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Vasectomy and ovary-sparing spay in dogs: comparison of health and behavior outcomes with gonadectomized and sexually intact dogs

Chris Zink, DVM, PhD, DACVSMR[1*]; Mikel M. Delgado, PhD[2]; Judith L. Stella, PhD[2]

[1]Zink Integrative Sports Medicine, Ellicott City, MD
[2]Good Dog, New York, NY

*Corresponding author: Dr. Zink (cz@caninesports.com)

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OBJECTIVE
To compare health and behavior outcomes for dogs that underwent vasectomy or ovary-sparing spay (hysterectomy) with sexually intact dogs or dogs that had undergone traditional castration or spay.

SAMPLE
6,018 dog owners responded to a web-based survey between November 3, 2021, and January 7, 2022.

PROCEDURES
Participants were asked demographic questions and to provide information about 1 or more dogs (living or deceased). Options for reproductive status were as follows: sexually intact, castrated, spayed (ovariohysterectomy or ovariectomy), vasectomy, or ovary-sparing spay (hysterectomy). Participants were asked questions about orthopedic and other health problems, cancer, and problematic behavior. Logistic regression models, survival analyses, and descriptive statistics were used to assess relationships between reproductive status and outcomes.

RESULTS
Owners provided valid surveys for 6,018 dogs, including 1,056 sexually intact, 1,672 castrated, and 58 vasectomized male dogs and 792 sexually intact, 2,281 spayed, and 159 female dogs that had undergone ovary-sparing spay. Longer exposure to gonadal hormones, regardless of reproductive status, was associated with reduced odds of general health problems and both problematic and nuisance behaviors.

CLINICAL RELEVANCE
TTo our knowledge, this study provides the first data on health and behavior outcomes of vasectomy and ovary-sparing spay in dogs and is the first to compare these outcomes to sexually intact and gonadectomized dogs. It adds to accumulating data on the mixed benefits and risks of removing the gonads to prevent reproduction and emphasizes the importance of developing an informed, case-by-case assessment of each patient, taking into consideration the potential risks and benefits of spaying or neutering and alternative reproductive surgeries.

Previous research[1] suggests that the prevalence of surgery to prevent reproduction in dogs in the US is approximately 64% (861,300/1,339,860 dogs). The predominant surgical method for preventing reproduction in North America is removal of the gonads. The most common reasons for the recommendation of gonadectomy in dogs are population control and behavioral and health benefits.[2–4]

While early research has suggested that gonadectomy provides substantial health benefits to dogs, a recent publication[5] demonstrated that the issue is complex and health effects might also be partly dependent on the breed of dog and age at which the dog was spayed or neutered. Removal of the testes in males prevents the development of testicular tumors, particularly in cryptorchid dogs,[6] and testosterone-induced conditions such as benign prostatic hyperplasia[7] and perianal adenoma,[8] but it also increases the risk of prostatic carcinoma.[9] In females, removal of both ovaries and the uterus prevents the development of ovarian tumors and pyometra and reduces the risk of mammary cancer,[10] although the validity of studies assessing the risk of mammary cancer has been questioned.[11]

Gonadectomy is associated with increased risk of a number of serious cancers in dogs, including hemangiosarcoma, lymphoma, mast cell tumors, transitional cell carcinoma of the bladder, and osteosarcoma.[12–17] Larger breeds of dogs appear to be at greater risk for the carcinogenic effects of gonadectomy, and there also appear to be breed differences.[18,19] One study[14] demonstrated that cancer is diagnosed at a younger age in gonadectomized Vizslas.

An association has been reported[20] between gonadectomy and increased risk of obesity, which significantly reduces lifespan.[21] Gonadectomy is also associated with increased risk of developing orthopedic disorders, including cranial cruciate ligament insufficiency,[22–26] hip dysplasia,[18,22,27,28] and patellar luxation.[29] Studies suggest gonadectomized dogs may also be at increased risk for numerous immune and autoimmune disorders,[30] vaccine reactions,[31] hypothyroidism,[30] pancreatitis,[32] and cognitive impairment.[30]

Early studies[2–4] have suggested that gonadectomy is effective in altering undesirable behaviors such as urine marking, mounting, aggression, and roaming in a large percentage of dogs. Canine aggression increases the risk of relinquishment to shelters and behavioral euthanasia[33,34] and may be an indicator of poor welfare.[35] More recent studies,[36–39] however, have reported conflicting data on the effects of gonadectomy on aggression, which, in addition to the welfare implications, is arguably the most important behavior issue in terms of human health and safety. Further, it has been suggested that as sexually intact dogs age, undesirable behaviors, particularly fearfulness and aggression, decline to a greater extent than in gonadectomized dogs.[40]

Given the complexity of the risks and benefits of gonadectomy in dogs, veterinarians and concerned dog owners have investigated alternative surgical options, such as vasectomy (VS) and hysterectomy (ovary-sparing spay [OSS]), that would prevent reproduction while still allowing dogs to retain the potential benefits of sex hormones.[41] Hysterectomy is chosen rather than other options such as salpingectomy because it prevents reproduction while abrogating the risk of pyometra. Demand is increasing for alternative surgical methods to prevent reproduction,[41,42] and on social media there are groups in which clients and veterinarians share their experiences with these procedures.

The objective of this study was to compare health and behavior outcomes for dogs that underwent VS or OSS (hysterectomy) with sexually intact dogs or dogs that had undergone traditional castration or spay. To the best of our knowledge, there are no published reports of the effects of VS or hysterectomy on canine health, behavior, or lifespan, or how these effects compare to dogs that are sexually intact or gonadectomized. These data are important if veterinarians are to offer these alternative reproductive surgeries and so that they can appropriately advise clients of the risks and benefits of these procedures. We hypothesized that dogs that received a VS or OSS would have health and behavior profiles like those of sexually intact dogs because of retention of gonadal hormones.

Materials and Methods

Procedure

Participants were solicited for a web-based survey using the platform SurveyMonkey (Momentive) during a 6-week period from November 3, 2021, through December 14, 2021. Data continued to be collected only for vasectomized dogs and dogs with OSS until January 7, 2022. No incentives were offered to participants. Solicitation was primarily through Good Dog's community newsletters and Facebook.

Participants were asked demographic questions (age, gender, and country of residence) and then invited to provide information about a dog (living or deceased), including the dog's name, breed, healthy adult weight, whether currently living, age at time of survey completion or age when deceased, and reproductive status **(Supplementary Appendix S1)**. There were no limits on the number of dogs for which an applicant could complete the survey.

