Journal of Veterinary Behavior 62 (2023) 47–52

Contents lists available at ScienceDirect

Journal of Veterinary Behavior

journal homepage: www.elsevier.com/locate/jveb

Desexing dogs as a means of decreasing the generally regarded sexually dimorphic behaviors of urine marking, mounting, and roaming

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ARTICLE INFO

Article history:
Received 15 November 2022
Received in revised form 24 January 2023
Accepted 24 January 2023
Available online 3 February 2023

Keywords:
Desexing
Dogs
Behavior
Urine marking
Mounting
Roaming

ABSTRACT

Desexing (castrating, ovariectomizing/neutering) and a dog's sex are topics of relevance to many dog owners. We studied the relationship between desexing and three behaviors that are presumed sexually dimorphic, that is, differ in occurrence between the sexes. Urine marking, mounting, and roaming were used as models for studying the effects of desexing on (unwanted) behavior in dogs. We assessed the relationships between the occurrences of the three behaviors and the four factors of the dogs' sex, sexual status, desexing age, and age in general. A convenience sample of dog owner reports was collected with an online survey and 982 records were analyzed with Chi-square tests. Counts were expressed in cross- tables of the behavior being present or absent and one of the aforementioned four factors. Urine marking occurred most frequently in intact male dogs (78%, N = 188), with significant differences compared with intact females (41%, N = 48; $P < 0.001$) and desexed males (66%, N = 202; $P = 0.002$). There was a trend for mounting occurring more frequently in intact males (25%, N = 60) compared with intact females (17%, N = 19; $P = 0.085$), and a significant difference between intact and desexed males (25%, N = 60 vs. 18%, N = 54; $P = 0.043$). Roaming occurred similarly in males and females, and in intact and desexed male dogs. For none of the three behaviors, there were differences between intact and desexed female dogs. In intact male dogs, age-related differences were found for the occurrence of mounting (39%, N = 29 of the dogs < 2 years vs. 13%, N = 4 of the dogs > 8 years) and roaming (46%, N = 34 of the dogs < 2 years vs. 20%, N = 6 of the dogs > 8 years). Such differences were not found for females or for urine marking in males. Mounting and roaming occurring less often in older male dogs suggest that these behaviors may decrease with age, naturally or through other factors. Our cross-sectional study shares with many earlier studies that its setup does not establish causal effects of desexing and we recommend large-scale prospective studies as a next step in providing scientific evidence for how behavior is affected by desexing. More knowledge of the influence of sex hormones on behavior in dogs is needed to support decisions on desexing individual dogs for reasons of unwanted behavior, which will benefit both the dogs and their owners.
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Introduction

Desexing (castrating, ovariectomizing/neutering) dogs regards the surgical removal of the testes in males or the ovaries in females. This is common practice, even in countries such as the Netherlands where dog reproduction is under control and not a community or public health problem. Desexing percentages in the Dutch dog population were 69% (N = 258 out of 374) of the females and 51% (N = 249 out of 491) of the males, as reported by dog owners (Roulaux et al., 2020). The reasons for desexing a dog included the correction of unwanted behavior, and more often so for male than female dogs (58%, N = 145 vs. 11%, N = 28). The effects of desexing on (unwanted) behavior are assumingly caused by a reduction in sex hormones. Testosterone is of particular interest here, since especially male dogs are often desexed to correct behavior (Roulaux et al., 2020). The blood levels of testosterone differ between the sexes and the median basal testosterone levels are almost 300 times higher in intact male dogs (17.44 nmol/l, N = 14) than in intact anestrus female dogs (0.06 nmol/l, N = 14; De Gier et al., 2012). The regulation of behavior by testosterone, as a key mechanism in the desexing of males, is expected to show most clearly in behaviors that are sexually dimorphic. Generally regarded sexually dimorphic behaviors in

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https://doi.org/10.1016/j.jveb.2023.01.006
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dogs include urine marking, mounting, and roaming (Hopkins et al., 1976; Hart and Eckstein, 1997; Maarschalkerweerd et al., 1997; Neilson et al., 1997). These three behaviors are studied here to better understand the effects of desexing on dog behavior.

