# Average Tibial Plateau Angle of 3,922 Stifles Undergoing Surgical Stabilization for Cranial Cruciate Ligament Rupture

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## Abstract

**Objective** The aim of this study was to report the average tibial plateau angle (TPA) from a large sample of dogs and to determine if breed or gonadectomy had a significant association with abnormal TPA.

**Study Design** This was a retrospective case study.

**Materials and Methods** Medical records from 2006 to 2015 were reviewed for dogs that were diagnosed with cranial cruciate ligament (CrCL) rupture and underwent dynamic surgical stabilization. Signalment, examination findings, preoperative TPA and surgical report were reviewed.

**Results** A total of 3,249 dogs underwent CrCL stabilization surgery from 2006 to 2015. Of the 3,249 dogs, 3,054 dogs met the inclusion criteria for a total of 3,922 stifles to be evaluated. The average preoperative TPA was $29° \pm 3.7°$. Average breed-specific preoperative TPA ranged from 27° to 35.1°, with four breeds having significantly lesser TPA and four breeds significantly greater TPA than the overall mean of dogs. Neutered dogs had a higher TPA of $28.87° \pm 3.8°$ than non-neutered dogs with an average TPA of $26.88° \pm 4.0°$, $p < 0.001$. There was not a significant difference in average TPA between females and males, regardless of the neuter status.

**Conclusion and Clinical Relevance** Our reported preoperative TPA in a large sample of dogs is higher than what has been previously published. In reviewing 3,922 stifles, the average preoperative TPA was 29°. We report the average preoperative TPA in specific breeds and report that neutered dogs have a significantly higher TPA than intact dogs. This updated information may guide clinicians in management decisions regarding treatment for CrCL rupture.

**Keywords**

- cruciate ligament disease
- tibial plateau angle
- dog
- breed
- gonadectomy



## Introduction

Cranial cruciate ligament rupture is one of the most common orthopaedic pathologies diagnosed in dogs.[1] Approximately 2.55% of the canine population is diagnosed with some degree of cranial cruciate ligament insufficiency.[1] Rupture of the cranial cruciate ligament leads to joint instability and associated secondary synovitis, osteoarthritis and possible meniscal injury.[2] While many factors have been proposed to contribute to cranial cruciate ligament rupture, it is generally considered to be a degenerative process in dogs.[3] Several potential risk factors for cranial cruciate ligament degeneration have been studied and include tibial plateau angle (TPA), breed, age, sex, body condition and neuter status.[4] Slocum and Devine looked at the relationship between cranial cruciate ligament disease and its correlation to TPA, as it has been suggested that an excessive TPA may predispose dogs to cranial cruciate ligament rupture.[5]

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It was initially suggested that a TPA equal to or greater than 22.6° was considered abnormal or excessive and results in predisposition to cranial cruciate ligament rupture.[5] In contrast, an additional study reported that Labrador Retrievers that do not have clinical signs of cranial cruciate ligament insufficiency have an average TPA of 27.97°, while Labrador Retrievers with cranial cruciate ligament insufficiency have an average TPA of 25.55°. This would suggest that dogs with steep TPA may not be at a higher risk of cranial cruciate ligament rupture.[6] Another study reported that TPA in dogs with cranial cruciate ligament insufficiency had an average of 23.76° but 18.1° in unaffected dogs.[7] Unfortunately, most of the studies investigating the average TPA of dogs with cranial cruciate ligament insufficiency involved small sample sizes, ranging from 3 stifles to 275 stifles.[5–37] Fitzpatrick and Solano reported one of the largest population, consisting of 1,000 dogs and 1,146 stifles. This study reported a median TPA of 25°.[38] Later Coletti and colleagues also utilized a high sample size, consisting of 943 dogs and 1,519 stifles, which revealed a median TPA of 27°, ranging from 18° to 45°.[39]