The options for reproductive status were as follows: sexually intact, no reproductive organs removed or at least 1 testicle remaining; castration (neuter), both testes removed; spay, both ovaries and the uterus removed or ovariectomy (ovaries removed, leaving the uterus intact); VS, vas deferens surgically cut and sealed; or OSS (hysterectomy), uterus removed and ovaries intact. If dogs had a reproductive surgery, participants were asked for the age of the dog at the time of the procedure and their reasons for their choice of procedure.

All participants were asked questions about the dog's orthopedic health and diagnoses of cancer and other health problems (eg, thyroid disorders and obesity). Participants were asked about 2 categories of behavior problems: problematic behavior, including aggression, anxiety-based behaviors, and extreme fears, and nuisance behaviors (urine marking and mounting behavior, normal canid behaviors that are objectionable to many dog owners).[43] For sexually intact dogs, participants responded about the dog's health and behavior during the lifetime of the dog. For dogs that had reproductive surgery, participants were asked about health and behavior prior to and after the surgery. Participants could also add information regarding additional health or behavioral problems that were not included in the available list of responses.

If a participant's dog experienced cancer, the participant was asked for the dog's age at diagnosis. Participants were asked whether their dogs had experienced any complications from reproductive procedures, and all participants could leave comments at the end of the survey.

Statistical analysis

All statistical analyses were performed using SAS OnDemand for Academics (SAS Institute Inc) and OpenRefine (Metaweb Technologies Inc). Logistic regression models and descriptive statistics were used to assess the population and relationships between reproductive status and outcomes.

Health and behavior outcomes were coded into binomial variables on the basis of whether the dog had or had not experienced them. Outcomes were categorized as follows: orthopedic problems (eg, hip or elbow dysplasia, patellar luxation), cancer (any malignant neoplasia), problematic behaviors (eg, aggression and anxiety-related problems), nuisance behaviors (mounting and marking), obesity, endocrine disorders (eg, thyroid disease or diabetes), reproductive disorders (eg, pyometra or prostate infection), and other health problems (any clearly explained diagnosed health issue, including dental disease, heart disease, kidney disease, and disorders of the eye).

Logistic regression models contained the following predictor variables: age (in years), weight group (a categorical variable with 7 levels: < 4.5 kg, 4.5 to 9.1 kg, 9.2 to 18.2 kg, 18.3 to 27.3 kg, 27.4 to 36.4 kg, 36.5 to 45.5 kg, or > 45.5 kg), whether the dog was living or deceased at the time of the survey, reproductive status (sexually intact male [IM], sexually intact female [IF], neutered male [NM], spayed female [SF], VS, and OSS), and the duration gonads were present (for sexually intact dogs and dogs with a VS or OSS, the current age of the dog in months; for all other dogs, the age at the time gonads were removed in months). A separate model was run for each of the binomial health and behavior outcomes as the dependent variable.

Data were checked to determine that they met the assumptions of the logistic regression model. Continuous independent variables were tested for linearity in the logit, and a square root transformation was performed on variables that violated this assumption.[44] To address any violations of the assumption that independent variables were not correlated, each logistic regression model was first run with both variables, then with each predictor omitted. Akaike information criterion (a measure of relative quality of models being compared, with lower values indicating a better fit) and receiver operating characteristic (ROC) curves (the probabilities that predict a binary outcome, with higher values indicating better predictive value) were used to determine which model best fit the data. In all analyses except for orthopedic conditions, the full model was used.

To compare the age of cancer diagnosis among dogs that experienced cancer, an ANOVA was conducted, with reproductive group (sexually intact, gonadectomized, or VS-OSS) and duration gonads were present as the predictor variables and the outcome variable of age at cancer diagnosis.

Lifespan based on reproductive group was compared using a Kaplan-Meier analysis, comparing lifespan between groups with a log rank test. Cox proportional hazard regression analysis was also performed to investigate the effects of reproductive group, age, duration gonads were present, whether the dog was living, and the presence of a health or behavioral condition on lifespan. α was set to < 0.05 for all analyses unless otherwise indicated.

Results

Descriptive statistics

In total, 6,475 participants started the survey, which resulted in 6,018 valid surveys. Reasons for invalid surveys included duplicates (based on participant demographics, dog information, and internet protocol address) and incomplete surveys (n = 271), those collected after the initial 6 weeks of the survey if dogs were not in the VS or OSS (hysterectomy) reproductive categories (85), and those for dogs under a year of age at the time of the survey (101).

The final data set included surveys representing 3,753 dogs that were living at the time of the survey and 2,265 dogs that were deceased. This included data for 1,056 sexually intact, 1,672 castrated, and 58 vasectomized males and 792 sexually intact, 2,281 spayed, and 159 females that had undergone an OSS.

Of respondents who specified their gender, 95% identified as female (5,693/6,018) and 3% (201/6,018) identified as male. Most participants lived in the US (4,240/6,018 [70%]) or Canada (992/6,018 [16%]). The ranges of participant ages were as follows: 18 to 24 (138/6,018 [2%]), 25 to 34 (632/6,018 [< 11%]), 35 to 44 (917/6,018 [15%]), 45 to 54 (1,210/6,018 [20%]), 55 to 64 (1,726/6,018 [29%]), and ≥ 65 (1,273/6,018 [21%]).

The reported mean age of all dogs in the study was 8.85 years (SD, 4.38 years), with a range from 1 to 21 years of age. Mean ages by reproductive status were 6.9 ± 4.4 years for IMs, 9.9 ± 4 years for castrated males, 5.5 ± 3.5 years for vasectomized males, 5.8 ± 3.8 years for IFs, 10.2 ± 3.9 years for SFs, and 7.1 ± 3.8 years for hysterectomized females.

Mean duration that gonads were present was 82.9 ± 53 months for IMs, 30 ± 34.3 months for castrated males, 22.9 ± 20.6 months for vasectomized males, 70 ± 46 months for IFs, 35.6 ± 33.7 months for SFs, and 45.4 ± 34.6 months for hysterectomized females.