The urinary posture is sexually dimorphic in dogs. Male dogs that have gone through puberty display a urinary posture with a raised hind leg, juvenile male dogs display a lean-forward posture while standing on four legs, and female dogs display a squatting position, during which they sometimes raise a hind leg (Martins and Valle, 1948; Sprague and Anisko, 1973; Beach, 1974). This urinary posture is influenced by desexing and/or testosterone treatment.

During the first two months after birth, untreated intact female Beagles (Normal Female, NF, N = 11) displayed a squatting position in 92% of the observed urinations compared with only 7% of the urinations of untreated intact males (Normal Male, NM, N = 10; Ranson and Beach, 1985). The other urinations were done in a lean-forward posture while standing. The percentage of urinations in a squatting position was 46% for females that were treated with testosterone *in utero* (Female exposed to Testosterone in Utero, FTU, N = 5) and 51% for females that were treated with testosterone both in utero and during the first 30–40 days postnatally (Female exposed to Testosterone in Utero and during Infancy, FTUI, N = 5). At fourteen months of age, the FTUI displayed the adult male posture with a raised hind leg approximately as often as NM (91% of observed urinations), even though the adult FTUI was no longer administered testosterone at that time. The same applied to males that were desexed soon after birth and given testosterone treatment for the first 90 days postnatally (Castrated Male exposed to Testosterone, CMT). The NF and FTU never displayed the adult male posture. Males that were desexed postnatally without testosterone replacement treatment (Castrated Male, CM) displayed the adult male posture in only 31% of the observed urinations (Ranson and Beach, 1985). Thus, once established, the adult male urinary posture is unaltered by desexing, even though it develops perinatally under the influence of sex hormones. This could also be the case for other behaviors, which should be kept in mind when desexing to correct unwanted behavior.

Urine marking behavior was assessed also by Ranson and Beach (1985) and the wooden posts in the dogs' urination pen were inspected more often by adult NM, CMT, and FTUI than by CM, FTU, and NF. Also, the former more often urinated at targets such as these posts and their frequency of urination was approximately fifteen times higher. Investigation of targets and targeted frequent urinations represent scent marking, which is pronounced in male dogs (Martins and Valle, 1948; Pal, 2003) and done also by female dogs, as female Jack Russell terriers urinated more frequently and directed more of their urinations at targets when walked outside compared with within their territory (Wirant and McGuire, 2004).

The frequency of urination is higher in male dogs than in female dogs (Beach, 1974; Ranson and Beach, 1985) and may be increased by administration of testosterone. Testosterone treatment both *in utero* and during infancy caused a higher frequency of urination in female dogs compared with untreated females and administration of testosterone to male dogs castrated in adulthood increased the frequency of urination (Beach, 1974; Ranson and Beach, 1985). The frequency of urination was unrelated to desexing in privately owned female Labrador retrievers (Balogh et al., 2018) and female shelter dogs (McGuire, 2019), unlike the frequency of urination in male dogs. This frequency was recorded during walks (N = 672) and desexed males had an almost 40% lower urination rate than intact males (McGuire, 2019). Additionally, the frequency of urination in male shelter dogs decreased following desexing in 16 out of 17 dogs in a within-dog study (McGuire, 2019). Remarkably, the extent of the decrease ranged from 14% to 72%. In contrast, Hart (1974) found no difference in the frequency of urination in 7 dogs observed before and after desexing. The effect size of desexing on male dogs' urine marking varies across studies, with decreases in as few as 23% of the dogs (N = 13; Maarschalkerweerd et al., 1997), to about half (N = 10; Hopkins et al., 1976), up to as many as 78% (N = 18; Neilson et al., 1997). Small sample sizes in the within-dog studies may partly explain this variation across studies.