Complicating this matter is that there are specific dog breeds diagnosed with cranial cruciate ligament insufficiency more frequently. Newfoundlands have been reported to have the highest prevalence of cranial cruciate ligament rupture, followed by Rottweilers and American Staffordshire Terriers.[3,4] A study[33] reported a 22% hospital prevalence of cranial cruciate ligament rupture in Newfoundlands, while additional studies[7,40] have stated that the most common patients presented for cranial cruciate ligament disease are Labrador Retrievers,[7,40] German Shepherd Dogs[41] and Golden Retrievers.[7,10] Guastella and colleagues reported that the four most common breeds seen at their hospital were the Labrador Retriever, Rottweiler, Boxer and German Shepherd Dog.[22] Their results reported an average TPA measurement of 25.9°, 26.2°, 25.9° and 28.2° respectively, concluding that the TPA for German Shepherd Dogs appears to be significantly higher than all other breeds.[22]

From the potential risk factors of cranial cruciate ligament degeneration, an excessive or steep tibial plateau may predispose dogs to cranial cruciate ligament rupture due to the increased stress on the cranial cruciate ligament when weight-bearing.[6,8] A study by Duerr and colleagues suggested early gonadectomy was a significant risk factor for developing an excessive TPA. The case–control study compared dogs with TPA greater than 35° to dogs with a TPA less than or equal to 30°.[8] All dogs were clinically diagnosed with cranial cruciate ligament rupture and suggested that the dogs with excessive TPA in both hind limbs were 13.6 times as likely to have been neutered prior to 6 months of age.[8]

At the authors' institution, it was noted that dogs diagnosed with cranial cruciate ligament insufficiency have a higher TPA than what is currently reported in the literature. The purpose of our study was to determine the average TPA in a large population of dogs diagnosed with cranial cruciate ligament insufficiency. After determining the average TPA, our goal was to determine if there are not only breed-specific differences in TPA, but also if there are differences in TPA in relation to sex or neuter status. Our primary hypothesis was that neutered dogs have a higher TPA than sexually intact dogs. Our secondary hypothesis was there are differences in TPA based on breed.

## Materials and Methods

Patient records identified for this retrospective study were from one institution. For inclusion, patients must have been presented with suspected cranial cruciate ligament insufficiency at the time of initial examination from 2 March 2006 to 31 December 2015 at the Veterinary Orthopedic and Sports Medicine Group. Of the selected patients, criteria for inclusion required both a preoperative TPA measurement and confirmation of cranial cruciate ligament insufficiency intraoperatively. Each patient record was reviewed for history, signalment, initial examination findings, preoperative TPA, surgical report and postoperative recovery. Incomplete medical records or lack of a preoperative TPA listed were excluded.

Preoperative TPA was determined with a mediolateral tibial radiograph consisting of a 90° stifle and hock flexion, with the greater trochanter, lateral femoral condyle and lateral malleolus in direct contact with the table. Superimposition of the femoral condyles was required in the projection as previously reported.[42] The radiographs were then measured using a computer-assisted planning software, eFilm Workstation (Merge Healthcare Corporate Headquarters; Chicago, Illinois, United States) or VetPACS OrthoPlanner (INFINITT Healthcare Co., Ltd, Phillipsburg, New Jersey, United States). All TPA measurements were performed by veterinarians who have extensive experience with measuring TPA. A line along the tibial mechanical axis was drawn from the intercondylar eminence of the tibia to the centre of the talus bone. A second line was drawn parallel to the tibial plateau. The TPA for each stifle was determined by a perpendicular bisect of the tibial axis and the angle created between that line and the tibial plateau.[42]

Data were then categorized and compared to view the TPA in correlation to overall sample, breed and sex. The averages, medians and standard deviations were calculated for each TPA measurement reviewed. The distributions and the relationships between the calculated bell curves and plotted raw data were visually reviewed. This was done for both the overall sample data and specific breed groups. With confirmed approximate normal distribution of the overall data, parametric statistics were performed on a subcategory of the sample, based on the most common breeds seen at this institution: 26 breeds, listed in ►**Table 1**. This subcategory will be referred to as Subset A. For inclusion in Subset A, gender, neuter status and preoperative TPA all had to be recorded in the patient record. Therefore, 1,606 dogs of the 1,774 listed in ►**Table 1** were incorporated in a statistical analysis for Subset A, as some patients were missing gender or neuter status and subsequently excluded from the analysis. A SPSS General Linear Model procedure was conducted to form an analysis of variance (ANOVA) on the average TPA values as they relate to gender of the dog, whether or not the