Most dogs (77% [4,626/6,018]) had a healthy adult weight of between 9.1 and 36.3 kg (weight distribution: < 4.5 kg, 3% [183/6,018]; 4.5 to 9.1 kg, < 11% [642/6,018]; 9.2 to 18.2 kg, 21% [1,256/6,018]; 18.3 to 27.3 kg, 33% [1,986/6,018]; 27.4 to 36.4 kg, 23% [1,384/6,018]; 36.5 to 45.5 kg, 6% [352/6,018]; or > 45.5 kg, < 4% [215/6,018]).

The prevalence of health conditions **(Supplementary Table S1)** and behavior problems **(Supplementary Table S2)** was as follows: orthopedic conditions (759/6,018 [12.6%]), cancer (1,127/6,018 [18.7%]), obesity (192/6,018 [3.2%]), endocrine disorders (320/6,018 [5.3%]), reproductive conditions (194/6,018 [3.2%]), other health conditions (1,074/6,018 [17.8]), problematic behaviors (2,035/6,018 [33.8%]), and nuisance behaviors (484/6,018 [8%]).

Logistic regression models

There were no outliers in the data. Before running logistic regression models, we performed a square root transformation on the duration gonads were present because it violated the assumption for linearity in the logit. The independent variables reproductive group and duration gonads were present were statistically related (ANOVA results, F [2, 5,865] = 355.61; P < .001). To address this violation of the assumption that independent variables are not correlated, each logistic regression model was first run with both variables (reproductive group and duration gonads were present), then with each predictor omitted. Results are reported including a Bonferroni correction of α < 0.003 to address comparisons between reproductive groups.

Health problems

Orthopedic problems—The overall model was statistically significant ($X^2[8] = 168.74$; $P < .001$). Odds of an orthopedic problem increased with gonadectomy so that NM (353/1,672 [21%]) and SF dogs (442/2,281 [19%]) had more reported orthopedic problems compared to IM (72/1,056 [7%]), IF (26/792 [3%]), and OSS dogs (12/159 [8%]). IM dogs also had higher odds of orthopedic problems compared to IF dogs. Increasing size (OR = 1.12; CI, 1.06 to 1.19; $P < .001$) and age (OR = 1.07; CI, 1.05 to 1.10; $P < .001$) were associated with increased odds of orthopedic problems. Being alive at the time of the survey was not a significant predictor. Duration that gonads were present was dropped from the model due to issues with multicollinearity **(Table 1)**.

Table 1—Odds ratios for orthopedic conditions, cancer, and obesity for 6,018 dogs as reported by their owners in an online survey conducted between November 3, 2021, and January 7, 2022, to gather patient-related information about health and behavior outcomes in dogs that underwent vasectomy or ovary-sparing spay (OSS), compared with sexually intact dogs or dogs that had undergone traditional castration or spay.

Predictor	OR	95% CI
Orthopedic		
Reproductive groups[a]		
NM-IM	1.40*	1.09–1.79
NM-IF	2.15*	1.55–3.01
NM-OSS	2.60*	1.30–5.18
SF-IM	1.40*	1.10–1.77
SF-IF	2.16**	1.56–2.99
SF-OSS	2.60*	1.31–5.17
IM-IF	1.55*	1.08–2.22
Gonads (mo)[b]†	Removed	
Body weight group	1.12*	1.06–1.19
Living (yes)	0.90	0.75–1.08
Age (y)	1.07*	1.05–1.10
Cancer		
Reproductive groups[a]		
NM-IM	1.42*	1.11–1.82
SF-IM	1.49**	1.17–1.90
Gonads (mo)[b]	1.00	0.98–1.03
Body weight group	1.20*	1.13–1.27
Living (yes)	0.06*	0.04–0.07
Age (y)	0.99	0.96–1.01
Obesity		
Reproductive groups[a]		
NM-IM	29.98**	7.19–125.09
NM-IF	7.80**	3.04–20.03
OSS-IM	14.17**	2.57–78.11
SF-IM	25.60**	6.26–104.60
SF-IF	6.63**	2.60–16.92
Gonads (mo)[b]	1.01	0.96–1.06
Body weight group	1.23*	1.09–1.38
Living (yes)	0.81	0.58–1.16
Age (y)	1.01	0.97–1.06

IF = Sexually intact female. IM = Sexually intact male. NM = Neutered male. OSS = Ovary-sparing spayed female. SF = Spayed female. VS = Vasectomized dog.

[a]For reproductive groups, the first listed is the reference group for the OR. [b]Gonads = Duration gonads were present, in months. [c]Body weight groups: < 4.5 kg, 4.5 to 9.1 kg, 9.2 to 18.2 kg, 18.3 to 27.3 kg, 27.4 to 36.4 kg, 36.5 to 45.5 kg, or > 45.5kg.

*Statistically significant at $\alpha < 0.05$. **Statistically significant with Bonferroni correction of $\alpha < 0.003$.

[f]†Independent variable removed due to collinearity.

The ROC curve for the model showed the area under the curve was 0.69, indicating low predictive ability of the model. The sensitivity (true positives) was 0, and the specificity (true negatives) was 100. The Hosmer-Lemeshow χ^2 test was not significant ($P = .18$), suggesting that the model was a good fit.

Cancer—The overall model was statistically significant ($X^2[9] = 1,511.92$; $P < .001$). IM dogs (93/1,056 [9%]) were less likely to have cancer than gonadectomized dogs (NM, 464/1,672 [28%]; SF, 582/2,281 [26%]; Table 1). Increased size was associated with increased odds of being diagnosed with cancer (OR = 1.20; CI, 1.13 to 1.27; $P < .001$). Dogs that were living were less likely to have had a cancer diagnosis (OR = 0.06; CI, 0.04 to 0.07; $P < .001$) than deceased dogs. The age of the dog and the duration gonads were present were not significant predictors of having cancer.

The ROC curve for the model showed the area under the curve was 0.83, indicating good predictive ability of the model. The sensitivity was 19.5, and the specificity was 95.5. The Hosmer-Lemeshow χ^2 test suggested the observed number of cancer cases did not match the expected event rates in population subgroups ($X^2[8] = 21.16$; $P = .007$).

No VS-OSS dogs were diagnosed with cancer before their surgery. Twenty-three (10.6% [23/217]) VS-OSS dogs were diagnosed with cancer after their reproductive surgery, and 205 (11% [205/1,848]) sexually intact dogs were diagnosed with cancer.

We compared the age at cancer diagnosis between reproductive groups. Gonadectomized dogs that were diagnosed with cancer before being gonadectomized (98/3,953 [2.5%]) were diagnosed by a mean age of 7.63 years (SD, 3.18 years), and those that were diagnosed with cancer after being gonadectomized (942/3,953 [23.8%]) were diagnosed by a mean age of 10.15 years (SD, 2.77 years).

