoption experience. J. Appl. Anim. Welf. Sci. 8, 187–198.

Shore, E.R., Burdsal, C., Douglas, D.K., 2008. Pet owners' views of pet behavior problems and willingness to consult experts for assistance. J. Appl. Anim. Welf. Sci 11, 63–73.

Shore, E.R., Petersen, C.L., Douglas, D.K., 2003. Moving as a reason for pet relinquishment: a closer look. J. Appl. Anim. Welf. Sci. 6, 39–52.

Spain, C.V., Scarlett, J.M., Cully, S.M., 2002. When to neuter dogs and cats: a survey of New York state veterinarians' practices and beliefs. J. Am. Anim. Hosp. Assoc. 38, 482–488.

Spain, C.V., Scarlett, J.M., Houpt, K.A., 2004. Long-term risks and benefits of early age gonadectomy in cats. J. Am. Vet. Med. Assoc. 224, 372–379.

Stubbs, W.P., Bloomberg, M.S., Scruggs, S.L., Shille, V.M., Lane, T.J., 1996. Effects of prepubertal gonadectomy on physical and behavioral development in cats. J. Am. Vet. Med. Assoc. 209, 1864–1871.

Stubbs, W.P., Salmeri, K.R., Bloomberg, M.S., 1995. Early neutering of the dog and cat. In: Bonagura, J.D., Kirk, R.W. (Eds.), Kirk's Current Veterinary Therapy XII Small Animal Practice. WB Saunders & co, Philadelphia, USA, pp. 1037–1040.

Wright, J.C., Amoss, R.T., 2004. Prevalence of house soiling and aggression in kittens during the first year after adoption from a humane society. J. Am. Vet. Med. Assoc. 224, 1790–1795.