**Table 1** Average TPA and significance of difference from mean of all stifles of Subset A, based on the breed of dogs

| Breed | Number of dogs in subset A | Average TPA (°) | Standard deviation (°) | *p*-Value |
|---|---|---|---|---|
| Akita | 17 | 28.12 | 3.4 | 0.706 |
| American Bulldog | 26 | 29.31 | 3.6 | 0.399 |
| American Staffordshire Terrier | 24 | 29.04 | 4.0 | 0.566 |
| Australian Shepherd | 31 | 28.58 | 3.3 | 0.436 |
| Beagle | 35 | 31.71 | 3.6 | 0.367 |
| Bernese Mountain Dog | 40 | 30.00 | 3.5 | 0.858 |
| **Bichon Frise** | **28** | **32.29** | **4.4** | **0.002** |
| Border Collie | 37 | 27.70 | 3.3 | 0.092 |
| Boxer | 117 | 28.20 | 3.4 | 0.191 |
| **Cane Corso** | **20** | **27.15** | **3.1** | **0.031** |
| Chesapeake Bay Retriever | 28 | 28.36 | 3.4 | 0.078 |
| Cocker Spaniel | 31 | 30.29 | 3.5 | 0.462 |
| **Doberman Pinscher** | **26** | **28.92** | **4.3** | **0.030** |
| English Bulldog | 58 | 28.78 | 3.7 | 0.118 |
| English Mastiff | 33 | 28.73 | 4.6 | 0.268 |
| **German Shepherd Dog** | **96** | **27.57** | **3.5** | **0.009** |
| Golden Retriever | 128 | 28.05 | 2.9 | 0.069 |
| Great Dane | 24 | 30.08 | 3.3 | 0.083 |
| **Labrador Retriever** | **491** | **28.08** | **3.5** | **0.002** |
| Mastiff | 35 | 28.4 | 3.8 | 0.503 |
| Newfoundland | 43 | 29.12 | 3.0 | 0.440 |
| Pitbull Terrier | 61 | 29.97 | 3.2 | 0.078 |
| **Rottweiler** | **108** | **27.63** | **4.5** | **0.001** |
| Welsh Corgi Pembroke | 22 | 27.14 | 4.3 | 0.168 |
| **West Highland Terrier** | **30** | **35.37** | **3.2** | **< 0.001** |
| **Yorkshire Terrier** | **17** | **28.68** | **3.8** | **< 0.001** |
| Overall Mean of Subset A | 1,606 | 28.67 | 3.8 | |

Abbreviation: TPA, tibial plateau angle.
Note: Breeds of significance ($p < 0.05$) are bolded.

dog was neutered, and the breed of the dog from a list of the most common breeds seen in the sample.

An ANOVA was also performed for the remaining dogs excluded from Subset A to compare the average TPA of neutered and non-neutered dogs, as well as male versus female dogs. This subcategory will be referred to as Subset B, consisting of 1,361 dogs. A final unequal variances-assumed *t*-test was performed to compare the average TPA of Subset A to the average TPA of Subset B. All statistical analyses were performed with significance being $p < 0.05$.

## Results

From March 2006 to December 2015, 3,249 dogs were presented for cranial cruciate ligament insufficiency. Of the 3,249 patients, 195 patients were excluded for insufficient records. This resulted in a total of 3,054 patients or 3,922 stifles with reported preoperative TPA. Of the 3,922 included stifles, the average preoperative TPA was 29° ± 3.7° and the median TPA was 29°, as shown in ►**Fig. 1**. The overall sample consisted of 126 intact males (141 stifles), 118 intact females (142 stifles), 1,267 castrated males (1,626 stifles) and 1,541 spayed females (2,013 stifles). The average TPA were 26.62° ± 4.2°, 28.15° ± 3.8°, 29.29° ± 3.7° and 29.03° ± 3.6°, respectively.