The mean age at which VS-OSS dogs were diagnosed with cancer after their reproductive surgery (9.18 years; SD, 3.14 years) was not significantly different from the mean age at which sexually intact dogs were diagnosed with cancer (9.30 years; SD, 2.74 years). Gonadectomized dogs had a later mean age of cancer diagnosis ($F[2, 1,167] = 8.73$; $P < .001$) compared to both sexually intact and VS-OSS dogs.

Thus, although gonadectomized dogs overall had a later cancer diagnosis, significantly more gonadectomized dogs were diagnosed with cancer compared to sexually intact dogs. Longer duration that gonads were present correlated with a later age of cancer diagnosis ($r = 0.12$; $P < .001$).

Twenty-six IFs were diagnosed with mammary cancer (26/792 [3.2%] of IFs); among SFs, 39 were diagnosed with mammary cancer before spay surgery (39/2,281 [1.7%] of SFs) and 42 were diagnosed after spay surgery (42/2,281 [1.8%] of SFs). Four dogs were diagnosed with mammary cancer after the OSS procedure (4/159 [2.5%] of OSS dogs).

Obesity—The overall model was statistically significant ($X^2[9] = 127.28$; $P < .001$). IM (2/1,056 [< 1%]) and IF dogs (0/792) were less likely to be reported as obese compared to NM (91/1,672 [5%]) and SF dogs

(100/2,281 [4%]). IM dogs were also less likely to be reported as obese than OSS dogs (1/159 [< 1%]). There was no relationship between obesity and duration gonads were present, age, or being alive at the time of the survey. The associated odds of obesity increased as size increased (OR = 1.23; CI, 1.09 to 1.38; $P < .001$; Table 1).

The ROC curve for the model showed the area under the curve was 0.72, indicating fair predictive ability of the model. The sensitivity was 0, and the specificity was 100. The Hosmer-Lemeshow χ^2 test was not significant ($P = .20$), suggesting the model was a good fit.

Endocrine conditions—The overall model was statistically significant ($X^2[9] = 157.73$; $P < .001$). IF dogs (12/792 [< 2%]) were less likely to have an endocrine condition compared to IM (45/1,056 [4%]), NM (107/1,672 [6%]), and SF dogs (163/2,281 [7%]). Duration gonads were present and size were not related to the presence of an endocrine condition. Increasing age was associated with increased odds of being diagnosed with an endocrine condition (OR = 1.13; CI, 1.09 to 1.18; $P < .001$). Being alive at the time of the survey was associated with decreased odds of endocrine-related disease compared to deceased dogs (OR = 0.66; CI, 0.50 to 0.88; $P = .004$; **Table 2**).

Table 2—Odds ratios for endocrine and reproductive disorders and other health problems for 6,018 dogs as reported by their owners in an online survey conducted between November 3, 2021, and January 7, 2022, to gather patient-related information about health and behavior outcomes in dogs that underwent vasectomy or OSS, compared with sexually intact dogs or dogs that had undergone traditional castration or spay.

Predictor	OR	95% CI
Endocrine		
Reproductive groups		
IM-IF	2.38*	1.24–4.56
NM-IF	2.04*	1.05–3.95
SF-IF	2.32*	1.22–4.43
Gonads (mo)[b]	0.97	0.93–1.01
Size group	1.05	0.96–1.16
Living (yes)	0.66*	0.50–0.88
Age (y)	1.13*	1.09–1.18
Reproductive		
Reproductive groups		
IM-NM	4.11**	1.97–8.59
IF-NM	4.65**	2.17–10.02
SF-NM	4.33**	2.19–8.56
OSS-NM	8.32**	3.23–21.38
Gonads (mo)[b]	1.36*	1.25–1.47
Body weight group	1.12*	1.02–1.30
Living (yes)	0.53*	0.37–0.77
Age	0.99	0.93–1.06
Other health		
Reproductive groups		
SF-IM	1.45*	1.13–1.86
SF-IF	2.00**	1.46–2.72
SF-NM	1.72**	1.46–2.04
IM-IF	1.39*	1.01–1.90
Gonads (mo)[b]	0.97*	0.94–0.99
Body weight group	1.10*	1.04–1.17
Living (yes)	0.71*	0.60–0.84
Age (y)	1.12*	1.09–1.14

*Statistically significant at $\alpha < 0.05$. **Statistically significant with Bonferroni correction of $\alpha < 0.003$.

See Table 1 for the rest of the key.

The ROC curve for the model showed the area under the curve was 0.70, indicating fair predictive ability of the model. The sensitivity was 0, and the specificity was 100. The Hosmer-Lemeshow χ^2 test was significant ($X^2[8] = 27.01$; $P < .001$), suggesting that the observed number of endocrine problems did not match the expected event rates in population subgroups.

Reproductive conditions—The overall model was statistically significant ($X^2[9] = 280.35$; $P < .001$). NMs (6/1,672 [< 1%]) were less likely to have a reported reproductive health problem compared to IM (71/1,056 [7%]), IF (33/792 [4%]), OSS (11/159 [7%]), and SF dogs (60/2,281 [3%]; Table 2). Increasing duration that gonads were present (OR = 1.36; CI, 1.25 to 1.47; $P < .001$) and increasing size (OR = 1.15; CI, 1.02 to 1.30; $P = .02$) were associated with increased odds of a reproductive health problem. Being alive at the time of the survey decreased the likelihood of having at least 1 diagnosed reproductive health problem (OR = 0.53; CI, 0.37 to 0.77; $P < .001$). Age was not associated with having a reproductive health problem (Table 2).

The ROC curve for the model showed the area under the curve was 0.82, indicating good predictive ability of the model. The sensitivity was 0, and the specificity was 100. The Hosmer-Lemeshow χ^2 test was not significant ($P = 0.18$), suggesting the model was a good fit.