Mounting behavior is a part of normal sexual behavior in dogs (Beach, 1947) and is displayed typically by mammalian males (Hart, 1974), albeit not exclusively. Mounting behavior, including pelvic thrusting, is displayed by female dogs and females of other mammalian species such as cats, cows, primates, rodents, and sows (reviewed by Beach, 1947). Only male dogs mounted, in a study with 36 male dogs and 24 females that visited an off-leash dog park (Ottenheimer Carrier et al., 2013). Three of the seven male dogs that mounted were sexually intact, which was an overrepresentation as this 43% compared with only 19% of the study males being sexually intact. In the dog park, there were no fertile females around and the frequency of mounting behavior was positively correlated with the frequency of play behavior. Likely, mounting was displayed in the context of play rather than sexual, which could mask the possible effects of desexing. The effects of desexing on the display of mounting behavior have been studied in male dogs only. Decreases vary from 26% to 57% of the desexed dogs (N = 56), depending on the target at which the behavior was directed (Maarschalkerweerd et al., 1997), up to approximately 68% of the dogs (N = 15; Hopkins et al., 1976 and N = 16; Neilson et al., 1997).

Roaming is performed by female dogs in heat and especially male dogs respond to such females (Beach and Gilmore, 1949). This roaming is a reason for dog owners to desex their dog, particularly for those owning a male dog (Hopkins et al., 1976; Maarschalkerweerd et al., 1997; Neilson et al., 1997). Roaming in male dogs is sensitive to desexing and was reduced in 66% of one study group (N = 15; Neilson et al., 1997), and in up to over 90% in another (N = 16; Hopkins et al., 1976). The regulation of roaming by sex hormones is questionable in contexts without reproductive triggers. Suburban dogs in a residential area of Berkeley, California, that were given the opportunity to roam freely, did so regardless of the presence of possible sexual partners (Berman and Dunbar, 1983). In one study, a fixed route was driven 105 times at different times throughout the day for approximately half a year, during which the presence of free-roaming dogs and dogs with handlers was recorded (Berman and Dunbar, 1983). Roaming was not associated with the presence of other dogs of the opposite sex in this study (Berman and Dunbar, 1983). The different conditions under which dogs roam may determine the outcomes of desexing. Desexing decreased roaming in 64% of the male dogs when females in heat were nearby in comparison to only 23% in other contexts (N = 56; Maarschalkerweerd et al., 1997).

Male dogs are often desexed to correct unwanted behavior, but for many behaviors, the causal scientific evidence for changes due to desexing is lacking, so the subject warrants further research. Sexually dimorphic behaviors are likely candidates to sensitively respond to desexing and knowledge about the effects of sexual dimorphism helps, in a general sense, in understanding the behavioral consequences of desexing dogs.

As discussed above, urine marking and urinary postures are demonstrably different between male dogs and females, with known effects of desexing and/or perinatal testosterone treatment. Mounting and roaming are generally thought to be easily influenced by desexing, at least in male dogs, but here the literature shows mixed results, and concerns are raised by findings being based on small sample sizes. Furthermore, the occurrence of mounting and roaming in female dogs, and the possible influence of the female reproductive cycle on these behaviors, is understudied.

We determined the occurrences of urine marking, mounting, and roaming in both male and female dogs and how these occurrences were associated with desexing by comparing dog owner reports on desexed and sexually intact dogs. Additionally, we considered the effects of dog age, female reproductive cycle, and desexing age on

the occurrences of the three sexually dimorphic behaviors. Our study aims to add knowledge on how desexing dogs may affect their behavior, which ultimately benefits both the dog and the owner.

Methods

Web-based survey and participant recruitment

A convenience sample of Dutch dog owners completed an Internet survey on the occurrence of sexually dimorphic behaviors in their dog and the effect of desexing on these behaviors. The introduction to the survey explained how we considered intact as 'no modification' and desexed as 'surgical removal of testes or ovaria'. Survey items were constructed and tested on native speakers for understanding and readability. We targeted dog owners via websites, social media channels, and newsletters, after which the survey could be shared by dog owners and content managers. Demographics were collected to describe our study sample. We compared dog owner reports on the occurrence of urine marking, roaming, and mounting in dogs that were desexed or intact, male or female, and we analyzed how occurrences were associated with the dog's age, the age at desexing, and the female reproductive cycle. Reports on chemically desexed dogs were excluded since our focus was on irreversible surgical desexing.