The overall sample included 148 purebred breeds. Purebred breeds consisting of 18 dogs or more, along with the number of stifles included and average TPA, are listed in ►**Table 1**. Labrador Retrievers was the largest breed represented, consisting of 546 dogs or 652 stifles with an average TPA of 28.2° ± 3.4° and a median TPA of 28°. Following Labrador Retrievers, the breeds with the largest population included Golden Retrievers, Boxers, Rottweilers and German Shepherd Dogs. Our median TPA results for these breeds

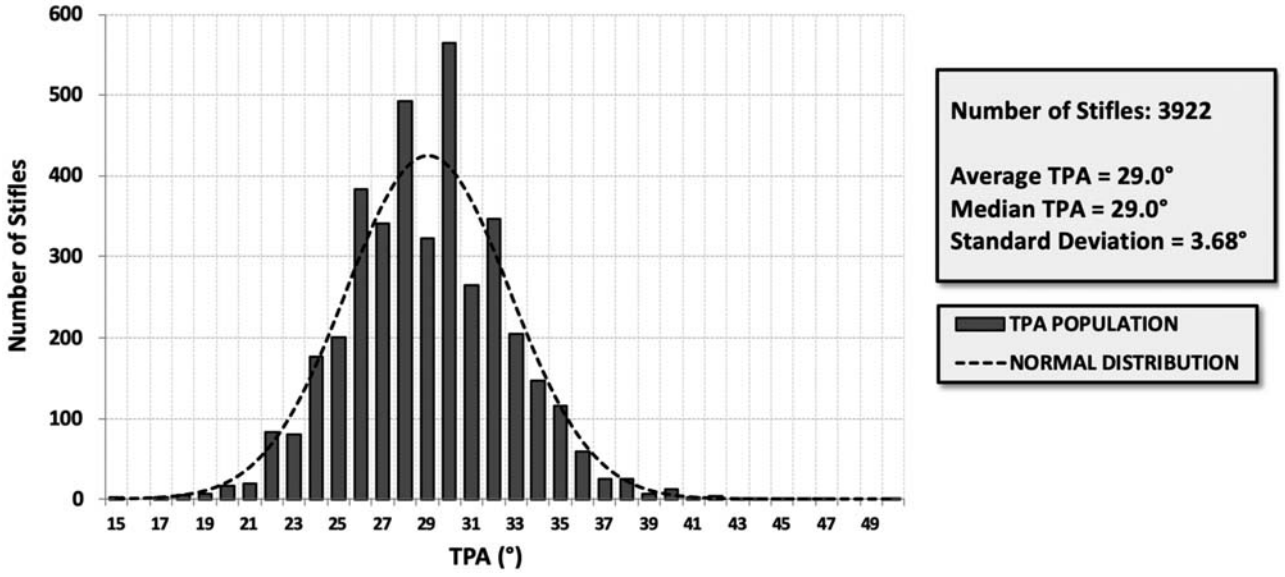


**Fig. 1** Overall preoperative tibial plateau angles for 3,922 stifles.

included 28° for Golden Retrievers, 28° for Boxers, 27° for Rottweilers and 28° for German Shepherd Dogs. Newfoundlands had a median TPA of 30° and American Staffordshire Terriers had a median TPA of 28.5°. Small breed dogs also had a higher TPA compared with larger breed dogs in our study with Beagles, Bichon Frises, West-Highland Terriers and Yorkshire Terriers, having a median TPA of 32°, 34°, 35° and 34° respectively.