Other health problems—The overall model was statistically significant ($X^2[9] = 391.24$; $P < .001$). SFs (586/2,281 [26%]) were more likely to have a reported health problem compared to IM (139/1,056 [13%]), IF (67/792 [8%]), and NM dogs (288/1,672 [17%]), and IMs were more likely to have a reported health problem compared to IF dogs. Longer duration that gonads were present reduced the likelihood of experiencing another health problem (OR = 0.97; CI, 0.94 to 0.99; $P = .02$). The associated OR of another health problem increased as age and size increased (OR = 1.12; CI, 1.09 to 1.14; $P < .001$; and OR = 1.10; CI, 1.04 to 1.17; $P < .001$, respectively). Dogs that were alive at the time of the survey were less likely to have had another health problem than dogs that were not (OR = 0.71; CI, 0.60 to 0.84; $P < .001$; Table 2).

The ROC curve for the model showed the area under the curve was 0.69, indicating low predictive ability of the model. The sensitivity was 0.1, and the specificity was 100. The Hosmer-Lemeshow χ^2 test was significant ($X^2[8] = 51.72$; $P < .001$), suggesting that the observed number of other health problems did not match the expected event rates in population subgroups.

Problematic behaviors

The overall model was statistically significant ($X^2[9] = 237.19$; $P < .001$). NM dogs (881/1,672 [53%]) were more likely to be reported to have a problematic behavior compared to IM (373/1,056 [35%]), IF (221/792 [28%]), SF (939/2,281 [41%]), and OSS dogs (69/159[43%]; **Table 3**).

Table 3—Odds ratios for problematic and nuisance behavior of 6,018 dogs as reported by their owners in an online survey conducted between November 3, 2021, and January 7, 2022, to gather patient-related information about health and behavior outcomes in dogs that underwent vasectomy or OSS, compared with sexually intact dogs or dogs that had undergone traditional castration or spay.

Predictor	OR	95% CI
Problematic behaviors		
Reproductive groups		
NM-IM	1.48**	1.21–1.81
NM-IF	1.79**	1.44–2.23
NM-SF	1.45**	1.27–1.66
NM-OSS	1.58*	1.10–2.27
Gonads (mo)[b]	0.91*	0.89–0.93
Body weight group	0.92*	0.88–0.96
Living (yes)	1.23*	1.07–1.42
Age (y)	1.01	0.99–1.03
Nuisance behaviors		
Reproductive groups		
IM-IF	3.79**	2.52–5.71
NM-IF	2.97**	1.90–4.63
VS-IF	5.77**	2.73–12.19
OSS-IF	2.80**	1.47–5.30
IM-SF	2.67**	1.93–3.70
NM-SF	2.09**	1.65–2.66
VS-SF	4.07**	2.07–7.99
OSS-SF	1.97*	1.13–3.45
Gonads (mo)[b]	0.95*	0.92–0.99
Body weight group	0.78*	0.72–0.84
Living (yes)	1.37*	1.06–1.76
Age (y)	1.00	0.97–1.03

[a]*Statistically significant at α = 0.05. [b]**Statistically significant with Bonferroni correction of α < 0.003

See Table 1 for the rest of the key.

The associated odds of problematic behavior decreased as duration gonads were present and size increased (OR = 0.91; CI, 0.89 to 0.93; $P < .001$; and OR = 0.92; CI, 0.88 to 0.96; $P < .001$, respectively). Dogs that were alive at the time of the survey were more likely to be described as having problematic behavior (OR = 1.23; CI, 1.07 to 1.42; $P = .005$), regardless of reproductive status. There was no effect of age on the likelihood of problematic behavior (Table 3).

The ROC curve for the model showed the area under the curve was 0.62, indicating low predictive ability of the model. The sensitivity was 9.3, and the specificity was 95.8. The Hosmer-Lemeshow χ^2 test was significant ($X^2[8] = 19.4$; $P = .01$), suggesting that the observed number of behavior cases did not match the expected event rates in population subgroups.

Nuisance behaviors—The overall model was statistically significant ($X^2[9] = 149.67$; $P < .001$). IF (32/792 [4%]) and SF dogs (133/2,281 [6%]) were less likely to exhibit nuisance behaviors compared to IM (133/1,056 [13%]), NM (187/1,672 [11%]), VS (12/58 [21%]), and OSS dogs (16/159 [10%]). Longer duration that gonads were present reduced the likelihood of nuisance behaviors (OR = 0.95; CI, 0.92 to 1.00; $P = .02$). Dogs that were alive at the time of the survey were more likely to display mounting or marking (OR = 1.37; CI, 1.06 to 1.76; $P = .015$). The associated odds of displaying nuisance behaviors decreased as size increased (OR = 0.78; CI, 0.72 to 0.84; $P < .001$). Age was not a significant predictor of nuisance behaviors (Table 3).

The ROC curve for the model showed the area under the curve was 0.66, indicating low predictive ability of the model. The sensitivity was 0, and the specificity was 100. The Hosmer-Lemeshow χ^2 test was not significant ($P = 0.37$), suggesting that the model was a good fit.

Lifespan analysis

The Kaplan-Meier test estimating survival probabilities found significant differences among the 6 reproductive groups ($X^2[5] = 17.86$; $P = .003$); however, in pairwise comparisons (α adjusted to < 0.003), the only statistical difference was between NM and SF dogs ($X^2[1] = 12.59$; $P < .001$). The results of the Cox proportional hazards model **(Table 4)** found that IM and IF dogs had higher hazard ratios (shorter lifespans) compared to all other reproductive groups. Being larger and having cancer were associated with a higher hazard ratio (shorter lifespan). Longer duration that gonads were present and exhibiting nuisance behaviors were associated with a longer lifespan.

Table 4—Results of the Cox proportional hazards regression model with lifespan as outcome.

Predictor	Hazard ratio	95% CI	*P* value
Reproductive groups			
IF-SF	3.08	2.41–3.94	< .001
IF-NM	2.85	2.21–3.66	< .001
IF-VS	6.43	2.02–20.46	.002
IF-OSS	2.56	1.68–3.91	< .001
IM-SF	2.67	2.16–3.30	< .001
IM-NM	2.46	1.98–3.06	< .001
IM-VS	5.56	1.76–17.58	.004
IM-OSS	2.22	1.48–3.31	< .001
Duration gonads were present	0.99	0.99–0.99	< .001
Body weight group	1.34	1.29–1.39	< .001
Orthopedic	0.85	0.76–0.96	.007
Cancer	2.18	2.00–2.38	< .001
Obesity	1.08	0.87–1.36	.48
Endocrine	0.99	0.83–1.18	.91
Reproductive health	1.00	0.81–1.24	.98
Other health	0.99	0.88–1.12	.88
Problematic behavior	0.91	0.83–1.00	.06
Nuisance behavior	0.82	0.69–0.98	.03

See Table 1 for the key.