The survey consisted of a first part that was fixed and a second part that varied in length, depending on the dog being intact or desexed (see S1 Appendix for survey items). The first part assessed characteristics of the owner and dog, being the owner's sex, education level and age and the dog's sex, current age, age at acquisition by the current owner, breed, pedigree, and desexing status. Participants indicated the percentage of time that they took care of the dog for which they filled in the survey, and we excluded dog owners who provided less than 50% of the daily care. There were items on how often the dog showed urine marking, roaming, and mounting behavior, which owners rated on a five-point Likert scale. Specifically, urine marking was scored as influencing the speed and direction of the dog and owner during walks, from 'very little influence' to 'very much influence'. When inapplicable, for instance due to the dog rarely or never being taken for walks, the question could be left unanswered. Roaming behavior was scored as occurring '(almost) never' to '(almost) always' whenever the dog had a chance to roam. Mounting behavior was scored as occurring '(almost) never' to 'multiple times a day'. The outcomes were skewed toward the lower scores, and we therefore performed statistical analyses on binary scores, with 0 representing the lowest score and 1 representing the four higher scores. The descriptive statistics are given also for the original categories.

In the second part of the survey, owners of intact female dogs indicated whether the occurrences of urine marking, roaming, and mounting behavior were influenced by the dog being in heat. Answer options were 'the behavior occurs only when the dog is in heat', 'the behavior occurs more often when the dog is in heat, but also outside of that period', and 'there is no difference'. The dog's age at the moment of desexing was recorded and owners of female dogs indicated if their dog had been in heat before desexing, and if so, how many times. Finally, owners of desexed dogs indicated whether or not urine marking, mounting, and roaming had been a reason for desexing. This, on a four-point Likert scale that ranged from 'not problematic' to 'the main problem to be corrected by desexing', from which a binary division was made with 1 indicating that the behavior had been a problem that they aimed to correct, and 0 meaning it was not.

Data processing and statistical analyses

From our full sample, we excluded the participants who did not indicate their dog's sex (male or female) and/or status (desexed or intact) and/or who provided less than 50% of the dog's daily care. From the remaining sample of 1028 owner reports, we excluded those that involved dogs that were chemically desexed (N = 46), leaving 982 owner reports for analysis. The online survey allowed that the occasional question was left unanswered and the precise sample sizes used for analyses are given in the Results section.

Data were analyzed using SPSS Statistics 27. We used Pearson's Chi-square tests to test how the occurrence of sexually dimorphic behaviors differed between intact male and female dogs, between intact and desexed males, and between intact and desexed females. Further tests assessed influences by current age (intact dogs only) or age at the moment of desexing. The Chi-square test outcomes include the standardized residuals to identify the cells with the largest contribution to the Chi-square test statistic. We considered residuals $|>2|$ as a significant deviation between observed and expected values (Sharpe, 2015), maintained a level of significance of $P < 0.05$, and regarded $P < 0.10$ as a possible significance, that is, a trend.

Results

Participants and their dogs

The participating Dutch dog owners (N = 982) were typically women (91%, N = 892; men: 9%, N = 84) and over 44 years of age (< 35 years: 28%, N = 275; 35–44 years: 19%, N = 190; 45–54 years: 29%, N = 285; > 54 years: 23%, N = 229). The majority had completed higher professional education (53%, N = 518; vocational education above high school level: 32%, N = 313; below this level: 15%, N = 144). Most dogs had been obtained by the owner before they were ten weeks old (60%, N = 587). The remainder was obtained between ten weeks and one-year-old (24%, N = 240; > 1-year-old: 15%, N = 151). Dogs were of various breeds and about half were certified pedigree dogs (51%, N = 500; 49% look-a-like or mixed breed, N = 478). Most dogs were between two and eight years old (< 1 year: 5%, N = 51; 1–2 years: 13%, N = 129; 2–4 years: 26%, N = 251; 4–6 years: 19%, N = 184; 6–8 years: 14%, N = 139; > 8 years: 23%, N = 225). The study group contained slightly more male than female dogs (male: 56%, N = 547; female: 44%, N = 435) and most were desexed (64%, N = 624; intact: 37%, N = 358). Nearly three-quarters of the female dogs were desexed (73%, N = 319; intact: 27%, N = 116) versus only 56% (N = 305) of the male dogs (intact: 44%, N = 242). Desexing had occurred mostly when the dog was with the current owner (85%, N = 529), but in some cases before that (15%, N = 95). Only the former group reported on reasons for having their dog desexed. Owners of male dogs indicated most often that correcting unwanted behavior(s) had played a role (mounting 31%, N = 80, urine marking 18%, N = 46, and roaming 14%, N = 36). Desexing dogs for (in part) reasons to correct their behavior was relatively rare among owners of female dogs (2% for mounting, N = 5, roaming, N = 5, and urine marking, N = 6).