Subset A consisted of 1,606 dogs and 26 breeds: Akita ($n = 17$), American bulldogs ($n = 26$), American Staffordshire Terrier ($n = 24$), Australian Shepherd ($n = 31$), Beagle ($n = 35$), Bernese Mountain Dog ($n = 40$), Bichon Frise ($n = 28$), Border Collie ($n = 37$), Boxer ($n = 117$), Cane Corso ($n = 20$), Chesapeake Bay Retriever ($n = 28$), Cocker Spaniel ($n = 31$), Doberman Pinscher ($n = 26$), English Bulldog ($n = 58$), English Mastiff ($n = 33$), German Shepherd Dog ($n = 96$), Golden Retriever ($n = 128$), Great Dane ($n = 24$), Labrador Retriever ($n = 491$), Mastiff ($n = 35$), Newfoundland ($n = 43$), Pitbull Terrier ($n = 61$), Rottweiler (108), Welsh Corgi Pembroke ($n = 22$), West Highland Terrier ($n = 30$) and Yorkshire Terrier ($n = 17$). Of the 1,606 dogs, 157 dogs were intact and 1,449 were neutered: 84 intact male dogs, 73 intact female dogs, 637 castrated male dogs and 812 spayed female dogs. The ANOVA on mean TPA values as they relate to gender of the dog, whether or not the dog was neutered, and the breed of the dogs from the list of 26 breeds, with each comparison adjusting for the other factors in the analysis, concluded that there are significant differences in mean TPA between neutered and not neutered dogs. Neutered dogs had a significantly higher mean TPA value of 28.87° ± 3.8° than non-neutered dogs with a mean TPA of 26.88° ± 4.0°, $p < 0.001$ There was not a significant difference in mean TPA between females and males, regardless of the neuter status.

In addition, we found there were significant differences in mean TPA values between breeds, $p < 0.001$. Breeds that were significantly smaller than the mean TPA of Subset A ($p < 0.05$) were Cane Corso (27.15° ± 3.1°, $p = 0.031$), German Shepherd Dogs (27.57° ± 3.5°, $p = 0.009$), Labrador Retriever (28.08° ± 3.5°, $p = 0.002$) and Rottweiler (27.63° ± 4.5°, $p = 0.001$). Breeds that were significantly larger than the mean TPA of Subset A ($p < 0.05$) were Bichon Frise (32.29° ± 4.4°, $p = 0.002$), Doberman Pinscher (28.92° ± 4.3°, $p = 0.030$), West Highland Terrier (35.37° ± 3.2°, $p < 0.001$) and Yorkshire Terrier (28.68° ± 3.8°, $p < 0.001$).

For Subset B, there were a total of 1,361 dogs for inclusion with a mean TPA of 29.33° ± 3.6°, consisting of 43 intact male dogs, 42 intact female dogs, 590 castrated male dogs and 686 spayed female dogs. The mean TPA of Subset B for intact dogs was 28.47° ± 4.0° and the mean TPA of Subset B for neutered dogs was 29.38° ± 3.6°. These mean TPA are significantly different, with $p = 0.023$. The mean TPA for males was not statistically different from the mean TPA of females.

Comparing subsets, the mean TPA of Subset A was 28.67° ± 3.8° and the mean TPA of Subset B was 29.33° ± 3.6°. Using an unequal-variances-assumed *t*-test, these differences in mean TPA are statistically significant, $p < 0.001$.

## Discussion

The goal of this study was to report the average preoperative TPA in dogs with cranial cruciate ligament insufficiency, as well as to determine if there are breed-specific and sex-specific differences in TPA. The overall TPA in our population dogs appears to be higher than what has been previously reported, consisting of an average and median TPA of 29° for 3,922 stifles. The data also supported our first hypothesis that neutered dogs would have a higher TPA than non-neutered dogs.

It is proposed that the timing of sexual altering may play a role in the development of a higher TPA due to delay in growth plate closure in early neutered dogs. Based on our data for the most common breeds seen at our institution (Subset A) for cranial cruciate ligament rupture, neutered

patients (TPA of 28.87° ± 3.8°) have a significantly higher average TPA than non-neutered dogs (TPA of 26.88° ± 4.0°), $p < 0.001$. In addition, amongst the remaining dogs that were not of common breeds for cranial cruciate ligament rupture (Subset B), the neutered dogs (TPA of 29.38 ± 3.6) had a significantly higher TPA than non-neutered dogs (TPA of 28.47° ± 4.0°), $p = 0.023$. Interestingly, there was no difference between males or females regardless of neuter status. Therefore, when based on TPA alone, neutering recommendations can be similar for both males and females.