Reasons for reproductive choice

The most common reasons for keeping male and female dogs sexually intact included wanting to breed the dog (1,074/1,848 [58%]) or compete in conformation (778/1,848 [42%]), a belief that sexually intact dogs are healthier (861/1,848 [47%]), because the participant saw no reason to perform the surgery (648/1,056 [61%] owners of IM dogs and 344/792 [43%] owners of IF dogs), and concerns about orthopedic problems (693/1,848 [38%]). Participants whose dogs had an OSS or VS felt that these procedures resulted in healthier dogs (142/217 [65%]), and they wanted to prevent breeding (84/217 [39%]) or, in the case of female dogs, pyometra (74/159 [47%]).

For SFs, participants wanted to prevent breeding (774/2,281 [34%]) and pyometra (726/2,281 [32%]) and avoid managing a dog in heat (663/2,281 [29%]). Concern of mammary cancer was not a major consideration, with only 20% of participants with spayed dogs endorsing this item. The most common reasons for castrating male dogs were to prevent breeding (462/1,672 [28%]), because a veterinarian recommended it (352/1,672 [21%]), and that it was required by a breeder or rescue (323/1,672 [19%]).

Complications from alternative surgical procedures

Seven participants (7/58 [12%]) reported complications for vasectomized dogs, including localized pain (n = 1), swelling or infection at the suture site (4), an atrophied testicle (1), and a reaction to anesthesia (1). Twelve participants (12/159 [7%]) reported complications related to OSS. Two participants noted personality changes in their dog postsurgery. One dog developed pyometra, and another had a benign cyst of the uterine stump. Other complications included difficult surgery or recovery (n = 4), a lost tooth due to the breathing tube (1), and heavy bleeding or frequent heat cycles (3). We did not ask participants if their dogs experienced complications from traditional spay or castration.

Discussion

To our knowledge, this study was the first to examine the health and behavior outcomes of dogs that underwent VS or OSS (hysterectomy) surgeries and to compare those outcomes to sexually intact or gonadectomized dogs. We hypothesized that the increased exposure to gonadal hormones would give these dogs health and behavioral profiles similar to sexually intact dogs. Our most important finding was that longer duration that gonads were present, regardless of reproductive status, was associated with fewer general health problems and both problematic and nuisance behaviors. It was also associated with an increased lifespan. Because VS and OSS permit dogs to experience longer gonadal hormone exposure times, these data suggest that, when electing surgery to prevent reproduction, dogs might benefit from these alternative surgeries with respect to general health and experience better behavior outcomes compared to undergoing traditional spay-neuter surgery. Delaying traditional spay-neuter surgery could offer similar benefits.

Being sexually intact or having an OSS were associated with lower odds of orthopedic problems, consistent with other studies[14,18,22,26–28] showing lower risks of a variety of orthopedic problems in sexually intact dogs as compared to gonadectomized dogs. Our data also showed that orthopedic conditions were more common in larger dogs and older dogs.

Our results were also consistent with previous studies[14,22,27] indicating that the associated odds of cancer is significantly lower for sexually intact dogs than gonadectomized dogs. Although gonadectomized dogs had a later cancer diagnosis, significantly more gonadectomized dogs were diagnosed with cancer compared to sexually intact dogs. This is consistent with a study[14] of gonadectomy in Vizslas that found that the later dogs underwent gonadectomy, the later their diagnosis of cancer. The finding of more cancer in larger dogs is also consistent with previous research.[19]

There were other effects of reproductive status on outcomes. Gonadectomized dogs and dogs that underwent OSS were more likely to be obese than sexually intact dogs, but there was no relationship between duration that gonads were present and obesity. This suggests that the causes of obesity are more complex than just the absence of gonadal hormones.

Longer duration that gonads were present was associated with a small but significant reduced likelihood of experiencing health problems other than the ones we provided as options for participants. Contrary to previous studies[45,46] that found that removal of gonadal hormones may lead to an imbalance in the feedback mechanisms of the pituitary-adrenal axis, we found no relationship between reproductive status nor duration gonads were present with the presence of an endocrine condition.

Our data also indicated that the associated prevalence of both problematic and nuisance behaviors decreased with increased exposure to gonadal hormones. Male dogs of all reproductive groups and dogs with an OSS were reportedly more likely to mark or mount than sexually intact and SF dogs. Further, there was no difference in marking or mounting between gonadectomized and IM dogs.

Taken together, these data suggest that gonadal hormone exposure time may be a more sensitive way to examine the effects of reproductive surgery on health and behavior than categorizing dogs into groups by type of reproductive surgery. This is likely because there may be significant overlap in the length of exposure to gonadal hormones between the 6 groups examined in this study.

The major limitations of this study were the relatively low number of dogs represented in the survey that had undergone VS or OSS (n = 217), as well as a generally low prevalence of reported health conditions. This likely reduced our ability to detect differences between groups for some of the health conditions and behavior issues (cancer, endocrine conditions, and problematic behaviors) that were targeted. As with any retrospective study, these survey data were limited by recall bias. Survey respondents needed internet access and computer skills to find and respond to the survey, and many respondents were members of Good Dog, an organization that promotes responsible dog breeding, so the survey data likely represented information from larger numbers of purebred dogs than might be seen in the overall population of North American dogs. Finally, the data might have been altered by cause-and-effect issues. For example, some dogs might have been spayed or neutered because of health problems and some of the health problems examined were likely just a typical part of aging.

Nonetheless, these data demonstrated potential health and behavior benefits to dogs of both sexes experiencing longer exposure to gonadal hormones. Given the relatively low risk of these alternative surgeries, particularly in the hands of experienced veterinary practitioners, veterinarians might consider offering these alternative reproductive surgeries to allow dogs to obtain these benefits without experiencing unintentional reproduction. Additional studies are needed before these alternative surgeries can be presented as a routine option for prevention of reproduction in dogs. There is a need for studies examining whether there are any long-term hormone-related consequences of removal of the uterus with retention of the ovaries, such as increased risk of mammary cancer. There were too few dogs undergoing OSS in this study to accurately detect changes in the risk of mammary cancer in these dogs. While hysterectomy is performed on hundreds of thousands of women annually,[47] there are too many differences in the reproductive biology of humans and dogs to assume that dogs will respond in the same way as women. Furthermore, we refer the reader to the American College of Theriogenologists' position statement on gonad-sparing sterilization procedures.[48]

To our knowledge, this study provided the first data on the health and behavior outcomes of VS and OSS in dogs and was the first to compare these outcomes to sexually intact and gonadectomized dogs. Our findings emphasize the importance of gonadal hormone exposure to canine health and behavior. This evidence supports the 2021 statement by Dr. Kendall Houlihan, the AVMA's Associate Director of Animal Welfare: "AVMA promotes the professional judgment of the veterinarian in developing an informed, case-by-case assessment of each individual patient, taking into account all the potential risks and benefits of spay/neuter."[49] We encourage veterinary schools to discuss with their students the evidence for the various surgical options available to prevent reproduction while optimizing the health and behavior of dogs.