Occurrences of urine marking, mounting, and roaming behavior

Urine marking was reported for 60% of the dogs (N = 590), mounting for 17% (N = 168), and roaming for 30% (N = 290). Urine marking was reported with a mean (± SD) score of 1.13 ± 1.14 on a scale of 0–4 (0, N = 391; 1, N = 229; 2, N = 230; 3, N = 102; 4, N = 29), and 0.60 ± 0.49 when expressed on a binary scale (0, N = 391; ≥1, N = 590). Similarly, mounting scored respectively 0.30 ± 0.74 (0, N = 810; 1, N = 75; 2, N = 60; 3, N = 31; 4, N = 2), and 0.17 ± 0.38 (0, N = 810; ≥1, N = 168). Scores for roaming were 0.49 ± 0.93 (0, N = 689; 1, N = 183; 2, N = 51; 3, N = 29; 4, N = 27) and 0.30 ± 0.46 (0, N = 689; ≥1, N = 290).

Effect of dog sex, dog age, and the female reproductive cycle on the occurrence of sexually dimorphic behavior in intact dogs

Urine marking occurred almost twice as much in intact male dogs (78%, N = 188) as in intact female dogs (41%, N = 48; $\chi2 = 46.89$, $P < 0.001$, df=1, N = 357; counts and residuals are in Table A in S2 Appendix). For mounting behavior, there was a possible significance, a trend found (intact male dogs 25%, N = 60 vs. intact female dogs 17%, N = 19; $\chi2 = 2.96$, $P = 0.085$, df=1, N = 356). Roaming behavior did not differ between intact males (32% N = 78) and intact females (27% N = 31; $\chi2 = 1.07$, $P = 0.300$, df=1, N = 356).

For intact male dogs, we found no differences between the age categories for the occurrence of urine marking ($\chi2 = 5.40$, $P = 0.145$, df=3, N = 240; counts and residuals are in Table B in S2 Appendix). Mounting occurred less often in older intact male dogs ($\chi2 = 12.45$, $P = 0.006$, df=3, N = 241). It occurred in 39% (N = 29 of 75) of the immature dogs (< 2 years), 16% (N = 10 of 62) of the young adults (2–4 years), 23% (N = 17 of 74) of the adults (4–8 years), and 13% (N = 4 of 30) of the senior dogs (> 8 years). Roaming also occurred less often in older intact male dogs ($\chi2 = 11.36$, $P = 0.010$, df=3, N = 240). It occurred in 46% (N = 34 of 74) of the immature dogs, 32% (N = 20 of 62) of the young adults, 23% (N = 17 of 74) of the adults, and 20% (N = 6 of 30) of the senior dogs. For intact female dogs, we found no differences between the age categories for the occurrence of urine marking ($\chi2 = 0.74$, $P = 0.865$, df=3, N = 116), mounting ($\chi2 = 3.20$, $P = 0.362$, df=3, N = 114), or roaming ($\chi2 = 1.53$, $P = 0.676$, df=3, N = 115).

Owners of intact female dogs that displayed urine marking, mounting, and/or roaming behavior reported whether such behavior occurred more often when the dog was in heat, which would indicate a connection to the reproductive cycle. Urine marking occurred more often during heat in 86% of the intact female dogs (N = 37 of 43), mounting in 44% (N = 7 of 16), and roaming in 45% (N = 9 of 20).

