

EFFECTS OF SPAYING AND NEUTERING ON THE PREVALENCE OF ACL INJURY IN DOGS

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Introduction: Anterior Cruciate Ligament (ACL) injury occurs 2 – 10 times more frequently in human females than males. The prevalence of ACL injury in the general population is approximately 0.38 per 1000 people. Both intrinsic and extrinsic factors likely affect susceptibility to ACL injury. Gender differences in ACL injury have been associated with phases of the menstrual cycle and with specific neuromuscular traits like medial knee collapse during landing from a jump. The question of whether hormones affect susceptibility to ACL injury is controversial. Study of a non-human animal model with a high prevalence of ACL injury would eliminate most extrinsic factors (shoe wear, surface type, coaching, and gender social biases) that complicate human studies, thereby enabling more focused analysis of specific intrinsic differences like gender and the presence or absence of sex hormones.

ACL rupture is a relatively common cause of lameness in animals treated in veterinary practices. Unlike previous studies, which focused only on university-based practices, we looked at a rural community practice, possibly eliminating selection bias inherent to tertiary referral centers. Here, we tested the hypothesis that gonadal sex affects the prevalence of ACL injury in all dogs treated in a single veterinarian's orthopedic surgical practice.

Methods: The records of all dogs seen and evaluated over a two-year period in a single-surgeon orthopedic veterinary practice were retrospectively reviewed. Each dog was identified and was counted as a single unit of observation regardless of the number of visits. No dogs were excluded from the general population in the clinic. Dogs with a documented ACL tear, confirmed by positive anterior drawer and identification of a torn ACL at the time of surgery, were included in the injured population. Breed, gender, neuter status, and spay status were recorded for all dogs.

Prevalence was calculated by gender and gonadally intact status by identifying the total number of dogs with ACL rupture in the sample. To test whether gender was associated with the probability of ACL rupture, we used three logistic regression models. The first model was a univariate logistic regression with a single correlate gender that had four categories: sexually intact female, sexually intact male, spayed female and neutered male. The first category served as the comparison group in the regression. Whether sexually intact males, spayed females, and neutered males, respectively, had higher probabilities than sexually intact females of having ACL ruptures was tested by comparing the estimated odds ratios (OR; OR = the probability in the test group divided by probability prevalence in sexually intact females.) The significance of the odds ratios was determined by using a threshold p value of 0.05. The second logistic regression model investigated the sex difference controlling for breed. Finally, we estimated a third logistic model controlling for dogs' sizes. A dog's size was categorized as large, medium or small based on mean breed height at the withers. Heights less than 40cm were deemed small breeds and those over 60cm were deemed large. Dogs whose sizes could not be determined for various reasons were assigned to a fourth category, "missing size," for the size variable.

Results: Among the 3,218 dogs included in this study, the overall prevalence of ACL rupture was 3.48%. As compared with the other three gonadal sex categories, spayed females had

the highest prevalence of ACL rupture (5.15%), and sexually intact males the lowest prevalence (2.09%). In addition, prevalence of ACL rupture in spayed females and neutered males was 2.1-fold higher than in sexually intact animals.

Analysis by the first model (univariate logistic model not controlled for breed) revealed that the probability of injury rate in spayed females was higher than that in sexually intact females (OR=2.19, $p<0.01$). Also in the post estimation test, spayed females were more likely than sexually intact males to have ACL injury (OR=2.51, $p<0.05$). Analysis by the second model wherein breed was considered as a confounding factor revealed that as compared with sexually intact females, neutered males (OR=2.04, $p=0.04$) and spayed females (OR=2.57, $p<0.01$) were more likely to have ACL ruptures. In addition, the post estimation test identified that spayed females had higher probabilities of sustaining ACL injuries than sexually intact males (OR=2.64, $p<0.01$); differences between sexually intact males and spayed females were also demonstrated ($p<0.01$). No significant difference was found, however, between sexually intact females and sexually intact males, between sexually intact males and neutered males, or between neutered males and spayed females.

Among the 3,218 dogs, 229 (7.12%) were large, 1,053 (32.72%) were medium, 1,509 (46.89%) were small, and 427 (13.27%) had an undetermined size. In the third model, which controlled for dog size, spayed females were more likely than sexually intact females to have ACL rupture (OR=2.27, $p<0.01$). In addition, the post estimation tests indicated that probability of ACL injuries was lower among sexually intact males than among neutered males (OR=0.51; $p<0.01$) and the probability of ACL injuries was lower in sexually intact males than among spayed females (OR=0.38; $p<0.01$). Furthermore, as compared with large dogs, medium (OR=0.38, $p<0.01$) and small dogs (OR=0.38, $p<0.01$) were less likely to sustain ACL injury. However, no significant difference was found between medium and small sizes ($p=0.99$).

Discussion: The dog may be a useful animal model for studying aspects of ACL rupture that are relevant to human susceptibility to this injury. In the dog, most extrinsic factors that may affect ACL injury either do not apply or can be minimized. Hence effects of intrinsic differences such as sex, hormone status, or gonadectomy on ACL injury prevalence can be assessed accurately.

Gonadectomy increased the prevalence of ACL injury across sizes and breeds of dogs of either sex. Altering the amount and presentation of sex hormones through spaying or neutering a dog may mimic the conditions of oligomenorrhea or amenorrhea that occur in female athletes. The finding that gonadectomy in dogs is associated with increased prevalence of ACL injury supports that idea that sex hormones affect the ACL's material properties, size, or both.

We conclude that ACL injury occurs with a high prevalence in dogs, and that spaying or neutering significantly increases the prevalence of this injury. These findings have established an alternative model by which the effect of gonadal sex on ACL injury can be studied, and are consistent with the view that ACL injury in humans is, in part, related to sex differences in hormone production and presentation.