With 3,922 stifles reported, castrated male dogs (1,626 stifles) had an average of 29.3° and spayed females (2,013 stifles) had an average of 29.0°. Fitzpatrick and Solano[38] revealed a higher percentage of intact male and female dogs (13.3 and 12.7%), where our sample consisted of a higher percentage of sexually altered dogs, with only 4.1% intact males and 3.9% intact females. This could explain the difference between our sample having an overall median of 29° as compared with their study having an overall median of 25°. In addition, this could also be explained by the different recommendations between the United States and other countries in regard to timing of gonadectomy. Therefore, early gonadectomy may be a risk factor for increased TPA. Recent publications have suggested that the risks of prepubertal gonadectomies may outweigh the benefits in owned large-breed dogs, particularly in orthopaedic diseases.[43,44] A retrospective study in 2014 concluded that prepubertal gonadectomy of Golden Retrievers had a three to five times higher incidence of developing joint diseases than intact dogs.[45] These authors followed with an additional study,[46] reporting that German Shepherd Dogs gonadectomized before 12 months of age had an increased risk for cranial cruciate ligament insufficiency compared with sexually intact dogs. In human medicine, a study used canine cranial cruciate ligament rupture as a model for human anterior cruciate ligament tears and reported a 4.71% prevalence of cranial cruciate ligament rupture in gonadectomized dogs compared with intact dogs with a 2.25% prevalence, resulting in an overall 3.48% prevalence in the overall sample of 3,218 dogs.[47] It has also been suggested that an oestradiol surge is necessary to promote epiphyseal fusion in rabbits.[48] With this potential link between early gonadectomy and the development of TPA, further research is necessary to explore its relationship and possible predisposition to cranial cruciate ligament insufficiency.

For breed specific average TPA, there were eight breed groups significantly different from the average TPA and therefore, we were able to accept our second hypothesis. Our largest purebred sample was the Labrador Retriever, consisting of 546 dogs and 652 stifles, with an average preoperative TPA of 28.2°. This was higher than previously reported studies, with average TPA of 25.5°,[6] 26°,[17] 23.5°,[30] and 25.9°[11] for Labrador Retrievers with cranial cruciate ligament insufficiency. Other average preoperative TPA in our sample included 28.1° for Golden Retrievers, 27.9° for Boxers, 27.5° for Rottweilers and 27.5° for German Shepherd Dogs. Our average TPA varied from other studies[22,49] reporting breed-specific TPA and although the explanation for this is unknown, it could be due to the differences in populations or it could be in relationship to interobserver variability when measuring the TPA. A difference was noted in terms of the correlation to a normal distribution curve depending on the sample reviewed. When reviewing all 3,922 stifles to the calculated normal distribution curve, the raw data shows both a close correlation and a resemblance to a normal population distribution (►**Fig. 1**). However, when reviewing specific breeds, for example, with only 66 stifles for Newfoundlands the distribution does not appear to have as strong of a correlation to the breed group's normal distribution curve (►**Fig. 2**). Because of this, small sample sizes of dogs could potentially skew the average TPA when compared with the current world population of dogs, and therefore further investigation is required. Further studies are also needed to look at the