Effect of desexing on the occurrence of sexually dimorphic behavior

Desexing effects on the occurrence of sexually dimorphic behavior were investigated by comparing intact male dogs (N = 242) to desexed male dogs (N = 305). Urine marking occurred more often in intact male dogs (78%, N = 188) than in desexed male dogs (66%, N = 202; $\chi2 = 9.15$, $P = 0.002$, df=1, N = 546, for counts and residuals see Table C in S2 Appendix). The same was true for mounting (intact 25%, N = 60 vs. desexed 18%, N = 54; $\chi2 = 4.11$, $P = 0.043$, df=1, N = 547), but not for roaming (intact 32%, N = 78 vs. desexed 31%, N = 96; $\chi2 = 0.05$, $P = 0.825$, df=1, N = 546). Comparisons between female dogs that were intact (N = 116) and desexed (N = 319) revealed no differences in the occurrence of urine marking (intact 41%, N = 48; desexed 48%, N = 152; $\chi2 = 1.35$, $P = 0.246$, df=1, N = 435), mounting (intact 17%, N = 19; desexed 11%, N = 35; $\chi2 = 2.42$, $P = 0.120$, df=1, N = 431), or roaming (intact 27%, N = 31; desexed 27%, N = 85; $\chi2 = 0.00$, $P = 0.962$, df=1, N = 433).

Desexing age and its effect on the occurrence of sexually dimorphic behavior

Of the dogs that had been desexed by their current owner (N = 529), 29% (N = 29) had been desexed before one year, 39% (N = 203) between one and two years, and 33% (N = 173) after this age. The age at the time of desexing did not differ between male and female dogs ($\chi2 = 1.85$, $P = 0.397$, df=2, N = 527; for details see Table D in S2 Appendix). Of the desexed female dogs (N = 319), 17% (N = 45) were desexed before their first heat, 34% (N = 88) after their first heat, 14% (N = 37) after their second heat, and 35% (N = 90) after having been in heat more than twice.

We compared the owner-reported occurrence of urine marking, roaming, and mounting behavior for dogs that were desexed before one year, between one and two years, and after this age, and we did this for male and female dogs separately. We found no differences in Chi-square tests (for details see Table E in S2 Appendix).

Discussion

Urine marking, mounting, and roaming behaviors are often unwanted in dogs and, together with other considerations, are a reason for desexing. These behaviors are generally seen as sexually dimorphic, meaning that occurrences differ between the sexes under the influence of sex hormones. This underlies the idea that unwanted behaviors such as these are prevented or remedied by desexing (Hopkins et al., 1976; Maarschalkerweerd et al., 1997; Neilson et al., 1997), particularly in male dogs (Hart and Eckstein, 1997) as desexing decreased their median basal testosterone levels from 17.44 to 0.06 nmol/l (N = 14; De Gier et al., 2012). However, studies on the effects of desexing on sexually dimorphic behaviors such as mounting and roaming behavior are scarce, based on small sample sizes and mostly include male dogs only. More knowledge is needed about the relationships between desexing and presumed sexually dimorphic behaviors. Here, we focused on urine marking, mounting, and roaming. We used dog owner reports to determine the occurrences of these behaviors in a large sample of both male and female dogs and assessed associations with desexing.

The present study group of Dutch dog owners (N = 982) reported in an online survey how urine marking was displayed by 60% of the dogs. It was the most distinct sexually dimorphic behavior of the three studied behaviors, occurring twice as much in male dogs as in female dogs (78% vs. 41% respectively, $P < 0.001$). This matched earlier findings of more frequent urination in male dogs (Martins and Valle, 1948; Ranson and Beach, 1985; Pal, 2003). Urine marking seems under the influence of sex hormones, as in male dogs it occurred 15% less often in the desexed group than in the intact group. The presence of testosterone early in life seems necessary to develop adult male urinary behavior, but testosterone may be less important to preserve this behavior later in life (Ranson and Beach, 1985). Urine marking differed in occurrence between intact and desexed male shelter dogs (N = 368; McGuire, 2019), though the reported effects of desexing vary greatly (Hopkins et al., 1976; Maarschalkerweerd et al., 1997; Neilson et al., 1997). Female dogs' urine marking has been found to be unaffected by desexing (Balogh et al., 2018), and our findings confirm this. However, we did trace sex hormone influences in that 86% of the intact female dogs that displayed urine marking, did so more frequently or exclusively when in heat. This is in line with the finding that ten intact female Jack Russell Terriers urine marked more often and directed a larger proportion of their urinations at a target when they were in heat (Wirant et al., 2007). Urine marking in dogs is sexually dimorphic and influenced by sex hormones, but its reduction by desexing is inconsistent across studies. Early-life organizational effects of sex hormones may cause individual variation in dogs' long-term behavioral responses to desexing at later age, among other factors, and with our present understanding of the matter, it is difficult to predict the behavioral outcomes of desexing for individual dogs.