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References

1. Trevejo R, Yang M, Lund EM. Epidemiology of surgical castration of dogs and cats in the United States. *J Am Vet Med Assoc*. 2011;238(7):898–904. doi:10.2460/javma.238.7.898
2. Neilson JC, Eckstein RA, Hart BL. Effects of castration on problem behaviors in male dogs with reference to age and duration of behavior. *J Am Vet Med Assoc*. 1997;211(2):180–182.
3. Hopkins SG, Schubert TA, Hart BL. Castration of adult male dogs: effects on roaming, aggression, urine marking, and mounting. *J Am Vet Med Assoc*. 1976;168(12):1108–1110.
4. Maarschalkerweerd RJ, Endenburg N, Kirpensteijn J, Knol BW. Influence of orchiectomy on canine behaviour. *Vet Rec*. 1997;140(24):617–619. doi:10.1136/vr.140.24.617
5. Hart LA, Hart BL. An ancient practice but a new paradigm: personal choice for the age to spay or neuter a dog. *Front Vet Sci*. 2021;8:603257. doi:10.3389/fvets.2021.603257
6. Liao AT, Chu PY, Yeh LS, Lin CT, Liu CH. A 12-year retrospective study of canine testicular tumors. *J Vet Med Sci*. 2009;71(7):919–923. doi:10.1292/jvms.71.919
7. Juniewicz PE, Berry SJ, Coffey DS, Strandberg JD, Ewing LL. The requirement of the testis in establishing the sensitivity of the canine prostate to develop benign prostatic hyperplasia. *J Urol*. 1994;152(3):996–1001. doi:10.1016/s0022-5347(17)32641-1
8. Park C, Yoo JH, Kim HJ, et al. Cyclosporine treatment of perianal gland adenoma concurrent with benign prostatic hyperplasia in a dog. *Can Vet J*. 2010;51(11):1279–1282.
9. Sorenmo KU, Goldschmidt M, Shofer F, Goldkamp C, Ferracone J. Immunohistochemical characterization of canine prostatic carcinoma and correlation with castration status and castration time. *Vet Comp Oncol*. 2003;1(1):48–56. doi:10.1046/j.1476-5829.2003.00007.x
10. Schneider R, Dorn CR, Taylor DO. Factors influencing canine mammary cancer development and postsurgical survival. *J Natl Cancer Inst*. 1969;43(6):1249–1261.
11. Beauvais W, Cardwell JM, Brodbelt DC. The effect of neutering on the risk of mammary tumours in dogs–a systematic review. *J Small Anim Pract*. 2012;53(6):314–322. doi:10.1111/j.1748-5827.2011.01220.x
12. Hart BL, Hart LA, Thigpen AP, Willits NH. Assisting decision-making on age of neutering for 35 breeds of dogs: associated joint disorders, cancers, and urinary incontinence. *Front Vet Sci*. 2020;7:388. doi:10.1111/j.1748-5827.2011.01220.x
13. Prymak C, McKee LJ, Goldschmidt MH, Glickman LT. Epidemiologic, clinical, pathologic, and prognostic characteristics of splenic hemangiosarcoma and splenic hematoma in dogs: 217 cases (1985). *J Am Vet Med Assoc*. 1988;193(6):706–712.
14. Zink MC, Farhoody P, Elser SE, Ruffini LD, Gibbons TA, Rieger RH. Evaluation of the risk and age of onset of cancer and behavioral disorders in gonadectomized Vizslas. *J Am Vet Med Assoc*. 2014;244(3):309–319. doi:10.2460/javma.244.3.309
15. Norris AM, Laing EJ, Valli VE, et al. Canine bladder and urethral tumors: a retrospective study of 115 cases (1980–1985). *J Vet Intern Med*. 1992;6(3):145–153.
16. Brodey RS, Riser WH. Canine osteosarcoma. A clinicopathologic study of 194 cases. *Clin Orthop Relat Res.* 1969;62:54–64.
17. Villamil JA, Henry CJ, Hahn AW, Bryan JN, Tyler JW, Caldwell CW. Hormonal and sex impact on the epidemiology of canine lymphoma. *J Cancer Epidemiol*. 2009;2009:591753. doi:10.1155/2009/591753
18. Hart BL, Hart LA, Thigpen AP, Willits NH. Long-term health effects of neutering dogs: comparison of Labrador Retrievers with Golden Retrievers. *PLoS One*. 2014;9(7):e102241. doi:10.1371/journal.pone.0102241
19. Schwartz SM, Urfer SR, White M, et al. Lifetime prevalence of malignant and benign tumours in companion dogs: cross-sectional analysis of Dog Aging Project baseline survey. *Vet Comp Oncol*. 2022;20(4):797–804. doi:10.1111/vco.12839
20. Lefebvre SL, Yang MY, Wang MS, et al. Effect of age at gonadectomy on the probability of dogs becoming overweight. *J Am Vet Med Assoc*. 2013;243(2):236–243. doi:10.2460/javma.243.2.236
21. Salt C, Morris PJ, Wilson D, Lund EM, German AJ. Association between life span and body condition in neutered client-owned dogs. *J Vet Intern Med*. 2019;33(1):89–99. doi:10.1111/jvim.15367

