

Background: Hypothyroidism, an endocrine disorder in which the thyroid gland produces too little hormone, can occur in dogs. While unspayed female dogs seem to have a lower risk of hypothyroidism compared to spayed female dogs, evidence of whether this holds true for male dogs is less clear. It is known that the risk of poor health conditions increases with age, and certain dog breeds, specifically Golden Retrievers and Doberman Pinschers, are at a greater risk for hypothyroidism. With consideration of other variables, we sought to examine whether there is an association between neuter status and hypothyroidism among male dogs.

Study Design: A case-control study was conducted among X male dogs between X-X years of age. For every one case of hypothyroidism, three controls were sampled. Data was collected on age (years), weight (lbs), neuter status (neutered or intact), and breed type (breed 1, breed 2, breed 3, and breed 4).

Statistical Methods: Descriptive statistics of baseline characteristics were calculated and stratified by case status, including the proportion of dogs that are neutered, the proportion belonging to each breed type, and average ages and weights in each group. To investigate whether neuter status is associated with hypothyroidism in male dogs, we fit a multiple logistic regression model of neuter status on hypothyroidism adjusting for age (continuous linear) and dog breed (categorical) as covariates. Breed was treated as a confounder, as there is scientific evidence that certain breeds are associated with hypothyroidism, and some breeds are less likely to be neutered for breeding purposes. We hypothesized that aging is associated with hypothyroidism but not associated with neuter status for the ages of dogs included in our dataset (X-X years), and as such we treated age as a possible precision variable (Figure 1). We did not adjust for weight because many dogs in the dataset are mixed breed or 'other purebred,' and thus weight is more indicative of true breed rather than health status. Hypothesis tests were conducted using Wald tests and an alpha level of 0.05. Odds ratios were calculated with 95% confidence intervals constructed using robust Wald standard errors.

Results: In comparing cases and control, cases were on average older and heavier in weight, and a smaller proportion of cases had been neutered compared with controls (Table 1). The proportion of purebred dogs of breed 2 among the cases (X.XX%) was

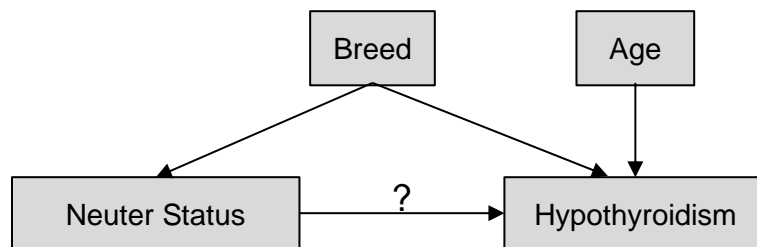
more than X the proportion among controls (X.XX%). There were no missing values in the dataset. When adjusting for both age and breed, we found that intact male dogs had an estimated X.XX (95% CI: X.XX, X.XX) times odds of being diagnosed with hypothyroidism than neutered male dogs (Table 2). Based on the Wald test statistic for the estimated coefficient, we reject the null hypothesis at the 0.05 level ($p\text{-value}=X.XX$) and conclude that there is an association between hypothyroidism and neuter status. Additionally, dogs of breed 2 had an estimated X.XX (95% CI: X.XX, X.XX) times odds of being diagnosed with hypothyroidism as compared to mixed breeds when adjusting for neuter status and age. We also found that when comparing dogs one year apart in age, older dogs had X.XX (95% CI: X.XX, X.XX) times odds of developing hypothyroidism compared to younger dogs while holding breed and neuter status constant.

Discussion: We found statistically significant evidence that, after adjusting for breed and age, male dogs that are intact have nearly X times odds of developing hypothyroidism. This is in contrast to previous literature that demonstrates that intact male dogs are less likely to develop hypothyroidism. Our study helps clarify previous mixed evidence regarding the relationship between neuter status and hypothyroidism in male dogs. Additionally, our findings that dogs of breed 2 and older dogs have X times odds to develop hypothyroidism complements previous literature.

These findings must be taken into context with several limitations. This is a single observational study that offers odds ratios as the estimate of interest which alone cannot determine causality. There were a relatively small number of individual breeds and many dogs were mixed/other breeds, which is a broad category that does not easily differentiate relationships between specific breeds. Small sample sizes within individual breeds also limited our power to estimate odds ratios for specific breeds.

Strengths of this study include utilizing a case/control study design for an outcome that is relatively rare. Future studies will be necessary to better understand the difference between hypothyroidism risk in male and female dogs and how the relationship may differ amongst breeds.

Figure 1: Hypothesized relationship between neuter status and hypothyroidism in dogs.



Directed acyclic graph (DAG) depicting causal relationships between neuter status, hypothyroidism, breed and age.

Table 1: Descriptive Characteristics by Hypothyroidism Among Male Dogs (N=X)

Variable	Cases n=X	Controls n=X
Age in years, mean (SD)		
Weight in pounds, mean (SD)		
Neutered, n (%)		
Breed, n (%)		
Breed 1		
Breed 2*		
Breed 3*		
Breed 4		

*All dogs of breed 2 and 3 in this study are purebred

Descriptive baseline statistics of cases (dogs with hypothyroidism) and controls (dogs without hypothyroidism) in a case-control study evaluating the relationship between neuter status and hypothyroidism. Summary statistics include the following

characteristics of the dogs in the study: age, weight, neuter status, and breed, reported as means and standard deviations or counts and percentages, as appropriate.

Table 2: Hypothyroidism logistic regression model coefficient estimates (N=920)

	Odds Ratio	Robust SE*	Exponentiated 95% CI*
Intercept			
Intact dogs			
Breed 2**			
Breed 3**			
Breed 4 **			
Age			
*SE: Standard Error, CI: Confidence Interval **Reference group: Mixed Breed			

Exponentiated coefficient estimates, robust standard errors, and exponentiated 95% confidence intervals for a multiple logistic regression model with hypothyroidism as the outcome and neuter status, breed, and age as covariates, where neuter status is the exposure of interest.