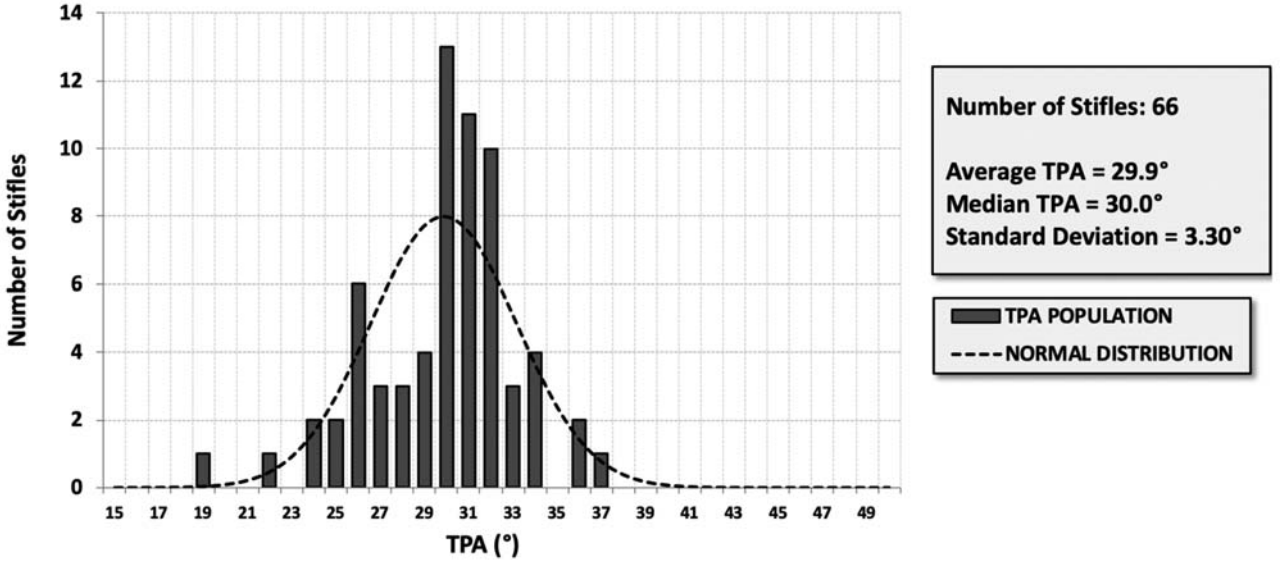


**Fig. 2** Preoperative tibial plateau angle (TPA) for Newfoundland breed group.

tibial conformation between breeds to determine if conformation plays a role in the differences of TPA.

Potential limitations of this study centre around its retrospective nature, such that some information could have been left out of the medical record; however, every attempt necessary was made to ensure that medical records were complete. Given the small sample size for intact male and female dogs presenting for cranial cruciate ligament insufficiency when comparing to our neutered sample, a larger sample of intact dogs may be warranted to compare the TPA and joint characteristics between neutered and non-neutered dogs. Furthermore, there was no information in the medical record indicating the age of gonadectomy in the dogs that were sexually altered. The authors do recommend further investigation into neuter status of patients presenting for orthopaedic disease to determine if a correlation is noted with timing of neutering. Given there were different veterinarians measuring the TPA, there is some inherent intra- and interobserver variability. Currently, the reported[19] intraobserver variability is 1.5° and the reported[19] interobserver variability is 0.8°. With this small difference between intra- and interobserver variability, we do not suspect this variability to account for the differences noted in our study. Lastly, additional limitations to consider include that body weight, body condition score and tibial conformation were not taken into consideration. Additional studies are needed for evaluating tibial conformation in relation to TPA.

In conclusion, we were able to demonstrate a higher TPA (29°) in patients diagnosed with cranial cruciate ligament insufficiency to our hospital. Based on the large sample size and statistical analysis, we believe that this reported TPA is an accurate representation of dogs in the United States. However, these data should be interpreted with caution when comparing it to patients outside of the United States, as gonadectomy recommendations differ in other countries. In this study, we were able to show that neutered dogs have a higher TPA than non-neutered dogs and that there are breed differences in TPA. Further work should be considered to evaluate whether the age of patients at the time of neutering influences both orthopaedic diseases and tibial conformation.

### Authors' Contributions

Elisabeth A. Fox and David L. Dycus contributed to conception of study, study design, acquisition of data and data analysis and interpretation. Sherman O. Canapp Jr and Christopher S. Leasure contributed to acquisition of data. Sherman O. Canapp Jr drafted and revised the manuscript. Elisabeth A. Fox, David L. Dycus and Herbert A. Fox drafted, revised and approved the submitted manuscript.

### Note

Ms. Elisabeth Fox was a third-year veterinary student at the time of publication.

### Conflict of Interest

None declared.

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