22. Torres de la Riva G, Hart BL, Farver TB, et al. Neutering dogs: effects on joint disorders and cancers in Golden Retrievers. *PLoS One*. 2013;8(2):e55937. doi:10.1371/journal.pone.0055937
23. Duerr FM, Duncan CG, Savicky RS, Park RD, Egger EL, Palmer RH. Risk factors for excessive tibial plateau angle in large-breed dogs with cranial cruciate ligament disease. *J Am Vet Med Assoc*. 2007;231(11):1688–1691. doi:10.2460/javma.231.11.1688
24. Duval JM, Budsberg SC, Flo GL, Sammarco JL. Breed, sex, and body weight as risk factors for rupture of the cranial cruciate ligament in young dogs. *J Am Vet Med Assoc*. 1999;215(6):811–814.
25. Whitehair JG, Vasseur PB, Willits NH. Epidemiology of cranial cruciate ligament rupture in dogs. *J Am Vet Med Assoc*. 1993;203(7):1016–1019.
26. Slauterbeck JR, Pankratz K, Xu KT, Bozeman SC, Hardy DM. Canine ovariohysterectomy and orchiectomy increases the prevalence of ACL injury. *Clin Orthop Relat Res*. 2004;429:301–305. doi:10.1097/01.blo.0000146469.08655.e2
27. Hart BL, Hart LA, Thigpen AP, Willits NH. Neutering of German Shepherd Dogs: associated joint disorders, cancers and urinary incontinence. *Vet Med Sci*. 2016;2(3):191–199. doi:10.1002/vms3.34
28. Simpson M, Albright S, Wolfe B, et al. Age at gonadectomy and risk of overweight/obesity and orthopedic injury in a cohort of Golden Retrievers. *PLoS One*. 2019;14(7):e0209131. doi:10.1371/journal.pone.0209131
29. Vidoni B, Sommerfeld-Stur I, Eisenmenger E. Diagnostic and genetic aspects of patellar luxation in small and miniature breed dogs in Austria. *Wien Tierarztl Monatsschr*. 2005;92(8):170–181.
30. Sundburg CR, Belanger JM, Bannasch DL, Famula TR, Oberbauer AM. Gonadectomy effects on the risk of immune disorders in the dog: a retrospective study. *BMC Vet Res*. 2016;12(1):278. doi:10.1186/s12917-016-0911-5
31. Moore GE, Guptill LF, Ward MP, et al. Adverse events diagnosed within three days of vaccine administration in dogs. *J Am Vet Med Assoc*. 2005;227(7):1102–1108. doi:10.2460/javma.2005.227.1102
32. Lem KY, Fosgate GT, Norby B, Steiner JM. Associations between dietary factors and pancreatitis in dogs. *J Am Vet Med Assoc*. 2008;233(9):1425–1431. doi:10.2460/javma.233.9.1425
33. Salman MD, Hutchison J, Ruch-Gallie R, et al. Behavioral reasons for relinquishment of dogs and cats to 12 shelters. *J Appl Anim Welf Sci*. 2000;3(2):93–106. doi:10.1207/S15327604JAWS0302_2
34. Siracusa C, Provoost L, Reisner IR. Dog- and owner-related risk factors for consideration of euthanasia or rehoming before a referral behavioral consultation and for euthanizing or rehoming the dog after the consultation. *J Vet Behav*. 2017;22:46–56. doi:10.1016/j.jveb.2017.09.007
35. Flint HE, Coe JB, Serpell JA, Pearl DL, Niel L. Risk factors associated with stranger-directed aggression in domestic dogs. *Appl Anim Behav Sci*. 2017;197:45–54. doi:10.1016/j.applanim.2017.08.007
36. Farhoody P, Mallawaarachchi I, Tarwater PM, Serpell JA, Duffy DL, Zink C. Aggression toward familiar people, strangers, and conspecifics in gonadectomized and intact dogs. *Front Vet Sci*. 2018;5:18. doi:10.3389/fvets.2018.00018
37. Hsu Y, Serpell JA. Development and validation of a questionnaire for measuring behavior and temperament traits in pet dogs. *J Am Vet Med Assoc*. 2003;223(9):1293–1300. doi:10.2460/javma.2003.223.1293
38. Kim HH, Yeon SC, Houpt KA, Lee HC, Chang HH, Lee HJ. Effects of ovariohysterectomy on reactivity in German Shepherd Dogs. *Vet J*. 2006;172(1):154–159. doi:10.1016/j.tvjl.2005.02.028
39. Casey RA, Loftus B, Bolater C, Richards GJ, Blackwell EJ. Human directed aggression in domestic dogs (*Canis familiaris*): occurrence in different contexts and risk factors. *Appl Anim Behav Sci*. 2014;152:52–63. doi:10.1016/j.applanim.2013.12.003
40. McGreevy PD, Wilson B, Starling MJ, Serpell JA. Behavioural risks in male dogs with minimal lifetime exposure to gonadal hormones may complicate population-control benefits of desexing. *PLoS One*. 2018;13(5):e0196284. doi:10.1371/journal.pone.0196284
41. Kutzler MA. Gonad-sparing surgical sterilization in dogs. *Front Vet Sci*. 2020;7:342. doi:10.3389/fvets.2020.00342
42. Brent L. Growing interest in hormone sparing dog sterilization and recommendations for standard identification methods. *Clin Theriogenology*. 2019;11:254–266.
43. Hart BL, Eckstein RA. The role of gonadal hormones in the occurrence of objectionable behaviours in dogs and cats. *Appl Anim Behav Sci*. 1997;52:331–344.
44. Stoltzfus JC. Logistic regression: a brief primer. *Acad Emerg Med*. 2011;18(10):1099–1104. doi:10.1111/j.1553-2712.2011.01185.x
45. Schoemaker NJ. Ferret oncology: diseases, diagnostics, and therapeutics. *Vet Clin North Am Exot Anim Pract*. 2017;20(1):183–208. doi:10.1016/j.cvex.2016.07.004
46. Kutzler MA. Possible relationship between long-term adverse health effects of gonad-removing surgical sterilization and luteinizing hormone in dogs. *Animals (Basel)*. 2020;10(4):599. doi:10.3390/ani10040599
47. Whiteman MK, Hillis SD, Jamieson DJ, et al. Inpatient hysterectomy surveillance in the United States, 2000–2004. *Am J Obstet Gynecol* 2008;198(1):34.e1-7. doi:10.1016/j.ajog.2007.05.039
48. Summary position statement on gonad sparing sterilization procedures. American College of Theriogenologists and the Society for Theriogenology. Accessed August 21, 2022. https://cdn.ymaws.com/www.therio.org/resource/resmgr/files/oss_position_statement_with_.pdf
49. Nolen RS. When should we neuter dogs? It depends. JAVMA News. Accessed August 21, 2022. https://www.avma.org/javma-news/2021-03-01/when-should-we-neuter-dogs

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