Mounting was displayed by 17% of all the dogs in our sample, both intact and desexed. It was barely sexually dimorphic, with a trend for it occurring more often in intact male than in intact female dogs (25% vs. 17%, respectively, $P = 0.085$). Mounting behavior may naturally occur at relatively low levels or constitute a behavior for which owners have a low tolerance and correct dogs, given that it was one of the most frequently deterred behaviors when it was displayed by dogs in a dog park (Walsh et al., 2011). In male dogs, mounting seemed influenced by the presence of male sex hormones, since it occurred less often in the desexed group than in the intact

group (18% vs. 25%, respectively, $P = 0.043$). However, it was still shown by 18% of the desexed male dogs and by 13% of all female dogs. If mounting behavior in females is sexually motivated, it is likely to be displayed more frequently during or around ovulation, as is the case for instance in cows (Walker et al., 1996). This was the case in 44% of the intact females, so the majority showed no such hormonally induced change. Instead of being a sexually motivated behavior, mounting may be related to stress or anxiety. Human-directed mounting behavior was shown more by anxious dogs (65% of 185 dogs) than aggressive dogs (33% of 150 dogs), in a study sample of dogs that were brought to a behavioral clinic in Northern Italy (Cannas et al., 2018). Depending on the context in which mounting is shown, it could also be seen in the context of play behavior, which often comes with excitement (Ottenheimer Carrier et al., 2013). These different possible motivations for mounting behavior warrant caution and careful behavioral analysis to determine the motivation for the individual dog when aiming to reduce mounting behavior by desexing.

Roaming was displayed by 30% of the dogs in our study, without indications for it being sexually dimorphic or influenced by desexing. Its occurrence was similar for male and female dogs and for intact and desexed dogs of both sexes. Roaming is likely not solely sexually motivated and may result from needs for exercise and/or exploration. Escaping the property associated negatively with how often the dog was walked, in a study on 203 dogs in suburban Australia (Kobelt et al., 2003). The motivation behind roaming likely influences the effect of desexing (Maarschalkerweerd et al., 1997). Desexing had no effect on the roaming behavior of free-ranging male dogs in Chile (Garde et al., 2016), but other studies did link desexing to decreased roaming (Hopkins et al., 1976; Neilson et al., 1997). Earlier studies focused on male dogs and led to mixed results. The motivations that underlie roaming deserve more scientific attention and studies should include female dogs given that 45% of the female dogs in our study roamed more often during their heat. Understanding factors that drive roaming may contribute to preventing traffic accidents, straying, and other risks of dogs being away from owner management and care.

Desexing is often viewed as a solution to unwanted sexually dimorphic behavior, especially in male dogs. Of the desexed male dogs in our study sample, 18% were desexed to decrease urine marking, 31% to decrease mounting, and 14% to decrease roaming. For desexed female dogs, this was 2% for all behaviors. Such owner expectations about a desexing-induced behavior change in their male dog have some support in existing studies, but these are mainly cross-sectional and small-scale retrospective (Hopkins et al., 1976; Maarschalkerweerd et al., 1997; Neilson et al., 1997; McGuire, 2019). Typically, associations have been studied rather than causal effects, which obscures to what degree desexing affects behavior. From existing studies, including our findings, the causal effects of desexing cannot be established, and we feel that large-scale prospective studies could be a next step toward more conclusive evidence. Until the availability of data from large-scale prospective studies, it seems unjustified to use, for example, decreased mounting and roaming behavior as arguments for routine desexing, as was done by almost 90% of 973 surveyed UK veterinary practices (Diesel et al., 2010). Such routine desexing may not induce the desired behavioral changes and raises ethical concerns. Routine desexing of owned and supervised male dogs is unlikely to increase the dog's own welfare in countries such as The Netherlands, where most dogs live under close human supervision, when regarding the physical and behavioral consequences, as indicated in a review by Palmer et al. (2012). Instead of routine desexing dogs that live under close human supervision, we suggest evaluating whether desexing, on an individual dog basis, can be reasonably expected to decrease the behavior that is unwanted by the owner or causes welfare issues for the dog. This requires determining the factors that may drive the unwanted behavior, preferably in collaboration with a behavioral specialist. Some unwanted behaviors, even when unattended, will decrease with age. We found a 67% lower occurrence of mounting in senior versus immature intact male dogs ($P = 0.006$), and a 57% lower occurrence of roaming ($P = 0.010$). In men, testosterone levels increase strongly during puberty, stabilize in adulthood, and later gradually decrease (Vermeulen et al., 1972; Vermeulen et al., 1999), and although less intensely studied, this may be the case in male dogs (Pathirana et al., 2011). These natural changes in testosterone levels with age may explain at least part of the age-related decrease in mounting and roaming.

We found an association between the desexing age and the occurrences of the three behaviors of our interest, so our data do not indicate risks of postponing desexing to see if unwanted behavior decreases naturally and/or through a dog's training or behavioral change program. This is in line with earlier findings on the behavioral effects of desexing being unaffected by dog age or duration of unwanted behavior (Neilson et al., 1997).

The limitations of our study prevent us from inferring causality and extrapolation of our findings to the general dog population should be done with caution. Though our study sample is large ($N = 982$), it is based on a convenience sample using online recruitment and included 91% female dog owners. This matters as men and women likely report differently on dog behavior and have different views on desexing and desexed dogs (Diverio et al., 2016; Wongsaengchan and McKeegan, 2019); thus, our findings may apply predominantly to female owners. Furthermore, our sample likely consists of dogs living under close human supervision. Our findings may not apply to dogs living under different circumstances and the contemplation of whether or not to desex a dog may vary depending on those circumstances. Notwithstanding the limitations of our study, we found associations between owner-reported occurrences of three assumed sexually dimorphic behaviors in dogs to the dogs' sex, reproductive status, and female reproductive cycle. Further, detailed prospective studies are needed if we are to understand the behavioral consequences of desexing.

Conclusion

We studied the occurrences of three presumed sexually dimorphic behaviors as models for the effects of desexing on (unwanted) behavior in dogs. Lack of sexual dimorphism would question the effectiveness of desexing as a means to decrease unwanted behavior.

Urine marking was clearly sexually dimorphic in our study and occurred more often in intact than desexed male dogs.

Mounting occurred more often in intact than desexed male dogs, but there was only a trend for it being sexually dimorphic.

Roaming was not sexually dimorphic, nor did the occurrence differ between intact and desexed dogs.

Furthermore, mounting and roaming occurred respectively 67% and 57% less often in older than younger intact male dogs, suggesting that these behaviors may decrease with age, although there could be multiple reasons for an age-related decrease. Mounting and roaming may not be as sexually dimorphic nor easily influenced by desexing as often thought.

Our cross-sectional study setup prohibits us from concluding causal effects of desexing. We recommend large-scale prospective studies to better understand the effects of desexing on behavior. The effect of the female reproductive cycle on the occurrence of sexually dimorphic behaviors and the occurrence in female dogs in general are additional interesting areas of research. More knowledge allows dog owners to assess how desexing may or may not affect an unwanted behavior, in cases where the decision factor is not (unwanted) reproduction, but the individual dog's behavior, health, and welfare.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or nonprofit sectors.

Author contribution

The idea for the paper was conceived by Pascalle Roulaux. The survey was designed and distributed by Pascalle Roulaux, with Supervision by Ineke van Herwijnen and Bonne Beerda. Data were analyzed by all three authors. The original draft was written by Pascalle Roulaux and Ineke van Herwijnen. All three authors did review and editing.

Ethical considerations statement

The online survey's introduction explained the purpose of the research and the study did not involve treatments or interventions in the life of participants or their dogs. The survey was not repeated, meaning it did not interfere significantly with normal daily life, and did not include questions that were psychologically burdening. This exempts the study from review by our ethics committee, according to the guidelines of Wageningen University Medical Ethics Review Committee (Medisch Ethische Toetsingscommissie van Wageningen University, METC-WU). Informed consent was not obtained as participants chose to participate freely via Internet and the purpose of the research was stated at the start of the online survey.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jveb.2023.01.006.

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